Fuzzy Logic Model to Assess Desertification Intensity Based on Vulnerability Indices

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Abstract: Executive practices on desertification control should be based on recognizing the current desertification state and its severity. So, it is essential to assess the ways to give zoning based on logic, active principles, and theoretical foundation for the management of desert regions. For this aim, 30 useful indices on desertification were determined in two human and natural sections. The significance of indices relative to each other and each index's importance per work unit was determined using the Delphi method. The Bonissone method in the framework of the Fuzzy Multiple Attribute Decision Making (FMADM) method was used to combine indices and determine desertification intensity in each working unit. Then, data were converted to the Fuzzy layer using Chen and Wang method, and Fuzzy analysis was performed on data. Finally, Fuzzy data were changed to non-Fuzzy, and desertification intensity was estimated. The results showed that 9.35% of the study area was in a very high class regarding desertification intensity and 9.36% of the region was in relatively high class. Desertification with moderate intensity (50.64%) and a relatively moderate intensity (29.45%) had the most shares in the study area, respectively. The quantitative value of desertification potential in the whole area from all of the components was obtained as 0.083, relatively high. This study shows the efficiency and ease of Fuzzy logic application for assessing desertification intensity.

Keywords: fuzzy logic; Bonissone method; artificial intelligence; vulnerability; zoning

1 Introduction

Desertification means land degradation in arid, semi-arid, and dry sub-humid areas resulting from climatic changes or human activities [31]. According to the United Nations Convention to Combat Desertification (UNCCD), desertification will threaten more than 785 million people living in arid areas, accounting for 17.7% of the world's population [15]. In Iran, desertification is a severe threat because 16 provinces with 57.5 million hectares are located in desert regions [18]. In these communities, desertification is a primary restriction for sustainable development [30]. So identification of the status quo is a fundamental step to achieve balanced growth. Identifying the status quo and determining ecological capacity in each region prevent environmental degradation during development, ensure the additional value of national and regional investment in the most stable and appropriate state, and make it possible to achieve the desired goals and policies. Hence, methods of assessing desertification intensity and preparing a zoning map of desertification are considered the essential tools for planning and managing natural resources to achieve sustainable development [33]. Desertification assessment determines the most critical desertification component and provides a map of desertification intensity after assessing work units' indices. The application of these maps increases the efficiency of control, reconstruction, and rehabilitation projects of lands at risk of desertification and prevents capital loss. So, according to these maps' practical importance, providing quantitative methods with fewer errors, higher reliability coefficient, and achieving more accurate results is essential.

Many studies have been done about the assessment of desertification potential in different areas. For example, preliminary research for assessing classification map of desertification [12], Environment Sensitive Area to Desertification (ESA) [10], Iranian classification of desertification (ICD) [11], Iranian Model of Desertification Potential Assessment (IMDPA) [2], Modify Numerical Taxonomy (MNT) [21], Environmental vulnerability index (EVI) [22], Shannon Entropy Model [24], Principal Component Analysis (PCA) [27] and Multi-Attribute Utility Theory (MAUT) model [20]. In 1984, FAO-UNEP published a method entitled "preliminary research for assessing classification map of desertification." In this method, the current situation, rate, and risk of desertification are described. In this research, Desertification processes include the destruction of vegetation, wind erosion, soil structure erosion and degradation, reduction of soil organic matter, salinity and alkalinity, waterlogging, and accumulation of toxins. These processes are based on ground observations, aerial photos interpretation, and available information classified into four classes (low, moderate, high, and very high) using statistical modeling [12]. In 1996, Ekhtesasi and Mohajeri provided a method for classifying the type and severity of desertification in Iran. In this method, active factors in desertification are evaluating with the weight balance method, and criteria for assessing these factors are usually descriptive and qualitative [11]. In

1999, United Nation provided the ESA model in the Mediterranean Desertification and Land Use project (MEDALUS) to assess and map desertification. In this model, four indices, including soil quality, climate quality, plant cover quality, and management, were defined as the most essential desertification indices. Finally, a desertification map was obtained from the geometric average of the mentioned indices [10]. In 2006, the Iranian Model of Desertification Potential Assessment (IMDPA) was provided at the University of Tehran, Faculty of natural resources. This model tried to classify selective criteria and indices according to the environmental conditions of Iran. Therefore nine following criteria were considered: climate, geology, soil, plant cover, agriculture, erosion (wind and water), water and irrigation, socio-economic issues and industry, and urbanism. Also, 35 indices were considered by experts for assessing desertification potential. Criteria scoring was expressed as a ranking way to minimize the error of rating and ease of rating [2]. Sadeghravesh et al. (2009) provided a model entitled Modify Numerical Taxonomy (MNT) [21]. This model has a hierarchical structure and is based on paired comparisons. To reduce the error of indicators valuation, this method uses the incompatibility index for automatic control on judgments in addition to the Delphi method, which is based on questionnaires.

The studies conducted on these methods have shown some defects, including non-native and qualitative indices, the degree of error, the small-scale, impossibility of separating human and natural factors in conclusion, etc. Although these defects were resolved mainly in other models, especially in the Taxonomy model, these models have still significant weaknesses, so that in evaluating indices, only the absolute value of each index is considered per work unit, and their priority is not considered in creating the critical condition which leads to unrealistic results. Hence, Sadeghravesh presented three models, including the EVI (Environmental Vulnerability Index), Shannon Entropy Model, Principle Component Analysis model, and Multi-Attribute Utility Theory (MAUT) model during 2012-2020 [9]. Like the MNT model, these models have a hierarchical structure and estimate desertification potential or region vulnerability based on indices priority and each index importance per work unit. But these models have a restriction and ignore the Fuzzy judgment of decision-makers. Real phenomena are always Fuzzy, imprecise, and vague, and Fuzzy logic is more realistic and closer to human behavior when it's necessary to select and make a decision [6] [16]. Some studies with the application of Fuzzy logic are as follow: Assessment of water management projects [29], security management in production [8], selecting resources planning systems [7], staff selection [9] [13], the election of suppliers [32], assessing companies efficiency [3], selecting the location of waste disposal site [17], prioritization and ranking of desertification indices [20], assessment of energy resources [16], zoning of wind erosion potential [23] and evaluation of desertification strategies [25] [26].

The usual methods using definitive data are ambiguous in the evaluation and ranking of indicators. In other words, there is no rational framework for uncertainty in decision making. But in natural options, including the identification and evaluation of desertification indicators, the researcher faces uncertainty. According to investigations, it was apparent that the Fuzzy method has not been used in desertification intensity zoning, while this method quickly developed in different science. This study, using fuzzy logic and inaccurate and non-deterministic data, makes it possible to study the conditions of uncertainty in the ranking and prioritization of desertification indicators. Bonissone Fuzzy method was used to achieve zoning purpose in the framework of multiple attribute decision making models. In this model, desertification intensity is estimated based on indices' priority and importance in each work unit. The results can be the basis for a new method and modification of the proposed methods to manage risk, evaluate, and monitor desertification.

2 Materials and Methods

2.1 Study Area

Khezr Abad region with an area of 78180 ha is located 10 km west of Yazd. This region extends from 53° 55' to 54° 20' eastern longitude and from 31° 45' to 32° 15' northern latitude. The region's average height is 1397 m, and 84.79% of the study area (663 km^2) has a slope lower than 10%. So the most extent of this area includes flat land with an average gradient of 9.41%. The region's soil resources are usually Entisols containing salt and gypsum formed under physical degradation and are affected by water and wind erosion and degradation. Soil temperature regime is thermic, and soil moisture regime is aridic. The climate of this region is cold and arid based on the Amberje climate classification method. The annual mean precipitation of this region is 121 mm. The dominant wind direction is Northwest, with an occurrence frequency of 16.97% and a maximum speed of 16.3 km/hr. About 130 km^2 (16.5%) of the region include dunes. Ashkezar erg, site of sandstorms occurrence, with an area of 89 km^2 and eroded and degraded faces located in the north part of the study area. About 1,995 ha (26.5%) of all agricultural lands of the region consists of degraded lands resulting from human activities and natural factors. These characteristics of the area show its typical desertification condition and a requirement to identify and prepare a desertification vulnerability map.

2.2 Methodology

There are different quantitative techniques for estimating and zoning desertification, facilitating planning, and assisting in decision-making. In this research, the Multiple Attribute Decision-Making method was used considering the number of useful indices in desertification zoning; also, fuzzy logic was used for combining indices. The usual process within the MADM method and Fuzzy logic consists of 6 stages: determining effective indices, determining work units, determining the importance of indices, and each index importance in each work unit, Fuzzy data making, Fuzzy process, and converting Fuzzy data to non-Fuzzy.

2.2.1 Determining Effective Indices to Assess Desertification Intensity

Thirty effective indices on desertification were determined in two human and natural sections based on the gained data through natural resources assessment and field study (Table 1). To select indices, three main factors, including the relationship with desertification, ease of access, and ease of updating, were considered in the framework of time and expense factors [19] [22] [26].

Table 1
Effective indices on desertification vulnerability of the study area

Natural, effective indices on vulnerability	Human effective indices on vulnerability
Annual mean precipitation (mm)	Tilling and fallow
Average wind speed (m/s)	Irrigation method
Aridity index (P/ET_p)	Irrigation efficiency (%)
Soil texture	Irrigation system
Soil salinity (EC-mmhos/cm)	Groundwater depletion
Soil drainage (in/h)	Soil moisture
Soil depth (cm)	Use of machinery, chemical and organic fertilizer
Slope (%)	Cropping pattern & production
Wind and water erosion	People's participation
Water salinity (EC-μmohs/cm)	Literacy (%)
The depth of groundwater level (cm)	Employment status
Vegetation cover density (%)	Population biological density (N/Km^2)
Shrubs and trees removing (%)	Land-use changes
Carrying capacity rangelands (AU/100 day)	Awareness of degradation results
Livestock pressure (capacity of rangeland/ existing livestock)	The land division into small parts

Climatic indicators were considered based on the ability to affect the available water of plants. These indicators include average annual rainfall, wind speed, drought, etc. The yearly average rainfall index was assessed because rainfall

equivalent to 300 mm is considered a critical threshold in the process of soil erosion and plant growth [28]. Estimating the most critical parameter, water availability to the plants needs a lot of information on soil conditions. Therefore, the FAO drought index was used in this study. The drought index is the annual rainfall ratio to annual potential evapotranspiration [28]. Investigation of wind erosion was done using the IRIFER method [1]. In this method, nine effective wind erosion parameters, including lithology, land formation and topography, wind speed and condition, soil condition and its surface cover, canopy type and percentage, soil moisture, soil surface erosion forms, land management, and land use were considered. For the investigation of water erosion, the PSIAC method was used [1]. In this method, parameters such as lithology, soil, climate, runoff, morphology, vegetation, and land use were considered. For estimating excessive grazing, which causes soil erosion, an animal unit (AU) was used. In this study, the animal unit was calculated based on the areas occupied by livestock [19]

2.2.2 Determining Work Units

Work units were determined using the geomorphology method to provide a proper framework for preparing a vulnerability zoning map of desertification [1]. For this aim, after collecting data from the interpretation of aerial photos, available digital data in map format, and reports of organizations and offices, digital data were entered into ArcGIS software. Finally, maps of geomorphology, land use, and vegetation types were obtained. These layers were overlapped, and then the final layer of work units was formed (Fig. 1). Twelve work units were selected according to the study goals.

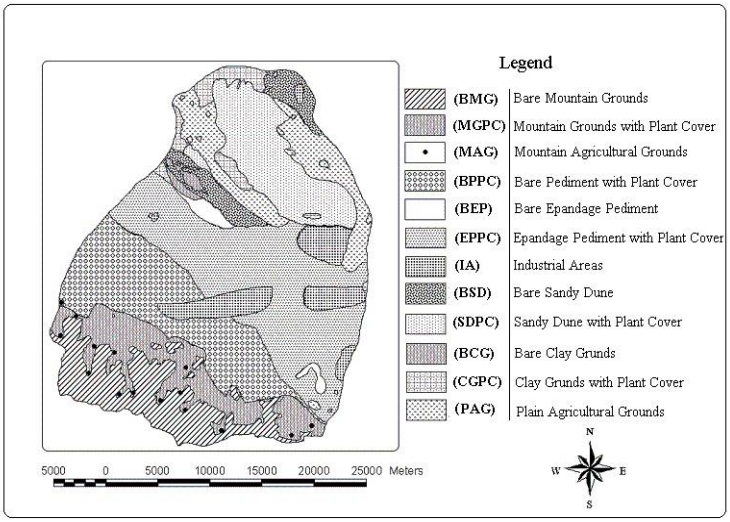

Figure 1
Work units of Khezr Abad

2.2.3 Determining the Importance of Effective Indices on Desertification Relative to Each Other and Also in Each Work Unit

The significance of indices relative to each other (w_j) and the importance of each index per work unit (r_{ij}) was determined using the Delphi method in the framework of MADM. To assess w_j and r_{ij}, a questionnaire was prepared and filled based on Chen and Wang's seven-rank scale by experts familiar with the study area.

Table 2

Fuzzy preference and importance degree, Chen and Wang method

Linguistic indicators	Numerical value	Number of Linguistic indicators			
		2	3	5	7
Very Low	0≤, >1			(0, 0, 0, 1.2)	(0, 0, 1, 0)
Low	1≤, >2		(0, 0, 0,2, 0.4)	(0.1, 0.25, 0.25, 0.4)	(0.1, 0.2, 0.2, 0.3)
Relatively Moderate	2≤, >3				(0.2, 0.3, 0.4, 0.5)
Moderate	3≤, >4	(0.4, 0.5, 0.5, 0.8)	(0.2, 0.5, 0.5, 0.7)	(0.3, 0.5, 0.5, 0.7)	(0.4, 0.5, 0.5, 0.6)
Relatively High	4≤, >5				(0.5, 0.6, 0.7, 0.8)
High	5≤, >6	(0.5, 0.8, 0.8, 1)	(0.6, 0.8,1 , 1)	(0.6, 0.75, 0.75, 0.9)	(0.7, 0.8, 0.8, 0.9)
Very High	6≤, >7			(0.8, 0.9, 1, 1)	(0.8, 0.9, 1, 1)

Then judgments were combined using a geometric mean (Eq.1), and a pairwise comparison matrix was gained. It was assumed that all experts' comments have the same importance degree.

$$\bar{a}i = \left(\prod_{N}^{K=1} ai^{k} \right)^{1/N} \tag{1}$$

a_i^k is related to k^{th} person in estimating the importance degree of each index.

Then, using the concept of normalization (Eq. 2) and weighted mean or the average of each row in the normalized matrix (Eq. 3), the importance of indices (W_j) was estimated (Table 3) [5].

$$z_{ij} = \frac{a_{ij}}{\sum_{i=1}^{M} a_{ij}} \tag{2}$$

$$W_i = \frac{\sum_{i=1}^{N} z_{ij}}{N} \tag{3}$$

Table 3
The normalized matrix of the importance of indices relative to each other and determining the priority of each index

Indicator (I_i)	I_1	I_2	…	I_n	^2W_i
I_1	$^1z_{11}$	Z_{12}	…	Z_{1N}	W_1
I_1	a_{21}	a_{22}	…	Z_{2N}	W_2
:	:	:	…	:	:
I_M	Z_{M1}	Z_{M2}	…	Z_{MN}	W_M

2.2.4 Making Fuzzy Data

This process includes shifting and converting inputs by the Fuzzy controller. The process has two stages, including membership and rating functions. Membership function has different forms, such as triangular, trapezoidal, and arched. In this study, a trapezoidal-shaped membership function was used.

The basis of Fuzzy logic is Fuzzy sets, which are a general state of sets theory. These sets range from discontinuous set {0, 1} to continuous sets {0, 1}.

In the Fuzzy sets, each variable's assessment is performed using linguistic variables by importance degree and based on normal logic generalization to multi-valued or continuous logic. Linguistic variables performance of a reference set like U in a trapezoidal function operates according to Eq. 4.

$$\tilde{A}(x) = \begin{cases} \frac{(e-x)}{(L-M)}e & L < x < M \\ e & M \leq x < M' \\ \frac{(U-x)}{(U-M')} & M' \leq x \leq U \\ 0 \end{cases} \quad (4)$$

Otherwise, the membership function is trapezoidal-shaped.

Due to the multiplicity of linguistic variables, the Fuzzy numbers corresponding to them were used. Different methods have been provided for converting linguistic variables to the Fuzzy numbers corresponding to them. In this study, the seven-ranking scale of Chen and Wang was used (Table. 2).

According to the type of selected Fuzzy numbers (trapezoidal), The Bonissone method was chosen among multiple attribute decision-making methods. In this method, it's assumed that algebraic operations on Fuzzy trapezoidal numbers (L-R) can be estimated as parametric. Bonissone showed each Fuzzy trapezoidal number ($\tilde{D}$) with four parameters (L, M, M′, and U) as the following equations:

The first Fuzzy number: $\tilde{D}_1 = (L_1, M_1, M_1', U_1)$ (5)

The second Fuzzy number: $\tilde{D}_2 = (L_2, M_2, M_2', U_2)$ (6)

Algebraic operations on these numbers are defined as the following equations (7-10):

$$\tilde{D}_1 + \tilde{D}_2 = (L_1 + L_2, M_1 + M_2, M_1' + M_2', U_1 + U_2) \quad (7)$$

$$\tilde{D}_1 - \tilde{D}_2 = (L_1 - U_2, M_1 - M_2', M_1' - M_2, U_1 - L_2) \quad (8)$$

$$\tilde{D}_1 \times \tilde{D}_2 = (L_1 \times L_2, M_1 \times M_2, M_1' \times M_2', U_1 \times U_2) \quad (9)$$

$$\frac{\tilde{D}_1}{\tilde{D}_2} = \left(\frac{L_1}{U_2}, \frac{M_1}{M_2'}, \frac{M_1'}{M_2}, \frac{U_1}{L_2}\right) \quad (10)$$

2.2.5 Converting Fuzzy Data to Non-Fuzzy and Assessment of Desertification Intensity

2.2.5.1 Determining the Utility of Each Work Unit (Ui)

A fuzzy utility index was used to assess efficiency. This index is a combination of indices' relative Fuzzy importance compared to each other (W_j) and each index Fuzzy influence in each work unit (R_{ij}) regarding desertification. It was calculated based on equation 11 in each work unit [4] [6].

$$U_i = \sum_{j=1}^{n} W_j \,.\, R_{ij} \quad (11)$$

2.2.5.2 Calculating the Importance Degree of Any Trapezoidal Fuzzy Utility Number from Another Fuzzy Number

It's necessary to arrange all U_i to determine the work units' weight or desertification intensity. So the importance degree of each Fuzzy number relative to other Fuzzy numbers was computed using equation 12, and the matrix of each work unit's magnitude degree was formed.

$$\begin{cases} V(D_1 \geq D_2) = 1, \\ M_1 \geq M_2' \\ V(D_1 \geq D_2) = hgt(D_1 \cap D_2) = \frac{U_1 - L_2}{(U_1 - L_2) + (M_2 - M_1')} \\ Otherwise \end{cases} \quad (12)$$

2.2.5.3 Calculating the Importance Degree of Any Trapezoidal Fuzzy Utility Number from Other k- Fuzzy Trapezoidal Numbers (Pi)

After determining each Fuzzy number's magnitude degree relative to different Fuzzy numbers, the importance of any trapezoidal Fuzzy utility number from other k- Fuzzy trapezoidal numbers (P_i) was calculated using equation 13.

$$P_i = min \quad V(D_1 \geq D_K), \quad i,k = 1,2,\dots,n \tag{13}$$

The numbers gained from this process shows abnormal weights of work units.

2.2.5.4 Normalization of Abnormal Weights of Work Units and Assessing Desertification Potential

Finally, using equation 14, abnormal weights of work units were normalized to estimate desertification potential in each work unit [4] [6].

$$N_i = \frac{P_i}{\sum_{i=1}^{k} P_i} \quad i = 1,2,\dots,n \tag{14}$$

3 Result

After determining effective indices (Table 1) and preparing maps of work units (Fig. 1), a group matrix of the indices' importance relative to each other (W_j) and the importance of each index in each work unit (r_{ij}) was formed (Table 4).

Table 4

Group matrix of each index importance relative to each other and in each work unit regarding desertification

Desertification index	1	2	…	29	30
Group matrix of the indices importance relative to each other					
Importance	0.89	3.9	…	4	5.5
Linguistic words	Very low	Moderate	…	Relatively high	high
Trapezoidal Fuzzy component ($\tilde{D}$)	(0, 0, 0.1)	(0.4,0.5, 0.5, 0.6)	…	(0.5, 0.6, 0.7, 0.8)	(0.7, 0.8, 0.8, 0.9)
Group matrix of each index importance in each work unit					
BMG	3.5	3.8	…	0.75	0.78
MGPC	4.6	3.8	…	0.63	0.5
.	…	…	…	…	…

.	…	…	…	…	…
IA	4.4	3.8	…	0.35	0.95
MAG	3.6	3.8	…	0.5	4.8

Then, to make Fuzzy data, Chen and Wang scale (Table 2) were used (Tabs. 4-5).

Table 5
Fuzzy group matrix of each index importance in each work unit

I / TMUs	1	2	…	29	30
(BMG)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	…	(0, 0.1, 0)	(0, 0.1, 0)
(MGPC)	(0.5, 0.6, 0.7, 0.8)	(0.4, 0.5, 0.5, 0.6)	…	(0, 0.1, 0)	(0, 0.1, 0)
.	…	…	…	…	…
.	…	...	…	...	...
(IA)	(0.5, 0.6, 0.7, 0.8)	(0.4, 0.5, 0.5, 0.6)	…	(0, 0.1, 0)	(0, 0.1, 0)
(MAG)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	…	(0, 0.1, 0)	(0.5, 0.6, 0.7, 0.8)

Then Fuzzy utility index (U_i) of all work units was estimated using equation 11, and a utility matrix was formed (Table 6).

Table 6
The utility of each work unit based on Fuzzy logic

Fuzzy numbers / TMUs	U	M′	M	L
(BMG)	7.03	4.45	3.91	2.76
(MGPC)	7.2	4.47	3.99	2.77
(BPPC)	7.02	4.14	3.65	2.43
(BEP)	5.95	3.33	2.91	1.95
(EPPC)	6.44	3.53	3.26	2.21
(PAG)	11.28	8.02	6.91	4.62
(CGPC)	7.53	4.68	4.14	2.82
(BCG)	6.64	3.9	3.39	2.28
(BSD)	6.21	3.51	3.13	2.07
(SDPC)	7.08	4.23	3.82	2.58
(IA)	7.48	4.49	3.86	2.48
(MAG)	12.5	9.14	7.99	5.5

Finally, to determine desertification intensity, the magnitude degree of each Fuzzy number relative to other Fuzzy numbers was calculated using equation 12. The matrix of all work units' magnitude degree close to each other was formed. Then, the abnormal weight of all work units (P_i) was determined using equation 13. These weights were normalized (N_i) using equation 14 (Table 7).

Table 7

The matrix of each work unit magnitude degree

TMUs	(BMG)	(MGPC)	…	…	(IA)	(MA)	P_i	N_i
(BMG)	1		…	…	1.1548	0.3029	0.3029	0.066
(MGPC)	1.1384	1	…	…	1.1428	0.3244	0.3244	0.071
...	…	…	…	…	…	…	…	…
...	…	…	…	…	…	…	…	…
(IA)	1.1400		…	…	1	0.3613	0.3613	0.079
(MAG)	1	1	…	…	1	1	1	0.22

Estimated values of desertification intensity (N_i) using equation 14 are continuous values, estimated due to the ease of reading and understanding the results. Based on Table 8, the desertification intensity of the study area was classified into six levels.

Table 8

Classification of desertification intensity in Khezr Abad region and the area of each class

Class	Desertification intensity	Class	Area	
			Km^2	%
Low	$0.025 \leq N_i$	I	0.943	1.2
Relatively Moderate	$0.05 \leq N_i < 0.025$	II	23.113	29.45
Moderate	$0.075 \leq N_i < 0.05$	III	39.756	50.65
Relatively high	$0.1 \leq N_i < 0.075$	IV	7.339	9.35
High	$0.125 \leq N_i < 0.1$	V	-	-
Very High	$0.125 > N_i$	VI	7.336	9.35

Each work unit was located in one of the desertification classes. Eventually, from combining the work units with the same classes, the final map of desertification potential with a scale of 1.50000 was gained using ArcGIS (Fig. 2).

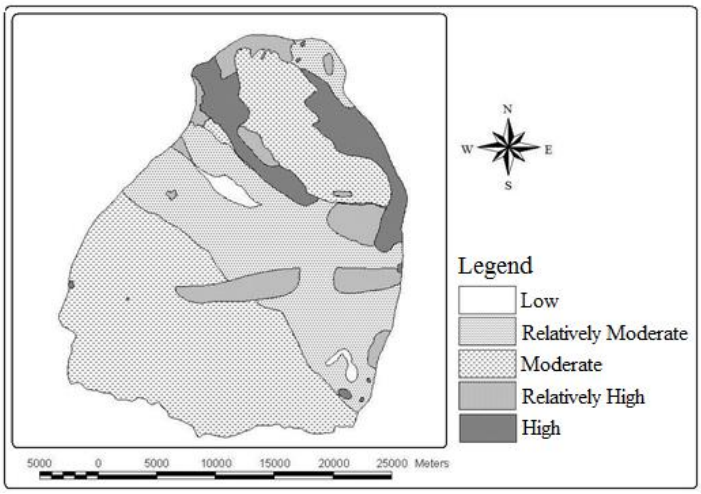

Figure 2
Zoning map of desertification intensity in Khezr Abad

4 Discussion

The following results were gained based on assessing desertification intensity in each work unit. In terms of vulnerability caused by desertification, mountain agricultural grounds (MAG) and plain agricultural grounds (PAG) units were in very high class, with the most quantitative value equal to 22%. Clay grounds with plant cover (CPGC) with a quantitative value of 0.083, and industrial areas with a quantitative value of 0.079 were in relatively high class. Other work units were located in moderate, relatively moderate, and low classes.

In determining the importance of indices relative to each other, the groundwater level's quantitative values, irrigation system, irrigation method, and soil depth were estimated equal to 7 or very high. The quantitative costs of irrigation efficiency, tilling and fallow, the land division into small parts, cropping pattern and production management, biological population density, carrying capacity of rangelands, and livestock pressure were estimated equal to 6 or high. Other indicators were not crucial in the assessment of desertification, according to experts. The essential human indices affecting desertification in units include inappropriate tilling and fallow (30-50% of lands are not cultivated due to different factors), improper and low use of agricultural machinery, overuse of pesticides and fertilizers, traditional and inappropriate irrigation method with low efficiency (less than 40%), a severe drop of groundwater table (45 cm/year), high population density (between 200 to 550 people per square kilometer), improper

land-use changes, unemployment, the insignificant extent of agricultural lands and low participation of native people. The most important natural indices affecting desertification in units include an extended dry period in which much of the area has a no wet month, several days with Aeolian sand (more than ten days per year), winds with a velocity more than the threshold velocity of erosion (39%), the low ratio of precipitation to evapotranspiration (0.03- 0.05).

Low rainfall (less than 60 mm/ year), soils with medium to fine texture and poor drainage (0.5 to 1 inch per hour), having limiting gypsum and limestone layers in soil depth especially in units CGPC, BCG and PAG, dunes movement (up to 10 meters per year), high amount of salt and chlorine in groundwater (7620 mmohs/cm and 2350 mg/liter respectively), poor plant types of rangeland with the negative tendency due to overgrazing and livestock pressure (3.7 to 5.1 times more than the tolerable level) and digging plants (40% to 50%). The results of assessing desertification intensity based on Fuzzy logic were compared to the effects of the Environmental Vulnerability Index [22], Shannon Entropy model [24], Principle Components Analysis model [27], which estimate desertification intensity based on indices priority relative to each other and also each index importance in every work unit. In all four models, mountain agricultural ground unit (MAG) and plain agricultural ground unit (PAG) have the most potential of desertification, and in the next stage, clay ground with plant cover (CGPC) and industrial areas are located. So, this study's results were consistent with the results of EVI, Shannon Entropy, and Principle Component Analysis models. But the quantitative values of various models are different. This occurs because of the models nature, which provides quantitative values in different ranges and also the different classifications of quantitative values based on the range of acquired values in each study. The final significance in the fuzzy model, like other desertification intensity zoning decision-making models, was estimated based on the linear sum of the significance coefficient of the indicators relative to each other (Wj) in the weights of each index in each work unit (rij). Estimating the weights of the indicators in each work unit was based on the Delphi method and consulting experts in all of these models. Also, in this method, unlike the Shannon Entropy model and Multi Attribute Utility Theory (MAUT) model in which the importance of indices is gained from the Entropy method and without considering the expert's judgment, the influence of indices was acquired using the Delphi technique, like EVI and PCA models. In the Fuzzy way, the significance of indices was assessed based on Chen and Wang scale, while in EVI and PCA models, the final influence was gained based on the nine-Saaty scale, normalization logic, weighted mean, and rotated principal component vector, respectively. The results of this study seem to be more accurate owing to the use of Fuzzy logic for determining the importance of indices relative to each other and also each index importance in each work unit.

The vital point in this research is the importance of accuracy in determining the weights related to each criterion, which plays an essential role in the results.

Accurate estimation of these weights leads to more realistic and reliable results. The fuzzy technique in the framework of multi-criteria decision models with prioritization of effective indicators from Delphi method and group judgment and also by providing the zoning based on this prioritization, as well as taking into account the relationships between the criteria and the closeness of the criteria comparisons to human thinking has a significant role in results accuracy. The results show that the evaluation of indicators and map of desertification intensity is dynamic and continuous. Different intensity classes are changeable, and the ranges of intensities can be redefined in various land management and reclamation scenarios. According to the evaluation of desertification intensity in work units, the quantitative value of desertification for the whole region was equal to 0.083 (class IV or relatively high).

Conclusions

Generally, the results showed that from the entire region, 7336 hectares (9.35%) was in class VI or very high, 7339 hectares (9.36%) was in IV class or relatively high, 39756 hectares (50.65%) was in class III or medium, 23113 hectares (29.45%) was in class II or relatively medium, and 943 hectares (1.2%) was in I or low desertification intensity class (Table 5 and Fig. 2). These results can be considered in future evaluations to invest in sustainable development, ensure the additional value of investments, and also protect marginal ecosystems of the study area. On the other hand, these results help the manager of desert areas to utilize limited facilities and stock allocated to the control of desertification phenomenon in regions with more vulnerability and prevent the waste of national funds. To use this model in other regions, influential factors in desertification should be considered inherent vulnerability indices, and also the impact of each parameter on desertification should be emphasized.

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Cyber Threats and Cyber Deception in Hybrid Warfare

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Abstract: Paper deals with the design of the model of hybrid threats and cyber deception platform and solution for cyber threat detection. National networks face a broad range of cyber threats. It includes advanced and persistent peril that can evade commercially available detection tools and defeat generic security measures. Cyber attacks are becoming more intense and complex as they reflect an increasing level of sophistication, e. g. by advanced persistent threat (APT) activity. This environment of menace is of a global nature when transcending geographic boundaries and characterized by the emerging development of offensive cyber capabilities that are an inherent part of conflicts. Deception methods and techniques are being successfully employed by attackers to breach networks and remain undetected in the physical and in the virtual worlds. However, in the world of cyber security, deception as a tactic and element of a more robust defensive strategy has been still largely underexploited. The broad concepts of deception within cyber security were introduced decades ago. Still, these were technological solutions focused on providing technical capabilities to distract, mislead or misdirect the attacker. Only recently has the focus shifted on to how to shape the attackers' sense-making of what is happening as they illegitimately explore networks. In this way, Cyber Deception nowadays provides an opportunity to scare, deter, and retaliate against those that violate organizations' systems. In connection with the foregoing authors created and presented the novel model of hybrid threats in hybrid warfare as a combination of multiple conventional and unconventional tools of warfare. Authors investigate the cyber deception platform and industrial model and solution for threat detection using deception-based methods.

Keywords: cyber attack; cyber deception; cyber threats; hybrid threats; hybrid warfare

1 Introduction

The goal of this paper is to construct new Hybrid Threats Model and investigate the cyber deception platform and industrial model and solution for threat detection using deception-based methods.
Our online dependency is going to strongly influence the security of the society. In light of the introduced trends, data integrity, privacy, data security, individual safety and even public safety can be threatened [18]. To summarize, the spread of connected devices and the growing influence of the cyberspace on our life will make it necessary to improve the protection of safety and security [17]. A cyber attack is an act or action initiated in cyberspace to disrupt, deny, degrade or destroy by compromising communication, information and other electronic systems, or the information that is stored, processed or transmitted on these systems. Cyber Defense is the means to achieve and executive defensive measures to counter cyber threats and mitigate their effects, and thus preserve and restore the security of communications, information or other electronic systems, or the information that is stored, processed or transmitted on these systems [12]. Global security depends on international stability and global prosperity. The fast-paced development and spread of technology and communications have enabled new means of influence and coercion. Adversaries continuously operate below the threshold of armed conflict. Extending one's influence without resorting to physical action is the "new normal". It is possible to provoke and intimidate citizens and organizations without fear of legal or military consequences. The constraints under which the member nations have chosen to operate in cyberspace, which include the adoption of a traditionally high threshold for response to adversarial activity, are well known. This insight may be used to exploit dependencies and vulnerabilities in cyberspace; systems, processes and values [20, 26]. Aims of these actions include to weaken democratic institutions and gain economic, diplomatic and military advantages. Ensuring common defense and security is the ultimate objective to be sustained by its core activities, and that large-scale or irregular armed conflict or hybrid war is an undesirable aspect of international relations. We are living in a world of competition and conflict, in which adversaries are positioning their other elements of power (political/social, diplomatic and economic) in such a way that they have a clear advantage. If the way of positioning ourselves before any existing conflict does not grant us freedom of movement and sometimes information superiority, we may not be able to survive. The tendency to clearly divide areas of expertise such as cyberspace, electronic warfare, signals intelligence etc. [22, 23], and treat them separately may prevent from having a broader view and realizing that being shaped by the adversary's intent. Cyber Deception exploits technical assets such as honeypots and honeytokens to spy on and manipulate the activities of a network attacker [13, 32]. Honeypots are effective precisely because attackers do not know if they are there and where they will be. However, honeypots are also a controversial technique; they essentially bait and capture intruders skirting the fine line between keeping attackers out of a network versus inviting them in [31]. We look at Cyber Deception in a national defense context across the five layers of cyberspace (Figure 1); from the physical through to the persona layers. The current practice should be explored and expand the scope of this rapidly developing new area. Cyber Deception is tipped to be one of the biggest

growing sectors of Cyber Defense and Security in the coming years. There is a fundamental difference between how deception-based mechanisms work in contrast to traditional security controls. Deception-based techniques provide significant advantages over traditional security controls [25, 27]. Cyber deception considers trends and developments in deception technologies, threat hunting, analysis, and sensor capabilities, evolving tactics, techniques and procedures (TTPs) of hostile attackers and explores the contribution that it can make to defeat them as well as additional opportunities for capability enhancements in the near-term [6].

Section 2 deals with basic notions on hybrid threats and Cyber Deception Technology. Section 3 explains Hybrid Threats Model, including convergence between Cyberoperations and Electronic Warfare. Case study on Deception based Defense Platform Design is described in Section 4. Conclusive last section reveals benefits which can be achieved by application of proposed concept. The approach itself is open for enlargement, dynamic adjustments and extensions needed to fulfill business and cybersecurity system needs.

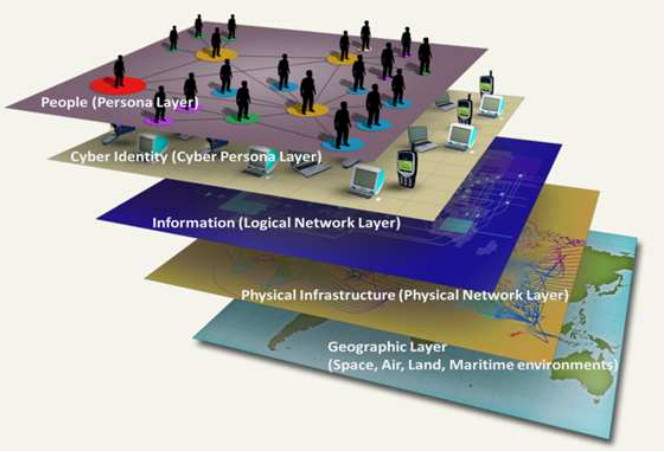

Figure 1
Cyber Environment

2 Basic Notions on Hybrid Threats and Cyber Deception Technology

A cyber attack can be invisible, asymmetric, multi-role, deniable, global/instantaneous and a complete doctrine changer when the attacker has the advantage, which makes it an ideal toolset for big and small actors alike. A wide variety of parties (actors) are active in cyberspace, including own forces, allied forces, neutrals and adversaries. A range of the actors can be classified as threats, actual or potential:

- Nation-states: nation-states are well-resourced actors that are characterized by geopolitical-, economic- and/or military motivations. They are capable of launching enduring and/or sophisticated attacks, often for intelligence and/or sabotage purpose. Nation-states often work through proxies.

- State-proxies: state-proxies are private organizations and/or institutions that are sponsored and supported by a government to help that government to achieve its geopolitical, economic or military objectives.
- Cyber terrorists: groups of people or individuals who attack or influence networks, systems and information, especially against civilians, to spread terror or in the pursuit of political aims.
- Cyber criminals: criminal groups driven by profits. They are typically looking for personally identifiable information (PII), critical digital resources to hijack for ransom or lucrative ways to conduct their classic criminal business online.
- Hacktivists: individuals who adhere to a specific cause and set up attacks to distribute propaganda or to damage organizations to which they are opposed.
- Insider threats: individuals from within the own organization who misuse privileges and resources accidentally or on purpose (e.g. disgruntled employees).

Overlaps may exist between different categories of threat actors as particular actors may choose to employ other categories as proxies. Extensive reuse of TTPs by different types of threat actors renders the distinguishing of categories by this means a hazardous proposition [14]. This paper aims to construct the novel model of hybrid threats as well as to investigate actions for cybersecurity and cyber defense in conditions of increasing challenge of cyber attacks and the limited capabilities to respond to this threat. Secondly, the aim is to describe the platform and solution for threat detection using deception-based methods putting it into the context of the aforementioned developed model. Deception Technology was one of the most researched hot topics in 2019, only second to Zero Trust. Analysts have also increased their coverage and endorsement of cyber deception as a foundational threat detection solution for organizations of all sizes. Deception has materially changed in its capabilities as well as operational efficiency over the last decade. It is now a far cry from the original honeypot [3].
In comparison with the newest related work in the area related to security operations technologies and services innovations aiming to help security and risk management leaders enhance their strategy [5, 16], our paper originality lays in investigation of the cyber deception platform and industrial model and solution for threat detection using deception based methods, within the Hybrid Threats Model.

2.1 Hybrid Threats

New information technologies have reduced appreciably the distance – physical, temporal, and informational – between the troops and their superiors. Remote engagement of the enemy 'at arm's length' is turning into the principal tactic to achieve the goals of combat action or operation. Adversary targets are now attacked at any point of enemy territory. Differences between strategic, operational, and tactical actions, and between offense and defense are leveling off. High-precision weapons are used on a growing scale. Weapons based on new physical principles and robot-controlled systems are going into service in large quantities [9]. The rapid devel-

opment of information technologies in the late 20^{th} and early 21^{st} centuries, and widespread use of information in society and the leading countries' armed forces have changed significantly nature, methods, and techniques used by state and government political and economic agencies, affected social relationships and the nature, methods, and techniques of military operations, and created new information threats and challenges [10]. Characteristics of hybrid threats are [15]:

- Coordinated and synchronized,
- Deliberately target democratic states' and institutions' systemic vulnerabilities,
- Use a wide range of means,
- Exploit the threshold of detection and attribution as well as the border between war and peace,
- Aim to influence different forms of decision making at the local (regional), state, or institutional level.

Hybrid Warfare is a combination of multiple conventional and unconventional tools of warfare (Figure 2) [15].

Figure 2
Hybrid Warfare

2.2 Cyber Deception Technology

Cyber defense focuses on preventing, detecting and providing timely responses to attacks or threats so that no infrastructure or information is tampered with. Security operations technologies and services defend information technology (IT) systems from attack through the identification of threats and exposure to vulnerability, enabling effective response and remediation [21, 28, 29, 30]. The innovations included here aim to help security and risk management leaders enhance their strategy. The

focus of Gartner's Hype Cycle for Security Operations 2020 report's approach to deception is an organization's readiness for deception [5, 16].
The next three paragraphs explain the following terms in connection with cybersecurity: Security leaders, Data points and Maturity.
Security Leaders. It will prove to be an impossible task for any leadership team to be confident that their current security control set allows them to be prepared for every eventuality. More importantly, leadership teams need to try and deliver cyber resilience and keep systems operational. Therefore, being able to detect threats on its own may not be enough. Detection and prevention need to be fused together to deliver operational resilience. The key here is not to spend the security budget entirely on detection but to think about being able to detect attack vectors well before they get anywhere near your networks. This is referenced in the Gartner report as "intelligent business-driven decisions". The challenge for security leaders is how to get to the point whereby they are empowered to make those types of decisions. To make the right decision the correct data points are needed.
Data points. For data points to empower decision making, they need to possess a number of key characteristics. The data points must be contextualized, relevant, timely and have a very low operational overhead to generate and process. Deception technology and security tools can produce these types of data sets in an automated manner, delivering the right data at the right time, thus empowering decision making that is business-centric and intelligent. Most importantly, we do not have to wait to detect the attackers once they are inside our network and impacting our operational processes. Having the ability to deploy deception campaigns beyond our network perimeter (including cloud or a hybrid infrastructure) empowers us to get ahead of our adversaries. Understanding what tactics, techniques and procedures are being used against the organization's TTPs will enable a preventative posture to be adopted by leadership teams. There's a need to collect the correct data sets on attackers that enable to detect them whilst they are trying to breach an organization's network and not after the event.
Maturity. It all sounds like the kind of activity that the very large global organizations would be undertaking because they have the resources that allow them to think about and execute intelligent business-driven security operations. In the Hype Cycle Report, it is made clear that organizations of all security maturity should be examining the value that deception can bring them – allowing them to fuse prevention and detection into a fully strategic security operations model. The next three paragraphs describe Low, Medium and High Maturity organizations levels. For each maturity level, the key strategic benefits of deception technology should be defined.
Low maturity organizations. Those that are defined as not being capable of managing solutions such as Security Information and Event Management technologies (SIEMs) due to a lack of resources. This type of organizations would benefit enormously from deception technology. The Cyber Deception Platform not only scales seamlessly but the scarcity of false positives and high fidelity of alerts powerfully remediates the pain points commonly suffered by such organizations. But it does much more than remediate paint points; it enables powerful new functionalities such as the ability to generate threat intelligence that is specific to such organizations and fully correlated and contextualized. Pivot away from simple detection and into prevention and actionable intelligence.

Medium-Maturity Organizations. Defined as organizations that may already have SIEM and Endpoint Detection and Response as an emerging technology that addresses the need for continuous monitoring and response to advanced threats (EDR) type technologies. The cost in terms of time and resources can make leveraging such technology to deliver preventive security very difficult. EDR is also up against a number of different techniques that can circumvent it, such as process hollowing. To mitigate these pain points, deception technologies can provide a different means of detecting the attackers, by forcing the attackers to be right all of the time instead of those that are defending the network. There is a possibility to turn the probability of detecting an attacker in an organization's favor by forcing him into impossible choices. The solution that allows to pivot away from detection into prevention by allowing an organization to deploy campaigns that enable it to map and correlate attackers well before they get anywhere near the organization's network is needed. Fusing together detection and prevention into a single platform allows us to develop a defense-in-depth strategy that is coherent and forward-thinking.
High-maturity organizations. According to the report, may want to use deception technology in a number of different situations, such as in operational environments Supervisory Control and Data Acquisition (SCADA), Operational Technology (OT), where traditional security toolsets are not a viable option. In addition to this, the report states that deception technology can generate local threat intelligence. Mature security organizations use deception technology to actively collect data points on different types of threat vectors and actors that are looking to target them. Rather than wait for attackers to get inside the network, organizations have to map adversary behavior to draw out not only TTPs but also the strategic objectives of the threat actors. Understanding both data sets allows an organization to understand if currently deployed security controls would be effective against attackers with these particular strategic objectives in mind. With the cyber deception platform, multiple campaigns can be created and automated, allowing an organization to create intelligence-led deception campaigns that allow an organization to gather the intelligence they need to empower themselves and to make "intelligent business-driven decisions" [16].
The question is not if the organizations are mature enough for deception, but: if they want to make "intelligent business-driven decisions". If the answer is yes, then they have to leverage the power of cyber deception to empower the organization. Intelligence-led decisions will not only create a more cohesive security strategy, but it will drive down risk and the costs associated with those risks if they were ever to materialize [9].

3 Hybrid Threats Model

This Section, first of all, deals with Convergence between Cyberoperations and Electronic Warfare, given in Section 3.1. Then, in Section 3.2, New Generation War concept is explained. Section 3.3 explains such a terms as Identified Knowledge, Identified Risk and Unidentified Risk as qualitative approach to threats and risk identification and classification. In the last Section (3.4), some directions on further development of cyber deception are elaborated.

3.1 Convergence between Cyberoperations and Electronic Warfare

Communications and Information Systems (CIS) and weapon systems must face an increasing number of cyber-attacks using the Electro-Magnetic Spectrum (EMS) as a component of the kill chain. Moreover, a combination of cyber activities and Electronic Warfare (EW) are proliferating and tend to lessen systems' resilience to an unacceptable level. Therefore, cyber defensive operations have to integrate EMS comprehension and dominance as a key factor. Exploring similarities and differences between cyber and EW is yet necessary to strengthen detection and remediation of offensive Cyber Electro-Magnetic Activities (CEMA), and contribute to developing defensive CEMA schemes.
Cyberspace defensive operations can benefit from EW techniques when the electromagnetic spectrum is used as a vehicle for a cyber-attack. For example, active electronic scanned array (AESA) radars (which allow thousands of radio beams to transmit at once) and software-defined radios (which transform how a radio wave is transmitted) can rely on computer systems to manage their exposure to spectrum operations. The software can help shape how these radars and radios transmit, potentially making it difficult for an adversary to either detect jam or attack their transmissions. Changes to the software can easily transform a radar or radio from a receiver to a transmitter. Having small, adjustable arrays allows AESA radars, in particular, to focus small beams of radio energy on potential targets.
Electronic warfare is part of Electro-Magnetic Spectrum Operation. Spectrum Management Operations (SMO) mission is to manage the administrative, engineering and operation of the electromagnetic spectrum. Electronic warfare can also be defined in missions (such as support measures or countermeasures), which contain several objectives of actions.
We can define the following activities that would be part of cyber operations:

- offensive cyber operations (OCO);
- defensive cyber operations (DCO) (including active defense);
- cyber intelligence, surveillance and reconnaissance (cyber ISR); and
- cyber operational preparation of the environment (cyber OPE).

The convergence between cyber and EW is defined as the synchronization and coordination of offensive, defensive, inform and enabling activities, across the electromagnetic environment and cyberspace – CEMA (Cyber and Electro-Magnetic Activities).
Cyberspace can be described with the following properties:

– Bilateral Human and network engagement,
– Hyperconnectivity and networking,
– No geographical boundaries,
– Not owned or controlled by governments, but by commercial entities.

3.2 New Generation War

Cyber threats are multi-faceted and rapidly evolving. A military commander needs a cyber decision support system tailored to the mission to react quickly and assign tasks to subordinate units. Impact assessment and risk management are essential parts to evaluate the cyber situation and to offer remediation as part of a mitigation plan [7].
Exploring similarities and differences between cyber operations and Electronic Warfare we can notice that Electronic Warfare and Cyberspace are interdependent because as Electromagnetic spectrum is used as a medium for Cyberspace in a similar manner. Cyberspace can have an impact on Electromagnetic systems which are vital for military operations. The main challenges of conflicts where cyber-attacks are involved, affect all military domains. Digitalization provides opportunities but also new risks for cyber-attacks. With respect to the strategic and tactical planning, the biggest problem lies in attribution, i.e. finding out who carried out a cyber-attack. Attribution is vital when it comes to actions of retaliation against another nation-state and possibly engagement in a cyberwar. A malicious attack can easily be spoofed therefore disguise its actual origin, making it nearly impossible to trace back to the original source. This reality fosters covert cyber operations and becomes vital for cybercrime and cyberwar. In order to avoid international misinterpretations and retaliation against possibly innocent countries, it is necessary to develop an international system of order for the cyber world. The probability of starting a cyber war based on a misunderstanding and, or pre-emptive retaliation based on missing information, against an innocent actor, is high in the current unregulated cyber world that is directly connected to our future IoT (Internet of things) and our military IoBT (Internet of battle things) [7, 33].

3.3 Identified Knowledge, Identified Risk and Unidentified Risk as qualitative approach to threats and risk identification and classification

Although unknown unknowns may be unidentifiable, they might be presumed likely in some component of the system. A likely event cannot be thought to be unknown unknown because it is already identified, but its consequence may fall into the category of unknown unknowns. The occurrence of an event like a natural disaster may be forecasted easily, but its impact is not easy to predict or estimate because of knock-on effects. Despite that project risk management acts as “forward-looking radar” it is not possible to identify all risks in advance, in part for the following reasons [11]:

- Some risks are inherently unknowable.
- Some risks are time-dependent.
- Some risks are progress-dependent.
- Some risks are response-dependent.

A typical classification of risks is based on the level of knowledge about a risk event’s occurrence (either known or unknown) and the level of knowledge about its

Table 1
Schematic Structure of Modified Risk Categorization

Certainty / Identification	Certain (Known)	Uncertain (Unknown)
Identified (Known)	Known known (identified knowledge)	Known unknown (identified risk)
Unidentified (Unknown)	Unknown known (untapped knowledge)	Unknown unknown (unidentified risk)

impact (either known or unknown). This leads to four possibilities:

- Known–knowns (knowledge),
- Unknown–knowns (impact is unknown but existence is known, i.e., untapped knowledge)
- Known–unknowns (risks) and
- Unknown–unknowns (unfathomable uncertainty) [4].

The proposed model modifies and extends these categories to incorporate insights and explain how to use the model to identify hidden uncertainties and shows how recent catastrophes can be mapped to the model. Table 1 [11] shows a schematic structure of the risk categorization. In this table, the model categorizes events by "identification" and "certainty".

In this matrix, if the nature of an event is certain, it is more like a fact or knowledge. It could be what we already know, i.e., known known, or what we don't know yet, i.e., unknown known. If the nature of an event is uncertain, the occurrence can be uncertain, i.e., the probability of occurrence is less than 1, and the impact can be uncertain as well. For example, a hurricane has two basic uncertainties. One is a track, represented by the chance of landfall, and the other one is intensity, represented by wind speed or hurricane category. If either one of occurrence or impact is uncertain, that event is considered to be uncertain. Often, people know the identity of an uncertain event, which means known unknown. Sometimes, people even don't know what that is, which means "unknown unknown". Most natural disasters are uncertain events, but people already know what they are.
Once identified, an unknown unknown is converted to a known unknown and moved to the quadrant at the right top in this matrix. Converting unknown unknowns to known unknowns means reducing the number of unidentified uncertainties even though we don't know how many of them are still remaining unidentified. The more unknown unknowns are identified, the less chance a project will have to be affected by a surprise [8, 11].

3.4 Further Development of Cyber Deception

Following the establishment of UK National Cyber Deception Laboratory (NCDL) as a non-profit entity will bring together a unique range of internationally renowned practitioners and researchers in the field of Cyber Deception across government,

academia and industry. By building on this existing foundation NCDL aims to create an environment that catalyzes imaginative and innovative cyber deception research. Cranfield University, in partnership with the UK Defense Cyber School, will support the establishment of the NCDL which will facilitate, encourage and promote a world-class portfolio of research activity, and provide advice across the full spectrum of cyber deception operations. In particular, NCDL will conduct research aimed at exploring concepts within each of the following themes:

- Cyber Deception in the context of national defense and security,
- Denying attackers the freedom to operate within organizations' networks,
- Cyber Deception as an effective means of manoeuvre in cyberspace,
- Communicating intent to aggressively defend,
- Deterring Cyber attacks,
- Shaping the behavior of cyber attackers,
- The layered approach to defensive cyber operations,
- Developing the means to exploit cyberspace to the best advantage,
- Moving Cyber Defense on to the front foot.

4 Case Study

One reason for the bump of deception technologies is the typically low signal-to-noise ratio of traditional enterprise security systems, which disposed tons of data and not nearly enough meaningful, actionable priorities. Attivo's platform is designed to do the aforementioned while touching on important use cases for detection, verification, vulnerability management and analysis, controls and automation, and anti-malware. The method is to see and recognize critical behavioral signals among gobs of noise. The expectation is that network-based deception technologies will continue to rise in terms of relevance as a key adjunct to broad-based layered security, certainly in key verticals, and perhaps extending over the longer term to mainstream use.

4.1 Deception-based Defense Platform Design

Sometimes is heard that defensive security technologies need to adapt and play some offense, too. Offensive security includes capabilities and orientation to see and process intelligence and target opportunity data in the manner of an attacker. Target analysis is the focus of penetration testing, vulnerability management and attack simulators – each an area of intensified product and service innovation in recent years. Attack surface area has been broadly elevated to blatant conceptual risk, and technologies such as micro-perimeters can reduce and obfuscate application target profiles to very low levels. Network and endpoint targets are getting an upgrade as well, with deception technologies converting attacker data for active defense use

cases. Lack of dedication to improving contextual intelligence and work prioritization has come to the surface in the dialogue between customers and vendors. Vendors can look over customers' shoulders and see a range of underutilized commercial so-called 'solutions' – perhaps even their own. Deception technologies have evolved from honeypots and honeynets and are now mainstream in spots, such as a sandbox capability to overcome malware's resistance to emulation [2].

4.1.1 Example 1

Product. Attivo characterizes the market opportunity for its ThreatMatrix platform as one of continuous threat management, geared to early and high-efficacy detection, verification, and response to advanced external and internal threats. Deploys out of band using a switch trunk port; components emphasize a lightweight yet comprehensive presence, authentic and dynamic behavioral deception, early and accurate detection capabilities, and scalability. Competes roughly equally, we would say, on the basis of deception realism, detection accuracy and comprehensive capabilities. By its nature, post-breach deception technology has to be able to detect and inform on attacks that were able to overcome other defenses. ThreatMatrix for detection and tracking is designed and indicates that customers derive strong value from their ability to follow, in a safe environment, attack steps and lifecycles, including lateral movement, privilege escalation, polymorphic obfuscation, and time-triggered strategies. The ThreatMatrix platform includes BOTsink engagement servers and decoys, ThreatStrike endpoint deception suite, ThreatPath for attack path vulnerability assessment, and Central Manager for larger deployments and threat intelligence. An approach to deception is designed to facilitate simulation of user networks, endpoints, data center and cloud environments, industrial control systems, IoT and point-of-sale environments. Out-of-the-box integrations with major perimeter, endpoint and SIEM vendors facilitate automated blocking and quarantine of attacks based on ThreatMatrix detection and analysis. An additional console (ThreatOps, in development) will add bidirectional controls to bring Attivo's detection and verification capabilities to a wider security operations footprint, including attack intelligence sharing, playbook enhancements, attack scoring and threat hunting. BOTsink appliances and cloud instances are available in two sizes, depending on the number of virtual local area networks (VLANs) supported. ThreatStrike deception objects may include credentials, browser cookies, ransomware bait with attacker engagement and file detainment, and email phishing (ribbon bar) icons for users to submit suspicious messages for analysis. The suite includes an endpoint device. ThreatPath calculates potential vulnerabilities associated with misconfigurations and misused credentials and is priced by an endpoint, and complements adversary tracker, which indicates attacker movement and associated timelines. Management reports good trajectories for average deal size and renewals; service terms are typically twelve months, but occasionally run to multiyear.
Technology. Deception and other simulation technologies meet a growing need for advanced behavioral-driven detection and analysis to improve, if not change, traditional network security, and not merely perimeter-based weaknesses. Deception is but one example of simulation technique applied to cybersecurity challenges; security vendors leveraging simulation for a range of use cases may be on the cusp

of breaking into wider view. Deception technology platforms have evolved from honeypots and honeynets to encompass a cross-section of techniques, including detection through simulation (i.e., deception), sandboxing, attack verification, attacker surveillance through engagement, automation, forensic analysis, and increasingly wider assimilation with production environments. BOTsink engagement (deception) server hosts the company's core Multi-Correlation Detection Engine (MCDE), which includes a network sandbox. Management contends that the design approach for MCDE provides for not only high-fidelity attack verification and drill-down inspection, but also vital integration with incident response activities, including forensics, compliance (e.g., chain of custody) and automation. The company indicates that some customers are also using MCDE to ingest artifacts from other sensors and detection systems. MCDE analytic output (including IOC, PCAP, STIX, CSV formats) can be viewed through Threat Intelligence Dashboard or SIEM consoles and used by prevention, isolation, or remediation workflow systems. Components of a comprehensive deception setup include an engagement server and a diverse set of decoy lures (typically virtual machines) running over real OS instances, including network services, endpoints, credentials, data and file shares, servers, cloud environments and applications. Realism in decoy targets is critical and includes attributes such as golden images of customized environments, currency and logical proximity to actual targets, and protection with similar fortifications. Recently introduced Camouflage is a branded framework for authenticity through dynamic behavioral deception, and it underscores the company's targeted edge in terms of breadth and depth for the platform's lures. Camouflage updates in field trials include automated self-learning for disparate environments, and continuous post engagement bait freshening (i.e., decoy respins) to avoid attacker fingerprinting and evasion [2].

4.1.2 Example 2

Innovation in threat detection. Detection using deception-based methods provides the innovation required to non-disruptively evolve to an Active Defense security posture. By placing a detection net over endpoints or by deploying a fabric of decoy-based detection throughout the network stack, companies can achieve efficient detection for every threat vector, early in the life-cycle of an attack. Deception uses a mix of high-interaction decoys, lures, and misdirections to deceive attackers into revealing themselves, quickly alerting on and identifying the lateral movement of threats that have evaded other security controls (Figure 3) [2].
These solutions are proactively uncovering and responding to external, internal, and third-party threat actors. Organizations of all security maturity levels are aggressively adopting these technologies to mitigate risks related to employee credential theft, data exfiltration, ransomware, crypto-mining, and attacks that try to disrupt services or impact public safety. The accuracy and ease of use of this detection method have been a significant driver in its adoption and wide-spread deployment [2].

Solution. The ThreatDefend® Detection and Response Platform uses endpoint lures, misdirections, and high-interaction deception decoys that provide early visibility into in-network threats, efficient continuous threat management, and acceler-

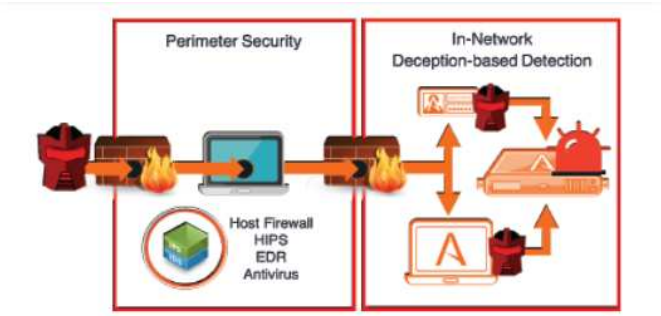

Figure 3
Deception-based Methods for Innovation and Evolvement to Active Defense

ated incident response.
The ThreatDefend platform, recognized as the industry's most comprehensive in-network detection solution provides a detection fabric for cloud, network, endpoint, application, data/database, and Active Directory decoys and is highly effective in detecting threats from virtually all vectors such as APTs, stolen credentials, Man-in-the-Middle, Active Directory, ransomware, port knocking and more. These deceptions can deploy within all types of networks, including endpoints, user networks, server, data center, ROBO, cloud, and specialty environments such as IoT, SCADA, POS, SWIFT, infrastructure, and telecommunications (Figure 4).
The ThreatDefend Deception Platform creates an active defense against cyber threats. It includes the BOTsink® deception servers for decoys, the Informer dashboard for displaying gathered threat intelligence, as well as the ThreatOps® incident response orchestration playbooks; and the Endpoint Detection Net suite, composed of the ThreatStrike® endpoint module, ThreatPath® for attack path visibility, and ADSecure for Active Directory defense. The ThreatDirect deception forwarders support remote and segmented networks, while the Central Manager (ACM) for BOTsink and the Endpoint Detection Manager for EDN deployments add enterprise-wide deception fabric management.

Detection and attack path visibility. The platform provides unparalleled visibility into threats inside the network and attacker lateral movements and tactics. The platform detects advanced threats propagating throughout the network by laying strategic decoys and lures to deceive, detect, and defend against attacks as they scan network clients, servers, and services to target and seek to harvest credentials.
Lures and decoys work together to attract and detect attackers in real-time, raising evidence-based alerts while actively engaging with them so that the platform can safely analyze their lateral movement and actions. For attacker believability, the decoy systems mirror-match production assets by running real operating systems, full services, and applications, along with the ability to customize the environment by importing the organization's golden images and applications. As a result, the platform creates environment designed to redirect attackers away from company assets. Machine learning prepares and deploys the decoys, keeping the network and endpoint deceptions fresh and making ongoing maintenance easy.

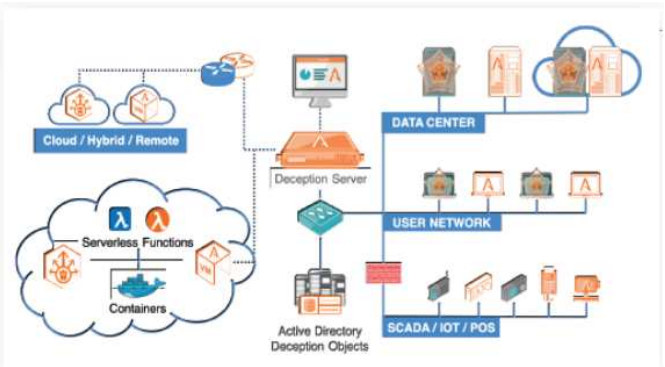

Figure 4
The ThreatDefend Platform

To increase decoy authenticity and for visibility into attempts to compromise systems or recon Active Directory, the solution creates AD decoys both as fake AD controllers and at the endpoints to modify unauthorized AD queries. By inserting deception into areas that attackers target for reconnaissance, the deployment appears as part of the production environment in multiple layers. The ADSecure solution looks out for unauthorized AD queries, alerts on the activity, and alters the response to return fake AD objects that lead to decoys for engagement. The solution disrupts network discovery attempts by detecting and alerting on ping sweeps and port scans. Additionally, it redirects any port scans that touch a closed port on a host to an open port on a decoy, making host fingerprinting difficult and misinforming the attacker as to the actual ports and services accessible on a host. This capability does not interfere with any production services while providing early detection of attacker lateral movement. The solution can natively isolate any inbound or outbound traffic on a host to connect only with the decoy environment. Endpoint deceptions and hidden mapped shares provide easy and highly effective redirection of attacks seeking to harvest credentials or execute a ransomware attack. Additionally, the endpoint defenses can hide local files, folders, removable drives. For remote workers, the ThreatDefend platform protects both the VPN infrastructure and credentials for VPN, cloud PaaS, IaaS, and SaaS. The solution can deploy decoys within the VPN network segment to identify network discovery and AD reconnaissance activities that indicate lateral movement. It seeds fake VPN credentials at remote endpoints that alert on remote theft and reuse and integrates with cloud services to monitor for unauthorized use. With the rapid migration to the cloud, the detection fabric needs to scale seamlessly anywhere the enterprise network sits. The ThreatDefend platform offers extensive support for AWS, Azure, Google, and Oracle cloud environments inclusive of decoys and lures for containers, storage buckets, and other native cloud technologies. The ThreatDefend platform capabilities include support for serverless functions, access keys, reconnaissance, credential harvesting, and verifying the efficacy of security controls, along with CloudWatch/SIEM monitoring for finding attempted use of deception credentials. The ThreatPath solution reduces the attack surface and proactively increases se-

curity by identifying misconfigurations and credential exposures that create attack paths for attackers to use for lateral movement. A topographical visualization and attack path associations provide a straight-forward view of how attacks can reach their target. When paired with the BOTsink server's threat intelligence and attack time-lapsed replay, defenders achieve unprecedented levels of threat visibility and the information required to build a pre-emptive defense against its adversaries [2].
Active defense and accelerated incident response. In addition to the early detection of attackers inside the network, the ThreatDefend platform's actionable alerts, automated analysis, and native integrations for incident handling work collectively to dramatically improve a responder's time-to-remediation. When an attacker engages with a decoy system, credential, application, data, or Active Directory object, the ThreatDefend platform records, and alerts on the activity while simultaneously responding to the attacker. The Informer dashboard consolidates the data and assembles forensics, correlates events, and raises evidence-based alerts on malicious activity. Alerts only occur on confirmed attacker interactions with the decoys or engage within the Endpoint Detection Net, and, unlike other detection methods, does not depend on signatures or behavioral analysis to detect an attack. The attack analysis substantiates alerts the security teams can use to automate the blocking of an attacker, to isolate an infected system, and to hunt for other compromises so that a company can completely eradicate the threat from the network. Minimizing false positives and creating high fidelity alerts save valuable hours for security teams in both investigation and response time. The Informer dashboard presents a comprehensive view of the incident and forensic information gathered during an attack. Forensic reports include identifying infected systems and command and control (C&C) addresses and available as exported IOC, PCAP, and STIX file formats to allow easy information sharing and attack recording. By correlating all relevant information and forensics from an event into a single interface, the Informer dashboard gives analysts and incident response teams a streamlined view of an attack to effectively contain and remediate the incident. This accelerates intelligence-driven response, enhances network visibility, and creates a predictive defense to improve their security posture. The solution enables offensive counterintelligence functions designed to disrupt the attacker's ability to collect accurate information. It also provides defensive counterintelligence functions as it diverts attacks from production assets, and collective counterintelligence information on attacker TTPs and IOCs, giving insight into attacker objectives. Additionally, DecoyDocs delivers data loss tracking, allowing organizations to track stolen documents inside or outside the network, and the ADSecure solution gives insight into attacker goals based on the high-priority AD objects they are targeting. Organizations can also use the ThreatOps functions of the BOTsink server to automate incident handling and create repeatable incident response playbooks. Organizations can fully customize this threat orchestration function to match their environment and policies so that security teams can make faster and better-informed incident response choices [2].

Conclusions

The future of warfare will be in a digitalized multi-domain environment, which needs new doctrines [24, 35] for the conduct of operations. To ensure the readiness of the capacities needed for this new environment, research in all relevant domain-specific cyber capabilities is needed. Each military domain has its own requirements for cyber as different sensors are used, different procedures and different tactics for automated responses are needed. The Cyber research requirements for the military cyber domain are often underestimated, as the research requirements are twofold. First, the military cyber domain needs to develop its own protection and attack capabilities, which are often not available on the market. Second, the military cyber domain needs to develop protection techniques, sensors and procedures to protect the military cyber infrastructure of all other military domains. Moreover, the military cyber domain needs to be prepared for attacks on the national cyber infrastructure, including infrastructure for civilian use, in case, commercial cyber protection measures are not working. This range of military cyber responsibilities is often underestimated. But the main result of the cyber threat assessment showed clearly, that the existing cyber defense strategies, need improvement to counteract the existing cyber threats [7].

New technologies are expected to increase the speed of conflict dramatically. The military strategy is confronted with the pervasive connectivity of sensors and various sources of information. The internet of the battle things (IoBT) will bring radical changes to the digitalization of the battlefield [34]. Solutions are yet to be tested on how this abundance of information is going to be leveraged, by new technologies like the use of big data (e.g. [19]). This fast transformation will also affect the commander's decisions and the way information is processed. In this context, the existence of a Global Information Grid (GIG) is evident. It comprises a group of networks to connect ground, maritime, air, space and cyberspace assets, able to communicate in a joint operation. The joint network must ensure a "secure register" to identify whether an asset is trustful or not. One of the main challenges affecting the "internet of the battle things" is that devices can be lost, reverse engineered and brought back to the battlefield by an opponent. To avoid losing our tactical advantage, a "secure register" is needed. Other features - to maintain the confidentiality, integrity and availability of the information handled by military communication and information systems – are interoperable secure sensors connected to the GIG, intelligent devices fed with AI algorithms to identify an exchange of meaningful information, the availability of secure clouds to store information and AI-supported multi-domain operations to achieve tactical and strategic effectiveness. In this realm, quantum computing [36] will be a crucial factor further increasing battlefield complexity. A holistic approach to new scenarios opens the operational environment to non-military aspects highlighting the need to implement information exchange practices with civilian actors. Moreover, apparently unrelated events in other sectors e.g. economy or energy may have consequences for military missions. These features, influence the design of future Command and Control (C2) systems and need to be considered when new processes, regulations and strategies, for military forces are developed to take full advantage of the digitization of military technology [7].

Organizations are applying deception and detection techniques to the global fight for information dominance, where they need an advantage against the adversary. Well-architected deceptive environment can be used in a tactical manner, to aid awareness, identification, and provide the necessary fidelity around alerts and adversarial movements. We can use deception to monitor the awareness of our attacker, and measure or assess the effectiveness and integrity of our response options [3].
Finally, Cyber Deception Platform and Industrial Solution are presented: Threat-Defend® Platform scalable solution for derailing attackers and reducing the attack surface within user networks, data centers, clouds, remote worksites, and specialized attack surfaces. The portfolio defends at the endpoint, Active Directory, and throughout the network with ground-breaking innovations for preventing and misdirecting lateral attack activity. Forensics, automated attack analysis, and third-party native integrations streamline incident response [1]. The novel constructed model of hybrid threats as well as the results of investigation of actions for cybersecurity and cyber defense in conditions of increasing challenge of cyber attacks and the limited capabilities to respond to this threat is presented.
Some future research should be conducted within NCDL (as mentioned in Section 3.4) where researchers, suppliers and customers will be brought together to address problems, explore opportunities and advance capabilities in a space not previously explored, in order to support collective understanding in the space of cyber deception to aid the development of capabilities and strategies as well as in the provision of advice and guidance on cyber deception in proactive defense more broadly [6].
We described the design and performance of industrial model – cyber deception platform and solution for threat detection using deception-based methods, introducing a novel approach to cybersecurity and cyber defense putting it into the context of the Hybrid Threats Model within Hybrid Warfare.
The ways (processes) and means (resources) of cyber deception pre-emptive approach can impair the effects of cyber-attacks through getting information about adversaries' behavior into an organization and consequently achieving the enhancement of the level of resilience by reducing "unknown unknowns" (unidentified risk: unidentified/uncertain), transferring them to identified risk (identified/uncertain) and "known knowns" (identified knowledge: identified/certain) sequentially.

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Adaptive Bagging Methods for Classification of Data Streams with Concept Drift

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Abstract: Data streams represent a continuous stream of data, in many forms, coming from different sources. Streams are often dynamic and its underlying structure usually changes over time. When solving predictive tasks on the streaming data, traditional models, trained on historical data, may become invalid, when such change occurs. Therefore, adaptive models, equipped with mechanisms to reflect the changes in the data, are suitable to solve these tasks. Adaptive ensemble models represent a popular group of such methods used in classification tasks on data streams. In this paper, we designed and implemented the modifications of the adaptive bagging methods, which utilizes internal class-weighting schemes for the model adaptation. Implemented models were evaluated on two simulated real-world data streams and compared with base classifiers and other adaptive methods. In addition to the performance evaluation, we also analyzed other models' characteristics, such as the duration of model update and memory requirements.

Keywords: concept drift; classification; data streams; ensemble learning

1 Introduction

Nowadays, the size of data is growing much faster, than in the past. Information is being collected from household appliances, tools, mobile devices, GPS, vehicles, various sensors, websites and many other sources. An increasingly large number of organizations are starting to analyze this big data, as the information obtained from these data can provide a competitive advantage over other businesses. Data collection from devices is often continuous, and the data comes in the form of data streams [1]. The data stream can be defined as potentially unlimited, ordered sequence of data items coming in over time. The data streams can be divided according to whether they provide data incrementally (sequentially, one item by one) or in blocks of data. The blocks usually have the same length, and their processing, evaluation or updating is done when all the examples in the new block are available.

There are two basic types of data streams: stationary and non-stationary [2]. For stationary streams, examples are drawn from a fixed, albeit unknown probability distribution. A significant change in attributes is not expected, so in case of predictive tasks applied on this type of stream, it is possible to use a model trained on historical data as expected to perform in constant accuracy over the time. Non-stationary data streams are characterized by changing data over time [2]. This results in a gradual or sudden fall of the models performance. In other words, the concept, which generates a data stream moves after a minimum period of stability. This phenomenon of shifting is called a concept drift or a covariant shift [3].

When solving predictive or classification tasks on streaming data, the data generation process is not strictly stationary and its underlying structure may change over time. From the model training perspective, one of the essential requirements is the ability to adapt and incorporate new data into the model to react to the potential drift occurrence [4]. In that field, the adaptive learning algorithms are advanced machine learning methods that can adapt to new data streams in real-time. There are multiple types of adaptive learning models available, including ensemble methods. Ensemble methods are based on a combination of several models and a combination of their individual predictions into a final one. Based on a different ensemble method types, those models are trained on different training set subsets, using different subsets of predictors. When classifying of a new instance, voting mechanisms are usually applied. Often, ensemble methods have superior performance. Also, due to the method's nature, it is relatively easy to scale such approaches to handle the big data. Among the most popular ensemble methods are boosting and bagging methods [5].

This paper describes the design and implementation of modifications of adaptive ensemble bagging algorithm with different mechanisms of weight-based individual models update. Two modifications of such mechanism are presented and evaluated on two different real-world data streams. The paper is organized as follows: the second section provides basic definitions related to concept drift in data streams and description of various drift types. The following section describes the actual state of the art in the area of the adaptive models used to handle the concept drift and defines the motivation for the presented approach. Next section describes the designed and implemented adaptive ensemble methods. The evaluation section, then describes experiments and results on two datasets. The last section concludes and summarizes the experimenal results and lastly, addresses some possible directions for future research.

2 Drifting Data Streams

For each point at time t, example x is generated, which has a common probability distribution $P_t(x, y)$. The concepts in the data are stable or stationary if all the examples are generated by the same distribution. However, the components in

$P_t(x, y)$ may change. If there is x between the two points t and $t + \Delta$, which holds the expression $P_t (x, y) \neq P_t + \Delta (x, y)$, then a concept is drift present. Some real-world examples of the drifting data may include:

- Traffic monitoring, where traffic may vary over time,
- Weather forecast where climate change and other natural anomalies can affect the final prognosis,
- Systems for tracking individuals' interests, such as personalized ads, where people can gradually change interests.

There are two different types of concept drift. The real drift represents a probability change $P(y/x)$. This can occur with or without changes in the probability $P(x)$. Virtual drift is defined as the change in the value of $P(x)$, or class distribution $P(s)$ that do not affect the decision boundary of the classifiers. Sometimes a virtual drift is defined as a change that does not affect later probabilities. Virtual drift is also referred to as temporary drift or sampling shift.

In addition to the differences between the cause and the effect of changes in concepts, we distinguish several ways these changes have occurred. According to the frequency and velocity of the concept drift, we can recognize four different categories [6]: incremental, gradual, sudden and reoccurring drift. A sudden drift occurs when, at time t, the target distribution S_t , is suddenly replaced by another distribution $S_{(t + 1)}$. For example, when city crime data is gathered, and the classifier tries to predict the development of crime based on these data, and a change in legislative may cause, that some crime types can be classified under a different kind or some cases are no longer considered as offences. With gradual drift, data transformations are not so radical and are associated with a slower rate of change that can only be tracked after a long-term view of the data stream. The gradual drift refers to the transition phase in which the probability of the sample from the first distribution P_j is reduced, while the probability of obtaining the examples from the following distribution $P_{(j + 1)}$ increases. The incremental drift consists of a sequence of small changes. If the difference is slight, the drift can be only captured during observation of a more extended period of data, for example, technological developments, where the gradual development of new technologies is beginning to replace the older ones. Such development is not initially visible but becomes evident in a longer time horizon. In some cases, the concepts can revert over time. A return to previous concepts (repeated in some cycles), represents a seasonal or reoccurring drift. For example, we can use data representing an offering of seasonal jobs, where their number rises significantly at a certain point in time but returns to the original numbers after then [7].

When processing the non-stationary drifting streams, the necessary feature of the predictive algorithms is their ability to adapt. Some of the algorithms are naturally incremental (e.g. Naive Bayes), while other ones require significant changes in the algorithm structure to enable incremental processing. Therefore, the learning

algorithms applied on the drifting streams are usually modified with the mechanisms to update the model with the newly appearing concepts and on the other hand, mechanisms able to forget the obsolete ones. Drift detectors are used to detect the concept drift in the data streams. These methods can detect the possible drift occurrence by analyzing the incoming data or monitoring the classifier performance. Drift detectors then usually trigger the update of the classification model. There are several drift detection methods, Drift Detection Method (DDM) [8], Early Drift Detection Method (EDDM) [9] as the most popular ones. Methods which utilize any type of drift detection are often called as active ones. Another group of adaptive models, also called passive methods, periodically update the model, without any prior knowledge about the drift occurrence.

A very popular group of adaptive models for the drifting data classification, are ensemble models. The ensemble model is in general, composed of a collection of classifiers, also called base learners or experts. The composed ensemble model then combines individual decisions to classify the new examples [10]. The primary motivation behind the ensemble models is the assumption that a set of "weak" classifiers together can achieve better performance than individual classifiers. Bagging (or bootstrap aggregation) represents a popular ensemble method. The basic principle of bagging is in the generation of the m training sets D_i (each of the same size) of the training set D by sampling with replacement. Sampling with replacement causes that some examples from the training set may be repeated in D_i. Then, m classifiers are trained on the created training sets. Outputs of the partial classifiers are combined using voting. Usually, decision trees are applied as base learners in the bagging approach, but it can be used with any kind of classification method. Bagging models are also suitable for data streams classification where target concepts change over time. The following section summarizes the use of ensembles (including bagging methods) in the classification of drifting streams.

3 Related Work

In this section, we describe the current state of the art in the area of adaptive ensemble classifiers used to classify the drifting data [11]. Various types of different adaptive models are available, one of the frequently used groups of such models are ensemble methods. There are several versions of bagging methods implemented for data streams processing with adaptive behaviors, e.g., Online Bagging (or OzaBagging) and Leveraging Bagging [12] [13]. The advantage of these methods is that they can be used not only for processing data streams but also for static data when there is a lack of memory and computing capacity for the processing in a single iteration as evaluation and possibly update of the models on relatively small data sets is less demanding for computing performance [14].

OzaBagging [15], on the other hand, which does not use random sampling from the data, but uses the Poisson distribution, to mimic the bootstrapping. These methods are also capable of handling continuously incrementing data and can adapt to different types of drift based on different weighting rules of individual classifiers. An interesting combination is also using ASHT Bagging (trees of different size) with the ADWIN (Adaptive Windowing) approach. OzaBagging can also be combined with ADWIN when ADWIN can detect the drift and reset the worst classifier in the ensemble [16].

Adaptive bagging was successfully used in the classification of the imbalanced data streams [17]. Moreover, by adapting scalable technologies, online bagging ensembles were successfully used to tackle with the big data [11].

Most of the mentioned ensemble methods are based on different modifications of adaptation rules and different variations of voting mechanisms. The main objective of work presented in this paper is to focus on model re-training mechanisms. We used an adaptive bagging algorithm as a basis and designed and implemented several different mechanisms of partial models re-training. Our idea was based on the evaluation of partial models quality within the bagging ensemble and specifying of rules which of the partial models and how they should be re-trained. For models re-training, we used different approaches, combining re-training using both newly arrived instances and historical data. As a base model, we used tree classifiers. We evaluated the designed and implemented algorithms on two data sets – network intrusion detection and energy consumption prediction data. For evaluation purposes, we used standard model quality metrics (e.g., precision, recall, F1). On the other hand, an essential aspect of adaptive models able to handle a concept drift is also a time and resources needed to re-train and deploy the updated model to react quickly as possible to the drift occurrence. Therefore, metrics describing the resources spent on re-training of the models were also considered.

4 Proposed Adaptive Bagging Methods

We designed and implemented two different variations of the basic adaptive bagging method, each with a different way of updating individual partial classifiers. The differences between them concerned the frequency of updates of the individual ensemble members as well as the number of updated models. Another factor was the way of combining newly arriving data with historical data when updating the ensemble. Either a new sample of data was added to the historical data, and a random set was chosen from this combined sample, based on which a particular classifier was trained, or an entirely new classifier was created using the most up-to-date data and replaced the older one.

Parameter description:

- *D* - a set of trained classification models
- *IW* (iterative window) – represent the data in the current batch
- L_{IW} – the length of the iterative window
- *M* - a list containing the results of metrics (precision, recovery, F1 score)
- *N* – the number of classifiers in the ensemble
- *NU* - the number of models to be updated in each iteration
- *PL* - a set of lists containing predictors for individual classifiers
- *R* - the difference between the *TW* and *IW* sizes
- *TW* (train window) - list consists of lists containing data that are used for classifiers training
- w_i - the weight of i^{th} classifier in the ensemble
- *YP* – list of predicted class values

As the simplest variant of the adaptive bagging algorithm, we used a bagging model which updates all of its ensemble members periodically in each iteration. Its main goal is to evaluate the data in an iteration of a specified length and then update all partial models in the ensemble using these newly obtained data. Initially, the method creates multiple equal subsets of TW_x data, which serve as training data for individual partial models. In the case of working with streaming data, we could simply adjust the processing queue to the required length. In each iteration, the individual D_x classifiers are first trained on the TW_x data. Each partial model in the ensemble then individually evaluates a set of newly arriving data from the last iteration window (*IW*). The results of partial models are sets of evaluated, and the most frequent predicted value is selected. These predicted values are stored and compared to the actual values obtained from the dataset. The last step of the process is to update the *TW* training set with currently received records from the previous iteration window. If the training window *TW* is larger than *IW*, the entire set of data that from the last iteration is included in the updated training set. The rest of the data are selected from the original training data.

4.1 Adaptive Bagging – Weight Update Classifiers (WUC)

This modification of the adaptive bagging method does not update all partial classifiers in each iteration but based on the calculated weights it takes the worst-performing *N* classifiers (with the highest error rate) and updates only those. Other ensemble members remain unchanged.

In the first step, the goal is to predict IW_x data using classifiers *D*. The results are compared to the actual real IW_y values and compute the *F1 metric* for each partial classifier. The *NB* weights, with the highest values, (e.g. *NB*=3, shown in Fig. 1),

represent the ensemble members who are worst-performing members. These classifiers will be updated by re-training them using new data from the stream. The predicted class will be chosen as a majority vote of remaining classifiers (in the current iteration).

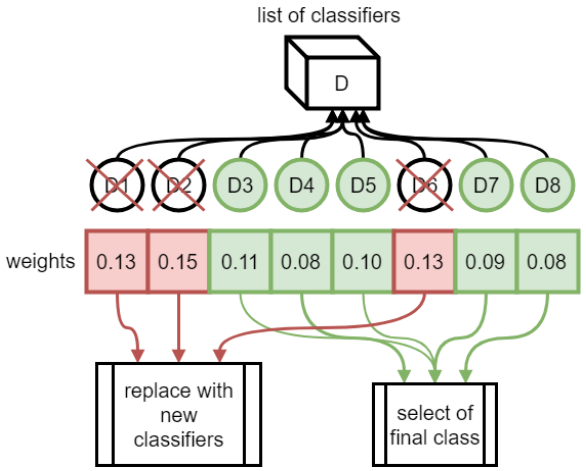

Figure 1
Determining the worst-performing members of the ensemble

This algorithm has not updated all classifiers in each iteration. It does so only with the specified number of worst-performing partial classifiers at a given time as well as it doesn't compute the prediction voting of all partial predictions but only of those that were not updated in the current iteration.

Adaptive Bagging – Weight Update Classifiers
Inputs: *N, LT, L_{IW}, NB*

Create random data samples
For $i = 1, ..., N$
  TW_i = A random sample of the training set
  $TW = TW_i \cup TW$
  Train the classifier D_i on the TW_i data

Return *TW, D*
For each new record in *IW*
  Prediction and evaluation of individual classifiers
  $PL = \emptyset$
  All weights w set to 1
  For $j = 1, ..., N$
    Add the predictions of D_j classifier on the IW_x to PL_j
    Calculate the *F1 Score* based on the true IW_y class values and predicted class values PL_j
    Weights $w_j = 1 - F1\ Score$

14: *worst_pos* = position *NB* worst performing ensemble members
15: *PLF* = the most common values only for those PL_w, that are not in the list *worst_pos*
Removing *NB* of the worst classifiers and replacing them with new ones
16: **For each** position *p* from the list *worst_pos*
17: **If** *part_fit* = true
18: Merge the lists TW_p and *IW*
19: TW_p = replace the original list of the random data on the size of the original data from the TW_p
20: **Else**
21: *R* = length of *TW* - *LIW*
22: **If** *R* <= *0*
23: TW_p = replace the original list of random data on the size of the original TW_p from the *IW* list
24: **Else**
25: TW'_p = select the last *R* data from TW_p
26: TW_p = merge the lists TW'_j and *IW* and then randomly select the specified % of these data
27: Train the D_p classifier on the TW_p data
28: Replace D_p in the list of classifiers *D* with new D_p
29: **Return** *TW, D*

4.2 Adaptive Bagging – Weight Update Classifiers Parameters (WUCP)

This modification of the adaptive bagging method is an improved version of the WUC adaptive bagging. The initial creation of training sets and initial model training are identical with WUC. WUCP method then works with recovery thresholds, which means that if the performance of a partial ensemble member drops below a certain threshold, then this particular member is updated. The determination of the final prediction is realized in the same way as for the WUC method. Based on the comparison of predicted *PW* data with actual *IW* data, the individual ensemble members are evaluated, and their error rate is transferred to the respective weights. Updates of individual ensemble members occur when their weights reach or exceed the recovery limit. The method works with two recovery thresholds which determine, how the particular ensemble member will be updated, e.g., what data will be used for re-training of the ensemble member.

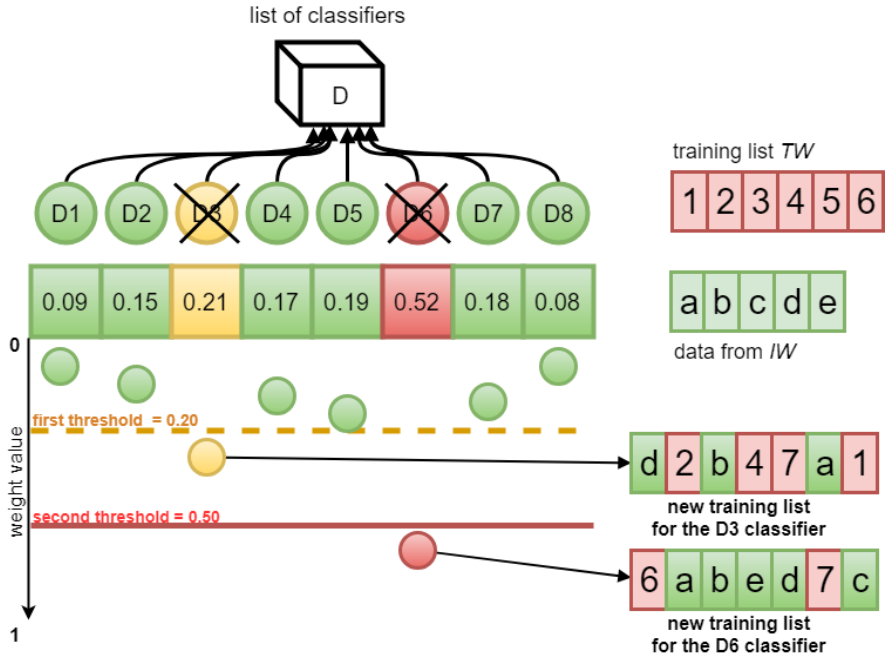

Figure 2

Adaptive ensemble with updated weights of base classifiers parameters

If a partial classifier's weight falls under the first threshold (yellow line depicted on Fig. 2), the ensemble member will be updated by re-training of the expert on a random selection from the dataset which is composed of the training set of the given classifier TW_i of the current IW data window. If the ensemble members weight exceeds the second threshold (red line on Fig. 3), it will be re-trained using just the latest IW data. If the training set TW were larger than IW, all IW data and the last data of the original TW_i would be included in the creation of the new classifier, which will help us achieve the required size of the training set.

Adaptive Bagging – Weight Update Classifiers Parameters
Inputs: N, L_{IW}, THR_1, THR_2

Create random data samples
1: **For** $i = 1, ..., N$
2: TW_i = random sample of data representing from the training set
3: $TW = TWi \cup TW$
4: Train the classifier D_i on the TW_i data
5: Save $D = D_i \cup D$
7: **Return** TW, D
8: **For Each** record in IW
Prediction and evaluation of individual classifiers
9: PL, $best\_pos$, $worst\_pos = Ø$

```
10:             All weights w set to 1
11:             For j = 1, ..., N
12:                 Add D_j predictions of IW_x records to PL_j
13:                 Calculate the F1 metric based on the actual IW_y classes
                    and predicted classes PL_j
14:                 Weights w_j = 1 – F1 Score
15:             End For
16:             best_pos – position NB of the best weights

                Removing NB of the worst classifiers and replacing them with
                new ones
17:             For Each weight w_x from w
18:                 If w_x > THR_1
19:                     R = length TW - LIW
20:                     If R <= 0
21:                         TW_p = replace random data from IW
22:                     Else
23:                         TW'_p - select the last R records from
                            TW_p
24:                         TW_p = merge the lists TW'j and IW
                            and randomly select the data sample
25:                     End If
26:                     Train the D_p classifier on the TW_p data
27:                     Update D_p members in the ensemble
28:                 Else If w_x > THR_2
29:                     Merge the lists TW_p and IW
30:                     TW_p = replace the random data of the size of
                        the original data from the TW_p
31:                     Train the D_p classifier on the TW_p data
32:                     Update D_p members in the ensemble
33:                 End If
34:             End For
35:     End For
```

5 Experiments

We used two datasets, from two different application domains, to conduct the experiments. Instead of using synthetic data, we focused on using real-world datasets. From the existing available real-world data used frequently in benchmarks, we considered two: network intrusion detection and electricity datasets. Both of the datasets contain a different type of concept drift.

The first dataset is from the KDD Cup competition in 1999 [18]. This data file is a listing of device logs in a LAN network collected over nine weeks. The sample

contains 494,021 rows. The class label is a binary one and specifies if a particular log represents any kind of network attack or normal connection. This dataset contains a sudden concept drift.

The second dataset considered in the experiments was the New South Wales Electricity Market dataset (commonly referenced as the ELEC dataset) [19]. In this case, we used the normalized version of the data. The dataset contains 45,312 instances. The class label identifies the change of the price relative to a moving average of the last 24 hours. These data contain a balanced class distribution and contains incremental concept drift.

On both datasets, we have performed two experiments. During the first set of the experiments, we compared the implemented adaptive bagging models them with baseline classifier (simple decision tree mode), non-adaptive bagging algorithm and basic adaptive bagging model with no weight adaptation mechanisms implemented. As a base classifier in the bagging ensemble, we used decision tree models. Our main objective was to measure the model quality metrics (precision, recall, F1 measure) as well as the time and resources needed to build and update the adaptive models. Lastly, we compared the best adaptive bagging algorithm with other similar adaptive models. Following sub-sections summarize the achieved results. The experiments were performed on a standard computer, equipped with an Intel processor, 8 Gigabytes of RAM running a Windows operating system.

5.1 Experiments on the ELEC Dataset

Table 1

Comparison of model performance on the ELEC data. Time is measured in seconds; performance metrics are calculated as the final percentage of examples over the complete data.

	Base classifier	Bagging	Adaptive Bagging	Adaptive Bagging - WUC	Adaptive Bagging - WUCP
Precision	70.39%	70.58%	82.05%	85.70%	88.22%
Recall	66.91%	66.39%	75.29%	81.58%	84.22%
F1	61.13%	61.14%	73.12%	79.89%	82.90%

Based on the results summarized in Tab. 1, the WUCP method achieved superior performance. Using the decision tree as a base classifier, it scored the highest score in all metrics. The optimal setting (also used in other experiments) of the offset size and the training set size is the value 1000 for both parameters.

During the second set of the experiments, we compared the performance of the adaptive bagging models with the other popular adaptive models. We used the following algorithms: DDM, ADWIN and Page-Hinkley method. Adaptive bagging models were set using the optimal parameters identified from the first set

of the experiments. Comparison of the model performance on the ELEC dataset visualized on Fig. 3 depicts, how the selected metrics evolved during the stream processing. The performance of basic methods decreases faster than adaptive, which makes me aware of the fact that these methods do not update over time and if the concept drift starts to occur in the data, so they have no way to find and further predict values on based on the classifiers learned at the beginning of the process. Adaptive methods also show a decrease in classifier accuracy, but it is not as significant, as static methods.

In the following experiments, our primary goal was to compare the designed adaptive ensemble methods with other adaptive methods. We chose the implementations based on Page-Hinkley, ADWIN, and DDM algorithms for comparison.

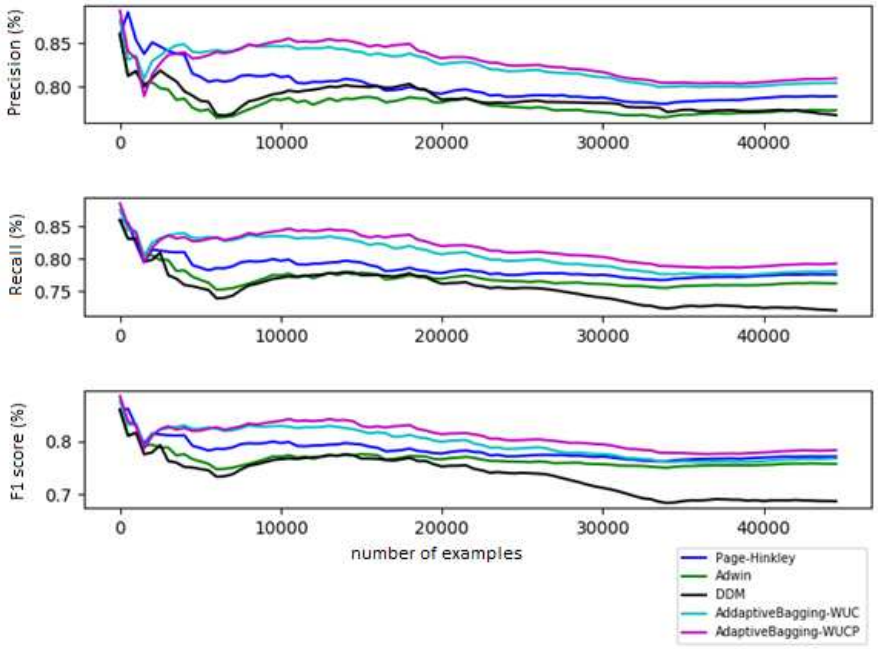

Figure 3
Performance metrics evolution comparison of the implemented models with the other adaptive models on the ELEC dataset

Fig. 3 depicts the performance evaluation of the WUC and WUCP Bagging methods with other adaptive methods. The experiments show that the adaptive bagging methods proved to be more efficient, especially when comparing to the DDM method.

5.2 Experiments on the KDD 99 Dataset

In the first series of the experiments, we compared the performance of the base classifier, standard bagging method, adaptive bagging with a constant update of the ensemble members with proposed adaptive bagging methods. The results are summarized in the Tab. 2. From the performance metrics, we can observe superior performance achieved by the WUCP adaptive bagging method.

Table 2
Comparison of the methods performance on the KDD 99 dataset

	Base classifier	Bagging	Adaptive Bagging	Adaptive Bagging - WUC	Adaptive Bagging - WUCP
Precision	82.95%	93.56%	91.87%	96.24%	99.05%
Recall	76.25%	93.95%	92.79%	96.37%	98.96%
F1	75.46%	93.51%	92.08%	95.76%	98.86%

In a similar fashion as during the experiments on the ELEC data, we compared the performance of the proposed methods to other adaptive models. We focused on the evolution of the F1 metric on the entire simulated data stream. Fig. 4 visualizes the F1 ratio on the simulated stream of the KDD 99 data. As it can be seen from the performance visualization, the adaptive bagging methods (both WUC and WUCP) recover faster from the drift occurrence when comparing with the other adaptive methods. On this dataset, the WUC bagging method proved to be the more efficient one.

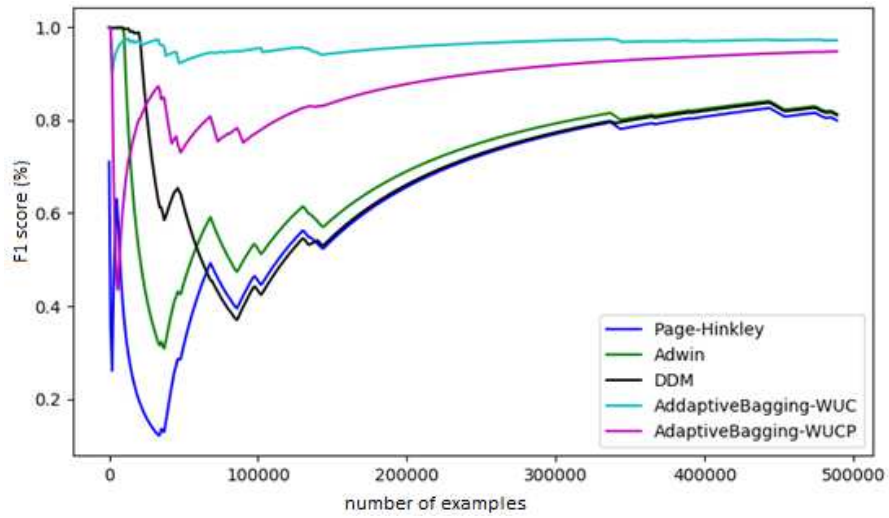

Figure 4
F1 metric evolution comparison of the implemented models with the other adaptive models on the KDD 99 dataset

When comparing adaptive methods on KDD CUP data, we can observe that all methods have a problem when drift occurs suddenly. The success of the method is based on how quickly they are able to adapt to the change. Adaptive bagging methods are able to recover faster when compared to other methods.

5.3 Memory and Computation Requirements Comparison

In this section, we compared how the implemented models performed in terms of their requirements on computational resources. An important aspect of the adaptive models is the fast recovery time - the time needed to update the classification model. In real-world scenarios, the aim is to minimize the recovery time in order to deploy the updated model as fast as possible. In this experiment, we observed how the implemented models utilized the RAM memory and measured the time to update the model during the process. Fig. 5 summarizes the results of the experiments. We can observe that the adaptive bagging methods with implemented class-weighting required slightly more memory. Update time also increased when comparing to the adaptive bagging with no class weighting scheme implemented.

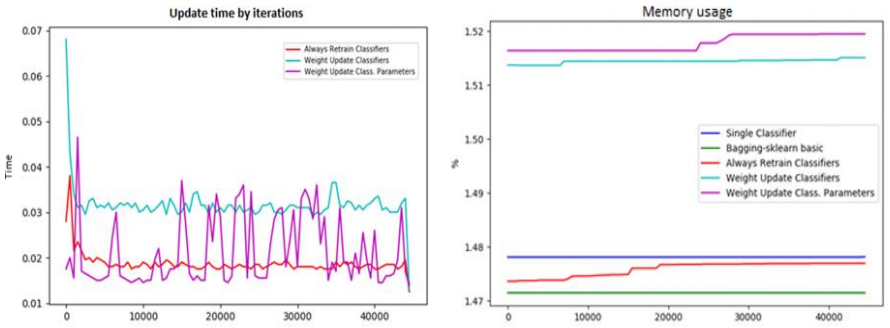

Figure 5

The update time of the adaptive bagging methods and memory usage of the classifiers during the stream processing (Time measured in ms)

The experiment was performed on the ELEC dataset. It is important to note that the observed metrics are highly dependent on the processed data. Data streams with a more complex structure (e.g. with large feature space) require more resources to process. Another important aspect is the actual real stream velocity (the number of items arriving per second), which determines the requirements for the recovery times.

Conclusions

The aim of the presented paper, is to propose weighted modifications, of adaptive bagging classification methods. We evaluated the models on two different real-world datasets that contain a different type of concept drift. In both experiments,

we compared the adaptive bagging methods with the baseline classifier as well as with other incremental od adaptive models. The results prove that the absence of classifier ability to update, when concept drift occurs, results in a gradual decrease of model performance. Adaptive bagging methods achieved relatively good performance results on both of the datasets. Their accuracy and speed of update depended on how large a set of data was used in each upgrade iteration and how many partial classifiers were needed to be retrained. When comparing concrete approaches to retrain the classifiers, we can conclude that it is better to use the partial update method, which is a random selection of historical data and recent examples of the current iteration. Performance-wise, the WUCP adaptive bagging algorithm achieved the best results. When compared to other adaptive methods, those methods performed fast enough and again yielded the best results on both datasets. Based on these findings, we can say that adaptive ensemble methods are well able to be adapted on the data in which the concept drift occurs and can be very useful to the classification method for processing of data streams in a dynamic and ever-changing environment. For future work, we aim to enhance the adaptive ensemble models with a semantic model of the application domain. Such a knowledge model, should be used to improve the classification by capturing the expert domain knowledge, which may be related to drift occurrences. These models could be used to detect the patterns leading to the drift and therefore, be used in drift detection or adaptation rules.

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Perception of the Quality of Educational System for Entrepreneurship – Comparative Analysis

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Abstract: High-quality entrepreneurial education has a positive influence on SMEs' development, the establishment of start-ups, business innovation, and many macroeconomic indicators. The aim of this study is to examine and evaluate the quality of the educational system from the standpoint of SME owners and managers. The analysis is aimed at detecting connections between respective respondent categories based on their region, type of business, industry, length of business operation, attained employees´ education, and gender. The comparative analysis aims at examining the differences between Czech and Slovak SME entrepreneurs' perceptions of the educational system quality. The research results prove that selected differential viewpoints enable us to see the differences in how the quality of high school and university education is perceived, partially due to managers' diverse demands as to the workforce in their respective enterprises, its integration into the work process, and the job position. This micro-view is complemented by a macro-view – demands and requirements regarding the workforce are differentiated also by the size of the enterprise, its type, length of operation, etc. in both countries. The results provide valuable information for the authors of economic and educational policies, as well as for regional strategic development planning. They also emphasize the importance of a systematic approach in solving the issue of entrepreneurial education and the need to ensure support for enterprises on all levels of education, including lifelong learning.

Keywords: SME; entrepreneurial education; key competences; quality of education; college education; educational policies; competitiveness of educational systems

1 Introduction

The topic of entrepreneurial education in state educational systems is the topic of many professional and scientific discussions and represents a large part of international legislative and legal platforms. Entrepreneurial education and the development of entrepreneurial skills are parts of the curriculum in primary and secondary schools in the Czech Republic and Slovakia. Primary schools, as opposed to secondary schools, do not have a complex program of entrepreneurial education in place. There is also a substantial difference between entrepreneurial education in secondary schools; however, it is included in the school curriculums of all study fields. The situation is different in university education where the greatest emphasis is put on gaining specific professional and key competences with the aim of producing a qualified workforce for the labour market. Entrepreneurial education in university environment is therefore viewed by Slovak experts as insufficient compared to tendencies that are predominant in many other countries [1].

Entrepreneurial education in Slovakia is defined as a mere cross-section field on the primary and secondary school level. Entrepreneurial skills are incorporated into secondary school curriculums as mandatory key competences in Social Studies classes. Many public and private organizations play an important role in this process (e.g. Slovak Centre for Training Firms, Junior Achievement Slovakia, Entrepreneurs Association of Slovakia, and Pontis Foundation), projects and initiatives aimed at entrepreneurial education and skills development [1]). Slovakia also participates in European projects such as The Entrepreneurial School (TES) [2], The European Entrepreneurship Education Network (EE HUB), Athéna++: The vision of the primary and secondary educational system in the 21st Century [3].

The Czech Republic supports entrepreneurial education through various programmes, e.g. National programme for education development in the Czech Republic, The Czech Republic strategy on educational policy till 2020, The Youth Support Framework of the Czech Republic 2014 – 2020, etc. The topic of entrepreneurial education remains inferior within these programs [4].

Entrepreneurial education nowadays belongs to the main stimuli of entrepreneurial development in the European countries and its significance is acknowledged not only in primary schools, high schools, and universities but also in lifelong education. This is confirmed by the strategic document "Europe 2020" in which the priorities of intellectual growth and inclusive growth combined with innovation, knowledge, economic support, and high employment rate are connected with education-related initiatives.

These consequent facts served as amotive for performing this research. Its aim is to examine and evaluate the quality of the educational system in the Czech Republic and Slovakia as viewed by SME entrepreneurs in both countries. They

expressed their views regarding the quality of a university and high school education in their respective countries, the state's ability to provide a workforce for businesses, and graduates' level of knowledge and skills.

The originality of this research lies in the evaluation of active feedback, i.e., students' readiness for real jobs in businesses as seen by the employers, as opposed to other available studies based more on the explicit research of entrepreneurial competences and skills in the process of education as seen by schools and graduates. It is the very employers who are best able to assess the quality of the workforce in their own business conditions and evaluate its effectiveness through the metrics of productivity, innovation development, flexibility, loyalty, etc. The research conducted by employers provide a valuable source of information about the differences between graduates' expected and actual key competences in real life. These show if and to what extent key entrepreneurial competences are incorporated into curriculums as explicit educational goals or as a merely intuitive, integral part of education.

2 Overview of National and International Research Studies

A number of research studies on entrepreneurial education often present the issue of achieving and developing key entrepreneurial competences. Their significance is dominant in the studies of e.g., Barbara Hansen Čechová [5], Suchožová [6], and others. National and European documents feature them in a more implicit way (e.g. [7], [8]). Key competences are also a subject of international research such as AHELO, PIAAC, and PISA [9], [10]. Many concepts examined within these studies serve also as a platform for comparative studies conducted in various countries [11], [12].

As seen in available national and international research studies, there is an obvious tendency to examine the topic of entrepreneurial education in two research lines: psycho-social and economic. They are interconnected and create a platform for examining heterogeneous aspects of entrepreneurial education. This is related to a basic dichotomy that exists between the evaluation of actual knowledge and the evaluation of competences. The dichotomy stems from differential standpoints. In his study, Gordon [13] presents interesting differential viewpoints, evaluating key competences on four levels: explicit evaluation, implicit evaluation, evaluation of competences pertaining to a school subject, and knowledge evaluation. There is an international trend of substituting the evaluation of factual knowledge with the evaluation of competences. In Slovakia, however, according to a study by Vančo et al. [14], there is a prevalence of the evaluation of competences related to school subjects and evaluation of knowledge.

From the economic point of view, it is important within entrepreneurial education to also examine financial literacy and financial self-confidence which may affect the attitude towards risk and consequently also financial decision-making [15], [16]. This has led to the increase in the number of research studies examining entrepreneurial education in connection with student financial literacy at all educational levels in the last two decades. It is a consequent fact, as students' inadequate financial literacy can have a highly negative economic and social impact in both the short and long-term. Examples of negative macroeconomic effects include an increase in debt due to short-term and long-term loans from commercial banks (e.g. [17]), increase in risky financial decisions (e.g. [18], [19]), deepening of the financial crisis, overall negative impact on socio-economic results due to intellectual potential decrease ([20]), etc. As a part of the legislative and legal field, the existence of national standards serves as evidence of a close connection between entrepreneurial education and financial literacy. Many countries are actively working on regulating financial literacy while measuring the impact on many economic dimensions. This can be proven by a number of international research studies aimed at the assessment of procedural and result trajectories of financial literacy regulation in specific countries (e.g. [21]) as well as by a variety of research with evidence of the importance of prerequisites of entrepreneurial intensions forming by means of university education, vocational training financed by enterprises [22]). The aspirations of young adults in entrepreneurial activities can be influenced by numerous social factors, however, an educational background remains one of the most significant ([23], [24]).

The quality of state educational systems can also be examined using the outcomes of international surveys such as Global Entrepreneurship Monitor (GEM) and Global Entrepreneurship Development Index (GEDI) [25]. In Slovakia, the Ministry of Education, Science, Research and Sport of the Slovak Republic studies the following key competences: digital, social, civil as well as initiative, and entrepreneurial skills [14]. As seen in findings of institutional research conducted in Slovakia, the significant limitation in studying key competences by universities is caused by the incorrect perception of their meaning, which leads to substantial misinterpretation of the results and limits the national and international comparative platform. Johnes et al. [26] generalize this problem by bringing it to an international level while pointing to problems in individual countries – analysis issues across countries and their significance for the referential evaluation of educational policies, the need to understand the impact of financial policies on the quality, effectiveness, fairness of education, and the need to analyse educational activities in a dynamic environment, etc. The authors state that feedback from students is also important in analysing the effectiveness of tertiary education and understanding the methodological processes, using various models of education effectiveness, alternative evaluation models, etc.

2 Aim, Data Base and Methodology

The aim of this study is to examine and evaluate the quality of the educational system as viewed by SME owners and managers. The analysis is aimed at detecting connections between respective respondent categories based on their region, type of business, industry, length of operating a business, attained education, and gender. The main topic of interest was the extent of similarities and differences in both Czech and Slovak SME owners' and managers' views on the quality of the educational system and graduates' readiness for real jobs.

In regard to the defined aim, survey-based research was conducted with enterprises operating in the SME segment in the Czech Republic and Slovakia in 2018. They were randomly selected from the "Albertina" and "Cribis" databases and approached via email asking them to fill in an online questionnaire. The questionnaire was intended for business owners or members of the top management. A total of 9400 SMEs were approached. 312 usable questionnaires were obtained in the Czech Republic and 329 in Slovakia. Factors indicating/reflecting/expressing the quality of the educational systems in the Czech Republic and Slovakia were examined using four questions defined and analysed in the following analytical section.

Crosstables were used to analyse the ratios of examined variables. They serve as a conventional tool for testing the relationship between two categorical or qualitative variables. The crosstables test the mutual correlation between pairs of attributes. The test compares the actual absolute numbers in individual fields with so-called expected absolute numbers that would be obtained if the questions did not correlate. The null hypothesis is as follows: the two given attributes have no correlation. Alternative hypothesis: the two given attributes correlate. If value p is larger than 0.05, then the null hypothesis claiming no correlation between the two attributes is accepted. If the value of p is smaller than 0.05, then the null hypothesis is rejected, meaning that the two given attributes correlate. The critical value of p was set at p = 0.001. Rejecting the null hypothesis does not express the type of correlation of the cause of the test's significance. The following variables will be used for testing the significance level of the two attributes' correlation. The actual count in row *i* and column *j* of the table is marked by a symbol.

If the sum in column j is:

$$c_j = \sum_{i=1}^{R} f_{ij}, \tag{1}$$

and the sum in row i is:

$$r_i = \sum_{j=1}^{C} f_{ij} \tag{2}$$

Then the total sum of the table is:

$$N = \sum_{i=1}^{R} r_i = \sum_{j=1}^{C} c_j. \tag{3}$$

The expected count therefore is:

$$E_{ij} = \frac{r_i c_j}{N} \tag{4}$$

Variable "Adjusted Residual" to be used is defined by:

$$AR_{ij} = \frac{R_{ij}}{\sqrt{E_{ij}\left(1-\frac{r_i}{N}\right)\left(1-\frac{c_j}{N}\right)}}. \tag{5}$$

The crosstable contains the abbreviation "AR" for "Adjusted Residual" in the absolute Count field. It is a variable indicating the deviation between the actual and the expected counts, as well as its direction [32]. If the AR value is negative, the real count is smaller than expected. If the value is positive, then the actual count is larger than expected (the number in the given field is larger than it should be). The numerical symbol indicates the deviation direction. Absolute value AR indicates the significance of the difference between the actual and the expected count. If |AR| is larger than 2, then the difference between the actual and the expected count is significant at the level of $p < 0.05$. If the value is larger than 2.6, then the difference between the actual and the expected count is significant at the level of $p < 0.01$. Given a large number of tests and a large count, the significant difference between the actual and the expected count is set at |AR| >3.3 in the given field. If the value is larger than 3.3, then the difference between the actual and the expected count has a significance level of $p < 0.001$.

Within the analysis, the following regions were observed at level 3 of the Nomenclature of Territorial Units for Statistics: CZ010 – Prague Region; CZ020 – Centre Czechia Region; CZ031 – South Czechia Region; CZ032 – Plzeň Region; CZ041 – Karlovy Vary Region; CZ042 – Ústí Region; CZ051 – Liberec Region; CZ052 – Hradec Králové Region; CZ053 – Pardubice Region; CZ063 –Vysočina Region; CZ064 – South Moravia Region; CZ071 – Olomouc Region; CZ072 – Zlín Region; CZ080 – Moravia-Silesia Region; SK010 – Bratislava Region; SK021 – Trnava Region; SK022 – Trenčín Region; SK023 – Nitra Region; SK031 – Žilina Region; SK032 – Banská Bystrica Region; SK041 – Prešov Region; and SK042 – Košice Region.

3 Analysis and Results

The analytical part of the study is divided into four sections (a–d), each one dealing with a separately verified claim made by the respondents. The first part (a) offers an analysis of the respondent's position on the claim that university education can be viewed as that of high quality. The second part (b) deals with a similar statement, but pertains to secondary education; the third part (c) refers to the claim that the state is able to provide a qualified workforce for businesses, and the last part (d) examines the claim that graduates have high quality knowledge and skills.

3.1 I See University Education as that of a High Quality

The claim that university education is that of high quality can be evaluated based on region, type of business, industry, and attained education. The length of operating a business and gender parameters do not show a statistical significance in either of the studied categories. In terms of region, the Trnava Region in the Slovak Republic, there is a considerably high residual of negative answers, which means that the actual number of neutral answers is lower than expected. The business type aspect is significant in the case of absolute negative answers by respondents from medium-sized enterprises (having more than 50 employees) where the residual reaches an extremely high positive value which means that there are many more answers from the Czech Republic than expected. The industry aspect is statistically significant in the manufacturing field whose respondents absolutely disagreed with the claim that university education is of high quality. There were fewer answers in the Czech Republic than expected. In Slovakia, the "agriculture" sector was statistically significant, as the number of answers was considerably lower than expected, but unlike in the Czech Republic, this is valid for the absolute positive standpoint. Education was the last category examined. In the Czech Republic, the respondents with secondary education expressed disagreement at a much higher rate than expected. A similar result was achieved in the case of respondents with a university diploma. However, they provided a much higher number of positive responses to the question about the quality of university education, which is a paradox, given the fact that the evaluation was done by managers with secondary education.

3.1.1. Comparison between Countries

Table 1 presents the statistical significance of answers to the question of whether a university education is that of a higher quality, based on country.

Table 1
Crosstab of answers to: "I see university education as that of a higher quality", based on country

Attribute			CZ	SK	Total
Answers	I absolutely disagree	count	14_a	14_a	28
		%	4.5	4.3	4.4
	I disagree	count	**62_a**	**133_b**	195
		%	**19.9**	**40.4**	30.4
	Neutral	count	107_a	66_b	173
		%	34.3	20.1	27.0
	I agree	count	119_a	107_a	226
		%	38.1	32.5	35.3
	I absolutely agree	count	10_a	9_a	19
		%	3.2	2.7	3.0
Total		count	312	329	641
		%	100.0	100.0	100.0

Source: own processing

All answers are statistically significant, while reaching the highest level of statistical significance with the exception of negative answers from respondents from Slovakia whose statistical significance is that of the second level.

Comparison based on gender for the given country

Table 2 shows the statistical significance of answers to the a question whether a university education is that of a higher quality, based on country and gender.

Table 2
Crosstab of "I see university education as that of a higher quality", based on country and gender

Attribute				CZ	SK	Total
Male	Answers	I absolutely disagree	count	11_a	13_a	24
			%	4.7	5.2	4.9
		I disagree	count	**52_a**	**99_b**	151
			%	**22.0**	**39.4**	31.0
		Neutral	count	**82_a**	**55_b**	137
			%	**34.7**	**21.9**	28.1
		I agree	count	83_a	78_a	161
			%	35.2	31.1	33.1
		I absolutely agree	count	8_a	6_a	14
			%	3.4	2.4	2.9
	Total		count	236	251	487
			%	100.0	100.0	100.0
Female	Answers	I absolutely disagree	count	3_a	1_a	4
			%	3.9	1.3	2.6

		I disagree	count	**10_a**	**34_b**	44
			%	**13.2**	**43.6**	28.6
		Neutral	count	**25_a**	**11_b**	36
			%	**32.9**	**14.1**	23.4
		I agree	count	36_a	29_a	65
			%	47.4	37.2	42.2
		I absolutely agree	count	2_a	3_a	5
			%	2.6	3.8	3.2
	Total		count	76	78	154
			%	100.0	100.0	100.0

Legend: statistical significance: a – 1st level, $p < 0.01$; b – 2nd level, $p < 0.05$.
Source: Own processing

All answers are statistically significant; the second level of statistical significance is reached in negative and neutral answers obtained from male respondents in Slovakia, and the same categories of female respondents in Slovakia. All other options can be assigned the highest level of statistical significance.

Comparison based on education

Table 3
Crosstab. of: "I see university education as that of a high quality", based on attained education level

Attribute		Education			Total
		High school without diploma	High school with diploma	University	
I absolutely disagree	count	4	12	12	28
	AR	0.9	0.8	-1.3	
I disagree	count	**6**	67	122	195
	AR	**-3.6**	-0.5	2.6	
Neutral	count	24	**85**	**64**	173
	AR	2.4	**4.3**	**-5.5**	
I agree	count	25	**62**	139	226
	AR	1.1	**-3.3**	2.5	
I absolutely agree	count	1	4	14	19
	AR	-0.6	-1.4	1.7	
Total	Count	60	230	351	641

Source: Own processing

The values of adjusted residuals reach statistically significant levels in negative answers of the respondents with secondary education without a diploma, as the negative residual value presents a higher number of answers than expected, given the source file. In the case of neutral answers, a statistically significant residual value was reached in the answers from the respondents with secondary education, where the maximum positive value of 4.3 represents a much lower number of

answers in this group than expected. The same goes for the opposite critical value in the case of the negative residual value reaching an even higher absolute level of 5.5 which means that there was a much higher number of answers than expected, given the source file. There is also a statistically significant value in the answers of the respondents with a secondary education with a diploma, where the residual value is negative, meaning that an unexpected number of the respondents in this category agreed with the statement that university education can be seen as that of high quality.

Comparison based on education for the given country

Table 4

Crosstab of: "I see university education as that of a higher quality ", based on attained education

Country/Answers			Education			Total
			Secondary school without diploma	Secondary school with diploma	University	
CZ	I absolutely disagree	count	3	7	4	14
		AR	0.6	0.5	-0.9	
	I disagree	count	3	30	29	62
		AR	-2.7	0.9	1.1	
	Neutral	count	23	59	**25**	107
		AR	1.9	3.1	**-4.5**	
	I agree	count	20	**37**	62	119
		AR	0.3	**-3.4**	3.2	
	I absolutely agree	count	1	2	7	10
		AR	-0.5	-1.5	1.9	
	Total	count	50	135	127	312
SK	I absolutely disagree	count	1	5	8	14
		AR	0.9	0.6	-0.9	
	I disagree	count	3	37	93	133
		AR	-0.7	-0.3	0.6	
	Neutral	count	1	26	39	66
		AR	-0.8	2.1	-1.8	
	I agree	count	5	25	77	107
		AR	1.2	-1.5	1.0	
	I absolutely agree	count	0	2	7	9
		AR	-0.5	-0.4	0.6	
	Total	count	10	95	224	329

Source: Own processing

As for education, there were two cases in the Czech Republic when the residuals reached statistically significant values. The first one was a case of the neutral

position of university-educated respondents with a negative residual, indicating an unexpectedly high number of people in this category having a neutral opinion of the quality of university education. The second was a case of positive standpoint towards the same claim, with a large number of answers from respondents with secondary education with a diploma. Slovak respondents, on the opposite, responded as expected; therefore, the residuals did not reach statistically significant values. Comparing the two countries, it is apparent that in the case of Slovak respondents, none of the categories is statistically significant, which means that the comparison between countries is not possible in this case.

3.2 I See Secondary Education as that of a High Quality

The length of business operation and gender parameters do not show a statistical significance in either of the studied categories. In terms of region, there are three cases of statistically significant residuals due to their positive values in the Czech Republic: the Hradec Králové Region with an absolute positive standpoint, the Olomouc Region with a negative standpoint, and the Zlín Region with an absolute negative standpoint. Unlike in the Czech Republic, in Slovakia, there is a case of negative residual value, namely in the Prešov Region, which had a considerably higher number of absolute positive answers than expected. At the same time, the same region also yielded positive statistically significant residuals in the case of a neutral standpoint with a lower number of answers than expected. The business type aspect is statistically significant in both countries. In the Czech Republic, there are two cases of positive residuals – in the "other industry" with a lower number of neutral answers than expected, and in the case of "manufacturing". Positive residuals are also found in Slovakia, but in different cases – in "services" and "other industry". As for the respondents' attained education aspect, a statistically significant residual value is present in the group of the respondents with a secondary education without a diploma who showed a higher than expected response rate to the claim that secondary education is of a higher quality by providing an absolute negative answer.

3.3 The State is Able to Provide a Qualified Workforce for Businesses

The education and gender aspects do not show a statistical significance in either of the studied categories. In terms of region, there are two cases of high positive residuals in the Czech Republic indicating that the respondents from the Central Bohemian Region and the Karlovy Vary Region absolutely disagree with the claim above to a much lesser degree than expected. In the Prešov Region in the Slovak Republic, the situation was similar as in the above-mentioned Czech regions, while the Bratislava Region and the Trnava Region yielded negative residuals indicating a considerably higher rate of negative answers than expected.

The business type aspect is statistically significant in the case of a negative and an absolute negative answer of the respondents from small enterprises with 10 – 50 employees in the Czech Republic, where a lower number of answers was observed than expected. This is the only situation of statistically significant residuals in two respondent standpoints within the same question. The situation is more diversified in Slovakia, as there is a considerably lower number of negative answers from small enterprises having 10 - 50 employees, but a much higher number of negative answers from micro-enterprises having up to 10 employees. Medium-sized enterprises having more than 50 employees yielded a considerably higher number of neutral answers than expected. The industry aspect is statistically significant in the Czech Republic in the "agriculture" sector which shows extremely high positive residuals. This means that the number of absolute negative answers is extremely low. In Slovakia, the "other industry" sector shows a low number of absolute negative answers. In the Czech Republic, the length of business operation aspect yielded a statistically significant positive residual in the case of absolute negative answers, which means that the respondents provided a much lower number of absolute negative answers than expected.

Comparison based on the size of business

Conclusion: the respondents from small enterprises (up to 10 employees) are less satisfied with their employees' education level than the respondents from medium-sized enterprises (10 - 50 employees).

Table 5

Crosstab of "The state is able to provide a qualified workforce for businesses", based on business size

Answers		Size of enterprise (number of employees)			Total
		up to 10	10-50	50-250	
I absolutely disagree	count	75	19	5	99
	AR	-0.3	0.4	-0.2	
I disagree	count	256	44	20	320
	AR	1.9	-2.7	0.9	
Neutral	count	**117**	15	2	134
	AR	**3.3**	-2.2	-2.3	
I agree	count	**42**	**34**	8	84
	AR	**-6.2**	**5.8**	1.8	
I absolutely agree	count	2	2	0	4
	AR	-1.3	1.7	-0.5	
Total	count	492	114	35	641

Source: Own processing

As shown in Table 5, a comparison based on the business size yields three cases of statistically significant residuals. The neutral standpoint of respondents can be validated due to a positive residual in the case of small enterprises having up to 10

employees. A higher number of answers was expected in this case. Another statistically significant case comes from the same business size group in which the residual reached an extremely low value of -6.2, indicating an unexpectedly high number of people agreeing with the claim that the state is able to provide a qualified workforce for businesses. At the same time, there was also an extreme case of a positive standpoint in an enterprise of 10 – 50 employees where the number of answers was considerably lower than expected.

Comparison based on size of the business for the given country

Conclusion: Slovak entrepreneurs from small enterprises show a lower degree of trust towards the state in providing qualified workforce for businesses, as opposed to medium-sized enterprises.

Table 6

Crosstab of "The state is able to provide a qualified workforce for businesses ", based on business size

			Size of enterprise (number of employees)			
			up to 10	10-50	50-250	Total
CZ	I absolutely disagree	count	40	9	1	50
		AR	-0.5	0.9	-0.6	
	I disagree	count	131	16	7	154
		AR	1.1	-1.7	1.0	
	Neutral	count	68	7	2	77
		AR	1.5	-1.4	-0.5	
	I agree	count	19	**10**	1	30
		AR	-2.9	**3.3**	-0.1	
	Absolutely agree	count	0	1	0	1
		AR	-2.2	2.5	-0.2	
	Total	count	258	43	11	312
SK	I absolutely disagree	count	35	10	4	49
		AR	0.1	-0.2	0.3	
	I disagree	count	125	28	13	166
		AR	1.7	-2.1	0.4	
	Neutral	count	49	8	0	57
		AR	2.7	-1.5	-2.3	
	I agree	count	**23**	**24**	7	54
		AR	**-5.1**	**4.5**	1.8	
	I absolutely agree	count	2	1	0	3
		AR	-0.2	0.5	-0.5	
	Total	count	234	71	24	329

Source: Own processing

The values of adjusted residuals reach statistically significant levels in positive answers of the respondents from enterprises of up to 10 employees or 10 – 50 employees. This is only valid for Slovakia. In the case of respondents from small enterprises having up to 10 employees, there was a case of negative residual indicating a considerably higher number of answers than expected. In medium-sized enterprises with 10–50 employees, a lower number of answers was obtained than expected. Unlike in Slovakia, there was a borderline case in the Czech Republic of statistically significant residual values in neutral answers in small enterprises having 10–50 employees.

3.4 Graduates have High-Quality Knowledge and Skills

The education and gender parameters do not show a statistical significance in either of the studied categories. Considering the region aspect, there is a considerably negative residual in the Bratislava Region of the Slovak Republic, meaning that the actual number of answers expressing an absolute positive standpoint towards the above claim is higher than expected. There was an opposite case in the Prešov Region, in which a high positive residual was observed in a case of negative answers in, indicating a considerably higher number of negative responses than expected. Considering the business type aspect, a statistically significant residual was observed in the Czech Republic where the respondents from medium-sized enterprises with more than 50 employees showed a considerably lower response rate in case of an absolute negative standpoint. The industry aspect is statistically significant in the Slovak "services" sector which yielded a much lower response rate than expected in case of an absolute positive standpoint.

Table 7

Evaluation of questions in the field of education in the Czech Republic and Slovakia

Question	Ratio of positive answers (in %) in Czech Republic	Ratio of positive answers (in %) in Slovakia	Z-score p-value CR/SR
I see university education as that of a higher quality (1)	7.7	9.1	0.516
I see secondary education as that of a higher quality (2)	30.1	30.7	0.873
The state is able to provide a qualified workforce for businesses (3)	11.2	15.5	0.112
Graduates have high quality knowledge and skills (4)	10.6	16.1	0.040

Source: own processing

The overview of positive answers shows a considerable disproportion between the respondents in both countries and confirms the fact that the higher rate of neutral

answers decreases the rate of positive answers. Only question 4 yields statistically significant answers, as the p-value of the Z-score statistical method is lower than the 5% significance level. Even though the p-value is higher in question 3, this question can be evaluated as well, but at a higher significance level than it reaches. It barely exceeds the standard 10% significance level. There was a prevalence of positive answers in all four questions in Slovakia.

Table 8
Average values of answers based on the Likert scale in respective regions

Region	Question (1)	Question (2)	Question (3)	Question (4)
CZ010	2.118	2.471	2.353	2.235
CZ020	2.286	2.5	3	2.714
CZ031	2.313	2.125	2.188	2.375
CZ032	1.955	2.045	1.955	2.136
CZ041	2.4	2.533	2.467	2.467
CZ042	1.667	2.074	2.259	2.185
CZ051	2.714	2.75	2.536	2.5
CZ052	2	2.353	2.824	2.765
CZ053	2	2.353	2.294	2.412
CZ063	2	2.16	1.88	1.88
CZ064	2.045	2.818	2.227	2.455
CZ071	2.731	2.769	2.769	2.654
CZ072	2.265	2.673	2.51	2.51
CZ080	2.353	2.235	2.353	2.353
SK010	2.036	2.179	1.839	2.393
SK021	2.333	2.222	1.889	2.63
SK022	2.1	1.85	1.9	2.3
SK023	1.765	1.941	1.765	2.118
SK031	1.607	1.679	1.393	1.75
SK032	2.267	2.133	1.967	2.467
SK041	2.553	3.053	2.658	3
SK042	2.68	2.493	2.627	2.88

Source: Own processing

Table 8 showing average values of answers based on the Likert scale in respective regions confirm a relative neutral standpoint in the case of the respondents from the Czech Republic. Slovak respondents avoided the neutral answer at a significant level. The lowest value was observed at 1.88 in the Vysočina Region in questions (3) and (4). Value 1.88 indicates the average position between an absolute negative answer and a negative answer. The maximum value of 3 was observed in the Central Bohemian Region in question (3), which indicates a neutral answer. In the case of extreme values, there is a larger variance of answers of the respondents in Slovakia than those in the Czech Republic. The minimum value of 1.607 is valid for the Žilina Region in question (1), while the maximum value of 3 was reached in the Prešov Region in question (4). The variance of average values based on the Likert scale is approximately twice as low.

4 Discussion

In the last decade, EU countries really strive to ensure the implementation of „entrepreneurial skills" as a key competence into their school curriculum's within primary, secondary, specialized, and higher education [1]. Turek [28] states that acquiring key competences is not merely the responsibility of an individual; favourable conditions within a social and ecological environment must exist as well. Based on the materials from the European Commission [7], it is necessary to encourage the development of 21st Century skills and prepare individuals for a career that can be very diversified and unpredictable. Young people should learn entrepreneurial behaviour to be able to adapt to dynamic changes on the labour market that they will encounter in their professional life [29].

Key competences are often monitored and evaluated mainly from the psycho-social point of view, which explains the difficulties in their quantification. Their connection with economic and social systems can only be seen in the past years through examining individual personalities and their success rate parameters, as well as leadership roles and psychological aspects of entrepreneurship. From the economic point of view, key competences positively have a positive impact on productivity growth and work effectivity, competitiveness, flexibility and workforce adaptation, the creation of an innovative and creative environment, etc. Business managers explicitly relate business effectivity to job performance, and monitor employees' job positions based on personal characteristics, attained education, experience, skills, and key competences [30]. These characteristics are usually examined and evaluated by managers as a whole, as systems for measuring performance are designed to define quantifiable parameters [31]. Human resources in businesses are the most sensitive performance parameter due to their high perception of economic success as well as risks and losses.

These consequent facts justify the importance of a wide array of workforce researches in order to receive the best possible real-life feedback. There is a limited number of workforce researches due to their methodological difficulty, complexity, and low return on research materials, institutional support is, therefore, very important. If provided, it can support the creation of national and international benchmarks in this field. Their very absence causes strong heterogeneity in research processes that monitor the quality of education and the comparative limitations on both national and international scale.

The research results prove that selected differential viewpoints enable us to see the differences in how the quality of high school and university education is perceived, partially due to managers´ diverse demands as to the workforce in their respective enterprises, its integration into the work process, and the job position. This micro-view is complemented by a macro-view – demands and requirements regarding the workforce are differentiated also by the size of the enterprise, its type, length of operation, etc. in both countries. There is an obvious tendency to study managers' satisfaction with the education level of their workforce depending on the sector, the position on the market, type of enterprise, etc. Sector analyses and studies examining managers' satisfaction with their employees' education levels considering the size of the enterprise, its life cycle, etc. are gaining importance. A small business owner/manager can make a better and faster evaluation of an employee's education level and key competences, which is given by shorter and more intense communication channels, a wider spectrum of tasks, and higher demands on his/her flexibility, inventiveness, etc.

Conclusion

The aim of this study was to examine and evaluate the quality of the educational system from the standpoint of SME owners and managers in the Czech Republic and Slovakia. The analysis was aimed at detecting connections between respective respondent categories based on their region, type of business, industry, length of business operation, attained education, and gender of employees.

The claim that university education is of a higher quality was confirmed by absolute positive answers from Slovak respondents in the field of "agriculture". In the Czech Republic, significantly more positive answers on the quality of university education were obtained from the respondents with a high school diploma. In Slovakia, the neutral standpoint was statistically significant from the point of view of the Trnava Region, which means that the actual number of neutral responses was lower than expected. There was a much higher number of negative answers than expected obtained from the respondents with a university diploma in the Czech Republic. The absolute negative standpoint is statistically significant in the case of the respondents from medium-sized enterprises in the Czech Republic, where the residual reaches an extremely high positive value, which means that there was a much higher number of answers than expected. Likewise, this response was statistically significant in the "manufacturing" sector, whose

respondents absolutely disagreed with the claim that university education is of a high quality. There were fewer responses in the Czech Republic than expected.

The claim that high school education is of a higher quality can be evaluated based on the region, type of business, industry, and the respondent's attained education. As opposed to the Czech Republic, there were cases in Slovakia, namely in the Prešov Region, of a significantly higher number of absolute positive answers than expected. Also, in the Prešov Region, a positive statistically significant residual can be found in the case of a negative standpoint, where the number of answers was lower than expected. As for the Czech Republic, the Hradec Králové Region showed an absolute positive standpoint from respondents. The "business type" aspect is statistically significant in both countries, while the respondents in the Czech Republic answered neutrally in the case of "other fields" to a lower degree than expected. The same goes for the "manufacturing" sector, as well as "services" and "other fields" in Slovakia.

The claim that the state is able to provide a qualified workforce for businesses was examined using the analysis of residuals based on region, type of business, industry, length of operating a business. Considering the region aspect, there are two cases of absolute disagreement of a much lesser degree than expected – in the Centre Czechia Region, the Karlovy Vary Region, and the Prešov Region. An extremely low number of negative answers were noted in the "agriculture" sector in the Czech Republic and in "other fields" in Slovakia. Absolute disagreement is statistically significant considering the "length of operating a business" aspect where a much lower number of answers was obtained than expected. A considerably higher than expected rate of negative answers was observed in the Bratislava Region and the Trnava Region. The "type of business" aspect is statistically significant in the case of a negative and absolute negative response from the respondents from small enterprises of 10–50 employees in the Czech Republic where the number of responses was lower than expected. In Slovakia, small enterprises of 10 - 50 employees yielded a considerably lower number of negative answers, while micro-enterprises with up to 10 employees provided a much higher number of negative answers.

The claim that graduates have high-quality knowledge and skills can be statistically measured based on region, type of business, industry, and length of business operation. In the Czech Republic, medium-sized enterprises having more than 50 employees yielded a much lower rate of negative answers than expected. There was an extreme case of a higher number of negative answers than expected in the Prešov Region. An absolute positive standpoint was observed at a higher rate than expected in the Bratislava Region.

Comparing the countries´ aggregated evaluations, Slovak managers were more satisfied in all four research questions in terms of the quality of secondary and university education. However, it is important to permanently ensure flexibility of educational systems in both countries and make sure that they can react to

dynamic demands on the job market. It is also necessary to improve educational policies, review them, set new goals, and implement them into strategic materials and action plans.

The analysis results provide valuable information for the authors of economic and educational policies, as well as for regional strategic development planning. They also emphasize the importance of a systematic approach in solving the issue of entrepreneurial education and the need to ensure support for enterprises at all levels of education, including lifelong learning.

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Secure Remote User Authentication Scheme on Health Care, IoT and Cloud Applications: A Multilayer Systematic Survey

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Abstract: Secure remote user authentication is an authentication technique in which the remote server authorizes the identity of the user through an insecure communication network. Since then diverse remote user authentication schemes have been proposed, but each category has its advantages and disadvantages. Besides its strength and weakness, remote user authentication systems have a great impact on real-time applications such as E-health applications, telemedicine applications, Internet of Things (IoT), Cloud, and Multi-server applications. The implementation of the Tele Medicine Information System (TMIS) over public networks continues to disclose confidential information to unauthorized entities. Similarly, remote user authentication techniques have become essential in accelerating IoT as well. Security is a major concern in IoT because it allows secure access to remote services. Cloud computing services and a Multi-server environment share data among different end-users through the internet which also needs security as its paramount concern. Although intensive efforts were made in designing remote user authentication scheme for health care, IoT, Multi-server and cloud applications, the majority of these applications suffers either from security attacks or lagging of critical features. This paper presents an analytical and comprehensive survey of various remote user authentication techniques and categorizes them based on different applications. Furthermore, the state of art recent remote user authentication techniques have been compared, their advantages, key features, computational cost, storage cost, and communication cost are highlighted.

Keywords: remote user authentication; e-health; telemedicine; internet of things; multi-server; security

1 Introduction

The Internet has become an important part of daily life. With the fast growth of Internet technology, we can enable any service from any location and at any time. In Health care, Internet of Things (IoT), Multi-Server environment, Cloud applications, remote user authentication is becoming an essential part to access the precious service or resource. Remote user authentication [1] is a vital component of every security architecture. Authorization provides Identity-Based privileges and without authentication, audit trails will not have transparency. When we can't accurately differentiate an authorized party from an illegal party, secrecy and dignity will be violated. Similarly to avail of the resource located at remote places every user should possess the proper access rights. One of the most basic and convenient protection mechanisms is the use of a password-based authentication scheme. Some of the examples of password-based authentication schemes are Automated Teller Machines (ATM), Database Management Systems, and Personal Digital Assistants (PDA). There are two main problems associated with the password mechanism one is passwords are stored in database systems as a plain not that can be easily accessed by the database administrator. The other problem is an attacker can impersonate a legitimate user by grabbing the user ID and PW from the table of passwords. To overcome these issues in a traditional authentication scheme dynamic id-based authentication scheme has been proposed. In addition to ID bases authentication, smart card-based authentication also seems to be one of the emerging authentication mechanisms. The researcher has presented that most of the smartcard-based authentication scheme overcomes the issues in dynamic ID and password scheme. Telemedicine is an evolving technology that supports a significant part of patient healthcare. This is a medical application that allows patients to have medical appointments outside hospitals using videoconferencing or digital imaging systems. Tier 1 uses the vital signals through wireless sensors, Data are transferred from Tier 2 to Tier 3. Tier 3 processes and generate responses. This enhances secure health monitoring through mobile health. IoT and Big data analytics are not point Information Communication Technology (ICT) paradigms that possess health care services. A smartcard-based efficient three-factor remote user authentication can be used to provide user anonymity and avoids security attacks or threats.

Recent advancement in research shows that IoT is useful in the surveillance of border controls, remote preparation, large scale deployment to enterprise-level, proactive maintenance of facilities, etc. In addition to health care, IoT, remote user authentication plays a major role in cloud computing applications. Remote cloud computing systems are, fundamentally, rather distributed in nature, and heterogeneous. In the mobile cloud computing environment, the mobile user authentication scheme should have a trusted third party, secure mobile user authentication, mutual authentication should exist among mobile users and cloud servers. Various symmetric and asymmetric algorithms can be employed to

provide the remote user authentication scheme. The most commonly used algorithm includes RSA, DES, AES, ECC, and Hyperelliptic curve cryptography. Each of these algorithms has its own merits and demerits. In this paper, multi-layer systematic reviews on remote user authentication schemes have been proposed. The first layer intends to survey on the impact of remote user authentication schemes on health care applications, telecare medicines, and wireless body area networks. The second layer aims to make a systematic survey on the impacts of remote user authentication on the Internet of Things applications. The third provides a detailed survey of multi-server and cloud computing applications. The fourth layer provides a detailed analysis of various security threats that those different systems have undergone. In addition to security attacks computational and communication analyses of different schemes were proposed (see Figure 1).

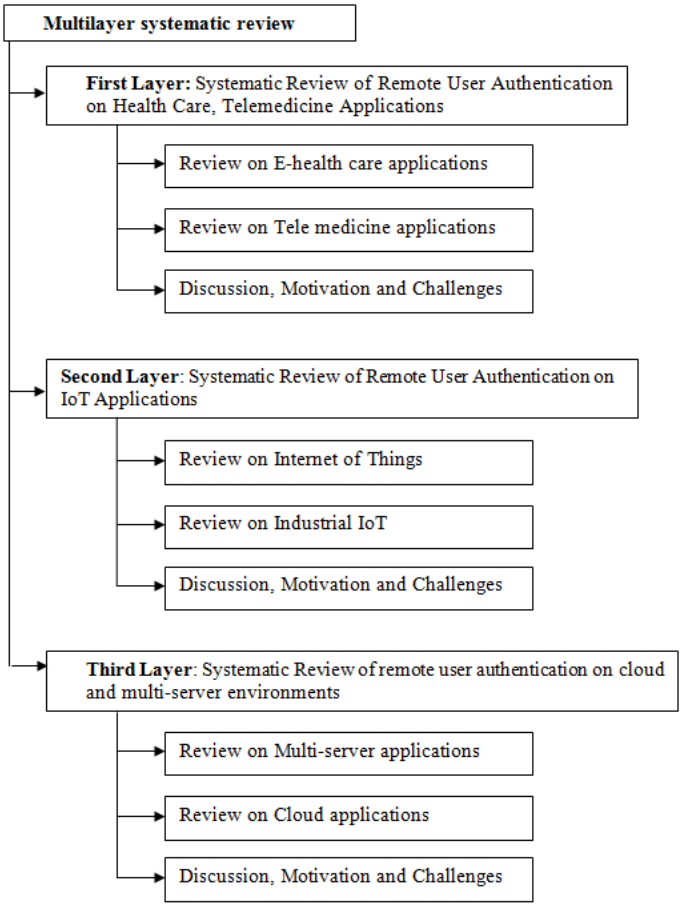

Figure 1
A framework of multi-layer remote authentication schemes

2 First Layer Systematic Review of Remote User Authentication on Health Care and Telemedicine Applications

Telemedicine technologies are commonly featured in scientific literature and have gained significant prominence recently. The keywords used for this survey are telemedicine, sensor, health care, security, authentication schemes. From the literature of varied databases such as science direct, IEEE explores, Web of Science the source of this layer was carefully screened. The study of this layer includes recent research in the field of telemedicine, healthcare for the last five years from 2015-2020.

2.1 Review of Authentication on Health Care Applications

Zhang et al. [2] design a dynamic privacy-protective measure that offers server-side biometric authentication. In their process, user confidentiality during authentication and key negotiation processes can be completely conserved. They have shown that their scheme is lightweight, as only hash and BioHash functions are taken into consideration. The advantage of their scheme:

- A dynamic verification table is provided to enhance the security
- Meet the demands of energy use and the protection needs of e-health systems.

The security tools used for their scheme are the Real-or-Random model. The communicational cost and computational costs are 164bytes and 0.0989 seconds respectively. Jiang et al. [3] proposed an efficient security protocol for wearable health monitoring services. Their methodology enables secure communication established between the medical professional and wearable sensors. This is an efficient end-end authentication protocol mainly developed based on quadratic residues. Their scheme enhances the security of Amin et al. protocol as their scheme prone to desynchronization attacks, mobile device attacks, sensor key exposure.

Xiong et al. [4] developed an enhanced 1-round authentication scheme for wireless body area networks. The communication cost of their scheme is 11.15 ms. Fatma et al. [5] developed an authentication protocol IoT-based health care application. They have added two important improvements in the recent M2C mutual authentication protocol that is based on health care RFID systems. The M2M authentication protocol they have developed is based on Elliptic Curve Cryptography RFID systems. The M2M authentication protocol they have developed based on Elliptic Curve Cryptography (ECC) and security was measured based on two well-known protocol verifier tools AVISPA and Proverif.

Their application is mainly used for resource-constrained devices. Yessad et al. [6] proposed a reliable authentication scheme for medical body area networks. It is proposed as a security solution. The routine activities of the patient such as walking, running, routine activities are periodically analyzed using sensors. They build an empirical model for assessing the physical and logical effect of attacks using the learning phase and the authentication phase.

2.2 Review of Authentication on the Telemedicine Information System (TMIS)

Telemedicine is an emerging concept in the field of health yet some challenges remain particularly in securing communication over the internet in remote monitoring systems. To improve protection, biometric features are used as a third factor in the design of a strong authentication scheme. Chaudry et al. [7] developed a multi-server biometric authentication scheme for establishing secure communication between the medical practitioner and patient. Chaudry et al. proposed that their scheme can change the password used in the authentication system without the intervention of the Central Management System (CMS). Proverif tool was used to ensure the security of their proposed scheme. The major advantage of their scheme is it is secure over an insecure channel and it assures perfect secrecy, light weightlessness. The security-related problems in the telemedicine world can be solved by improving the procedure of patient enrolment, which is a normal identity-proofing process.

Narwal et al. [8] proposed a mutual authentication and key agreement scheme for the telemedicine system which addresses the mobility and openness raising issues like complicated requirements and privacy leakage. It is analyzed with an ns2 simulator along with a counterpart scheme for end-end delay and throughput. SEEMAKA achieves superior performance with regard to overhead production, energy dissipation, and safety features. Zhang et al. [9] proposed a three-factor authentication scheme for telecare medicine systems based on chaotic map-based cryptography. Amin et al. [10] developed anonymity preserving mutual authentication scheme for wireless medical sensor networks. Their scheme offers robust mutual authentication and user-friendly password change phases included. It protects against mobile stolen attacks, offline password guessing attacks, and replay attacks. AVISPA and BAN Logic structures were used to verify the security of the proposed scheme. The main advantage includes cost-effectiveness and robustness compared to other existing approaches. Saracevic et al. [11, 12] proposed a novel iris recognition approach based on stylometric features. In the first stage, filtering and scanning to weed out duplicates and irrelevant studies of remote health monitoring systems focused on security concerns on health care and telemedicine. In the second stage of this layer, the authors performed a screening of papers collected from the first stage based on the security and privacy of telemedicine applications.

The comparison of remote user authentication schemes on health care and telemedicine application is specified in Table 1 (Legend: AS = Authentication Schemes; Y= Year; R = Reviewed on; K= Key feature; ST = Security tool used; CS1 = Computational cost; CS2= Communication cost).

Table 1

Comparison of remote user scheme on health care and telemedicine applications

AS	Y	R	K	ST	Performance parameters	
					CS1	CS2
Mohammed et al. [13]	2018	Existing authentication schemes	1.Secure and lightweight 2.Converts Patient biometric into key	AVISPA	200 ms	200 bytes
Sowjanya et al. [14]	2020	Li et al. [4] scheme	1.End-end authentication 2.Enhance medical data security	1.BAN logic 2.AVISPA	130 ms	2272 bits
Alzahrani et al. [15]	2020	Xu et al. [16] scheme	1. The Novel and robust patient monitoring scheme	1.BAN logic 2. Proverif	-	2624 bits
Jiang et al. [17]	2017	Lu et al. scheme [18]	1.Fulfills session key secrecy	Proverif	8.95 ms	1120 bits
Zhang et al. [2]	2017	-	1. Dynamic privacy protection scheme 2. Preserves user anonymity	Real-or-Random	0.09 seconds	164 bytes
Zhang et al. [9]	2017	Mishra's et al. [19] scheme	1.Chaotic map-based cryptography	-	4TC +3Ts+20 Th	1312 bits
Dhillon et al. [20]	2018	-	1. IoT based health care 2. Maintains key freshness	AVISPA	1TEXP + 14TH	-
Ravanbakhsh et al. [21]	2018	Amin et al. scheme [22]	1. Uses ECC and Fuzzy 2. Robust against privileged-insider	1.AVISPA 2.Random oracle	-	-
Chaudry et al. [7]	2016	Amin et al. [22]	1. Secure communication 2. Facility to change password	Proverif	15.63 ms	1664 bits

Merabat et al. [5]	2020	-	1. Efficient and scalable 2.Uses ECC for M2M	1.AVISPA 2.Proverif	485 ms	7N bits
Amin et al. [10]	2016	-	1. Anonymity preserving mutual authentication	1.BAN logic 2.AVISPA	0.0136 ms	2112 bits
Yessad et al. [6]	2017	-	1.Developed analytical model to mitigate attacks	BAN Logic	TAR-91.6%	Detection rate=97 %

3 Second Layer Systematic Review of Remote User Authentication on IoT Applications

Internet of Things (IoT) is any internet substructure entity associated with an advanced global dynamic network. The IoT is composed of three elements: things, communication networks, and Informatics. Before this, researchers focused on new strategies and successful approaches to properly integrating WSNs into the IoT situation.

3.1 Review of Authentication Schemes for IoT Applications

Li et al. [23] proposed a two-factor authentication scheme suitable for the Industrial Internet of Things (IIoT). They utilized improved requirements set for the commercial Internet of Things. They evaluate 42 specific schemes to prove their requirements are successful. Through implementing the "honeywords" strategy, how Xde capture attacks are detected and thwarted. Ostad et al. [24] identified a data transmission technique in IoT networks in which it is protected by three parties through the design of a lightweight authenticated key agreement. Their scheme offers perfect forward secrecy, best storage cost when compared to other related schemes. Their scheme resists id guessing, password guessing, replay, and impersonation attack. Result analysis concluded that their scheme is efficient and appropriate for real-time IoT-based wireless sensor applications.

Xuelei et al. [25] proposed an improved biometric authentication scheme using ECC. The security of the proposed scheme is analyzed with Random oracle and BAN logic [26]. Nikravan et al. [27] proposed an advanced multi-factor scheme based on the bilinear pairing of IoT. The protocol uses ECC, establishes a fresh session key, several security requirements are satisfied. Their result analysis has

shown that their scheme is resistant to well-known IoT related attacks and more suitable for well-known resource-constrained environments such as WSN.

Roy et al. [28] proposed an anonymous user authentication scheme that is based on an enotended chaotic map. Their scheme overcomes the higher computational cost of elliptic curve point multiplication and modular operation. Biometric fuzzy enotractors are utilized to enhance the performance metrics and this scheme is well suited for real-time e-healthcare systems. Dharminder et al. [29] analyzed flaws and construct a remote user authentication scheme based on smart cards. Their scheme uses lightweight cryptographic operations such as XOR operations and hash functions. The random oracle method was used to analyze the security of the proposed protocol [30]. Rajaram et al. [31] analyzed the security pitfalls of Awasthi's scheme and proposed eUASBP based mutual authentication scheme. It resists all possible attacks with smart card-based applications, enhances session key agreement, it detects the wrong password at the earliest possible.

Smart IoT architecture is composed of diverse microdevices and gathers different types of real-time information. It is not effective for realistic IoT systems, however, since the cost of computation and communication could be raised when the scale of the IoT networks and the distance between users is raised (see Table 2, Legend: AS = Authentication Schemes; Y= Year; R = Reviewed on; K= Key feature; ST = Security tool used; CS1 = Computational cost; CS2= Communication cost).

Table 2

Comparison of remote user scheme on IoT applications

AS	Y	R	K	ST	Performance parameters	
					CS1	CS2
Li et al. [23]	2019	Amin et al. scheme [10]	1. Evaluate 42 representative scheme to show the effectiveness	AVISPA	-	-
Ostad et al. [24]	2019	Amin et al. scheme [10]	1.Provides perfect forward secrecy 2. Best storage cost	AVISPA	0.0132 ms	5376 bits
Xuelei et al. [25]	2018	Lu et al. scheme [18]	1. Bio hash function and Elliptic curve authentication scheme using ECC.	1. Random oracle 2. BAN Logic	Communication cost=3TM + 11Th + 2Tsym	
Amintoosi et al. [26]	2019	-	1. Uses sparse representation 2. K singular value decomposition (K-SVD)	1.K-SVD 2. OMP suit	Accuracy=0.97 , sensitivity=0.983, specificity=0.978, prevalence=0.072	

Nikravan et al. [27]	2020	-	1. Uses the concept of bilinear pairing and identity-based cryptography	1.BAN Logic 2.AVISPA	1.2 sec	16th + 7tmul + 2tp + 8tex
Roy et al. [28]	2018	-	1. Enotended chaotic map-based user authentication 2. Uses biometric fuzzy enotractor	1.Real-or-random 2.Proverif 3.BAN Logic	23.52 ms	992 bits
Dharmindher et al. [29]	2020	Limbasiya et al. scheme [30]	1.Uses lightweight cryptographic operations	1.Random oracle	-	-
Rajaram et al. [31]	2020	Awasthi et al. scheme [32]	1. eUASBP ensures strong security and mutual authentication	BAN Logic	Storage cost= 1152 bits	1216 bits

4 Third Layer Systematic Review of Remote User Authentication on Cloud and Multi-Server Environments

Cloud computing is a cutting-edge technology that provides services without direct user control based on resource demand It is highly scalable, stable, and allows anywhere access to the data in indeed time.

4.1 Review of Authentication Schemes for Cloud Applications and Multi-Server Applications

Karuppiah et al. [33] proposed a generic authentication framework based on ID which provides roaming service. In GLOMONET, the construction of secure anonymous user authentication is difficult because the wireless networks are generally subjected to the vulnerability of attacks. Moreover, mobile devices are generally resource-constrained in terms of processing, storage, and communication [34, 35].

Feng et al. [36] proposed an anonymous key agreement scheme for a multi-server environment. They believed that biometrics is a preferred alternative for secure and reliable authentication and uses the elliptic curve cryptosystem.

The information can be analyzed in various cloud services where the user can access it remotely, whenever needed. Yet, the key concerns to safeguard data because the data has been in a remote server it is prone to malicious attacks and can be disrupted at times. So the advancement of a secure communications mechanism for data through authentication and access control is indispensable (see Table 3, Legend: AS = Authentication Schemes; Y= Year; R = Reviewed on; K= Key feature; ST = Security tool used; CS1 = Computational cost; CS2= Communication cost).

Table 3

Comparison of remote user scheme on Multi-server applications

AS	Y	R	K	ST	Performance parameters	
					CS1	CS2
Karuppiah et al. [33]	2017	Miyoung et al. scheme [34]	1.An ID-based generic framework for GLOMONET	Proverif	1.62 ms	2272 bits
Challa et al. [35]	2020	-	1. ECC based anonymous authentication scheme	1.AVISPA 2.BAN Logic	0.32 sec	1536 bits
Feng et al. [36]	2017	Kumari et al. scheme [37]	1. Elliptic curve cryptosystem and biometrics are combined	BAN Logic	0.708 seconds	3531 bits
Liu et al. [38]	2018	Lu et al. scheme [18]	1. Three handshake mechanism with privacy protection	BAN Logic	1.148 ms	Energy dissipation= 6.924 mJ
Joseph et al. [39]	2020	-	1. Multimodal biometric authentication (Finger + Palm print) 2. Uses AES, DES, and Blowfish algorithms	-	1. FAR=0.15 2. FRR=94.5	
Nunes et al. [40]	2019	-	1. Biometric authentication combining multi-party and fuzzy vault 2. Enrolls 1000 users within a second	-	GAR of ≈90% FAR of ≈3%.	

Sharma et al. [41]	2018	-	1. Authentication based on quantum key distribution 2.Entanglement based QKD	AVISPA	1.Key Rate=4.11 bit/s 2.Error rate=9.21%	
Shashidhara et al. [42]	2020	Xu et al. scheme [43]	1. Provable security established through mobile user	AVISPA	0.0187 seconds	2560 bits
Jangirala et al. [44]	2017	Shunmuganathan et al. scheme [45]	1. Dynamic identity-based authentication	1. BAN logic 2.AVISPA	(25 Th & 12Tx)	1120 bits
Zhang et al. [46]	2017	Odelu et al. scheme [47]	1.Uses secure sketch and Chebyshev chaotic map 2.Secure sketch to solve fuzzy in biometrics	1.BAN logic 2.Proverif	1.55 seconds	1952 bits
Nguyen et al. [48]	2018	-	1. Uses fuzzy commitment and random orthonormal projection scheme	-	1.FAR=7% 2.FRR=7%	
Ying et al. [49]	2019	-	1. Self-certified public-key cryptography based on ECC	-	3.54 ms	368 bytes
Chandrakar et al. [50]	2017	Wen et al. scheme [51]	1.Secure three-factor authentication scheme	1.BAN Logic 2.AVISPA	-	3232 bits

Liu et al. [38] proposed a lightweight and efficient multi-server authentication based on dynamic biometrics. They used three handshakes to establish mutual authentication and all the remote services are offered with privacy protection. The protocol is more robust and fault-tolerant.

Nunes et al. [40] proposed a biometric authentication scheme based on multi-party computation techniques and Fuzzy enotractors or vaults. Their scheme involves the development of a modular, scalable, and safe framework allowing non-interactive re-enrollment of users.

The main advantages of this scheme are around 1000 users are able to enroll within a second. Shashidhara et al. [42] developed an authentication protocol that achieves provable security. Jangirala et al. [44] proposed an identity-based

authentication scheme for a multi-server environment. The major application of their scheme is resource-constrained wireless sensor networks.

Zhang et al. [46] proposed a secure three-factor authentication scheme based on a sketch algorithm and Chebyshev chaotic map. The purpose of including a sketch algorithm is to solve the problems involved in fuzzy characters of biometrics.

Nguyen et al. [48] modeled a biometric-based authentication scheme that helps to mitigate malicious attacks. Their scheme specifically attacks against sensitive information threat and also protect against insider attacks.

Ying et al. [49] modeled a remote user authentication protocol that is lightweight and self-certified public-key cryptography. They developed this scheme for 5G multi-server networks and uses ECC for self-certified public-key cryptography.

The advantage of their scheme includes:

- Able to provide protection of privacy required in 5 G applications
- It has greater efficiency in terms of communication and computational cost.

Chandrakar et al. [50] identified a secure safe three-factor authentication scheme for a multi-server environment. Yao et al. [52] proposed an RLWE based remote user authentication that is privacy-preserving and developed mainly for single and multi-server environments. They have included user biometric in their authentication scheme to enhance security, which is termed as RLWE based Remote Biometric Authentication Scheme (RRBAS). Their scheme satisfies the authenticated key agreement scheme (AKA). which resists all types of security attacks and provides post-quantum secure features.

5 Motivation towards Security Requirements and Attacks

This section list out and describes the various security attacks that an optimal remote user authentication scheme should tolerate. The comparison of various security attacks on remote user authentication schemes is specified in Table 4.

Table 4

Comparison of security attacks on remote user authentication schemes

Authentication scheme	1	2	3	4	5	6	7	8	9	10	11	12	13
Mohammed et al. [13]	×	×	√	×	×	×	×	×	×	×	√	×	√
Sowjanya et al. [14]	√	×	×	√	×	×	×	×	×	√	√	×	√
Alzahrani et al. [15]	×	×	√	×	×	×	×	×	×	×	√	×	√

Jiang et al. [17]	×	×	√	×	×	×	×	×	×	×	√	×	√
Zhang et al. [2]	×	√	√	×	×	√	×	√	×	×	×	×	×
Zhang et al. [9]	×	×	×	×	×	×	×	×	×	×	×	×	×
Dhilon et al. [20]	×	√	×	×	×	×	×	×	×	×	√	√	×
Ravanbakhsh et al. [21]	×	×	×	×	×	×	×	×	×	×	×	×	×
Chaudry et al. [7]	√	√	×	×	×	×	×	×	√	×	×	×	×
Merabat et al. [5]	×	√	√	×	×	√	×	×	×	√	×	×	×
Amin et al. [10]	×	×	×	×	×	√	×	√	×	×	√	×	√
Yessad et al. [6]	×	×	√	×	×	×	×	×	×	×	√	×	√
Jiang et al. [3]	×	×	√	×	×	×	×	×	×	×	√	×	√
Li et al. [4]	×	√	×	×	√	×	√	√	×	×	×	×	×
Xrwal et al. [8]	×	×	×	√	×	×	×	×	√	×	×	×	×
Sasikaladevi et al. [53]	×	×	×	×	√	×	×	×	×	×	×	×	×
Li et al. [23]	×	×	√	×	×	×	×	×	×	×	√	×	√
Ostad et al. [24]	×	√	×	√	×	×	√	×	×	×	√	×	√
Xuelei et al. [25]	×	×	×	×	×	×	×	×	×	×	√	×	√
Nikravan et al. [27]	×	√	×	×	×	×	√	×	×	√	×	×	×
Roy et al. [28]	×	×	×	×	×	×	×	×	×	√	×	√	×
Dharminder et al. [29]	×	×	×	×	×	×	×	×	×	×	×	×	×
Rajaram et al. [31]	√	×	×	√	×	×	×	×	×	×	×	×	×
Punithavathi et al. [54]	×	×	×	×	×	√	×	×	×	×	×	×	√
Xiong et al. [55]	×	×	×	×	×	×	×	×	×	√	×	√	×

1) Password guessing attack: Many of the password authentication schemes possess less entropy that is susceptible to password guessing attack, in which an attacker accesses and stores authorization messages locally and then tries to use the guessed password to test for correctness.

2) Parallel session attack: An attacker may masquerade as the authorized user, despite knowing a user's password by generating a legitimate login message off any eavesdropped conversation between user and server. The attacker could also initiate a simultaneous attack by recreating the response message from the server at such a later stage as the login message from the user.

3) Forgery attack: An intruder attempts to alter captured messages to masquerade as the legitimate user for wireless system access to the resources. An Intruder could even masquerade as a legitimate server for the manipulation of confidential legal user data.

4) Denial of service attack: This attack prohibits the use or maintenance of communicating messages. This attack can impact a specific user. For example: an adversary can cause the server to refuse a particular user's login before it is re-registered. The DoS attack excludes all or individual users by aggressive behavior on the server or through a forgery of the password validation of the user.

5) Reflection attack: A reflection attack is a form of targeting an authentication device for the response to challenges that utilize a certain protocol through both directions. That is, both sides have used the same challenge-response protocol to validate the users. The attack's basic concept is to trap the target into offering the answer to its question.

6) Stolen verifier attack: The server stores hashed passwords in several applications, rather than plain tenot passwords. The stolen verifier assault implies an attacker who stoles the password verifier that is hashed password. And during the user authentication process, the server may use it explicitly to masquerade as just an authorized user.

7) Smart card loss attack: Unauthorized users can easily modify the smart card's password when the smart card is stolen or lost. Or can formulate a user's password by password guessing attacks, or can obtain by user signing into the program.

8) Replay attack: An intruder who has obtained previous communications can impersonate the authorized user to sign in to the system. The intruder will playback the messages that were intercepted. An attempt in which a legitimate transmission of information is maliciously or fraudulently replicated either by the originator or an attacker who intercepts the information and forward, probably as part of a masquerade assault.

9) Insider attack: An insider attack is a deliberate misuse of people allowed to use computers and networks. To get a password, the server insider will perform an off-line guessing attack. If it works, the server's attacker will try using a password to spoof users to log into other servers using standard password authentication methods

10) Man-in-the-middle attack: Man-in-the-middle (MITM) attack is a form of threat where attackers intervene in an existing two computer communication and then track, capture, and monitor the interaction. In Man-in-the-Middle Attack, an attacker assumes the identity of legitimate users to gain control of network traffic.

11) Lack of session key attack: Often session keys are called symmetric keys because the same key is used both for encryption and decryption. The key is transmitted along with every message during each session and is encrypted with the public key of the recipient. The key is transmitted along with every message during each session and is encrypted with the public key of the recipient. An attacker who attempts to gain this session key of a particular communication is called a session key attack.

12) Impersonation attack: An impersonation attack is an attack in which an attacker effectively assumes the identity of one of the legitimate parties in a contact protocol or program. The purpose of a strong identity or entity

authentication protocol is to make the possibility negligible to make impersonation in secure communication.

13) Biometric recognition error: Two types of biometric recognition errors have happened in any biometric device. A) False accept rate: The rate at which the device accepts an unauthorized person B) False reject rate: The rate at which the device falsely rejects an authorized person.

Conclusion

In this paper, a systematic review of recent advances in remote user authentication scheme has been proposed. Security attacks that every authentication should mitigate and security requirements that each authentication scheme should satisfy have been outlined. The remote user authentication scheme is categorized into three systematic layers in which the first layer depicts the remote user authentication scheme for health care applications, the second layer depicts the remote user authentication scheme on IoT applications and the third layer elaborates on the remote user authentication scheme on cloud and multi-server applications. E-healthcare is the active area of research in TMIS which gives mobility to its users.

Having considered the privacy of patients, medical information, authenticated, and secure access to medical data are needed. The comparative evaluation of the recent remote user authentication scheme has been pointed out. Given the growing speed and complexity of IoT devices in our society, the need for such devices to be authenticated would be much needed. Before actually supplying mobile users with any connection to the cloud service, mutual authentication of the cloud service provider and the mobile user is required. In this paper, around 100 recent remote user authentication schemes have been analyzed and compared concerning key features, security tool used, performance parameters such as computation cost, communication cost, storage cost, accuracy, FAR, FRR. Moreover, it is believed that the ongoing direction in a survey of remote user authentication scheme helps the researchers to easily point out the ideal properties, possible factors, and helps to outline the various security attacks. In future research, in addition to IoT, health care, cloud, and multi-server applications, remote user authentication will find its major concern in emerging real-time applications such as agriculture, E-governance, smart cities, E-passport, etc.

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Application of a Genetic Algorithm for Minimum Zone Method of Flatness

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Abstract: The geometric product specification (GPS), has an increasing importance in machine design, manufacturing and measuring. However, standards describe the interpretation of the different kinds of form and position tolerances; there are several methods in measuring, how these deviations can be evaluated. In this article the minimum zone method (MZ) is presented in case of flatness error by coordinate measuring device. Different search algorithms can be applied during the implementation, in order to solve the geometric problem of flatness evaluation. In this article, the genetic algorithm is investigated and compared with hill climbing algorithms. The optimization of the parameters of the genetic algorithm is also presented.

Keywords: geometric tolerances; coordinate measuring method; flatness; minimum zone method; genetic algorithm

1 Introduction

A plane surface is an often used geometric feature, in the machine design. The accuracy of a plane can be defined by many aspects, but the set of geometric deviations can ensure the most sophisticated description. The flatness error describes the deviation of a flat surface from the theoretical plane. The flatness is a type of geometric error and the flatness tolerance defines the permissible level of this error. The flatness tolerance is defined by standards [1] [2]. The application of geometric tolerances has several aspects. The first is the notation in the shop drawing, the second is the functional justification, the third is the manufacturing aspect and the fourth is the measuring aspect. The standards describe the first level only.

The flatness error is the distance of two parallel planes, which limit the produced flat surface. The two parallel planes have 3 degree of freedom (DOF), one linear, in perpendicular direction and two angular DOFs, in the horizontal plane. During the calculation of flatness error, the position of the parallel planes should be defined.

The geometric error of the different surfaces can be measured by coordinate measuring machines. There are several parameters, which defined the uncertainty of the measuring process [3]. The calculation method of the geometric errors is one of the key parameter.

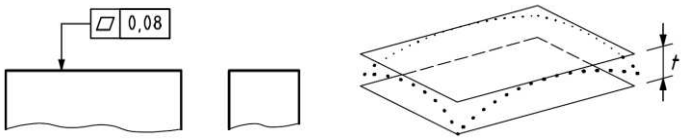


Figure 1
Indication and implementation of flatness based on ISO 1101

In current literature, there are several methods for solving the problem of evaluate flatness error, like regression method, envelope method, minimum zone method, but in the current article the minimum zone method (MZM) is investigated (applied). In case of MZM method, the position and orientation of the control planes are defined considering the minimal distance between the planes. This requires a recursive method, where the best position is reached by step by step.

Abdulshahed et al. [4] and Yang et al. [5] classified the optimization algorithms as deterministic (simplex method, downhill method, Newton-Raphson method, least square method (LSM), convex hull algorithm) and stochastic methods (Figure 2). Inside meta-heuristic stochastic method, the genetic algorithms (GA) and the different kind of particle swarm algorithms (PSO) are the most popular methods.

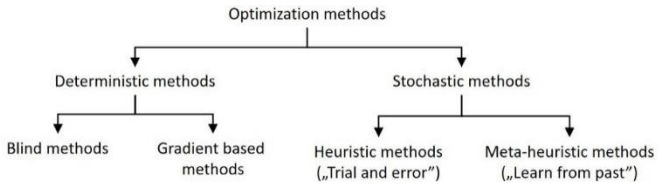


Figure 2
Classification of optimization methods

In case of evaluation of flatness, a wide range of optimization method can be used for determine the minimum zone of flatness. Kanada and Suzuki [6] compared downhill simplex method, with repetitive bracketing method. 8400 points were measured at test parts, which were machined by shaping, milling and hand finishing. The downhill method was found to be faster. Samuel and Shunmugam [7] and Hermann [8] investigated convex hull method. Abdulshaded et al. [4] a kind of swarm algorithm applied: the Cuckoo search optimization. Yang et al. [5] compared five types of algorithms: LSM, GA, PSO, teaching-learning based algorithm (TLBO) and adaptive hybrid TLBO. Based on different point clouds (number of points 25 and 32), the AH-TLBO algorithm showed faster regression and smaller flatness values.

Tseng [9] applied genetic algorithm (GA) for minimum zone flatness calculation. Arithmetic crossover and non-uniform mutation were applied. The size of the population was doubled, but other parameters are not published. The individuals were selected based on the roulette wheel method, when the selection is random, but the probability is proportion with the fitness. Based on literature based point clouds, the proposed GA method ensured better results than least square method or convex hull method. Wang et al. [10] presents a differential evolutionary algorithm (DE) for flatness calculation by minimum zone method. The population consists of 20 individuals in the implementation, the best individuals were selected for crossover and after 100 iterations the process was stopped. The authors found, that the proposed algorithm has the advantages of simplicity and flexibility. Wen et al. [11] applied an improved genetic algorithm (IGA) for minimum zone flatness evaluation, which ensures shorter processing time by real-code implementation. The blend crossover function was applied, when parents of a new individual was selected randomly. The investigated point cloud contained 20 points. The size of the population was 20, and during one iteration 20 new individuals were generated. The iteration was stopped at 200 cycles. Comparing with the least square method, the results were better. Khan and Ma [12] presents a real coded efficient genetic algorithm (EGA) in case of flatness assessment based on minimum zone method. The proposed algorithm converged in less than twenty generations. The implementation was performed in Matlab, the size of the population was 60, and the 50% of the population was regenerated by crossover in every generation. 10% of the generation was modified by a decreasing random mutation function.

During the previous research [13] four hill-climbing algorithms were compared, but they were single point methods, one solution was modified in several steps.

In this research, a genetic algorithm solution was implemented and investigated. The genetic algorithm is a stochastic optimization method based on the principle of population evolution [14]. An individual – a member of the population – is a potential solution of the problem, and through the evolution process the best individual will be the final result. The representation of the individuals can be binary or real-code, depending on the investigated problem. During the evolution, three operators are applied: selection, crossover and mutation. The selection for crossover of mutation can be random, statistical (like roulette wheel selection) or elitist (select the best). The crossover function creates new individuals based on selected individuals (parents), and the mutation function modifies the selected individual. The implementation of the genetic algorithm can be very different [14] [15], but based on the literature during the implementation the main questions are the following:

- How can the individual be described?
- How large population is required?
- What is the fitness function?

- How can the crossover and mutation be interpreted?
- How the individuals can be selected?
- How many individuals are made by crossover?
- How many individuals are modified by mutation?

The aim of the article is to present an implementation of the genetic algorithm in case of the evaluation of the flatness error and to investigate the effect of the different parameters of the algorithm on the performance of the algorithm. The optimization of the parameters is presented also.

2 GA Implementation

The flatness error of a measured point cloud can be defined as the difference of the closest and the farthest points from a reference plane. This definition harmonizes with the definition of the standard and realizes the minimum zone method. From the viewpoint of the genetic algorithm, the position of the reference plane means one solution of the problem, so the population consists of a set of reference planes. An individual means the N_X, N_Y and N_Z coordinates of the normal vector of a reference plane.

The fitness function of the genetic algorithm is the flatness error, which can be calculated by the normal vector and the set of points of plane surface. A plane can be defined by a point ($\underline{P_o}$) and the normal vector ($\underline{N}$). The P_o point hasn't got an importance in this application, so it can be (0;0;0). The distance of a point ($\underline{P_i}$) is calculated by equation (1):

$$D_i = \frac{N_x \cdot (P_{0x} - P_{ix}) + N_z \cdot (P_{0y} - P_{iy}) + N_z \cdot (P_{0z} - P_{iz})}{\sqrt{N_x^2 + N_y^2 + N_z^2}} \tag{1}$$

Based on the minimum zone method, the flatness error is the difference between the farthest and the closest point (2) on the surface:

$$FL = Max(D_i) - Min(D_i) \tag{2}$$

Individuals, which have the best fitness values, can generate new individuals by crossover function. In this case, the crossover function is implemented as a linear combination of selected normal vectors. The new normal vector is on the connection line of parent vectors. The position is selected randomly and the 25% external section is permitted too (Figure 3a). In case of mutation function, the normal vector is modified by ±10% randomly (Figure 3a).

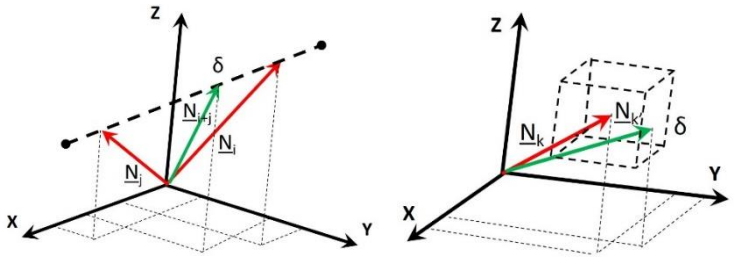


Figure 3
Implementation of crossover (a) and mutation (b) function

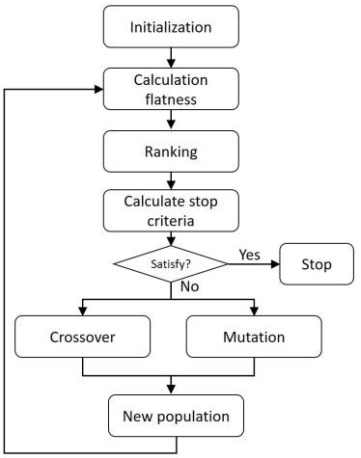


Figure 4
The GA process

During the preliminary investigation, the main questions were the size of the population, the number of new individuals, which can be generated by crossover and the number of individuals, which can be modified by mutation. Figure 4 shows the investigated algorithm. The initial population (a set of normal vector of the reference planes) is generated randomly during the initialization, the N_x and N_y coordinates were changed, the N_z was 1 in the current implementation. Then the flatness values are calculated for every individual (reference plane). Based on it, the ranking can be performed. Then the stop criterion is investigated: if the difference between the best and the worst flatness values is smaller than 0.00001 mm, or the number of iteration is 1000, the process stops. Otherwise, the crossover and the mutation functions are executed, and the process starts again with the new (modified) population. The algorithm was implemented in Free Pascal 1.0.12.

3 Test Environment

The performance of the genetic algorithm is defined by the main parameters, as the size of the population, the number of new individuals and the number of modified individuals. The optimization of these parameters improve the efficiency of the algorithm. In order to optimization several sets of parameters were defined and the results and performance were analysed. A full factorial plan was used for generate parameter sets, because of the fast calculation process. The number of variations was 4 x 8 x 6 = 192, and every set was repeated 25 times.

Three factors were varied:

- The size of the population. Pop = 15 – 20 – 25 – 30
- The number of new individuals: Cro = 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8
- The number of modified individuals: Mut = 1 – 2 – 3 – 4 – 5 – 6

The algorithm was tested on six machined flat surfaces of the same dimensions 175 mm × 155 mm. The test surfaces were machined using different technologies, methods and machine tools (Table 1). Surfaces #1 and #2 were machined in a conventional and CNC milling machine by zig-zag strategy, with the same cutting speed and feed per tooth. Surfaces #3 and #4 were machined by face turning with the same parameters, except the feed. As for #5 and #6 surfaces, face-milling technology was applied with the same tool and parameters, and with different tool path strategies.

Table 1
Machining conditions of test samples

Surface ID	**Sf#1**	**Sf#2**	**Sf#3**	**Sf#4**	**Sf#5**	**Sf#6**
Method	Face milling		Face turning		Face milling	
Strategy	Zig-Zag		-		Zig-Zag	Spiral
Machine tool	UF-231	MAZAK A410-II	E400-1000		MAZAK A410-II	
Type	Manual	CNC	Manual		CNC	
D_c [mm]	80	50	-		63	
z [-]	7	4	1		6	
v_c [m/min]	60		(100)		180	
n [1/min]	240	382	190		910	
f; f_z [mm]	0.046		0.6	0.2	0.09	
v_f [mm/min]	78	70	115	40	490	
a_p [mm]	1		0.5		1	
a_e [mm]	40	25	-		31.5	

D_c – Cutting tool diameter; z – Number of teeth; v_c – Cutting speed; n – Spindle speed; f, f_z – feed, feed per tooth; v_f – feed speed; a_p – depth of cut; a_e – width of cut

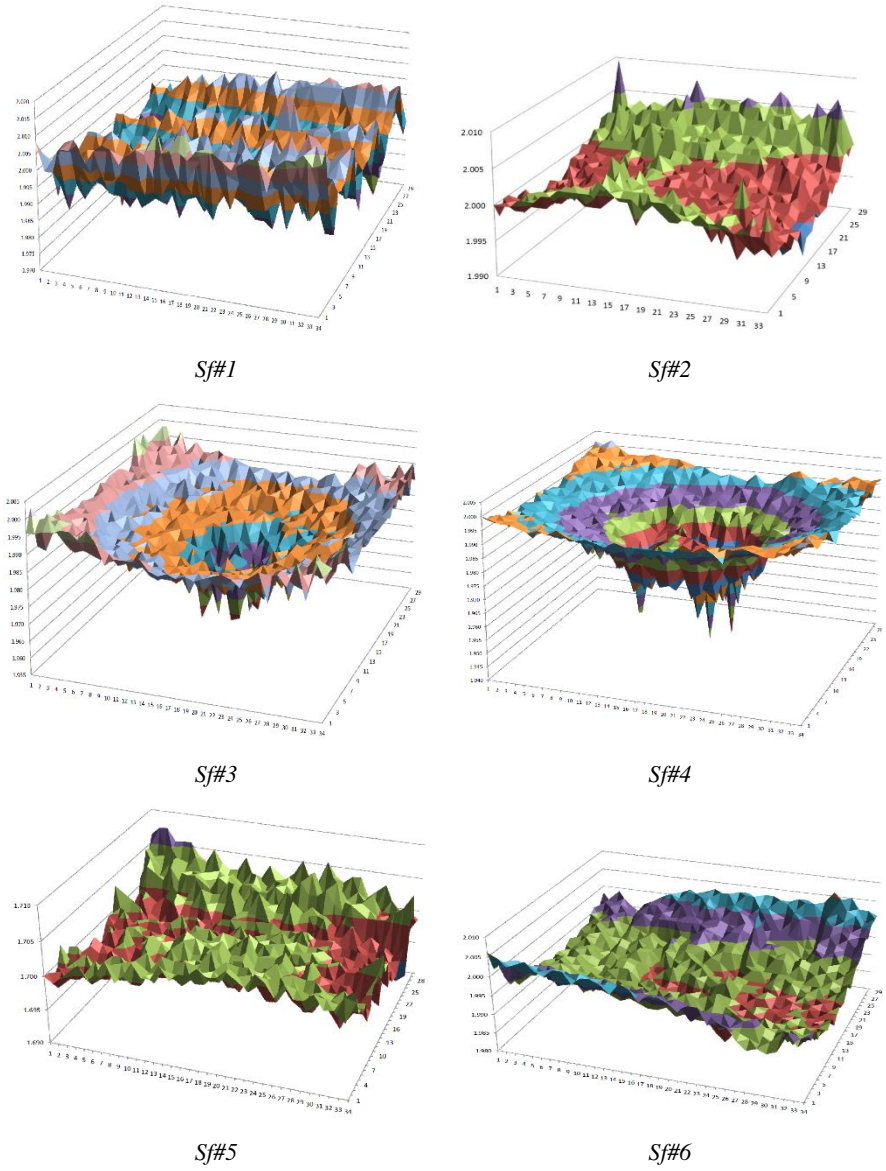


Figure 5
Maps of measured points in case of 6 test surfaces

The coordinate values of the investigated flat surfaces were measured with Mitutoyo Crysta-Plus 544 coordinate measuring machine. The measurement was performed in a discrete sampling mode with a contact probe (tip diameter is 3 mm). Sampling was carried out in 1020 uniformly distributed points on the

examined surface. The reference values of the flatness error were calculated by Kotem SurfaceProfile v5. The reference values can be seen in Table 2.

Table 2
Reference values of flatness in mm

	Sf#1	***Sf#2***	***Sf#3***	***Sf#4***	***Sf#5***	***Sf#6***
FL_Ref [mm]	*0.0343*	*0.0127*	*0.0427*	*0.0572*	*0.0124*	*0.0204*

Figure 5 shows the map of coordinate values of six specimens. The different nature of the surfaces, related to the machining technology, can be observed.

The total number of data for optimization was 192 x 25 x 6 = 28.800. The marking of the different cases is the next: Sf#4-20-4-6 means, the test was performed in for the data of Sf#4 test surface, the population consists of 20 individuals, 4 individuals were generated by crossover, and 6 individuals were modified by mutation.

The following parameters were calculated during the test:

- The value of flatness
- The average, the minimum and the maximum values, and the standard deviation of the flatness value of 25 repetitions
- The number of iteration till the stop condition
- The average, the minimum and the maximum values, and the standard deviation
- The ratio of the minimum and the average flatness to the reference values

4 Iteration Process and Results

As mentioned before in the current implementation the value of the *Z* coordinate of the normal vector of a reference plane is constant ($N_z = 1$). During the preliminary phase, the results of test runs were analysed in case of Sf#6. 15 individuals were generated, the number of crossover is changed from 1 to 8 and the number of mutation is changed from 1 to 6. The results were calculated based on 25 repeated runs. The results were analysed by MiniTab v14 software (Figure 6).

The Z parameter shows the differences. When all coordinates were changed, the $Z = 0$ (3D), and only if the N_x and N_y were changed (2D), then $Z = 1$. As main effects plots show, in case of $Z = 1$ the average value of the 25 repeated runs is closer to the reference value ($Av\text{-}Ref \rightarrow 0$), and the standard deviation of the flatness data is smaller. The standard deviation shows, then the repetition causes smaller difference in the flatness values, the algorithm has better repeatability.

Nevertheless, more iterations are required, until the stop condition, so the calculation need more time.

Investigating the changing of the flatness values during the iteration in case of 3D solution the value of the best individual changed just a little and the worst individual evolves close to the first. In case of 2D solution, the first and the worst individuals can evolve too, but it takes more generation (iteration).

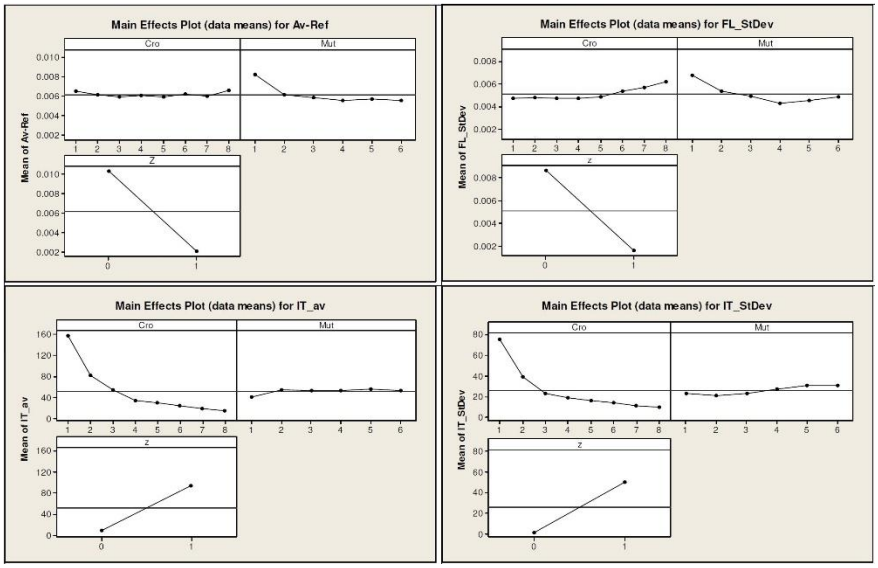
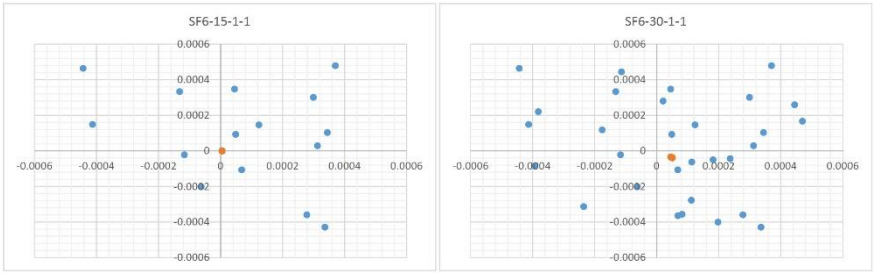


Figure 6
Main effects plot for 2D/3D comparison (Sf#6; Pop=15)

The Figure 7 shows the distribution of the individuals at the initial and the final step. As it seems, the initial population cover an area, but at final step, the individuals there are in same point. The final position is different in these two cases, because of the randomly generated initial positions. In case of 30 points, 15 points are same, as in the first example (Figure 7a) and one crossover and one mutation were applied. The flatness value in case of 15 populations is 0.0212 mm and it was reached at 294 iteration steps. In case of 30 individuals, the flatness is 0.0209 mm and 122 steps were performed.

During the iteration process, the flatness value of the best and the worst individuals is changed gradually. The process stops when the difference between the two values is less than 10E-5 mm (stop condition).

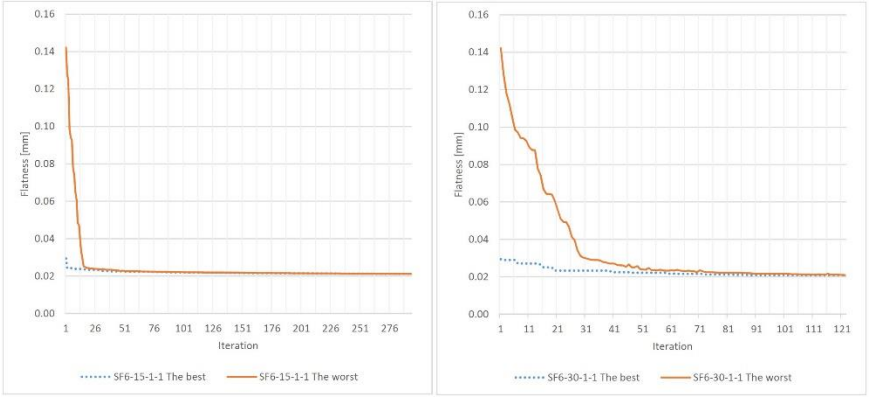


a) b)

Figure 7

Initial and final population in case of Sf#6-15-1-1 and Sf#6-30-1-1

As the Figure 8 shows, the changing of the values has different speed in case of two examples. Of course, the other individuals change too. However, the initial populations cover a very small area (0.001 x 0.001 mm), the difference in initial flatness values larger than 0.1 mm.



a) b)

Figure 8

The best and the worst flatness values in case of Sf#6-15-1-1 and Sf#6-30-1-1

In the previous research [13] three hill-climbing algorithms were compared. The hill climbing (HC) algorithm is an iterative search algorithm. The HC find the best set of parameters step by step, and in every iteration choose the best neighbour. The difference between the three compared algorithms is the definition of the distance of neighbours. In case of HC1 random distance was used, HC2 applied a decreasing random distance and HC3 used fix distance. The results can be seen on the Figure 9. The "GA" means the minimum flatness value from the test runs, so in case of different test surfaces different GA parameters were used. Based on the diagrams the GA solution gives the best results comparing with the reference value, but the aim of this research is to find the GA parameters, which can work properly in every test surfaces.

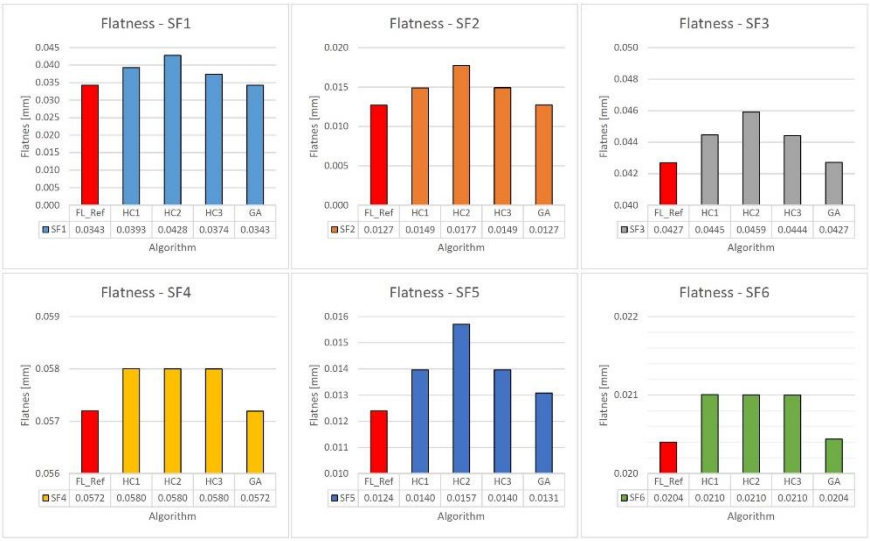


Figure 9
Comparison of the results of different algorithms

5 Investigation and Optimization of GA Parameters

The effect of the size of the population (Pop), the number of new individuals (Cro) and the number of modified individuals (Mut) was investigated by main effects plot (Figure 10). The Minitab v14 was used for the analyses.

In case of difference of minimum and reference value (Min-Ref) and the difference of average and reference value (Av-Ref) the goal is the 0, because in this case the evaluated flatness is close to the real (or reference) value. In case of standard deviation of the evaluated flatness, the aim is to reach zero, because it ensures the good repeatability of the algorithm.

The minimum value of a repeated runs is very close to the reference value. The increasing size of the population and the number of mutated individuals improve the ratio, but the number of new individuals worsens it. In case of the average values of the repeated runs, the parameters have same effect, but the effect of the number of new individuals is clearer and the ration of average and reference value is larger. The standard deviation of the flatness values indicates the repeatability of the algorithm. The number of modified individuals has a large effect on it. The higher number of mutated items causes smaller standard deviation on a set of repeated runs. The increasing number of new individuals increases the standard deviation; the size of the population shows a reverse proportionality. With up to three modified individuals, the changes are small.

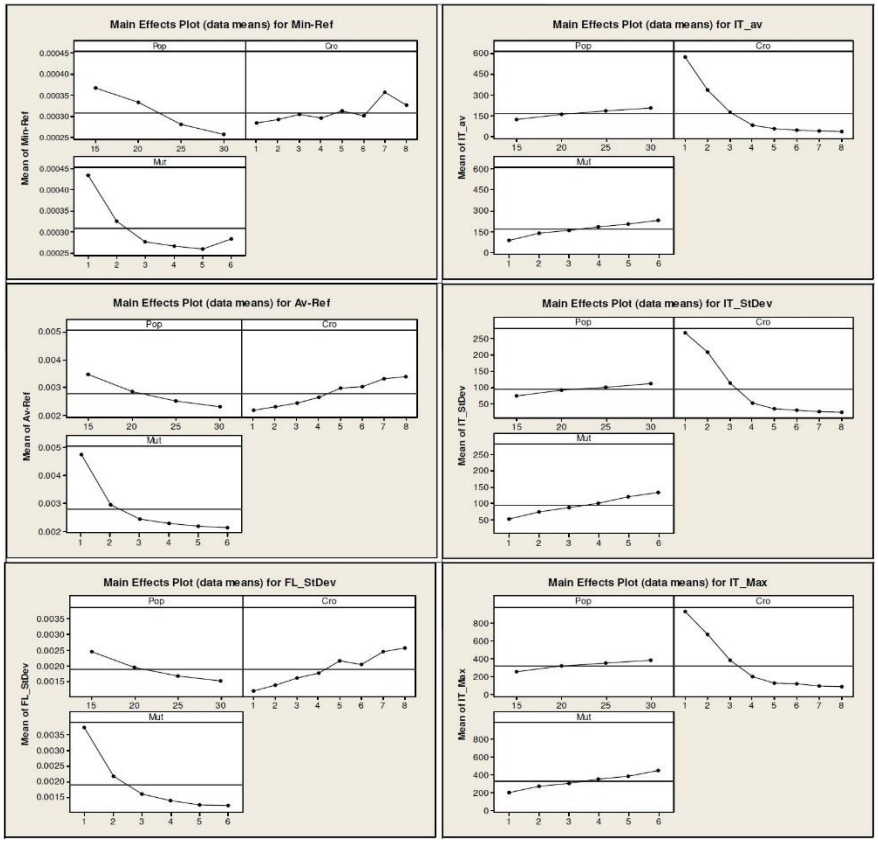


Figure 10
Main effects plots

The number of iterations until the stop condition indicates the speed of the algorithm. The average number of iteration, the maximum value and the standard deviation of the iteration are controlled by the number of new individuals, but up to 4, the improvement is small. The size of the population and the number of mutated individuals increase the number of iteration cycles, but the effect is smaller.

Unfortunately, the two investigated sets of indicators show opposite nature. If a parameter improves the accuracy, the running time will be longer. If a parameter ensures faster execution, the accuracy of the results worsen.

During the optimization of GA parameters, the best set of Pop, Cro and Mut parameters should be determined, from the viewpoint of best performance. Several performance parameters can be selected.

The "*Minimum flatness - Reference flatness = 0*" seems evident goal function, but the repeated runs got different flatness results, and if only one run is used, so there is no guarantee for the minimal flatness value.

Therefore, the "*Average flatness - Reference flatness = 0*" seems better, if the standard deviation of repeated runs is minimalized. The minimized standard deviation ensures the close range of results. Thus the accurate result can be calculated by a modification factor. The modification factor will consider the ratio between the average and the reference flatness. The number of iteration should be minimized, but the execution of the search is quite fast (less than one second), so it is not an important aspect.

Statistical analysis is performed to investigate the effects of GA parameters, i.e. Pop, Cro and Mut on the selected performance parameters. The main characteristics, which have important role in the performance, are the difference of Average flatness - Reference flatness (*Av - Ref*) and the standard deviation of the repeated flatness determination (*FL_StDev*).

General linear model (GLM) is created for the statistical analysis for both output parameters. The purpose of this research is not only to describe the processes but also to optimize the setting of GA parameters on both performance parameters simultaneously. The statistical analysis is related to the above-mentioned factors and their levels:

- Pop: fixed factor with 4 levels
- Cro: fixed factor with 8 levels
- Mut: fixed factor with 8 levels

During the GLM analysis the two-way and the three-way interactions are taken into account. The optimization goals are to minimize the standard deviation of the repeated flatness determination and *Av - Ref* value.

Table 3
ANOVA table for Av - Ref in case of the full data set (R^2=52.75%)

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Pop	3	0.000223	0.000074	38.56	0.000
Cro	7	0.000214	0.000031	15.83	0.000
Mut	5	0.000985	0.000197	102.08	0.000
Pop*Cro	21	0.000057	0.000003	1.42	0.100
Pop*Mut	15	0.000167	0.000011	5.78	0.000
Cro*Mut	35	0.000360	0.000010	5.32	0.000
Pop*Cro*Mut	105	0.000062	0.000001	0.31	1.000
Error	960	0.001853	0.000002		
Total	1151	0.003922			

It can be stated from the ANOVA table (Table 3) that the main factors (Pop, Cro, Mut) and the two-way interactions (Pop*Mut, Cro*Mut) have significant effect on the *Av - Ref* value. This model has good fitting on the simulated values as the residuals show random distribution (Figure 11).

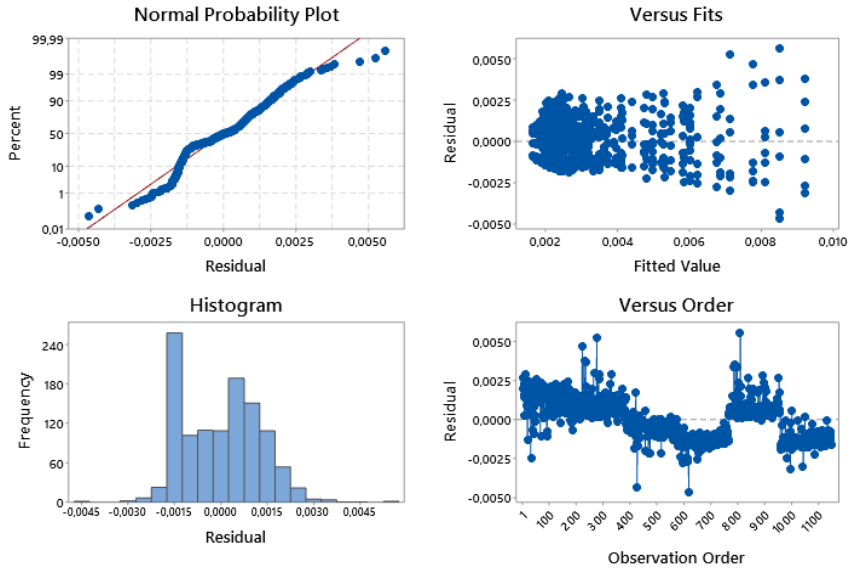


Figure 11
Residuals plots for the GLM of *Av - Ref*

The second GLM is related to the standard deviation of flatness determination. The results (Table 4) show that all main factors and two-way interactions have large effect on the output parameter. The residuals are randomly distributed (Figure 12).

Table 4
ANOVA table for FL_StDev in case of the full data set (R^2=58.04%)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Pop	3	0.000142	0.000047	35.46	0.000
Cro	7	0.000249	0.000036	26.67	0.000
Mut	5	0.000892	0.000178	133.80	0.000
Pop*Cro	21	0.000054	0.000003	1.91	0.008
Pop*Mut	15	0.000100	0.000007	5.00	0.000
Cro*Mut	35	0.000274	0.000008	5.86	0.000
Pop*Cro*Mut	105	0.000061	0.000001	0.43	1.000
Error	960	0.001280	0.000001		
Total	1151	0.003052			

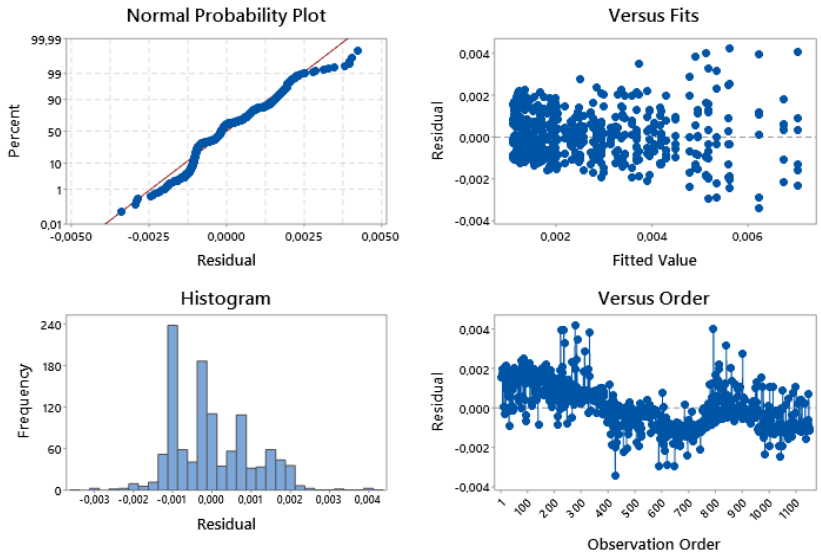


Figure 12

Residuals plots for the GLM of *FL_StDev*

During the optimization step, the two GLMs are optimised simultaneously. Within this models only the GA parameters and their interactions are taken into account. The goal is to minimize *Av – Ref* and the *FL_StDev* values. In case of all test parts the optimum parameters of the genetic algorithm are Pop=25, Cro=7 and Mut=5 (Figure 13). The reached *Av – Ref* value is 1.6 µm, the standard deviation for flatness determination is 1.2 µm.

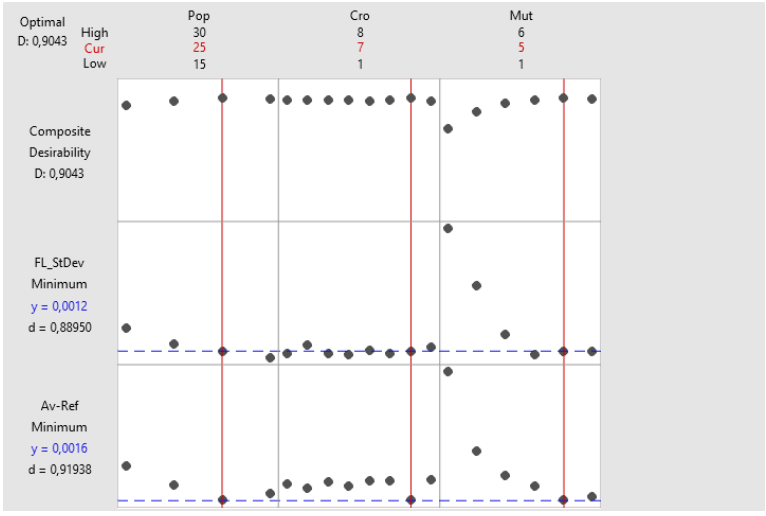


Figure 13

Multiple response (*Av - Ref* and *FL_StDev*) optimizer for the data

If the data of the test parts are viewed as individual sets and the surface IDs are taken into account with its 6 levels as a main factor, the ANOVA results for *Av – Ref* values (Table 5) and for *FL_StDev* values (Table 6) are better.

Table 5

ANOVA table for *Av - Ref* in case of the full data set with surface ID main factor (R^2=88.83%)

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Pop	3	0.000223	0.000074	162.31	0.000
Cro	7	0.000214	0.000031	66.64	0.000
Mut	5	0.000985	0.000197	429.70	0.000
Surface ID	5	0.001415	0.000283	617.22	0.000
Pop*Cro	21	0.000057	0.000003	5.97	0.000
Pop*Mut	15	0.000167	0.000011	24.33	0.000
Cro*Mut	35	0.000360	0.000010	22.40	0.000
Pop*Cro*Mut	105	0.000062	0.000001	1.29	0.033
Error	955	0.000438	0.000000		
Total	1151	0.003922			

Table 6

ANOVA table for *FL_StDev* in case of the full data set with surface ID main factor (R^2=86.71%)

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Pop	3	0.000142	0.000047	111.34	0.000
Cro	7	0.000249	0.000036	83.75	0.000
Mut	5	0.000892	0.000178	420.15	0.000
Surface ID	5	0.000875	0.000175	411.93	0.000
Pop*Cro	21	0.000054	0.000003	6.01	0.000
Pop*Mut	15	0.000100	0.000007	15.71	0.000
Cro*Mut	35	0.000274	0.000008	18.42	0.000
Pop*Cro*Mut	105	0.000061	0.000001	1.36	0.013
Error	955	0.000406	0.000000		
Total	1151	0.003052			

The multiple response optimization is performed for the six surfaces separately. Table 7 shows the results.

Table 7

Multiple response (*Av - Ref* and *FL_StDev*) optimizer for the data grouping by surfaces

Parameter/Surface ID	**Sf#1**	**Sf#2**	**Sf#3**	**Sf#4**	**Sf#5**	**Sf#6**
Pop	30	25	25	30	25	30
Cro	7	7	7	1	7	1
Mut	6	5	5	2	5	2

Av-Ref [mm]	0.0031	0.0027	0.0012	0.0005	0.0024	0.0005
FL_StDev [mm]	0.0025	0.0021	0.0009	0.0001	0.0013	0.0002

When the data examined separately, the optimal GA parameters are different. In case of Sf#2, Sf#3 and Sf#5, the parameters are the same, and in case of Sf#1 they are close to the overall parameters (25/7/5). Nevertheless, in case of Sf#4 and Sf#6 the number of crossover (Cro) and the number of mutation (Mut) is very different. These separated parameters can ensure better performance of the genetic algorithm, but in order for a general application, the nature of the investigated surface cannot be considered.

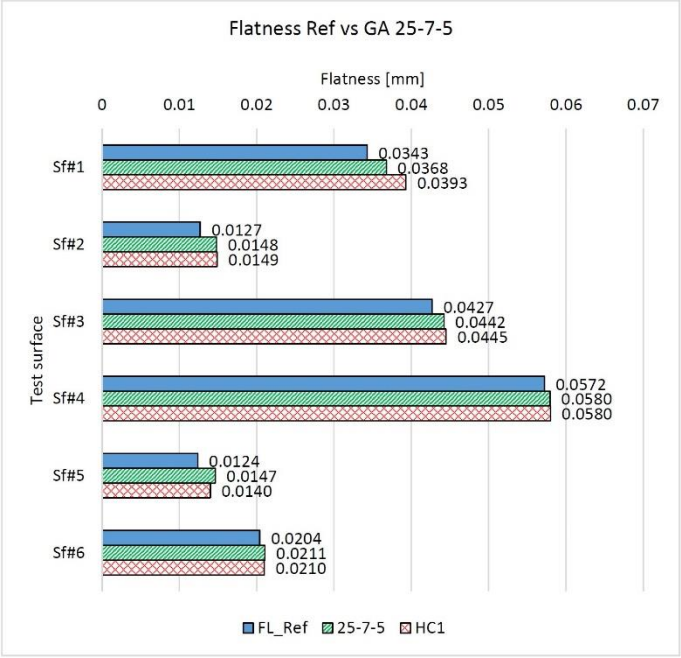


Figure 14
Comparison of flatness results

Figure 14 shows the results of the optimised genetic algorithm (25-7-5) comparing with the reference values (FL_Ref) and the results of random hill climbing algorithm (HC1). Generally, the optimized genetic algorithm achieves better results, but sometimes the differences are very small, less than 1 μm.

Conclusions

The description of a machine part requires not only the shape, the size or the material, but also, the tolerances. The geometric tolerances ensure a more sophisticated definition of shape and position deviations, but the use of coordinate metrology is necessary. The flatness describes the deviation of the machined

surface from a theoretical plane. However, the standards define the interpretation of flatness, but the mathematical evaluation process can be different. Different types of methods can be used, such as, the least square method and the minimum zone method of enveloping methods. In addition, the mathematical implementations can be very different.

In this work, the minimum zone method is presented, and the application of genetic algorithm (GA) is investigated. The GA has three basic parameters, which characterize the work of the algorithm. These parameters are (1) the size of the population (Pop); (2) the number of new individuals, which are created by crossover operator (Cro); and (3) the number of individuals, which are modified by mutation operator (Mut). These parameters were optimized based on measurement results of test surfaces. The size of the tests surfaces was 175x155 mm, and they were machined by milling or turning methods. The test point clouds contain 1020 coordinate points. The flatness values of genetic algorithm were compared with hill-climbing algorithm.

The most important statements of this research are:

- In case of the presented implementation, the genetic algorithm is able to solve the flatness evaluation problem considering the minimum zone method. Comparing with the previous results, the time of the evaluation is similar (less, than 1 s).
- The parameters of genetic algorithm can be optimized by statistical method, and in the investigated case the optimal parameters are Pop=25, Cro=7, Mut=5.
- The properties of the investigated surfaces have effect on the GA parameters, although the general use of the GA method does not allow these to be taken into account.
- The calculated flatness values of the optimized genetic algorithm generally better than the results of the hill climbing algorithm in case of the investigated surfaces. But the differences are very small, less than 1 μm.

In future research, the effects of surface parameters could be investigated, such as, the size, the machining technology and the surface roughness. Another task could be the application of other types of swarm algorithms, like bee colony, grey wolf optimizer, cuckoo search etc.

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Activity Diagram as an Orientation Catalyst within Source Code

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Abstract: There is a premise that the activity diagrams can communicate their knowledge to the source code. This article analyzes the opportunity of the activity diagrams to improve the comprehensibility, orientation, reading, and modularization of the source code. It proposes an Activity Diagram Driven Approach (ADDA) and verifies application suitability of the approach in comparison to Use Case and Package-based approach. It highlights the strengths and weaknesses of such behavior description and discusses the identified limits and benefits of the proposed approach. It proposes an extension of the source code modularization at metamodel level based on source code parts associated with certain elements of the activity diagram. The proposed solution is evaluated over several test cases from different aspects using implemented plug-in and the results show appropriate use of the proposed approach.

Keywords: UML; activity diagram; source code; orientation; comprehensibility; modularization

1 Introduction

Initial analysis of business processes often leads to a set of activity diagrams (AD) that describe how the work is carried out within the organization. These diagrams may contain so-called swimlines which visually distinguish contribution to the implementation of business processes and responsibility for implementation of sub-activities throughout the process. Implicitly, within these diagrams, there is documentation of explicit links between the actions and roles, players, i.e., the users. Such a depicted business process can gain representation in the form of software—to a human somehow readable form of a source code. Unlike behavior diagrams, source code is rather difficult to read and highly technical in nature with almost no business information. It is difficult to mentally grasp even related source code parts of the project with respect to its complexity and scope.

This problem met a resolution in the decomposition of a complex solution into smaller units [1] or packages [10] etc. Such a decomposition or in other words, modularization may carry into the software a considerable set of implications. One of them is the issue of preserving the intent in the source code [7], low cohesion and high coupling of the source code [8], [29] its readability [3] and comprehensibility or simply orientation at all. Preserving or grabbing source code intent is not only a problem of reading an unknown author's source code but even of its own ones, especially after some time. Actually, even the author himself has to make a lot of effort to get in his own source code after a while. To comprehend a certain business processes, a more or less complex ones already available in the form of source code, would not be so simple. One could feel the need to get rid of unnecessary details, to abstract or to see things from a higher perspective.

It is known that the system maintenance consumes approximately 70 percent of the total cost of the software product [13]. The use and benefits of the information stored in the behavioral diagrams and their mapping to the source code is confirmed by developers themselves when up to 17 of 19 developers would welcome a tool to help them navigate in the source code, especially if they do not know the source code [21]. The same developers have suggested that the error rate could be significantly reduced because the diagrams provide a better overview of what the developer may currently work on. This paper presents the design and implementation of the Activity Diagram Driven Approach (ADDA) and source code mapping, i.e., organizing source code into a structure based on activity diagrams in order to achieve better modularization, readability, comprehensibility, and orientation in the source code as such. The work is divided into several sections. Section 2 refers to the core principle of the activity diagram-driven source code modularization. Section 3 provides consideration in the context of the activity diagram's metamodel and its extension. Section 4 includes an extensive evaluation and reflects on related work.

2 Related Work

The proposed approach ADDA can be confronted across all phases of software development. One can come across activity diagrams within a workflow modeling during the requirements elicitation phase [14]. At this stage, we usually do not have any source code except for existing projects and for example specifications in the form of Changelog. Further analysis and design may only refine the identified model of the upcoming system. Connection with the implementation phase of software development is found in the study of the coverage degree of the source code by the activity diagram [19]. They proved that it is possible to generate source code not only from structural class diagrams but also from behavioral diagrams namely UML AD. To achieve automatic generation L. Jim and P. Klint had to define relatively complex stereotypes and limitations.

According to L. S. Jim and P. Klint [19], K. Hyungchoul [20] and Heinecke et al. [17], user-acceptance tests (UAT) can also be generated from UML AD.

A similar connection between the software development phases also provides another UML artifact. M. Bystrický in his work [5], [6] and [7] presented the idea of the source code modulation from the point of view of use cases. In this approach, it represents a use case by a single file - a markdown file. This file, in addition, contains business information and source code implementing the behavior of the use case. Thus, the user finds the relevant source code in one place. This is the most fundamental difference between M. Bystrický's approach and the proposed ADDA approach. Using UML AD even UML UC in both cases, is just a way of looking at the source code - simply a certain perspective of looking. Using different views, respectively projections, in relation to the source code has also been investigated by J. Porubän and M. Nosáľ [27] in "Leveraging Program Comprehension with Concern-Oriented Source Code Projections". The authors recognized the possible need to look at the source code from different viewing angles according to the actual needs of the programmer. ADDA approach can also be considered as one of the source code projections. However, J. Porubän and M. Nosáľ did not come with UML AD in their solution, so they chose a different approach for source code projections based on annotations. However, a number of authors have dealt with the UML activity diagrams [17], [19], [21], the use of a new view at the source code e.g. from the perspective of use cases [7] even from the perspective of interrelated pieces of (multidimensional) software knowledge [34] or readability [4] comprehensibility [26], [24], [29], reusability and manageability [12], [11]. There are several types of contributors that participate in the development process. They prefer different types of perspective according to Alistair Cockburn's [9] UC levels of abstraction. Software comprehension supported by structural diagrams is also provided [18] based on measuring the time and correctness of responses. In another experiment demonstrating the need for diagramming participants desired a wide range of information contained in diagrams. They also declare the need for flexible, adaptive, and responsive diagramming tool support. Just for that reason, the prototype ADACSCO (Activity Diagram As a Catalyst of a Source Code Overview) has been deployed as an extension of the existing IDE Eclipse.

3 Activity Diagram Driven Source Code Modularization

In principle, activity diagrams are used to communicate reality or ideas about business processes [17], [25], [42]. They offer comprehensive support for the control-flow of the majority of them [30] and they are at least one level of abstraction above compared to use cases presented in Cockburn's Five Level Use

Case Model [9]. However, activity diagrams besides their textual description, in addition, visualize the process control flow. It is possible to consider the case when one business process consists of more than one use case [15], [35]. In this case, one executable node may also represent just one use case that embodies lower-level steps in the overall activity according to UML Specification. All of this only confirms a higher or equal perspective of the activity diagram's view of a model in comparison to the perspective of use cases. In some literature, this is referred to as a difference in the granularity of the view of the model [2]. It also destroys misunderstanding of the activity diagrams as just a mean for a single-use case expression [22].

As mentioned above, activity diagrams are describing execution flows called – the flow of work, workflow, working process or business process represented by actions - nodes called ActivityNodes interconnected by edges. And so, the description of the workflow consists of ActivityNodes (ControlNodes, ObjectNodes, and ExecutableNodes) and flow-of-control constructs (synchronization, decision, and concurrency) principally analogous to Petri Nets. The activity diagramming is specific for its possibility to expose other artifacts such as real object instances [31], the naming of roles that cooperate in the business process, visualization of parallel sub-processes [32], and specification of event-driven behavior [13]. The considered approach of activity diagram-driven source code modularization attempts to use explicitly created links to map the activity diagram with the source code as close as possible. Additionally, classes would not be logically grouped in a suitable way by belonging to elements or activity diagrams. Element implementation information would be scattered throughout the code. However, the benefit of the alternative with comments and tags could be the assignment at the level of methods and attributes. The second alternative is to link classes or source files directly with an activity diagram's elements so that their relationship appears in the AD action tree rather than in the source code. However, mapping classes to AD elements represents a higher granularity of association abstraction in comparison to mapping methods or attributes to AD elements and of course, it brings in certain redundancy in the form of element-irrelevant parts of the source code. But, such a form of decomposition is not in contradiction with a possible more detailed implementation.

The modularization units that would account for such a structure are the activity diagrams and the elements of the activity diagram - predominantly actions. Each element of the activity diagram respectively the activity diagram itself may have its behavior implemented by a specific part of source code. In our experiments, those specific parts will be classes. The activity diagram element to source code relevance can be visualized for example by an explicit link between the element and the class. For a simpler and more transparent view, it is possible to document these associations in the form of a tree structure, where the root of the tree is the activity diagram, its nodes are the elements, and the tree leaves represent the

classes themselves. Creating these explicit links, respectively bindings allows defining the structure of the source code based on activity diagrams. Such a structure preserves a degree of business information that can help the user to orientate between the source code classes.

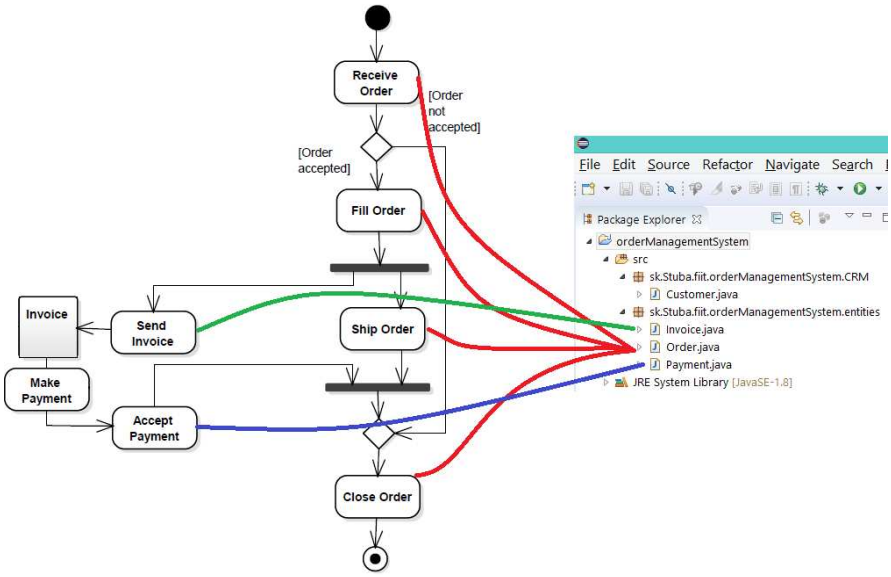

Figure 1

Associations between UML AD elements and classes in Package Explorer (PE)

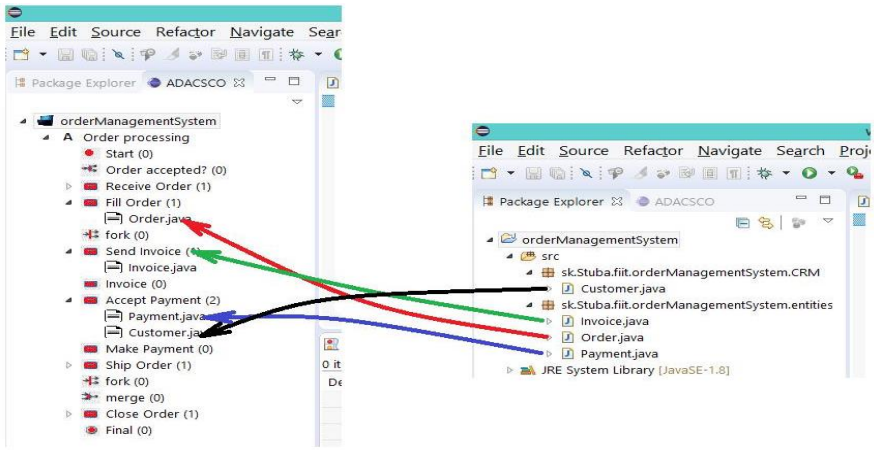

Figure 2

Tree structure organization of UML AD elements in ADACSCO plug-in

Colored lines in Figure 1 connect executable nodes of the activity diagram with classes of the Order Management System project listed in PE of the Integrated

Development Environment (IDE) Eclipse tool. The extension of the above visualization is illustrated by the Tree Structure Organization of UML AD in Figure 2 supplemented by the association orientation. The number in common brackets next to the name of each executable node expresses the number of classes participating in the implementation of the behavior behind the action. Implementation of the plug-in for IDE Eclipse seems to offer a new perspective for organizing the project - in terms of business processes. However, the principle is not only bound to the above mentioned IDE either language of the source code. Binding classes to actions assume the source code in the object-oriented paradigm. An interesting aspect is the direction of the binding. An arrow of the association goes from class to action. However, several different scenarios of modularization supported by an association AD with specific parts of the project - the source code can be considered. For the purpose of evaluation, we have created all diagrams in Enterprise Architect (EA). Interestingly, in this context, it seems to be an estimation of the burden resulting from the proposed approach. For the purpose of evaluation, prepared AD was neither difficult nor complex. It can be assumed that there is no potentially greater burden put on the developers neither in the case of enterprise projects nor projects with a higher number of AD. Hypothetically, this results from the fact that a discrete backlog task does not matter how processed (iteratively, agile. . .) will always be or should be just a subset of a particular AD. And for this purpose, each developer performs the synchronization of changes made to it for all affected repositories including the update in associations between AD elements and classes. The nature of the approach itself, as it is apparent from the description, suggests that it is a non-invasive method from the source code point of view. The above scenarios represent a way to modularize the source code driven by AD. Regarding the source code modularization, there are several ways of implementation e.g. based on packages, from the architectural point of view according to the MVC pattern or driven by use cases [7]. However, none of these directly support organizations according to the studied business processes in a complex view. All the things mentioned above especially modularization related are heading to improve orientation itself. Straight and tidy units, respectively parts of a project, create a premise for better orientation.

4 Activity Diagram Metamodel Extension

The proposed approach does not implement all of the elements for simplicity. This is also because they are not expected to be used frequently and could uselessly complicate the proposed solution and make the proposed structure less apparent. The yellow-colored element of the metamodel has been included in the alpha version of the implemented prototype. This approach proposes UML metamodel extension in the form of an association between the activity diagram element - ActivityNode and the SourceCode element by composition see Figure 3. One

ActivityNode can aggregate multiple parts of the source code. Deleting a particular activity from the activity diagram also results in an adequate response on the source code side. This synchronization is fully supported by the implemented prototype.

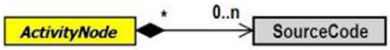

Figure 3
UML AD metamodel – Control node part. Based on OMG® Unified Modeling Language

In order to confirm or disprove all the above-mentioned assumptions even expectations including the extension of the metamodel within the ADDA approach, testing and evaluation were performed. For this purpose as the prototype ADACSCO plug-in has been implemented according to the above-mentioned specification in Java as an Open Source IDE Eclipse project.

5 Evaluation of the Proposed Approach

Orientation in UML AD is relatively simple following the instructions in the UML specification [25]. This good orientation in UML AD ensures the control of even object flow [33]. The swim lines may contribute as well. They group the elements of the activity diagram, e.g. according to the actor who performs these actions [25]. We expect these features can improve orientation in the source code. Experimental verification of these expectations is provided within the Evaluation by selected user types, Performing tasks by participants using ADDA and Multiple Users' Collaboration support.

Activity diagram driven approach proposed in this paper is expected to play the role of an imaginary catalyst that supports orientation within a source code. Let us assume that, AD is considered to be a catalyst (CA) according to a certain analogy with formal expression in chemistry, then

$$\mathbf{AD} \Leftrightarrow \mathbf{CA\#(1)}$$

AD is intended to be used in conjunction with the source code (SC) just as any other artefact, therefore

$$\mathbf{AD} + \mathbf{SC} \rightarrow \mathbf{ADSC}\ \#(\mathbf{2})$$

Of course, catalyst supported source code (ADSC) can be compiled by Compiler (C). Only the code is really compiled. In general, the catalyst does not affect the reaction balance in chemistry even in this analogous case for the source code compilation. So AD does not affect the way the code is compiled. AD remains unchanged by compilation. AD is just an artifact like many others,

$$\mathrm{C(ADSC)} \rightarrow \mathrm{CSC} + \mathrm{AD\#}(3)$$

As a result of compiling source code in the IDE with links to various artifacts not excluding AD is the Compiled Source Code (CSC). AD as a catalyst and at the same time one of the artifacts is not consumed and still remains. Concerning orientation (O) in the existing source code, we can assume a situation where at the beginning (in time denoted as t1) of the interaction with the source code, the degree of a user orientation is denoted as Ot1. After some time of interaction (in time denoted as t2), study or acquaintance with the source code, the degree of the user orientation will be referred to as Ot2. So, the duration of getting to know the source code Δt without the use of AD as a catalyst can be expressed as:

$$\mathrm{Ot1} \rightarrow \mathrm{Ot2}: \mathrm{t2} > \mathrm{t1}: \Delta\mathrm{t} = \mathrm{t2} - \mathrm{t1} \# (4)$$

Another situation occurs if we use AD as a catalyst. Catalyst - AD influences only the duration of the user's interaction with the source code ΔtAD in order to get the required level of the orientation. While Ot3 is the user orientation in the beginning and Ot4 is the user orientation after some time of interaction with the source code.

$$Ot3 \xrightarrow{AD} Ot4: t4 > t3: \Delta tAD = t4 - t3 \# (5)$$

So, we can express our hypothesis as:

$$\Delta tAD < \Delta t \# (6)$$

To prove this hypothesis, a series of tests were carried out under the same conditions with respect to the source code sample and the group of participants. The experimental group of participants - for evaluation purposes, a group of 12 participants was created. All participants who participated in the evaluation activities were all experienced in programming (each worked for at least 3 years as a developer) and recognized the Java language in which the source code sample was implemented. Four of the participants previously worked as testers and two of them have had practical experience with system analysis. The age of participants varied when the youngest was 28 and the oldest 49 years old. Source code's working set - a source code's working set is a set of source code classes to which the developer needs access throughout a particular assignment. For evaluation purposes, we have used a source code fragment whose characteristics are listed in Tables 1, 2, and 3.

Evaluation was performed by the following ten testing scenarios.

A.) Activity diagram coverage by ADACSCO. Implementation of ADACSCO, a data model has been created over which the plug-in is working. To confirm that, this data model covers all the important AD UML 2.5 elements (specifically ActivityNodes, flow-of-control constructs - decision and concurrency) we have compared it with the UML AD metamodel. Due to the limited space in the article, we do not provide a visualization of this mapping. Finally, all metamodel entities respectively the metamodel elements that were identified in the Activity diagram driven source code modularization section as necessary are included and implemented in the proposed data model.

B.) UML AD creating in ADACSCO. Source code and related eight sample ADs were prepared in Enterprise Architect and available in the form of .png images as well as .xml files. Respondents did not recognize the source code before. Each of the participants had to get in these ADs into ADACSCO in two ways - manually and automatically.

Manually creating a tree structure - in this case, participants had to redraw the ADs based on prepared images using ADACSCO editor functionality. The sequence of actions that participants had to perform was as follows: create a project in Eclipse IDE then redraw activity diagrams in ADACSCO including activity diagram elements for each and finally assign parts of the source code to AD elements. Respondents did not consider creating a project and activity diagram as problematic just as the creation of elements in these diagrams. They even marked them as actions that would be rarely performed. The complications were seen just in the assignment of the classes to the actions. Assigning classes to actions may occur in an ongoing project. Therefore, in such a case, it can be perceived as counterproductive. Of course, it can be argued that each developer would use ADACSCO only on the part of the AD that is the subject of his work. Therefore, he should assign classes only to selected and a significantly smaller number of elements. There could be a lot of duplicate work when two developers work on the same AD. In order to avoid similar situations, ADACSCO has been extended to support collaboration between developers by export and import functionality (described in Multiple Users' Collaboration support).

Automatically creating a tree structure - in this case, participants had to create ADs using a .xml file import ADACSCO functionality. This option unburdens the developer not only from the tree structure creation but also in certain cases from the manual assignment of classes to selected elements of the activity diagram. A prerequisite for using this functionality is a properly designed activity diagram (in our case in the Enterprise Architect) exported in the form of .xml file. ADACSCO can read the file, convert it properly into the tree structure and visualize it.

During the import phase, the AD and its elements are automatically created. Created links between actions are also supported by the plug-in. If the activity diagram has a relationship between the activity diagram element and a class, ADACSCO can create these links as well. So if the associated class already exists in the project, ADACSCO will offer link with the element based on name matching. If the class has not been created yet ADACSCO will offer an option for its creation. No negative comments were recorded by the participants in the assessment of the implemented functionality.

C.) Activity diagram elements data customizing. The ADACSCO plug-in allows creating of tagged values for each project, AD, or AD's elements. The tagged value consists of the name and the value that belongs to it. In this way, it is possible to record the required set of data in the tree structure of ADACSCO for each element of the AD. In assessing this functionality, each participant had to

find as many ways of applying the tagged values as possible, respectively through tagged values should store as much data as one thinks to be useful. The most commonly created tagged values were: priority - the importance of why a snippet of the code was attached to the AD element, complexity - the degree of implementation difficulty, dates - each participant gave at least one date, requirements - participants would welcome to add non-functional requirements related. There were also: information useful in the agile development process - participants saw the potential of tagged values also in recording information in agile development method when it could be recorded for example a sprint number, start and end date or product owner and attributes for implementing user acceptance tests (UAT) - tagged values can also be used in activity diagrams to generate UAT tests.

D. Created structure modification support. Evaluating the available options for modifying the structure of AD, participants were asked to edit the AD in EA. Then, transfer these changes into ADACSCO or they could skip editing the diagram in EA if they did not consider it important. As part of this evaluation, participants did not make any serious comments and did not notice any shortcomings of the plug-in as well.

E. Multiple Users' Collaboration support. Multiple Users' Collaboration has been evaluated at the source code level as well as ADACSCO Tree Structure. Source code level collaboration point of view - ADACSCO does not prevent or restrict users from using Git, SVN for collaboration. Because ADACSCO does not directly work with source files but only opens them with IDE Eclipse Editor (similar to PE), there are no temporary or permanent copies of the source code files. This behavior ensures that source code files management does not require any additional configuration or tracking of a different set of source code files. In other words, if one developer uses ADACSCO and the other does not, it has no impact on working with Git. This behavior was tested in the following scenario. Each of the two participants had their own computer while the first one updated the source code using ADACSCO, and the other used the standard PE. They used GitHub service through terminal commands. Description of the test scenario: Respondent 1 (PC 1): Updating the NaturalPerson.java class (ADACSCO); Inserting changes to the shared Git repository (push). Respondent 2 (PC 2): Downloading changes from shared Git repository (pull), Updating the NaturalPerson.java and LegalEntity.java (Package Explorer), Inserting changes to the shared Git repository (push). Respondent 1 (PC 1): Downloading changes from shared Git repository (pull). The result of evaluating the use of ADACSCO with Git was consistent with the assumption. This means that after the testing scenario, participant 2 had available changes made by participant 1, and participant 1, in turn, saw changes made by participant 2.

Collaboration at the Tree Structure level of ADACSCO plug-in - tree-level collaboration means sharing a previously created activity diagram, its elements including elements with the associated source files. The goal of enabling

ADACSCO activity diagrams to be shared is to avoid unnecessary duplicate activity with developers. If someone has already created the structure, it is unnecessary to create it again. Tree-level collaboration at the ADACSCO platform is made possible by AD exporting and importing. This means that the developer exports the already created activity diagram in ADACSCO. The diagram is stored in a .xml file that can be delivered to a different developer, e.g., by email. The tree-level collaboration was evaluated by all 12 participants. Eleven of them exported their AD and put the export on a common USB. The last twelfth participant imported these AD into ADACSCO. As a result of this evaluation, the twelfth participant had access to the tree structures created by his colleagues in his ADACSCO. This evaluation also successfully attempted to show a possible way of using the plug-in in an already running project, even when a large system is distributed among multiple developers.

F.) Modularization support. Modularization of the software is the distribution of monolithic code to modules having a certain modular structure [28]. Three ways of organizing the source code, namely Package-based approach, the Use Case-based approach, and the ADDA approach were confronted during the evaluation process. Package-based approach - traditional approach uses packages to organize classes. These packages used to be based on domains (as was the case in the evaluated sample code). The basic modularization unit is a package. Use Case-based approach - this approach uses an organization based on use cases. One use case is included in a file (a markdown file) that contains the source code needed to implement the flow of a given instance of the use case. The basic modularization unit is a single step of the use case. ADDA approach - a source code modularization approach that uses the structure based on the UML AD, where the main modularization unit is an action element of the activity diagram. This approach was described in more detail in section Activity diagram driven source code modularization. Each approach from those mentioned above provides a different source code modularization base. For a closer comparison of all three approaches, selected values were identified. The results are shown in Tables 1, 2, and 3. When comparing the results of the basic modularization units (package, activity diagram element and single use case step), we can see that the lowest average number of source code files per modularization unit is reported by the use case approach, see Table 3. The reason that the markdown file associated with the use case has the best results is that it contains only the source code for that use case. This means that it does not provide the user any unnecessary methods, attributes, comments, and so on.

However, when looking at the results, the activity diagram - the ADDA approach (see Table 2) shows nearly 8,308 source code rows per AD whereas the package has approximately 3,420 source code rows per packages, see Table 1.

Table 1
Modularization: Package based approach project perspective

Number of packages	12
Number of classes	157
Number of methods	689
Number of source code rows	41033
Average number of source code files per packages	13.08
Average number of methods per packages	57.42
Average number of source code rows per packages	3419.42

Table 2
Modularization: ADDA approach project perspective

Number of activity diagrams	8
Average number of elements per activity diagram	8.25
Average number of source code files per activity diagram	32.86
Average number of source code files per activity diagram element	4.59
Average number of methods per activity diagram	124.028
Average number of methods per activity diagram element	17.75
Average number of source code rows per activity diagram	8307.75
Average number of source code rows per activity diagram element	1164.57

However, this result is correct and expected because one class can participate in the implementation of multiple elements of the AD. This is why the ADDA approach shows a higher number of source code rows. This view, however, does not rule out the fact that repetitive occurrences of redundant parts of the code can be eliminated by more detailed methods to action binding. If we compare the ADDA and Package based approach depending on the working sets, we get 41,033 to 8,308 in favor of the ADDA approach. The ADDA approach shows a better result also in decomposition AD into its elements too. The average number of source code files per activity diagram element is only 4.59 to 13.08 in favor of the ADDA approach. We believe that a smaller number of files per modularization unit reduces the user's mental load. At the end of the modularization evaluation, a significant majority of all participants involved in the study opted for modularization based on ADs and use cases. Only one of them voted for modularization based on packages.

G.) Readability and comprehensibility evaluation. Readability and comprehensibility are the properties of the source code which can be evaluated not only on the basis of subjective evaluation of participants but also from the perspective of different metrics. As was already mentioned ADDA approach does not modify the source code in any way, but only provides a new look at its structure. Based on this argument it could be assumed that the metrics for Package-based approach and the ADDA approach will be identical. However, this assumption is not entirely correct. ADDA allows you to assign the same file of a

source code (e.g, class) to multiple elements. As a result of this behavior, ADACSCO creates duplicates in the tree structure. It is then possible to define two assumptions. When calculating metrics for both projects of both approaches, the ADDA approach will have worse results due to the duplicates mentioned above. When calculating metrics for the source code's working set (the set of source code files the developer will need when implementing the specified assignment), the ADDA approach will have better results because the Package working set contains many more source code files. In order to confirm both assumptions, but not exclusively (Number of Code Rows (NCR), Average Number of Classes (ANC), Average Method Complexity (AMC) - Average Cycling Complexity [23], Average Number of Direct Descendants of a class (ANDD), Average Number of Inherited Methods (ANIM) and the Average Coupling Between Object (ACBO) [16]) metrics have been calculated to identify ADDA's impact on readability and comprehensibility. All 6 metrics for readability and comprehensibility were calculated using the Eclipse IDE Metrics plug-in. Cyclomatic complexity for AMC was also verified by the CyVis tool. Table 4 lists the results of the experiment confirming the assumptions described above. Better results for the project have the Package-based approach and on the contrary, the results measured for the source code working set are in favor of the ADDA approach.

Based on the results shown in Table 4 it can be concluded that the ADDA approach improves the readability and comprehensibility of the source code the developer is working on, but only within the scope of one activity diagram. One backlog task usually does not exceed one use case which is comparable to the above AD range. The principle of problem decomposition always leads to simpler tasks. This may be a recommendation to create a backlog, consisting of tasks not exceeding one AD. Table 4 also shows that the ADDA approach reduces the working set of classes the developer needs at the time of implementation. It is worth mentioning another finding based on the participants' testimonies. Classes are not just class clusters, as it is in the case of packages because of the structure based on AD. This only confirms the conclusion obtained on the basis of the metrics calculation. So, readability and comprehensibility are better when working with classes in an ADDA manner more than working with them in package organization.

H.) Source code orientation catalyzation. This section does not reflect issues such as proper source code offsetting or use of appropriate names or decision and cyclic structures but it deals with simple quick and accurate identification of the file associated with actions. The key metric for the purpose of the evaluation was the time to find related artifacts. This should be supported by the tree structure itself based on activity diagrams and orientation-supporting elements - decorations in the form of graphical differentiation of individual elements of the activity diagram, graphical resolution based on integrity, information about node number of descendants, and prefix for structured activities.

Table 3
Modularization: Use case based approach project perspective

Number of use cases	11
Average number of source code files per use case's step	1
Average number of methods per use case	7.2
Average number of source code rows per use case	428.79

Graphical differentiation between activity diagram's elements in the plug-in is done using icons based on UML 2.5. Each element of the activity diagram stores information about implementation completeness and entails information about the number of source code files that are related to it. Improvement in the source code orientation was tested by participants in fulfilling selected tasks. Respondents' statements revealed a positive assessment of the above-mentioned artifacts to support orientation in the related source code.

Table 4
Metric results

Tool/Metrics	Package Explorer		ADACSCO	
	Project	Package	Project	AD
NCR	41033.0	3730.3	76 861.8	9 607.7
ANC	157.0	14.3	303.0	37.9
AMC	27.1	2.5	34.8	4.4
ANDD	0.714	0.1	0.9	0.1
ANIM	3.39	0.3	3.8	0.5
ACBO	2.1	0.2	2.7	0.3

I.) Performing tasks by participants using ADDA. Respondent's role was to perform several tasks (Modify VAT calculation from 20% to 15%, Change the notification email text after successful client creation, etc.) on a selected source code sample using three different approaches. All 12 participants attended the evaluation. Respondents were divided into three groups of four. The first group used a traditional approach based on packages the second used ADACSCO and ADDA approaches. The last third group used the Use Case-based approach implemented by the ADACSCO plug-in too. The time needed to identify the class was measured for each task, also the number of clicks and the number of open classes for each participant. None of the participants previously met the source code sample and did not have any more information about it. The evaluation results confirmed the expectations. The traditional Package-based organization has much worse (approximately four times worse) results than ADDA and Use Case-based approach see Figure 4. ADDA approach was not the best in terms of time but its results did not lag behind the results of UC-based approach. So, our assumption that the time required to obtain orientation in the source code in ADDA approach will be shorter than in the standard package-oriented approach has been confirmed. Performing tasks using Package Explorer; participants - who

did not know the source code - had to browse the classes that could have the required functionality based on the similarity in names. This observation was confirmed by the participants themselves.

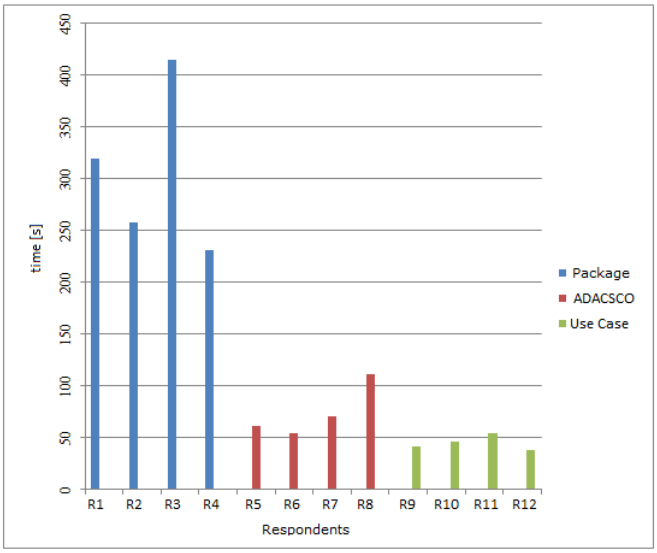

Figure 4
Task completion - time comparison between approaches

Respondents working with ADDA; have been much more successful in terms of time see Figure 4. They said it was useful that they were able to reduce the number of classes from about 150 to about 8 on the basis of functionalities. They found it great in finding the right class and of course very useful if someone did not know the code. Respondents' statements in further discussion only confirmed the results where model-based approaches that provide users with functionality information have a significant positive effect on the orientation between source code files. Previous testing has revealed that ADDA and use Case-based approaches have a significant impact on improving orientation. In order to make a subjective comparison between the two successful approaches participants have tried both approaches in the reverse order. Subsequently, participants' subjective opinion was investigated. It was not possible to distinguish which approach was better from participants' subjective statements because each response was based on personal preferences. As a result, 5 participants would use a UC-based approach and three of them approach based on activity diagrams.

J.) Evaluation by selected user types. ADDA's main asset is a source code extension by the information that may be beneficial not only for developers but also for testers, managers or analysts, see Activity diagram driven source code modularization. In order to verify this assumption, an interview was conducted with an analyst, project manager, and two testers (none of whom belonged to the

original group of 12 participants from the previous evaluation activities). Each of these four participants should subsequently confirm or refute the usefulness of the proposed approach in their normal workload. The participant, who works as an IT analyst, proposed an extension as it is possible to associate other types of files with AD – for example by GUI designs, data samples, etc. Improving the overview of the project, the project manager (PM) must have was appreciated by the respondent working as a project manager. He emphasized that it would be interesting to see how many processes are already implemented and how many still remain. Further use of the approach was mentioned according to a price estimation of future projects. It could be based on the overall business process duration or just a single action duration. Respondents - testers identified usage of the approach in unit testing. They claimed that as well as being able to associate the source code according to AD elements, it is also possible to associate the test scripts. Another option that they pointed out was directed to the description of errors directly related to the process or its particular part. They have appreciated the ability to add the time of the latest tests and versions. Test time and test version information could be recorded as tagged values. From the approach assessment by specialists, it can be assumed that the approach can also be beneficial to non-developers. This conclusion can only be put forward as just a premise. The actual benefit could only be tested and found within a real project in which ADDA and ADACSCO were not used.

Conclusions

This paper presented the idea of organizing source code from the activity diagram perspective denoted here as the ADDA approach to improve modularization, readability, comprehensibility, and mainly orientation in the source code. In order to achieve this goal, an analysis of the possible benefits of UML AD was performed. The result of this analysis was the identification of important features of the activity diagram which could make a significant contribution in binding with the source code. Based on the results of the analytical activities, ADDA has been suggested which mainly uses explicit associations between the source code parts and the activity diagram elements. These bindings allowed us to define a new modularization structure that can be depicted as a tree where the root of the tree is an activity diagram its nodes are the elements and the leaves are the classes themselves. The ADACSCO plug-in to Eclipse IDE has been implemented for evaluation purposes to create and work with a tree structure defined by the ADDA approach. ADDA approach evaluation using ADACSCO consisted of 6 parts: Evaluation of ADACSCO activity diagram coverage, Workflow evaluation, Modularization assessment, Readability and Comprehensibility assessment, Evaluation of orientation, and evaluation by selected user types. Twelve participants took part in the evaluation. Within the selected evaluation parts, a comparison has also been made with another two existing approaches – Package-based approach and Use Case-based approach. The ADACSCO AD coverage assessment was performed to demonstrate that each element of the activity

diagram identified in the ADDA proposed approach has its own representation in ADACSCO. The result was achieved by mapping the selected metamodel of the activity diagram to the ADACSCO data model. The orientation was evaluated in the form of subjective evaluation of 12 participants and was divided into two parts. The first one consisted of testing and commenting elements supporting the orientation in the source code. The second part of the evaluation was to perform certain tasks by participants using the Package-based approach, ADDA approach and Use Case-based approach. When performing these tasks, the values were measured: time, the number of clicks, and a number of open classes. The ADDA approach had the second-best results only slightly behind the Use Case-based approach. The Package-based approach, on the other hand, had worse results than the other two approaches. The reason for these differences between the results was that the Package-based approach did not contain any business information. Evaluation by selected user types has demonstrated the possibility of using ADDA and ADACSCO also for project team members such as analyst, project manager, and tester. Finally, it can be generalized that creating explicit links between the available artifacts in the development of the software supports the orientation in the source code itself. Defining the source code structure based on activity diagrams maintains a degree of business information that can help the user navigate between the source code classes.

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Software Platform for Learning about Brain Wave Acquisition and Analysis

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Abstract: Using brain waves, for user authentication, is an important emerging technology. The University of Defence, in the Belgrade and the Serbian Ministry of Defence (MoD), have recognized the importance of biometric applications in identity management. As a result, an intensive research, under the project named "Access control management of protected resources in Ministry of Defence and Serbian Armed Forces computer networks based on multimodal user identification", has been conducted over the last few years. The main contribution of this paper, is a software platform, for learning about brain wave acquisition and analysis. This platform was developed as a part of the project, with the main goal to improve and increase participant's knowledge in biometrics. A research study was conducted, with the aim of comparing traditional learning methods and learning methods based on the developed platform.

Keywords: biometrics; brain waves; learning tool; software platform; user authentication

1 Introduction

Access control to information systems is one of the most important aspects of protection, especially in systems that contain security sensitive data. It prevents people that have no rights to access a system and thereby misuse the information contained therein.

Traditional methods for establishing a person's identity are usually based on using passwords or tokens [1]. These methods have several disadvantages. Passwords are often used irresponsibly (they are usually designed to be easy to remember, or are stored inappropriately).

On the other hand, tokens can be intercepted and stolen. Therefore, there is a need for an alternative approach, biometric technologies can prove worthy. They provide the computer systems with the ability to identify a person using its physical or behavioral characteristics [2-4]. The main advantage of biometrics in comparison to passwords and tokens is the fact that biometric identity provides the information on who you are, rather than what you know (passwords), or what you possess (tokens). However, as biometric recognition relies on statistics, its output is not a yes/no decision, but matching score. This is a big disadvantage of biometrics as it leaves room for errors. Thus, there is a need to constantly improve precision of biometric systems, respecting biometric standards [5].

The University of Defence in Belgrade and the Serbian Ministry of Defence (MoD) have recognized importance of biometric applications for identity management. As a result, a project named "Access control management of protected resources in Ministry of Defence and Serbian Armed Forces computer networks based on multimodal user identification", it was started (VA-TT/3/18-20, 2018) with the main goal to design a modern, science-based model of managing access to protected resources of computer networks in the MoD and the Armed Forces, which will increase the reliability and security of computer networks, computer systems and their users. Achieving the basic goal is conditioned by the elaboration and realization of several sub-goals which are currently under development:

- Identification and scientific description of the existing model of managing access to protected resources of computer networks in the MoD and the Armed Forces
- Defining the strategy for managing access to protected resources of computer networks in the MoD and the Armed Forces
- Development of a model for selecting the optimal technology for registration, identification and authentication of resource users
- Development of models of security mechanisms for biometric data protection
- Development of security policy models

In order to achieve the stated sub-goals, we considered several biometric modalities, such as iris recognition, fingerprint and brain waves. We examined several presentations of these modalities. We found out that using brain waves, as biometric data for user authentication, was the most interesting and the most advanced technology for the participants, but most of them were unfamiliar with terminology. In order to overcome this issue, we developed an interactive software

platform for learning about brain wave (EEG) acquisition and analysis (elEEG) which is the main contribution of this paper.

In the next section, a brief overview of related research has been given. Section 3 contains overview of elEEG support platform and its functionalities. In section 4 we presented study settings, used methodology, profiles of participants, experimental results and discussion. In the last section, conclusions and further research are provided.

2 Related Work

Major research efforts in recent years were directed towards application of brain waves as a biometric characteristic that is unique and inherent for every person. The main challenge of this research is recreating the exclusive, person-related brainwave. EEG as a biometric characteristic lacks constancy and highly depends on stress, fatigue, medication, environment (electrical equipment) etc. To cope with this, researchers often use some kind of stimuli, to help in recreating the valid authentication EEG pattern, e.g. visualization of 3D object manipulation, counting, imagining letters and texts etc. [6].

Schomp [7] investigates the possibility of creating an authentication system based on the measurements of the human brain. An evaluation of the feasibility of brainwave authentication based on brain anatomy and behavior characteristics, conventional vs. dynamic authentication methods, the possibility of continuous authentication, and biometric ethical and security concerns are discussed. Jayarathne [8] provides an overview of crucial design considerations in handling EEG data for extended accuracy and practical applicability to authentication. Muhammad Azizi [9] discusses the applications of EEG as an alternative to mainstream biometrics. The state-of-the-art of several popular biometric modalities and technologies are outlined and specific applications where biometric recognition may be beneficially incorporated are provided by Ortega-Garcia [10]. Patrizio Campisi [11] recognizes many challenges which need to be properly addressed and represent an obstacle toward the deployment of biometric systems based on the analysis of brain activity in real life applications. He intended to provide a critical and comprehensive review of methods for EEG-based automatic user recognition. Campisi [12] shows that EEG is potentially more secure and privacy-compliant than traditional biometric identifiers. Reshmi [13] gives a novel approach on user recognition using EEG signals of brain. EEG recordings are acquired with portable and relatively inexpensive devices when compared to the other brain imaging techniques, like fMRI. The Emotiv EPOC EEG neuro headset with 14 saline electrodes and two reference sensors is used for the acquisition of brainwaves. Gui [14] presents an EEG-based biometric security framework. He proposed to reduce the noise level through ensemble averaging and low-pass

filter, extract frequency features using wavelet packet decomposition, and perform classification based on an artificial neural network. Experimental results show that the classification rates of distinguishing one subject or a small group of individuals (e.g., authorized personnel) from others (e.g., unauthorized personnel) can reach around 90%. Riera [15] presented authentication methodology using the experimental protocol that is common for EEG recording. Simple spectral features of the EEG are proposed by Miyamoto [16] to make the authentication system using the EEG more practical. The effectiveness of the proposed new features is evaluated in verification experiments with 23 users and the verification rate of 79% was obtained. Person identification based on parametric spectral analysis of the EEG signal is addressed by Poulos [17]. His proposed method was applied on a set of real EEG recordings made on healthy individuals, in an attempt to experimentally investigate the connection between a person's EEG and genetically-specific information. Paranjape [18] examines the effectiveness electroencephalogram (EEG) as a biometric identification of individual subjects in a pool of 40 normal subjects. The EEG's second order statistics are computed using autoregressive models of various orders. The coefficients in these models are then evaluated for their biometric potential. Discriminant functions applied to the model coefficients were used to examine the degree to which the subjects in the data pool can be identified. The results indicate that the EEG has significant biometric potential. Ravi [19] proposed a novel method to recognize persons using their brain patterns. These brain patterns are obtained when the individuals perceive a picture. High frequency brain energy is used as features that are classified by Elman backpropagation neural network. The experimental results using 1600 brain signals from 40 individuals give average classification rate of 96.63%. Nakanishi [20] examined the performance of verification based on the EEG during a mental task. In particular, assuming the verification of computer users, they adopted the mental task where users were thinking of the contents of documents. From experimental results using 20 subjects, it was confirmed that the verification using the EEG is applicable even when the users are doing the mental task. The system described by Soni [21] provides two-level authentication. First level is brain waves. Once the correct pattern of brain signal is provided the system will ask for a pass key as a second level of authentication. Nienke [22] explained what EEG devices do and do not measure. Ido [23] explains the brain-to-brain synchrony between perons (i.e., the similarity in their brain responses) and highlights recent developments in portable and wearable brain technologies. Shanmugam [24] gives different definitions of Brain computer interface and its types and how it can be used for authentication of a person. Sawsan [25] describes authentication system designed using the specified brain waves which are Gamma and Betta wave's features in order to generate the user authenticated sequence using Galois LFSRs.

3 The elEEG Software Platform Overview

The elEEG software platform consists of two applications. First, is for brain wave (EEG) data acquisition developed using C#, with Microsoft SQL Server as the database, for data storage. The second, is for brain wave analysis and visualization, developed in the ASP.NET technology. In the next sections, a brief overview of developed applications is described.

3.1 The elEEG Brain Wave Data Acquisition Application

In order to achieve the user identification phase, in terms of protection of information and communication systems, it is necessary to collect biometric data through biometric sensors which will be compared with already existing data registered in the system itself. The first step in creating such a system is the implementation of the data acquisition solution.

Acquisition is the collection of data from an external environment into a particular electrical device, i.e. a sensor. When it comes to biometric data, a biometric device for acquiring this type of data is required.

Biometric devices perform data acquisition by accepting data from a sensory receptor in the form of some sensation that occurs in or on the human organism and converts it to analog or digital signals that are used for further processing. The data thus collected can be used to identify particular person.

EEG authentication uses an electrophysiological system to monitor brain activity. This technology is very popular and can be used without any side effects on the brain.

There are several commercial devices with a variety of electrodes that are used to collect EEG data. Some of the sensors use dry electrodes, and some sensors use wet electrodes. The brain lobes emit EEG signals in response to different stimuli and mental states.

Neuro Sky Mind Wave 2-EEG device has been used for the purpose of collecting EEG data at this stage of project (Figure 1). This sensor performs measurement of alpha, beta, gamma, delta and theta brain waves, as well as the current state of focus - attention and relaxation of the subject whose brain waves are measured.

The screen of the software solution for EEG data acquisition from the sensor is shown in Figure 2. The solution was developed in the Microsoft Visual Studio 2017 using the C# programming language and the ThinkGear manufacturer's sensor library.

Figure 1
Neuro Sky Mind Wave 2-EEG device
(http://neurosky.com/biosensors/eeg-sensor/biosensors/)

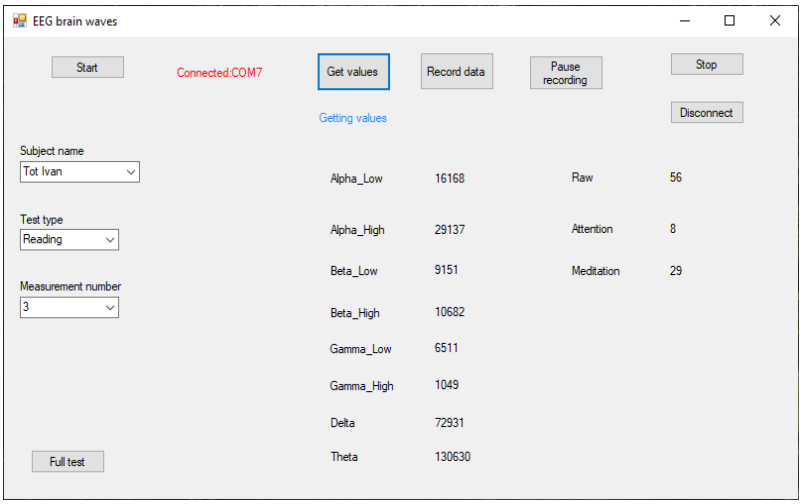

Figure 2
Software solution for EEG data acquisition

First, a Bluetooth connection with the sensor is established. After a successful connection, clicking the Get Values button will accept the values from the sensor and display them on the screen. The Stop button temporarily interrupts the acceptance of values from the sensor, and the Disconnect command button breaks the connection to the sensor.

Accepted values can be stored in a database implemented in Microsoft SQL Server Express 2014 by clicking the Full Test button. In this case it is necessary to choose the subject whose brain waves are measured, the type of test and the number of measurement. So far, we devised five types of tests:

1. Relaxed - the subject completely relaxes and closes their eyes
2. Reading - the subject reads text

3. Beautiful pictures - the subject looks at pictures that elicit positive emotions
4. Mathematics - the subject has a mathematical task that needs to be solved
5. Disturbing images - the subject looks at images that should elicit bad emotions (images of war crimes, mistreated animals, etc.)

Each one of the mentioned tests lasts for 20 seconds. During that time, at two second intervals, accepted values are stored in the database.

This procedure is conducted three times with each participant.

3.2 The elEEG Brain Wave Data Visualization and Analysis Application

To enable data visualization and analysis, a web application has been developed using Microsoft Visual Studio 2017 ASP.NET technology. The web application provides detailed information about alpha, beta, gamma, delta and theta brain waves. Moreover, in the application there are links which enable visualization, analysis and comparison of the obtained data as shown on Figures 3, 4 and 5. Finally, part of the implemented application is set of tasks in form of exercises for participants.

The web page shown in Figure 3 allows visualization and comparison of data obtained from the sensor for selected type of test, selected measurement and selected participants, by individual waves. The first-row charts show all the waves followed by charts that show the results of measurements performed by individual wave type (on the x-axis are time samples, and on the y-axis are the logarithmic values of the measured waves).

The web page shown in Figure 4 also allows visualization and comparison of data obtained from the sensor for a selected participant and selected type of test. For each measurement, columns show a summarized graph with all the waves (on the x-axis are time sample, and on the y-axis are the logarithmic values of the measured waves), followed by a single graph for each measured brain wave.

Finally, the web page shown in Figure 5, allows visualization and comparison of data obtained from the sensor by individual waves for a selected type of test and selected participant for all three measurements. Each chart shows the results of all measurements performed by wave types (on the x-axis are time samples and on the y-axis are the logarithmic values of the measured waves).

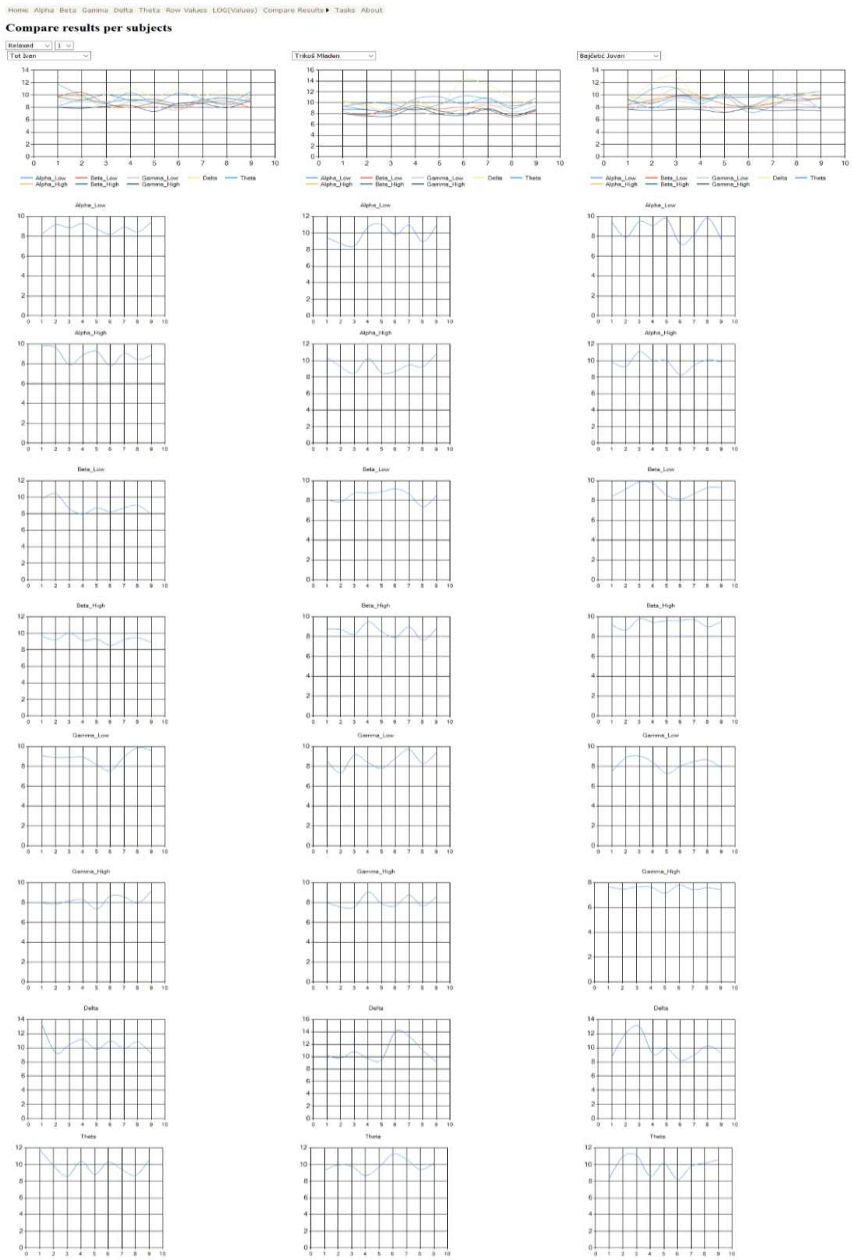

Figure 3
elEEG web page for comparison of data per subjects

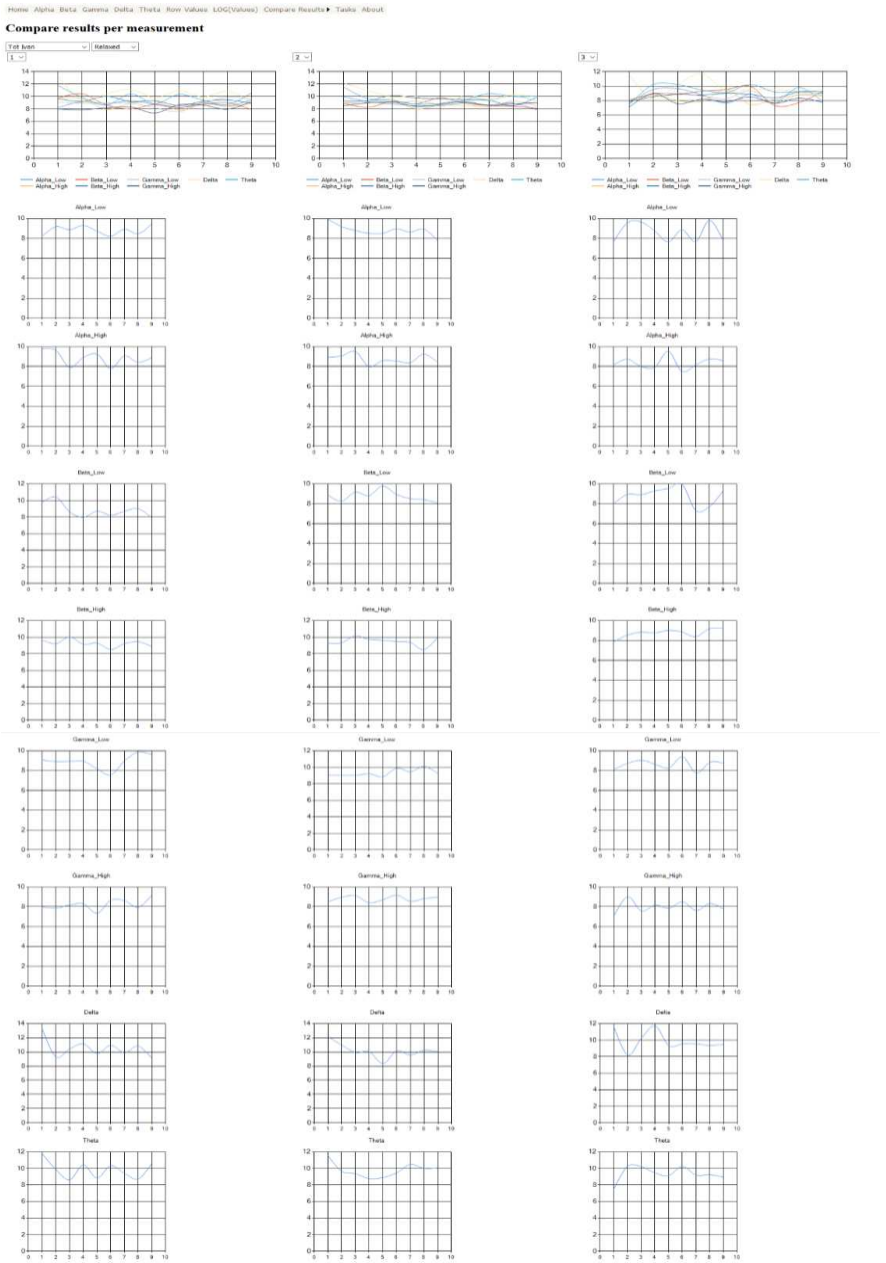

Figure 4
elEEG web page for comparison of data per measurement

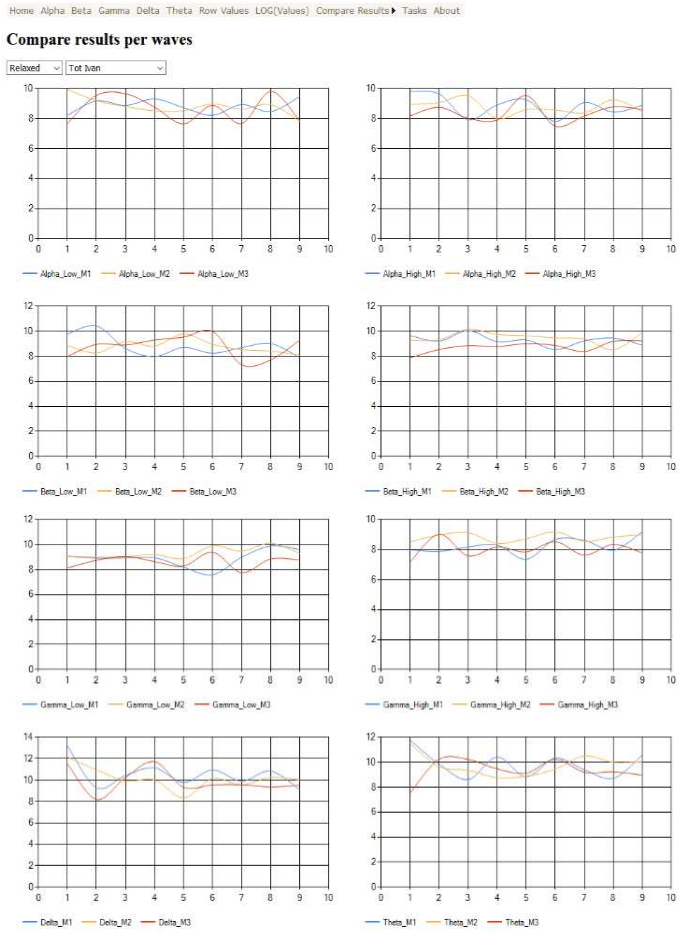

Figure 5
elEEG web page for comparison of data per waves

4 Experimental Results and Discussion

In order to evaluate benefits of using the elEEG platform, for learning about brain waves, we conducted research, in which, we compared two learning methods. The first method was traditional learning and the second was learning using the elEEG platform. The main goal was to determine which method provided more improvements in efficiency of learning, better motivation and engagement of participants in learning process. The participants in this research were divided into

two groups – first, as a control group, which had traditional regular classes in classrooms and second, the experimental group, which used the elEEG platform as a tool for learning. Large number of participants in both groups had almost no previous knowledge about brain waves.

Each member of the experimental group had a computer with support platform installed and Neuro Sky Mind Wave 2-EEG device for capturing brain waves. A teacher was present but his only role was to guide participants through the process. They firstly used elEEG platform to learn about different types of brain waves. Secondly, they used elEEG brain wave data acquisition application to practically capture brain waves. Finally, they used the platform to compere captured brain waves.

At this stage of the research, three measurements, of all tests during different days are done, with the 60 participants of the experimental group. Structure of participants by their level of education, gender and number of years is shown in Tables 1, 2 and 3.

Table 1
Structure of participants by level of education

Education level	Number
High School	2
Faculty student	27
Bachelor	17
Master	9
PhD	5
TOTAL	**60**

Table 2
Structure of participants by gender

Gender	Education level	Number
Female	High School	1
Female	Faculty student	11
Female	Bachelor	1
Female	Master	1
Female	PhD	2
TOTAL (female)		**16**
Male	High School	1
Male	Faculty student	16
Male	Bachelor	16
Male	Master	8
Male	PhD	3
TOTAL (male)		**44**

Table 3
Structure of participants by years

20 to 30 years	31 to 40 years	41 to 50 years
12 female	2 female	2 female
29 male	7 male	8 male
Total: 41	**Total: 9**	**Total: 10**

The control group consisted of similar number of participants, with similar structure. They had traditional lessons with slide show presentations lectured by a teacher and possibility to ask questions.

After each lesson the participants of both groups took a knowledge test which consisted of 20 questions and 5 practical problems. Each correctly answered question was graded with one point, while each solved problem was graded with two points. Unanswered questions and unsolved practical problems were not considered. Figure 6 presents average knowledge test results. As shown on Figure 6, there was a significant difference between the groups regarding the practical problems.

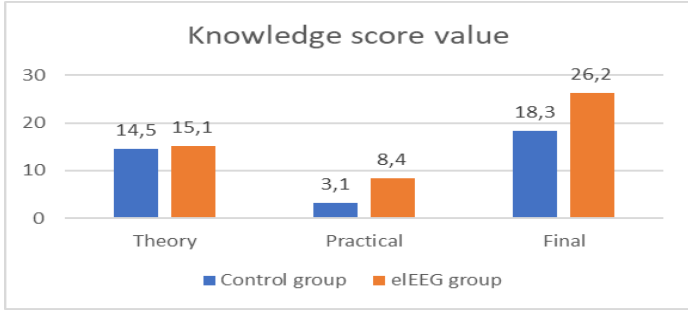

Figure 6
Average knowledge test scores

Upon finishing the knowledge tests, all participants filled in a questionnaire which included five questions related to motivational factors and 15 questions regarding the learning experience. All of them were based on principle of Likert scale [26] with the range of values from one to seven.

Figure 7 shows average scores to answers referring to learning experience. It can be concluded that the group which used the elEEG platform evaluated learning experience better. Significant difference can be seen in participant's experience that there is no theory and practice bond, there is too much information present and what is learned is valuable.

Figure 8 shows average level of agreement with statements regarding participants' motivation when learning about brain waves in one of tested ways. The results show that participants are more motivated when learning about brain ways by using the elEEG platform.

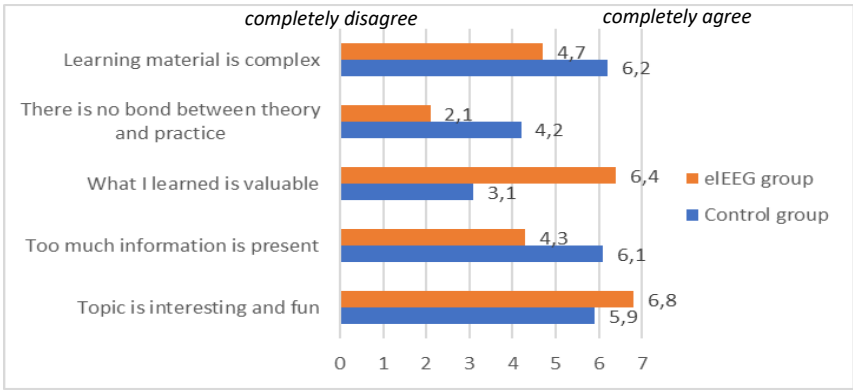

Figure 7
Learning experience average scores

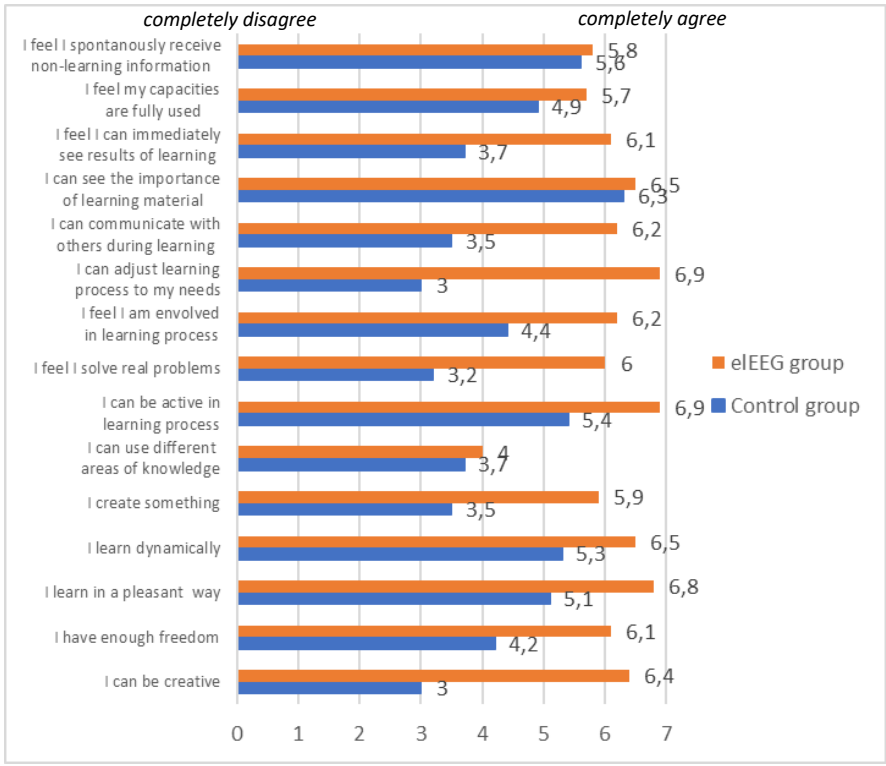

Figure 8
Average values of participants' learning motivation

Conclusions

The security of information systems is one of the most current and relevant issues of our time. Access control is particularly important, since it serves to block users, who do not have the right to access and use the system. Access by undesirable users, is very dangerous, because of the great possibility of abusing the system and the information that it contains.

The development of biometric systems and biometric sensors contributes to better protection through identity recognition and minimizes the possibility of abuse. Biometric technologies possess a great potential to improve system security and precision. The application of biometric systems improves the user's safety and also provides a much higher accuracy in identifying an operators identity.

Due to the importance of identifying users, it is necessary to constantly work on improving the system for precise proof of identity, that is, to improve performance, either through the development of biometric sensors, or through the improvement of the acquisition methods of biometric data. One of the potential ways is the use of brainwaves to authenticate users.

The basic idea of the whole project is to determine if there is a correlation of brain waves to the appropriate type of test for each subject, which could then be used to authenticate an operator. In the database, kept on a protected computer network, the images of the brainwaves of each user would be stored. When logging into the system, the real-time, measured brainwaves, of the user, would be compared with the recorded brainwave of user in the database. If there is a sufficiently high percentage of brain wave pattern matching, the authentication process would be considered, successfully completed.

So far, two applications have been developed in this project. One for acquiring sensor data and the other for visualizing that data.

In further research, a detailed analysis of the obtained data is planned, using different software packages and statistical tools to determine the correlation of brain waves, to the appropriate type of test, as well as, testing a significantly larger number of participants. This can only improve the accuracy if ID verification. When correlation is confirmed, brain waves could be used, reliably, to authenticate users.

Acknowledgement

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Optimum Design of an Air Tank for Fatigue and Fire Load

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Abstract: Pneumatic pressure vessels, or more commonly used names, air tanks, are used for storing compressed air to operate different pneumatic tools, for example, wrenches, grinders, sanders and others. The objective of design optimization of air tanks is cost reduction, by reducing the total mass of the vessel, the quantity of the welding seams with adequate strength and stiffness. This study describes the steps of this design optimization, but also deals with high cycle fatigue, to determine the lifetime of the equipment and the effect of the fire load. The optimization was made with the Generalized Reduced Gradient (GRG) method. Nozzles with the same geometry will have a different impact on the utilization, in the various diameters of shells. Therefore, the allowed number of cycles will change. The fire load was modelled as an ISO fire and corresponding temperature/pressure increase rates were investigated.

Keywords: pressure vessel; fire load; lumped model; optimization

1 Introduction

The transportation and storage of pressurized gases, such as methane or air, play an essential role in the economies of industrialized countries. Failure of these structures can cause fires or explosions, results in the contents flowing out and pollution of the environment, which can severely affect the company's production and have a detrimental effects on the environment. Most of the literature on this topic deals with pressure vessels containing liquid [1], where the authors have developed a new innovative approach to simulating pressurized vessels exposed to fire.

One of the most critical accidents is the fire exposure of pressure vessels. This may lead to catastrophic failure: explosion or the fireball effect. The severity of these events is influenced by energy accumulation during heating. The pressure inside the vessel increases as the temperature rises. Since the 1960s, there have

been a number of experiments and measurements [2], that initially addressed safety issues. Nowadays, instead of the zonal models [3], the equations of heat quantities and mass equations are solved by computer.

Many researchers are studying the possibilities of optimization support frames in the event of a fire load. Farkas and Jármai [4] investigated cross-sections of welded square boxes for overall and local buckling with and without fire protection. Protected sections have been shown to be cheaper than unprotected sections. For the optimization, systematic search method was used. Jármai and Száva [5] modeled the local fires by cylindrical and conical discretization, and determined the temperature and the carrying capacity of rolled and welded I-sections. Cabala and Jadlovsky [6] presented a multi-objective optimization method, which can be also acceptable to determine the minimal cross sections in case of a local fire.

In the event of fire in this equipment, the firefighters of the company extinguish the fire. Where possible, water is often used for cooling purposes, but that cooling affects the microstructure of the steel of which the pressure vessel and the supports are made. Thereafter, its mechanical properties will change (EN 10028-2), which affects the load-bearing capacity of the structure, especially under dynamic loads.

2 Optimization

The aim of the investigation involved an air tank with an internal volume of 1.5 m^3. The sizing was based on EN 13445-3, which calculates the necessary wall thickness of the shell and the ends. The calculations were completed with different temperatures from 20°C to 400°C. The ends of the vessel were chosen according to the DIN28011 standard, and the type was torispherical. The selected vessel material's (1.0425) yield strength and the tensile strength also depend on the temperature. The calculation of the given mechanical property is provided by the EN 10028-2 standard and the calculation was completed with linear interpolation. After determination of the geometry, the optimization was performed. The purpose of this method is to determine the optimal ratio between the height and the diameter of the pressure vessel to find the minimum weight and material cost of the vessel, where this ratio is a variable in the process. The constraints of the optimization were the volume of the vessel, which must be 1.5 m^3 while the raising stress was less than the allowed stress. The range of the variable (H/D) was between 1 and 6. For this, the Microsoft Excel Solver Addition was used with the "Generalized Reduced Gradient" method. During the calculation, the yield strength and tensile strength reduction was considered due to the temperature increase.

3 Fire Load

The fire which heats the pressure vessel can be a pool fire or a jet fire. In the event of a pool fire, a layer of a volatile liquid burns and a horizontal layer of fuel may float on a solid substance or on the surface of a liquid of a higher density. A jet fire is a turbulent diffusion flame that results from the combustion of fuel that is continuously released in a given direction. This article presents the pool fire mechanism, as a common problem in the chemical industry, since flammable substances can accumulate under pressure vessels.

3.1 ISO Fire

In this case, the amount of transferred heat is the effect of radiation and convection. According to the literature, the convection represents a smaller part, and the convective heat transfer coefficient (α_c) considerable with a value of 5-50 W/m^{2}K. However, the value of the radiative heat transfer coefficient (α_r) highly depends on the temperature difference of the flame and the wall temperatures. To calculate this value, the flame temperature must be known. This temperature is determined as a function of time by the ISO 834 standard [7], shown in Figure 1:

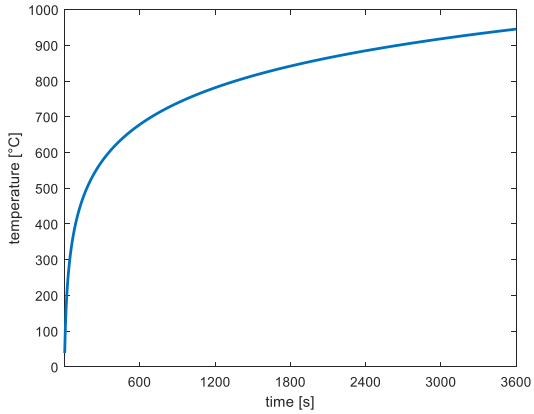

Figure 1
Standardized ISO 834 fire curve

3.2 Radiative Heat Transfer Coefficient

The following assumptions and simplifications are used to determine the radiative heat transfer coefficient in the case of a fire [8]:

- The properties of the fire are homogeneous in the volume examined.

- The hot gases and the vessel are assumed to be grey.
- The surface of the pressure vessel is assumed to be opaque.
- The fire and the vessel surface are two infinitely parallel grey planes.

With these considerations, the value of the radiative heat transfer coefficient is

$$\alpha_R = \frac{\varepsilon_f \varepsilon_S}{\varepsilon_f + \varepsilon_s - \varepsilon_f \varepsilon_S} \sigma \left[T_f^2(t) + T_v^2(t) \right] \left[T_f(t) + T_v(t) \right], \tag{1}$$

where ε_f is the emissivity of fire (assumed in the calculations to be 1), ε_s is the emissivity of the surface (assumed to be 0.8), σ is the Stefan Boltzmann constant ($5.67 \cdot 10^{-8}$ W/m^{2}K^4), T_f is the temperature of the fire and T_v is the temperature of the vessel (both expressed in K). The radiative and convective heat transfer coefficient shall be used together as the resulting heat transfer coefficient:

$$\alpha = \alpha_c + \alpha_R \tag{2}$$

4 Lumped Heat Capacity Model

The lumped parameter model simplifies the complex three-dimensional model into a simple one-dimensional model. However, the lumped model has a strict applicability condition: The *Bi* number (Biot number, which describes the ratio of the heat transfer resistances inside of a body and at the surface of a body) must be less than 0.1.

$$Bi = \frac{\alpha \cdot \frac{V}{A}}{\lambda} \tag{3}$$

where λ is the thermal conductivity of the wall (in W/mK), and *V/A* is the characteristic thickness, which is the ratio of the cross-section and the perimeter (m). The higher the characteristic thickness, the lower the temperature of the specimen will be at the temperature of fire. The added problem is that not only the temperature of the vessel will change, but also, the temperature of the air inside the tank, which means that the pressure of the air will also increase, due to the combined gas law. Consequently, the internal heat transfer coefficient must be calculated from the inside with an empirical correlation of free convection.

$$Nu = \left\{ 0.825 + \frac{0.387 \cdot Ra^{1/6}}{\left[1 + \left(\frac{0.492}{\mathrm{Pr}} \right)^{9/16} \right]^{8/27}} \right\}^2 \tag{4}$$

Where, Ra number is the production of Gr number (Grashof number, which describes the ratio between the buoyancy to viscous force acting on the fluid) and Pr number (Prandtl number, which describes the ratio of momentum diffusivity to thermal diffusivity).

Based on these considerations, the heat flow from the fire to the wall of the vessel is

$$\dot{Q}_{in}(t) = \alpha(t) \cdot \left[T_f(t) - T_v(t) \right] \cdot A, \tag{5}$$

and the heat flow from the vessel to the pressurized air is:

$$\dot{Q}_{out}(t) = \alpha_i(t) \cdot \left[T_v(t) - T_a(t) \right] \cdot A. \tag{6}$$

The average temperature increment of the vessel and the air using the lumped capacity heat method are:

$$\Delta T_v(t) = \frac{\dot{Q}_{in}(t) - \dot{Q}_{out}(t)}{V_v \cdot \rho_s \cdot c_{p,s}(t)} \cdot \Delta t \tag{7}$$

$$\Delta T_a(t) = \frac{\dot{Q}_{out}(t)}{V_a \cdot \rho_a(t) \cdot c_{p,a}(t)} \cdot \Delta t \tag{8}$$

and in the $(t+1)$ time step the temperatures are:

$$T_v(t+1) = T_v(t) + \Delta T_v(t) \tag{9}$$

$$T_a(t+1) = T_a(t) + \Delta T_a(t) \tag{10}$$

In Equations (4-10) the material properties of air (λ_a, $c_{p,a}$, ρ_a and η_a) depends on temperature and pressure, as well as, the properties of the steel, as a function of temperature.

Figure 2 and Figure 3 show that the specific heat and thermal conductivity highly temperature dependent and significant changes occur near the phase-change environment. The basic material properties for load-bearing calculations are the Young modulus and the yield strength, which temperature dependences are shown in Figure 4 according to the EN 1993.1.2:2005 [9] standard.

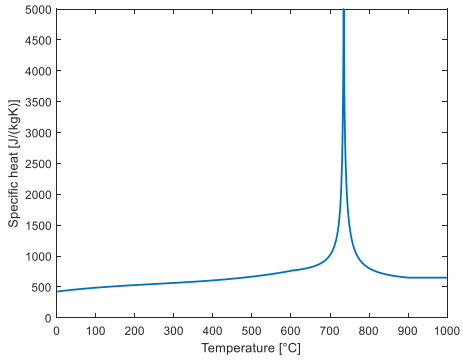

Figure 2
Temperature dependence of the specific heat of the Ferritic Steel

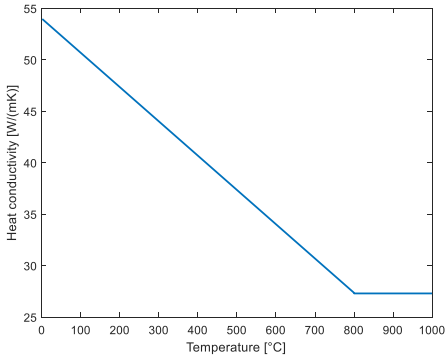

Figure 3
Temperature dependence of the heat conductivity of the ferritic steel

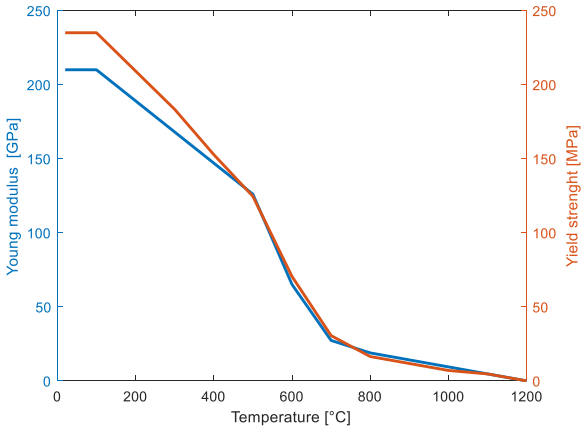

Figure 4
Mechanical properties of the steel

5 Results of the Calculations

5.1 The Heating Method

First, the heating phase caused by the fire load is shown below. At first the fire load case was described. In this model a pressure relief valve is also involved with 9.0 bar_g set pressure and 1590 mm^2 relief cross section. The calculation algorithm shown in Figure 5.

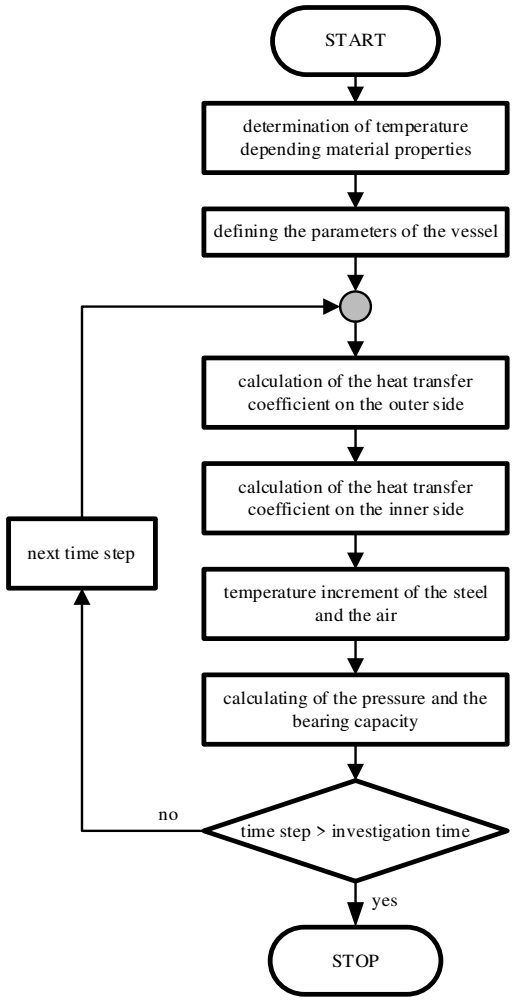

Figure 5
Algorithm of the fire load case

Calculations were performed on the optimized vessel with the following dimensions.

Table 1
Dimensions of the optimized vessel

External diameter	950 mm
Nominal wall thickness	6 mm
Cylinder length	1900 mm
Total volume	1.512 m^3
Heat transfer area	6.517 m^2

Heat transfer processes are driven by the temperature difference, therefore knowing the temperature during the heating process is essential in the calculations. These are shown in Figure 6.

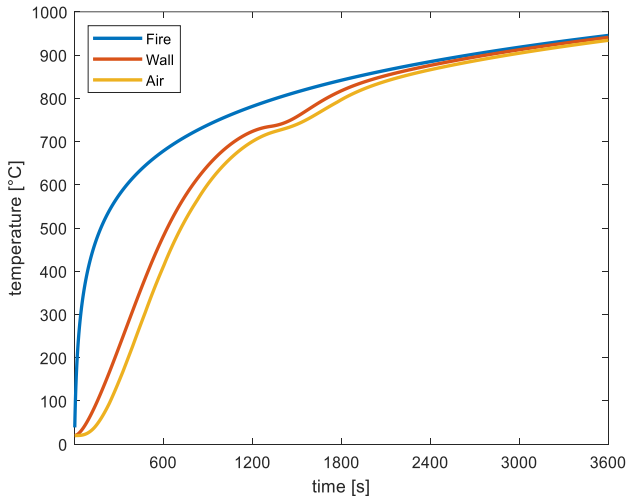

Figure 6
Temperatures of the vessel

Figure 7 shows the heat transfer coefficients on the internal (α_i) and external sides (α). The fluctuation of the internal side coefficient is the result of the operation of the relief valve.

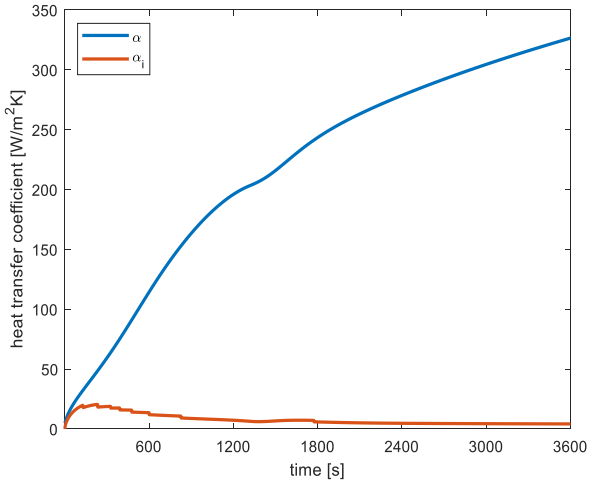

Figure 7
Heat transfer coefficients

With these geometrical parameters and material properties, the pressure of the air and the load-bearing capacity of the vessel shown in Figure 8.

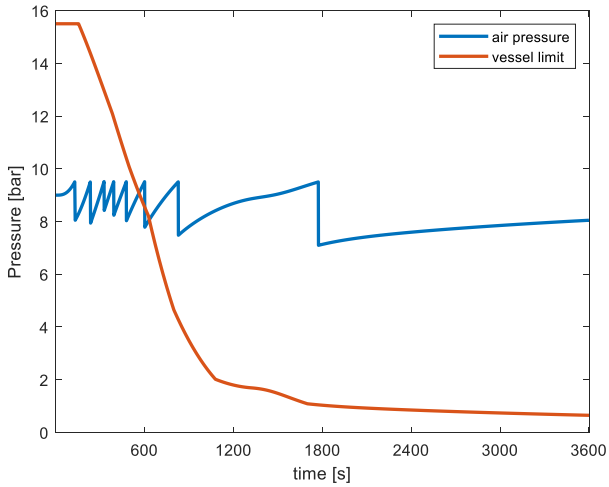

Figure 8
The pressure of air and load-bearing capacity

Figure 8 shows that considering the higher flame temperature, the heat flux from the flame to the vessel will be higher, and that will cause pressure increment, but due to the relief valve, the pressure should not exceed 9.5 bar. However, the material properties will decrease at higher temperatures, so the bearing capacity will also decrease. The moment the two graphs intersect, the vessel ruptures.

In this case, this time is 562 seconds. Although this load-bearing capacity is directly proportional to the wall thickness, the load-bearing time will not be the same. Table 2 summarizes the times of investigated vessel with different wall thicknesses.

Table 2
Loading times with different wall thicknesses

Nominal wall thickness (mm)	Load bearing time (s)
6	562
8	717
10	779
12	904
14	954
16	996

This can be explained by the fact that although the weight of the steel is higher, it has little effect on the temperature of the steel, but at such high temperatures, it has barely yield strength. The other fact is that the air has a relatively low specific heat; it warms up quickly and does not cool down the wall of the device. The behavior of a vessel filled with liquid, for example water, is quite different. Due to the higher mass and higher specific heat, the temperature rise is slower as the liquid cools the steel, so the failure occurs a longer time. An exception to this is a BLEVE (boiling liquid expanding vapor explosions) damaged vessel [10]. In this case, the liquid is in a liquid state at the beginning of the process; the temperature increases as a result of the heating. Nevertheless, the safety valve continuously decreases the pressure. This results in an operating state where the decreasing pressure forces the medium to change phase.

5.2 The Cooling Method

Accurate knowledge of the cooling process is just as important for the lifetime of the vessel as it is for heating. Cooling can cause a problem in two ways. During the heating process, the temperature rises, but due to the operation of the relief valve, the mass of the air has continuously decreased. As a result, cooling the warm and lower mass air to the initial temperature can result in lower pressure than the original, even in a vacuum, which can be dangerous to the device. Another problem is the cooling rate, because of the change of the microstructure of the steel. The P265GH steel is a weldable fine grained steel for pressure purposes with low carbon content. For this reason, the main criteria of the tempering was not fulfilled, since the carbon content is lower than 0.25%. There is still a chance to the alteration of the microstructure. It is primarily an increase in hardness and thus a decrease in impact strength. So the steel of the vessel can become rigid, less resistant to the dynamic loads [11].

The appearance of the martensite can occur when the temperature rises above the A3 temperature of the steel, which is around 850°C. The presence occurs when the cooling is fast enough, and it starts around 500°C. In the case of firefighting, the cooling is continuous. Thus, the change in the microstructure can be followed with the non-equilibrium transformation diagram, also called as C-curve. The continuous cooling curve for hypo eutectoid steel is shown in Figure 9.

As shown in Figure 9, the martensite appears when the cooling rate exceeds about 500°C/s. During firefighting, this cooling rate is unreachable, so the risk of the appearance of the martensite is relatively low. However other steels such as P460NL1 or structural steels such as S355J2 that can be used materials for leg supports of the pressure vessel have higher carbon content, and it could be a relevant problem in case of cooling.

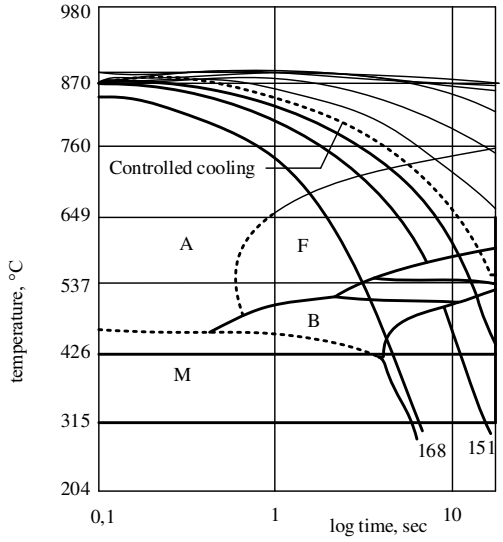

Figure 9
The relevant part of the CCT diagram for low carbon steel

Assuming that the cooling process is water cooling, the process can be divided into three parts, as shown in Figure 10.

In Phase 1 and 2, the wall temperature exceeds 100°C, so the cooling water boils. Due to the high heat transfer coefficient caused by the boiling, the wall temperature will decrease. The first part is the shortest phase. In this case, the wall temperature is the highest of the three temperatures (that means despite cooling the wall heats the enclosed air in the vessel and boils the cooling fluid).

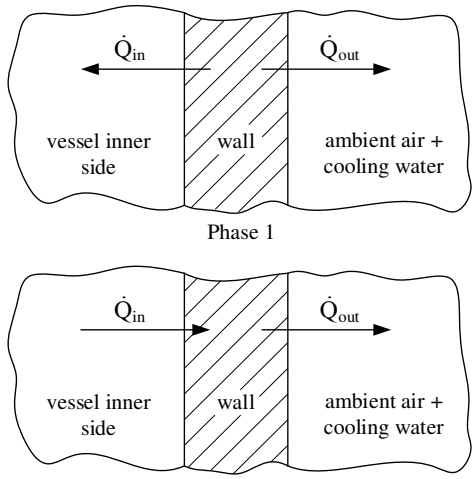

Figure 10
Phases of the cooling process

In the second part, the temperature of the air is higher than on the wall, so the direction of the heat flow is from the pressurized air to the ambient air (it is seen in Figure 10, Phase 2 and 3). In this case, the coolant fluid also boils because the wall temperature is higher than 100°C. The time period is one order of magnitude greater than in Phase 1.

In Phase 3 the direction of the heat flow is the same as described in Phase 2, but there is no boiling effect on the outside as the wall temperature is below 100°C. The value of the heat transfer coefficient is much smaller because there is no phase change. Considering these facts, the temperatures of the cooling section shown in Figure 11.

The other exciting and fundamental issue is the pressure of the air inside the vessel. Due to heating, the pressure increases with temperature. In order to hold the pressure and protect the vessel from harmful overpressure, the relief valve releases a certain amount of air. However, during cooling, the decreasing temperature also causes a pressure dependence. This is shown in Figure 12.

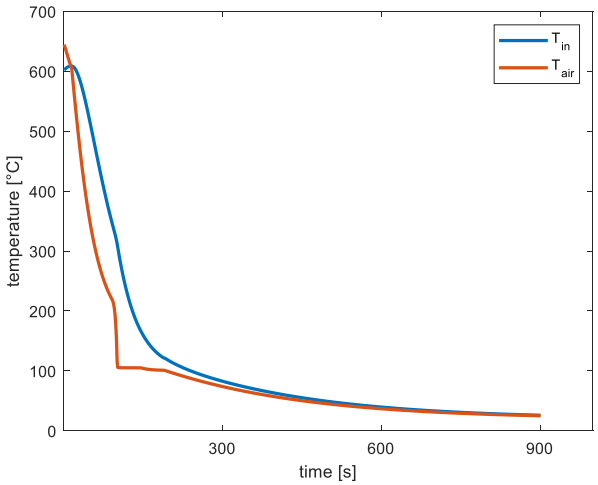

Figure 11
Temperatures during cooling

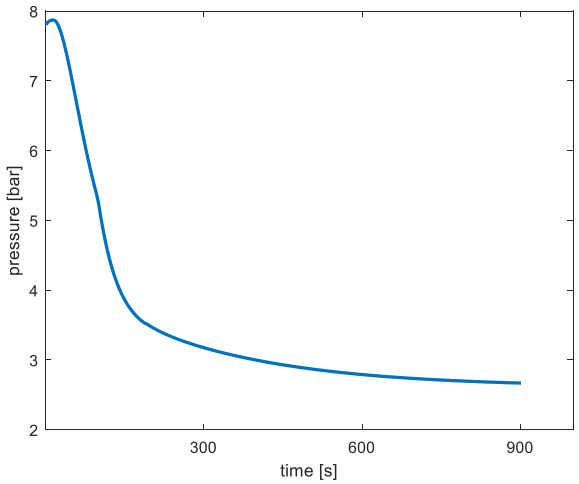

Figure 12
The pressure of air during cooling

It can be seen that this is not a problem, in this investigated case, but in the case of austenitic steel, where higher temperatures occur, the pressure inside the vessel can be vacuum at the end of the cooling, which can cause immediate failure.

Conclusions

The optimization of the tank was completed with the Solver Addition of Microsoft EXCEL to determine the optimal value of the ratio between the height and the diameter of the 1.5 m^3 tank. The objective function was the cost of the material.

This optimized tank has been investigated, in the event of a fire. The fire load used was a "pool" type fire with ISO 834 temperature-time function. Changes in mechanical and thermos-physical properties need to be considered. This is very important for calculating the heat transfer between steel and the internal and external phenomena. As the temperature rises, the pressure inside the tank is also increasing. To prevent the vessel from failing due to pressure, a safety valve was installed. The temperature of the shell also rises and the fire must be extinguished before the device collapses. The microstructure of the steel can also change. Martensite may appear after the fire, which reduces the strength of the steel. For this, the cooling rate is relatively high, higher than the cooling rate achievable by water extinguishing. Therefore, there is no significant change in the microstructure and the pressure vessel can be used after proper testing.

Acknowledgement

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Fuzzy-Terminal Sliding Mode Control of a Flexible Link Manipulator

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Abstract: In this study, a terminal sliding mode controller is introduced, for trajectory tracking control, of a flexible link robot manipulator. Two important parameters are considered; angle of the link and tip deflection. To demonstrate the effectiveness of the developed controller, control gain parameters in the sliding mode controller are determined by using Fuzzy Logic Control law. Another important feature of the developed controller is that it is robust against external disturbances. Stability analysis of the system is guaranteed by the Lyapunov theory. Trajectory tracking errors, angles and tip deflection of the links are investigated for two different trajectories. When the results are examined, it is seen that the developed controller, with fuzzy logic, is effective, even if there are external disturbances and parametric uncertainties in the system.

Keywords: flexible link manipulator; fuzzy controller; terminal sliding mode controller

1 Introduction

In recent decades, robot technology has started to serve in many fields. Especially, are the robots used in industry, that aim at obtaining high efficiencies. The rigid design of the robots, restricts application areas and the desired efficiency cannot be obtained from these types of rigid link robots. For this reason, instead of rigid robots, flexible manipulators are currently preferred. Li and Huang [1], designed an adaptive fuzzy terminal sliding mode controller for robotic manipulator. The control strategy is based on a Lyapunov function. Along with the fuzzy logic control method, they significantly reduced the chattering problem. Doğan et al. [2] examined the purpose of their work as developing an adaptive-robust controller for the two-link flexible robot. They used the dynamic state feedback controller to suppress elastic vibrations. This model approach has been adjusted adaptively for unknown external disturbances. Hasan et al. [3] have developed a new fuzzy logic controller, taking into account the problem of inadequate classical control methods due to the nonlinear dynamics of flexible robots. The results were compared with

the LQR controller and it was understood that the newly developed controller give better results. Shaheed and Tokhi [4], presented an investigation into the development of a closed-loop vibration control strategy for flexible manipulators. First, they introduced a proportional-derivative feedback control technique then they designed a command-filter vibration controller. They used low-pass and band-stop elliptic filters in the control law. They applied this developed controller to one link flexible manipulator. He et al. [5] deals with the problem of control design problem of flexible link manipulators. They designed an output feedback controller. The result of the study has been proven analytically and experimentally. Khairudin et al. [6] studied the dynamic modelling and characterization of a two-link flexible robot manipulator. They used Euler – Lagrange and assumed modes methods to design the dynamic model of the system. In case of a load in the system, they discussed the system response. Lee and Vukovich [7] designed the fuzzy logical control method in three stages. For the vibration and position control, the fuzzy logic controller was applied to one link flexible robot and the experimental results were examined. Tinkir et al. [8], proposed neuro-fuzzy control strategy for one link flexible manipulator. At first, a CAD model of the flexible link robot was created and the model was transferred to the SimMechanics program. They developed a fuzzy logical control method for the model's vibration control. Akyüz et al. [9], designed the cascade fuzzy logic controller to single link flexible joint manipulator. A number of experiments have been carried out to prove the effectiveness of the controller. Abdullahi et al. [10] presented and compared the fuzzy logic control and pole placement control of a rigid-flexible link manipulator. The input of the fuzzy logic control was the joint angle error and its derivative and the output of the controller was the controller signal. Computer simulations were performed and controllers were compared. Rouhani and Erfanian [11] developed a new adaptive fuzzy terminal sliding mode controller for uncertain nonlinear systems. The proposed controller is a combination of fuzzy logic control and terminal based gradient descent (GD) algorithm. Fuzzy logic controller is designed to estimate the nonlinear dynamics of the system and terminal based GD is used to update the parameters. This developed controller is applied to a two link robot manipulator. From the simulation results, it is seen that the tracking errors are converged to zero in a short time. Also proposed controller is applied to control of joint movement generated by functional electrical stimulation. Experimental results also proved that the controller is effective. Moghaddam et al. [12] designed a disturbance-observer-based fuzzy terminal sliding mode controller for multi-input and multi-output systems. They aimed to minimize the tracking error and to eliminate the external disturbances by disturbance observer. Also they developed this proposed controller to reduce chattering problem of uncertain systems. The Lyapunov Theorem is used to guaranteed the stability of the system. They applied this controller to an Unmanned Aerial Vehicle (UAV) to show the effectiveness of the controller. Wang et al. [13] presented a robust adaptive fuzzy terminal sliding mode controller with low pass filter. They wanted to minimize the trajectory

tracking error and to eliminate the external disturbances of the systems. Also, the chattering problem is solved by continuous control law. This proposed control law was applied to chain-series robot manipulator. Experimental results showed the effectiveness of the controller. Ba et al. [14] proposed position controller that combines fuzzy terminal sliding mode controller and time delay estimation. They designed the fuzzy controller to adjust the parameters in the terminal sliding mode control law. External disturbances in the system is also eliminated by time delay estimation. They applied proposed controller to hydraulic drive unit test platform. From the experimental results it is clearly seen that, the developed controller improves position control and robust to external disturbances. Vo et al. [15] developed a controller that the combination of non-singular fast terminal sliding variable and a continuous control algorithm. They also used fuzzy logic controller to update control law. The uncertainties of the system is eliminated without any chattering problem by switching control law. The robustness and the stability of the system is guaranteed by Lyapunov theory. Then, the 3-dof Puma 560 model was used to show the effectiveness of the controller. From the numerical results, it is understood that, the robot performs joint position tracking with minimum errors.

2 Terminal Sliding Mode Control Law for Flexible Link Manipulator

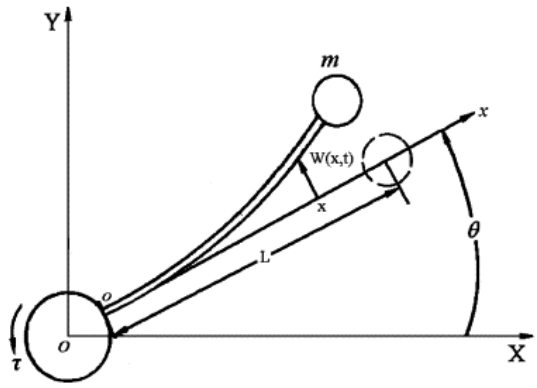


Figure 1
Flexible link manipulator [16]

The flexible link manipulator is given as in Figure 1 and the parameters of the manipulator is given in Table 1.

The model is considered as a cantilever beam model that can rotate around the z axis. w denotes the elastic deflection of the beam at the x point. Deviation is found by accepted modes method.

Table 1
Parameters of the manipulator [17]

P	Density of the link	0.7597	kgm^{-1}
L	Length of the link	0.22	M
EI	Bending stiffness	2.69	Nm^2
I_z	Moment of inertia	0.0007424	kgm^2

$$w(x,t) = \phi(x)\,q(t) \tag{1}$$

In the equation, q is the generalized coordinate corresponding to the vibration mode, and the mode is the shape function. Coordinate of any P on the link is: [17]

$$P = \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} x\cos\theta - w(x,t)\sin\theta \\ x\sin\theta + w(x,t)\cos\theta \end{bmatrix} \tag{2}$$

Dynamic model of a flexible link manipulator can be written in a Matrix form as:

$$\begin{bmatrix} M_{\theta\theta} & M_{\theta q} \\ M^T_{\theta q} & M_{qq} \end{bmatrix}\begin{bmatrix} \ddot{\theta} \\ \ddot{q} \end{bmatrix} + \begin{bmatrix} \dot{q}^T M_{qq} q & \dot{\theta} q^T M_{qq} \\ -\dot{\theta} q^T M_{qq} & 0 \end{bmatrix}\begin{bmatrix} \dot{\theta} \\ \dot{q} \end{bmatrix} + \begin{bmatrix} 0 \\ K_q q \end{bmatrix} = \begin{bmatrix} u \\ 0 \end{bmatrix} \tag{3}$$

Where,

$$M_{\theta\theta} = I_t + I_z + m_q \qquad M_{\theta q} = M^T_{\theta q} = m_{q\dot{\theta}} \qquad M_{qq} = m_q$$

$$K_q = EI\int_0^l \phi''^2 dx \quad I_t = \rho\int_0^l (x)^2 dx + I_z \quad m_{q\dot{\theta}} = \rho\int_0^l \phi(x)dx \quad m_q = \rho\int_0^l \phi^2 dx \tag{4}$$

The Equation (3) is written in the form as:

$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} + G(q) = Y(q,\dot{q},\ddot{q})\eta \tag{5}$$

Where,

$$Y = \begin{bmatrix} \ddot{\theta} & \ddot{\theta} + \dot{q}^T q\dot{\theta} + \dot{\theta} q^T \dot{q} & 0 & 0 \\ 0 & \dot{q} - \dot{\theta} q^T \dot{\theta} & \ddot{\theta} & q \end{bmatrix} \tag{6}$$

and

$$\eta = \begin{bmatrix} \eta_1 & \eta_2 & \eta_3 & \eta_4 \end{bmatrix}^T \tag{7}$$

Considering the equation 7, η values are given as:

$$\eta_1 = \rho\int_0^l (x)^2 dx + I_z \quad \eta_2 = \rho\int_0^l \phi^2 dx \quad \eta_3 = \rho\int_0^l \phi(x)dx \quad \eta_4 = EI\int_0^{l_1} \phi''^2 dx \tag{8}$$

Considering the terminal sliding mode control [18], the nominal control law is given for a flexible manipulator as:

$$\tau_0 = M_0(q)\ddot{q}_r + C_0(q,\dot{q})\dot{q} + g_0 - Ks^r \tag{9}$$

The $\dot{q}_r$ and $\ddot{q}_r$ is given as:

$$\dot{q}_r = \dot{q}_d - \Lambda\tilde{q}^p \text{ and } \quad \ddot{q}_r = \ddot{q}_d - p\Lambda \text{diag}\left[\tilde{q}_1^{p-1} \ldots\ldots \tilde{q}_n^{p-1}\right]\dot{\tilde{q}}; \tag{11}$$

The control gain parameters Λ and K are defined below:

$$\Lambda = \text{diag}\left[\lambda_1, \ldots\ldots, \lambda_n\right] \rangle 0 \text{ and } \quad K = \text{diag}\left[k_1, \ldots\ldots, k_n\right] \rangle 0 \tag{12}$$

The other parameters are:

$$\frac{1}{2} \langle p \le 1;\ 0 \langle r \le 1;\ p, r = \frac{z_1}{z_2};\ z_1, z_2 \in Z_+;\ z_1 \le z_2 \tag{14}$$

and s is the terminal sliding variable defined as [18]:

$$s = \dot{\tilde{q}} + \Lambda\tilde{q}^p \tag{15}$$

Then, the nominal control law (9) can be written in the following form as:

$$\tau_0 = Y_r\eta_0 - Ks^r \tag{16}$$

Where,

$$Y_r = \begin{bmatrix} \ddot{\theta}_r & \ddot{\theta}_r + \dot{q}_r^T q\dot{\theta}_r + \dot{\theta}_r q^T\dot{q}_r & 0 & 0 \\ 0 & \dot{q}_r - \dot{\theta}_r q^T\dot{\theta} & \ddot{\theta}_r & q \end{bmatrix} \tag{17}$$

The nominal fixed parameters are given as:

$$\eta_0 = \begin{bmatrix} \eta_{10} & \eta_{20} & \eta_{30} & \eta_{40} \end{bmatrix}^T \tag{18}$$

Then, the following control law is proposed in terms of the nominal control law as:

$$\tau = \tau_0 + Y_r\xi \tag{19}$$

$$= Y_r\left(\eta_0 + \xi\right) - Ks^r$$

ξ is the control input and designed to provide robustness to parametric uncertainty $\tilde{\eta}$. And $\tilde{\eta}$ is defined as; $\tilde{\eta} = \eta_0 - \eta$

Here, η_0 is the nominal parameters, represents the loaded state of the robot and η represents the unloaded parameters. If we add a load of 10% of the robot's weight to the end of the robot and if we change the length of the robot arm by 10%, parameter uncertainty in the system is defined as follows.

Table 2
$\tilde{\eta}$ values

$\tilde{\eta}_1$	$\tilde{\eta}_2$	$\tilde{\eta}_3$	$\tilde{\eta}_4$
0.006	0.6453	0.08	25962.9

Along with the uncertainties shown in Table 2, the uncertainty parameter is selected as follows:

$$\|\tilde{\eta}\| = \sum_{i=1}^{4}(\eta_i + \eta_0) \le \rho^2 \tag{21}$$

Thus ρ=25963

And, the additional control input w is defined as:

$$\xi = \begin{cases} -\rho \dfrac{Y^T s}{\|Y^T s\|} & \text{if} \quad \|Y^T s\| \rangle 0 \\ 0 & \text{if} \quad \|Y^T s\| = 0 \end{cases} \tag{22}$$

Considering the Eq. 5, 16 and 20, the following equation is obtained:

$$M(q)\dot{s} = Y(q, \dot{q}, \dot{q}_r, \ddot{q}_r)(\tilde{\eta} + \xi) - Ks^r \tag{23}$$

Where, $\tilde{\eta} = \eta_0 - \eta$ $\tilde{M} = M_0 - M$ $\tilde{C} = C_0 - C$ $\tilde{G} = G_0 - G$. In order to show the stability of the uncertain system, the following Lyapunov function is given:

$$V(t) = \frac{1}{2} s^T M s \tag{24}$$

The time derivative of the Lyapunov function is:

$$\dot{V}(t) = s^T M \dot{s} \tag{25}$$

Considering the Equation 23 and 25, the time derivative of the Lyapunov function (24) is obtained as:

$$\dot{V}_1(t) = -s^T K s^r + s^T Y(\tilde{\eta} + \xi) \tag{26}$$

The relations between the Lyapunov function and the first right-hand term in Eq. (26) are given as:

$$s^T K s^r = \sum_{i=1}^{n} k_i s_i^{r+1} \tag{27}$$

$$\ge \alpha \left\{ \sum_{i=1}^{n} \frac{1}{2} \bar{m} s_i^2 \right\}^n \tag{28}$$

$$\ge \alpha V_i^n \tag{29}$$

Where,

$$n = \frac{(1+r)}{2}; \alpha = k_{min} \left\{ \frac{2}{\bar{m}} \right\}; \quad k_{min} = \min_i \{k_i\} \tag{30}$$

From Equation (22), There are two cases for the second term of Equation (26). If $\left\|Y^T s\right\| = 0$, the second term in Eq. (26) will be zero, that is $s^T Y(\tilde{\eta} + \xi) = 0$. If $\left\|Y^T s\right\| > 0$, the second term in Equation (22) will be equal or less than zero.

$$\begin{aligned} s^T Y\left(\tilde{\eta} + \xi\right) &= s^T Y \left(\tilde{\eta} - \rho \frac{Y^T s}{\left\|Y^T s\right\|}\right) \\ &\leq \left\|s^T Y\right\|\left(\left\|\tilde{\eta}\right\| - \rho\right) \\ &\leq 0 \end{aligned} \tag{31}$$

From Eq. (29) and Eq. (31), the following equation is obtained.

$$\dot{V}_1(t) \leq \alpha V_1^{\eta} \tag{32}$$

The rest of the proof is given [18].

3 Fuzzy Logic Control

Fuzzy logic control strategy has its own definitions by membership functions. These membership functions are triangular, trapezoidal or bell curved shape. They take the values between [0,1].

Fuzzy Logic Controller consists of three stages (Fuzzification, Rule Evaluation and Defuzzification). In the Fuzzification stage, membership functions are defined for the variables, certain values are converted to fuzzy values. In the rule evaluation stage, rules are determined in accordance with the specified input and output parameters. And the final stage, fuzzy values are converted to certain values.

In this study, the inputs are the trajectory tracking error of the links (e1 and e2). The outputs are the p and r parameters of the terminal sliding mode controller. Block diagram of proposed fuzzy logic controller is shown in Fig. 2. Linguistic variables which implies inputs and outputs have been classified as: NO, NH, Z, PH, PO. Inputs are all normalized in the interval of [-1, 1] as shown in Fig. 3. And also outputs (p and r) are normalized in the interval of [0.5, 1] and [0, 1] shown in Fig, 4 and Fig. 5. The ranges of inputs and outputs are determined by trial and error method. The relationship between input and output has been obtained with the rule table. (Table 3)

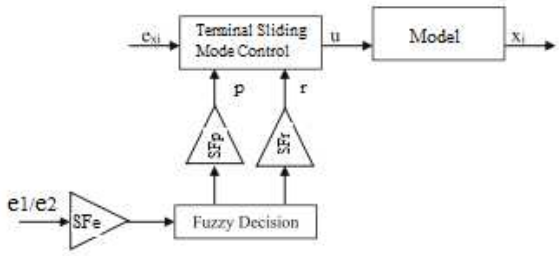


Figure 2
Block diagram of fuzzy logic controller

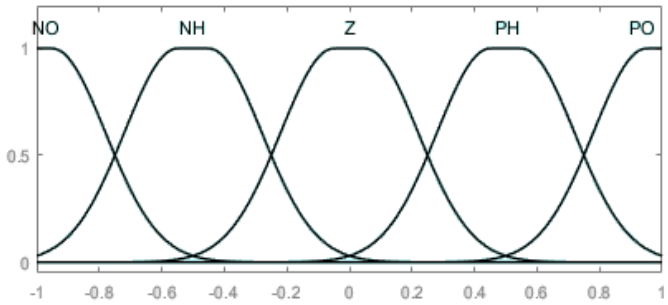


Figure 3
Membership functions of inputs (e_1, e_2)

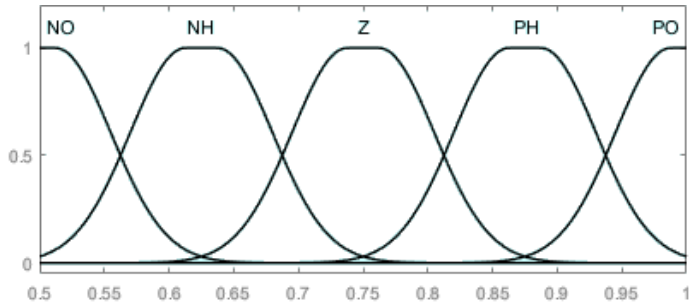


Figure 4
Membership functions of output (p)

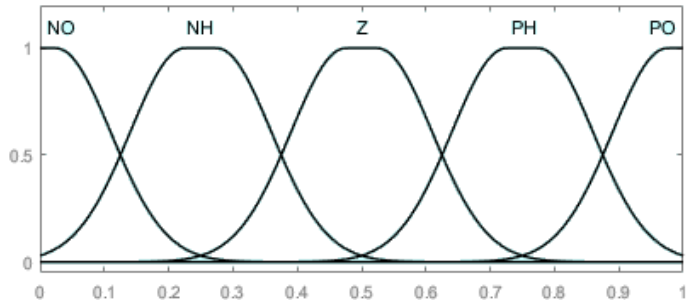


Figure 5
Membership functions of output (r)

Table 3
Decision table

$e_1 \backslash e_2$	NO	NH	Z	PH	PO
NO	NO	NO	NH	Z	Z
NH	NH	NH	Z	Z	PH
Z	NH	Z	Z	PH	PH
PH	Z	Z	PH	PH	PO
PO	Z	PH	PH	PO	PO

Table 3 shows the rule table between input and output. This table was created by trial and error method and should be interpreted as follows:

If the error of the first link is NO and the error of the second link is NO, then, the parameter p and r is NO.

If the error of the first link is NO and the error of the second link is NH, then, the parameter p and r is NO.

If the error of the first link is PO and the error of the second link is PH, then, the parameter p and r is PO.

If the error of the first link is PO and the error of the second link is PO, then, the parameter p and r is PO.

4 Results

In this study, terminal sliding mode controller and fuzzy-terminal sliding mode controller was applied to flexible link manipulator. The aim of this study is to minimize the displacement of the end point of the manipulator. Two different trajectories are used in order to analyze the performance of the controller. First, a bump trajectory in Fig. 6 is used and the results are presented in Figures 7-11.

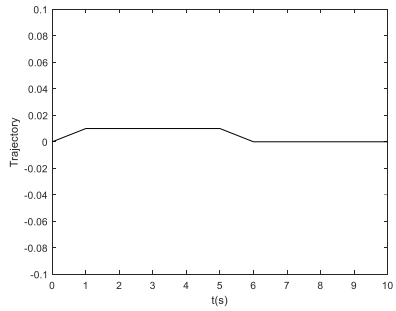
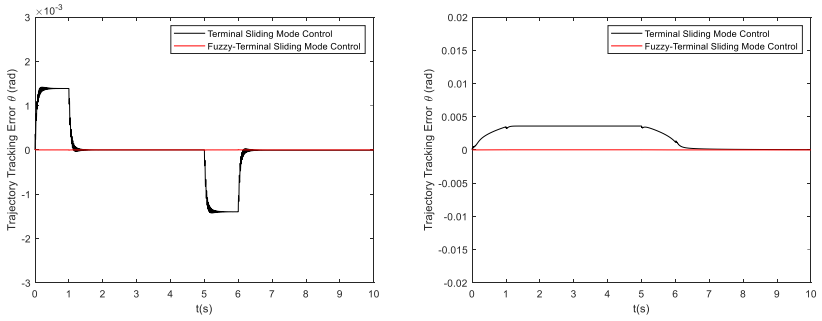


Figure 6
Desired trajectory

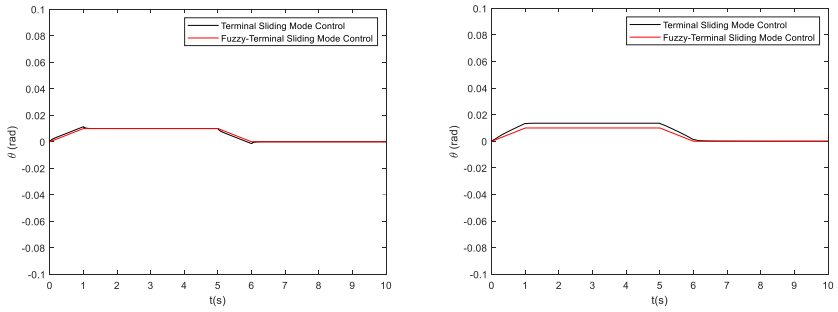
Figure 7 shows trajectory tracking error of θ over time both terminal sliding mode controller and fuzzy-terminal sliding mode controller. It is seen that the error is very small for both controllers. In the Figure 7a, the trajectory tracking error is about $1.5x10^{-6}$ rad for both controllers. Even if the external disturbance is involved, the trajectory tracking error is about 0.002 rad in terminal sliding mode controller. As shown in Figure 7b it is seen that the fuzzy logic controller reduces the trajectory tracking error and brings the tracking error to almost zero.



(a) (b)

Figure 7
Trajectory tracking error of angle θ with control parameters λ=diag (10 10) and K=diag(10 10)
a) Without disturbances b) With a disturbance torque

The time history of θ is given in Figure 8. When two figures are examined, it is seen that both controllers show a similar trend when there are no external disturbances. The effectiveness of the fuzzy controller seems clearly in the case of external disturbances. (Fig. 8b)



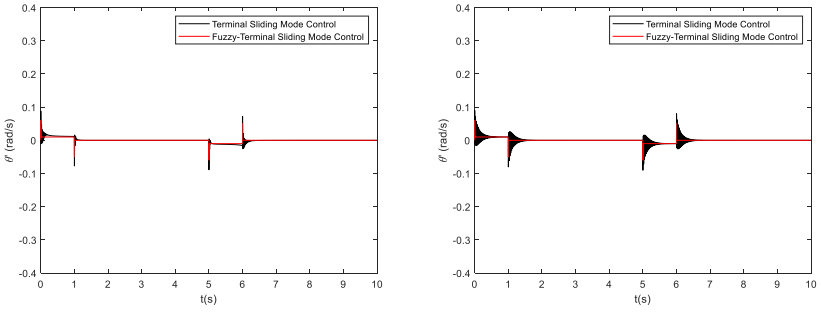
(a) (b)

Figure 8

Angle θ over time with control parameters λ=diag(10 10), K=diag(10 10)

a) Without disturbances b) With a disturbance torque

In Figure 9, the time derivative of θ is given. The system moves in regular regime with amplitudes of maximum 0.1 rad/s. In the case of external disturbances, it is seen that small chattering occurs in the terminal sliding mode controller. This problem is eliminated by the fuzzy logic controller. In particular, the efficiency of the fuzzy logic controller is clearly seen, in the graph in the case of external disturbances.



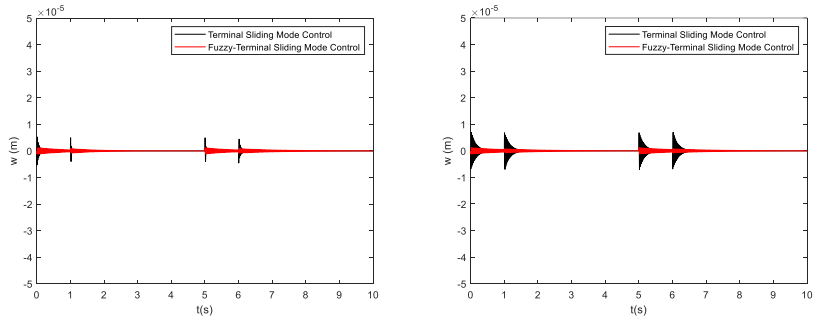
(a) (b)

Figure 9

Time derivative of angle θ over time with control parameters λ=diag(10 10), K=diag(10 10)

a) Without disturbances b) With a disturbance torque

Fig. 10 shows the response of flexible link endpoint displacement. The link returns to its former position in a short time with a deviation of maximum 0.1×10^{-6} meters. The displacement of the endpoint does not change greatly when external disturbances are involved.



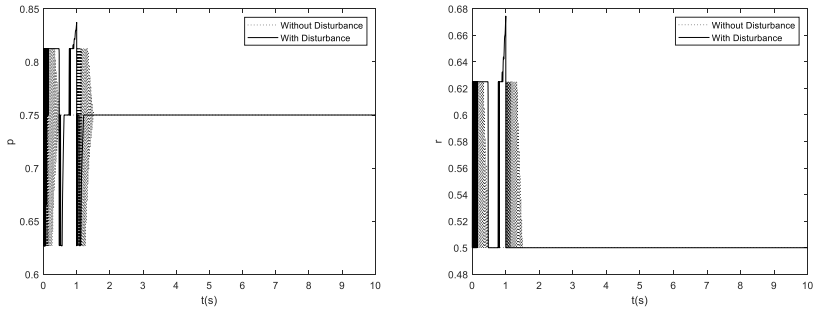
(a) (b)

Figure 10

Tip deflection w with control parameters λ=diag (10 10), K=diag(10 10)

a) Without disturbances b) With a disturbance torque

Figure 11 shows the change of the control parameters p and r with respect to time when fuzzy logic controller is used. Fuzzy logic controller provides the most accurate result by updating the control parameters according to the changes in the system. A certain limit is determined and the parameters are updated within those limits.



(a) (b)

Figure 11

Control parameter ‘p’ over time - Control parameter ‘r’ over time λ=diag (10 10), K=diag(10 10)

Sine wave trajectory in Figure 12 is used in order to analyze the performance of the controller. The results are given in Figures 13-17.

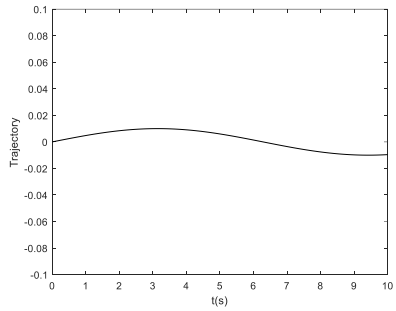


Figure 12
Desired trajectory

As seen in Figure 13, trajectory tracking error is small for both controllers. When external disturbances are included, the trajectory tracking error increases very little. (Fig. 13b) But even this is within tolerable limits. As shown in Figure 13, the fuzzy-terminal sliding mode controller is effective in both cases.

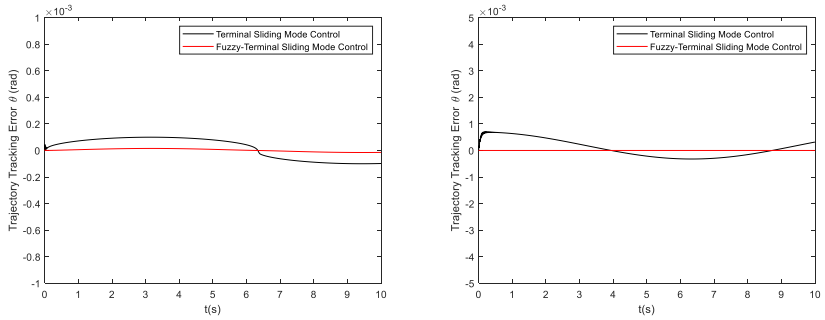
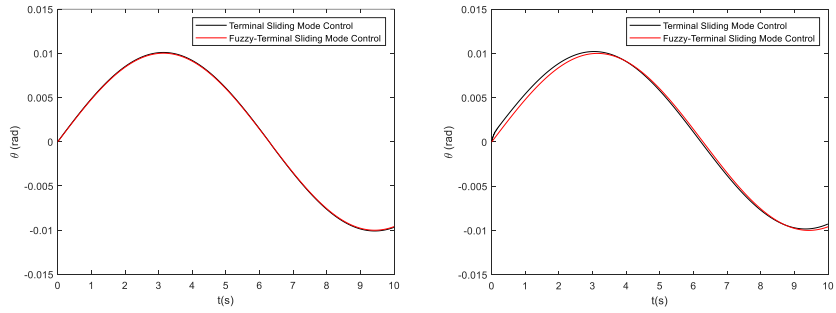


Figure 13
Trajectory tracking error of angle θ with control parameters λ=diag (10 10) and K=diag(10 10)
a) Without disturbances b) With a disturbance torque

The time-dependent variation of θ is shown in Figure 14. When the figures are examined, it is seen that the model tracks the trajectory smoothly. The effectiveness of the fuzzy controller seems clearly in the case of external disturbances.



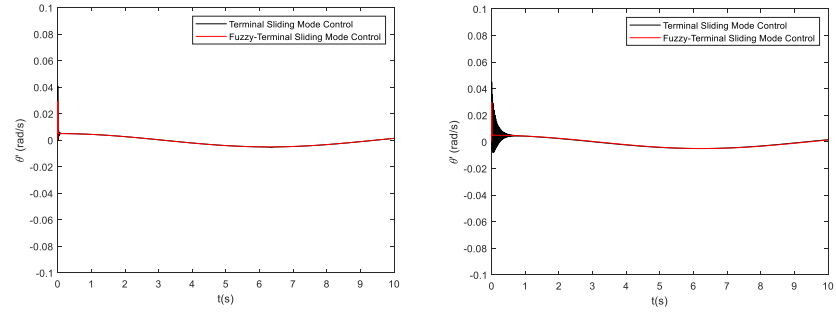
(a) (b)

Figure 14

Angle θ over time with control parameters λ=diag(10 10), K=diag(10 10)

a) Without disturbances b) With a disturbance torque

The time derivative of θ is shown in Figure 15. Both controllers appear to behave similarly when there are no external disturbances. And the highest value is around 0.04 rad/s. (Fig. 15a) In the case of external disturbance, it seems that the terminal sliding mode controller is slightly more affected but recovers quickly. The terminal sliding mode controller, on the other hand, seems to be slightly affected by the external disturbances. (Fig. 15b)



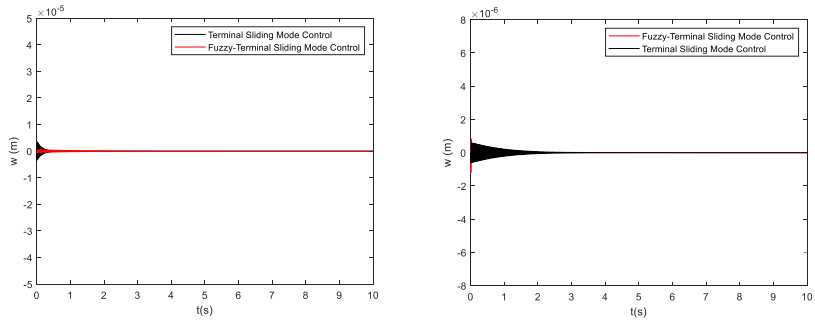
(a) (b)

Figure 15

Time derivative of angle θ over time with control parameters λ=diag(10 10), K=diag(10 10)

a) Without disturbances b) With a disturbance torque

One of the most important criteria in the model, is the displacement of the endpoint. Figure 16 shows the tip deflection of the model for both controllers and with and without external disturbance. In the Figure 16a, without external disturbances, two controllers give similar results. When there is an external disturbance, in the Figure 16b, it is seen that the terminal sliding mode controller generates a small amount of chattering. However, it is seen that the fuzzy sliding mode controller doesn't cause any problems.

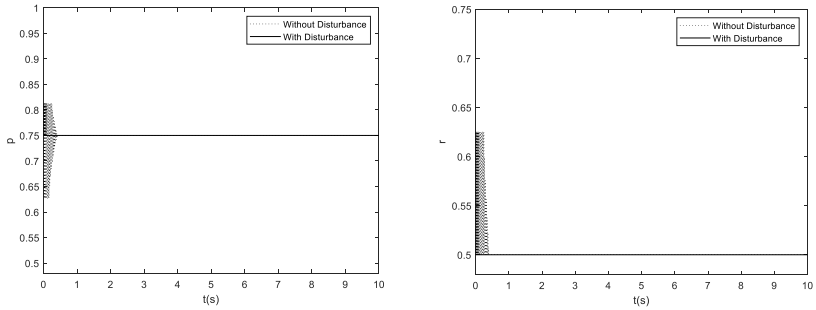


(a) (b)

Figure 16

Tip deflection w with control parameters λ=diag (10 10), K=diag(10 10)
a) Without disturbances b) With a disturbance torque

Figure 17 shows the change of control parameters p and r over time. These control parameters are determined using the fuzzy logic controller. The control parameter p is updated between 0.5 and 1 (Fig. 17a), and the r control parameter is updated between 0 and 1. (Fig. 17b) For both control parameters, it is understood that the controller updates the control parameters rapidly within external disturbances.



(a) (b)

Figure 17

Control parameter ‘p’ over time - Control parameter ‘r’ over time λ=diag (10 10), K=diag (10 10)

Conclusions

This study aimed to decrease the trajectory tracking error of the system, through the development of a fuzzy terminal sliding mode controller. The Fuzzy-terminal Sliding Mode Controller is design to control a one link flexible manipulator. The innovation in this study, is the determination of the most appropriate control parameters in the terminal sliding mode controller, by using a fuzzy controller in order to reduce tracking error. For this, a Fuzzy Logic Controller has been designed in this study. Input and output parameters, control rule and limits in fuzzy logic control law, are developed by a trial and error method. The stability of this controller is guaranteed by the Lyapunov function. The proposed controller is applied to a flexible link manipulator, with and without external disturbances.

When the results are examined for two trajectories, it is seen that the fuzzy-terminal sliding mode controller is effective. In addition, it is considered, that the proposed controller is effective following the trajectory, with a very small error, even if it has an external disturbance within the system. This shows the controller's robustness potential. The purpose of this study is to update the control parameters in the terminal sliding mode control law, with a fuzzy logic control method. From the results, it is seen, that the developed controller, is more effective than the terminal sliding mode controller. For this model, the most appropriate results are presented, according to the control law, obtained by the trial and error method. As a result of the study, it was understood that the controller is valid.

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Towards An Autonomous Landing System in Presence of Uncertain Obstacles in Indoor Environments

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Abstract: The landing task is fundamental to Micro air vehicles (MAVs) when attempting to land in an unpredictable environment (e.g., presence of static obstacles or moving obstacles). The MAV should immediately detect the environment through its sensors and decide its actions for landing. This paper addresses the problem of the autonomous landing approach of a commercial AR. Drone 2.0 in presence of uncertain obstacles in an indoor environment. A localization methodology to estimate the drone's pose based on the sensor fusion techniques which fuses IMU and Poxyz signals is proposed. In addition, a vision-based approach to detect and estimate the velocity, position of the moving obstacle in the drone's working environment is presented. To control the drone landing accurately, a cascade control based on an Accelerated Particle Swarm Optimization algorithm (APSO) is designed. The simulation and experimental results demonstrate that the obtained model is appropriate for the measured data.

Keywords: Micro air vehicles (MAVs); autonomous landing; obstacle avoidance; dynamics obstacle' velocity estimation; sensor fusion; optimal control

1 Introduction

Autonomous navigation is an essential requirement for intelligent mobile platforms [1], [2], [3]. Nowadays, intelligent autonomous navigation at low or super low-altitude is an important requirement for aircraft that must complete missions close to the ground, and such ability is extensively desired. Search and rescue operations allow benefit points at low altitudes. Similarly, Unmanned Aerial Vehicles (UAVs) performing reconnaissance, the military must fly at low altitude in the presence of known and unknown obstacles. Until now, UAVs have to land on a prepared position with prior knowledge of obstacle-free trajectories. In order to land on a location at which the safety requirement is unknown (e.g., presence of static obstacles or moving obstacles), the UAV should immediately detect the environment through its sensors and decide its actions for landing [4].

An interesting survey of advances in guidance, navigation, and control of UAV systems is described in [5]. The paper first presents the main research groups, then the development of frameworks and algorithms. These algorithms and systems are classified into different categories based on the autonomy level. In [6], a feasible trajectory for landing is investigated to make the decision during flight time to guarantee safety. In addition, the authors proposed the formula to reduce computation time. A required translation of the operating bounds of the aircraft is the disadvantage of this work. In [7], landing on a moving target has been simulated. The optimal trajectory is determined based on the Variational Hamiltonian and Euler-Lagrange equations. The kinematic model of the helicopter is used to derive an optimal controller to track and land on an arbitrary moving target. However, this model is a simplified version, therefore, there are some drawbacks in this research.

The Autonomous landing of a UAV on static and mobile platforms in absence of GPS is presented in [8]. Among different strategies, electro-optical sensors have been the most popular modality for landing site evaluation [9]. In [10], a vision system is used for control, terrain reconstruction, and tracking. Another study is in [11], where the UAV altitude is obtained by fusing GPS signals with stereo vision. Another safe landing area system based on multiple impulse-radio ultra-wide-band (IR-UWB) radar is proposed in [12]. In which, the detecting of ground property methodologies (slope and roughness) and obstacles using IR-UWB are studied.

Light Detection and Ranging (LIDAR) sensors have been broadly studied for safe landing-area determination for small helicopters [13], [14] and fixed-wing airplanes [15] while Global Positioning System (GPS) is chosen for navigation of aircraft [16], [17], [18]. An intelligent system, based on image segmentation procedures to recognize the relative orientation of the UAV and a platform, is presented in [19]. In [20], a robust adaptive nonlinear guidance and control design based on neuron-adaptive design philosophy is presented for the robust landing operation. The numerous simulations using the six-degrees-of-freedom nonlinear model of a prototype UAV is used to verify the proposed methodology. In which,

wind disturbances and ground effects are investigated. In [21], a biomimetic system is proposed that determines terrain appearances, such as large obstacles and precipitous slopes by using a monocular camera. In [23], a nonlinear controller model for take-off and landing purpose (VTOL) of a UAV is described using measurement optical flow. This method enables the UAV to hover and land on a moving platform, such as the deck of a sea-going vessel. Two different assignments are concerned in that study: (1) the stabilization of the UAV; (2) the regulation of automatic landing of the UAV onto a moving platform.

A dynamic target tracking and obstacle avoidance of a UAV is studied in [24]. A method of cooperation between two UAVs at different high and low altitudes is presented in [25] for autonomous navigation and landing. Based on the high flexibility and extensive vision, the higher UAV measures the position of the lower UAV and controls it to track the marker and land on it. In [26], a pose estimation process of a UAV using parallel image technique is studied. The system performs the capabilities of a high-performance Graphics Processing Unit/ Central Processing Unit (CPU/GPU) embedded system to provide safely autonomous take-off and landing processes.

In this study, the UAV landing is performed in presence of uncertain obstacles using sensor fusion which fuses Pozyx and onboard sensors' signals. In order to use Pozyx, some modifications had to be made to the drone which caused an imbalance at hovering. Additionally, we developed an algorithm to estimate the moving obstacle's velocity based on the onboard vision system. This velocity information can help autonomous UAV to interpret for the landing task in complex situations. The main contributions of this article are:

- the development of an autonomous landing system for a UAV.
- the design and implementation of sensor fusion technique.
- the estimation of moving obstacle's velocity based on vision approach.
- the design and implementation of a cascade control APSO algorithm for the drone landing task.

This paper is organized as follows. Section II provides a description of the setup system and localization method using onboard sensors, Pozyx, and sensor fusion method. The obstacle detection and landing algorithm are briefly outlined in Section III. Section IV presents the PID controller based on an APSO algorithm using transfer functions obtained by the identification process. Section V demonstrates simulations and experiment results based on the proposed approach. Section VI presents the conclusions and future works.

2 System Setup and Localization Method

In this section, the system setup and proposed localization based on sensor fusion are presented. Assume that the UAV performs the landing task for the victim's rescue application in presence of uncertain static and moving obstacles (Lego Robot) with the designed target (victim) position (marked as the blue star) as shown in Fig. 1.

Our approach consists of three major components running on a laptop (ground station) connected to the UAV via wireless communication. The first component is Pozyx localization, which allows the UAV to determine its coordinates in a working space. The second component is an inertial measurement unit (IMU) data process, which delivers and receives signals between the quadrotor and the ground station. To calculate a more accurate position of the UAV, the sensor fusion method is implemented. The last component is a cascade control based on the APSO algorithm. The ground station is a laptop Intel Core i7-6600U, 2.81Hz, 64-bit operating system.

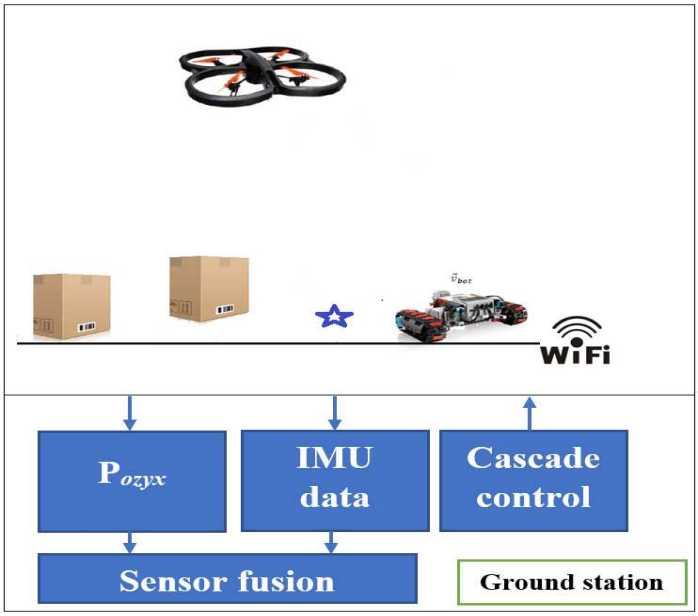


Figure 1
The proposed approach

In outdoor applications, GPS usually provides a reasonable estimation however, it is not an effective tool for indoor applications. There are several options for indoor position estimation such as visual navigation, the onboard IMU data, or extra sensors. This section concerns the state estimation of the UAV in an indoor environment using IMU, Pozyx, and sensor fusion techniques.

2.1 IMU Data Processing

The IMU measures the roll, pitch, and yaw angles. The velocity estimations are obtained by fusing the information from a 3-axis gyroscope with the information from a 3-axis accelerometer and a magnetometer. Position estimations can then be obtained by integrating the velocities. The *x* position of the drone is calculated in Equation 1.

$$x_k = x_{k-1} + \begin{bmatrix} \cos(\gamma) & -\sin(\gamma) & 0 \\ \sin(\gamma) & \cos(\gamma) & 0 \\ 0 & 0 & 1 \end{bmatrix} V\Delta t \tag{1}$$

where: V is the velocity of the drone; x_k, x_{k-1} are position of the drone in *x*-direction at sample k, $k-1$; Δt is sample time.

The *y* position is calculated in a similar approach. A better estimation of the height can be obtained by fusing the velocity in z-direction with the information from the ultrasonic sensor.

2.2 *Pozyx*

In this study, the drone is equipped with *Pozyx* as shown in Figure 2. The position estimation is obtained accurately by using ultra-wideband technology. Please refer to [27].

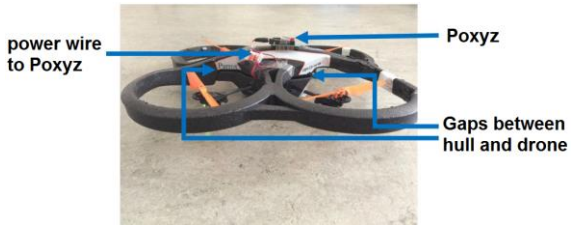


Figure 2
Pozyx on AR.Drone 2.0

Three anchors are placed in a room. The anchors should not be placed on one line or one plane. The absolute position of these anchors needs to be known in advance. By measuring the distance between the *Pozyx* tag and each anchor, the position of the *Pozyx* tag (UAV position) can be estimated. These were filtered out by defining a maximum allowed deviation of the current position compared to the previous one. When the deviation exceeds the threshold value, the current position is set equal to the previous one. The *Pozyx* offers a robust position estimation. However, this signal is noisy so that it is not recommended to use the *Pozyx* as the only source of information. The results obtained by unfiltered and filtered *Pozyx* are shown in Figure 3.

2.3 Sensor Fusion

To combine the advantage of IMU and *Pozyx*, there is opted to use a Kalman filter to fuse these signals. The Kalman filter combines the information of different sensors and the expected state from the physical model to estimate the state, (x; y; z; v_x; v_y; v_z)^T

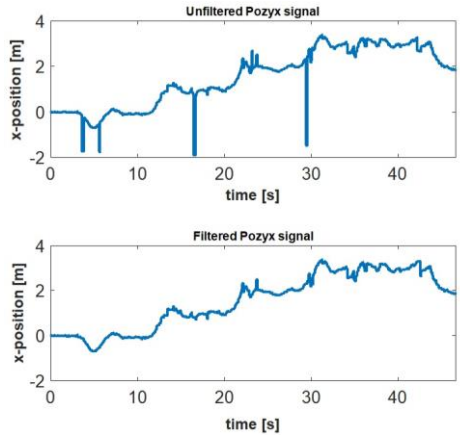


Figure 3
Unfiltered compared to Filtered *Pozyx* signal

There are two phases in the Kalman filter: the prediction phase and the update phase. In the first phase, the Kalman filter estimates the position and its uncertainty based on the physical model.

$$\hat{x}_k = A\hat{x}_{k-1} \tag{2}$$

$$P_k = AP_{k-1}A^T + Q \tag{3}$$

where

$\hat{x}_k, \hat{x}_{k-1}$ are estimated current state and previous state respectively;

A is the state-transition model;

Q is the covariance of process noise;

P_k, P_{k-1} are current and previous estimate co-variance.

In the second phase, the observed measurements are implemented to find the new best estimate as the following equations.

$$K = P_k C^T (CP_k C^T + R)^{-1} \tag{4}$$

$$\hat{x}_k = \hat{x}_k + K(z_k - C\hat{x}_k) \tag{5}$$

$$P_k = P_{k-1} - KCP_k \tag{6}$$

Where

K is the Kalman gain;

C is the observation model which converts the true state space into the observed space;

R is the co-variance of observation noise;

z_k is the measurement signal.

The transition matrix A was chosen as in Equation 7. The variable dt is equal to the mean execution time of the loop. With the used sensors, it is possible to directly measure the states; therefore, the measurement matrix C is equal to a unity matrix.

$$A = \begin{bmatrix} 1 & 0 & 0 & dt & 0 & 0 \\ 0 & 1 & 0 & 0 & dt & 0 \\ 0 & 0 & 1 & 0 & 0 & dt \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{7}$$

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{8}$$

In order to design the Kalman filter, the process noise covariance Q and the measurement noise covariance R are added. The co-variances of the *Pozyx* were then tuned manually until the desired result was obtained.

$$Q = \begin{bmatrix} 0.1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.3 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.3 \end{bmatrix} \tag{9}$$

$$R = \begin{bmatrix} 10 & 0 & 0 & 0 & 0 & 0 \\ 0 & 10 & 0 & 0 & 0 & 0 \\ 0 & 0 & 10 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.05 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.05 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.05 \end{bmatrix} \tag{10}$$

Figure 4 shows an estimation of the position with the Kalman filter, *Pozyx,* and the IMU. In this experiment, the drone starts at x ≈ 0 m, then goes around 21 seconds to x ≈ 1 m, and finally goes around 30 seconds to x ≈ 2 m. As the IMU estimation drift very quickly, it is not possible to use it as the pure reference

resource. The disadvantage of *Pozyx* is its noise. The proposed sensor fusion method which combines the advantages of both signals is a better option with robust estimation without noise.

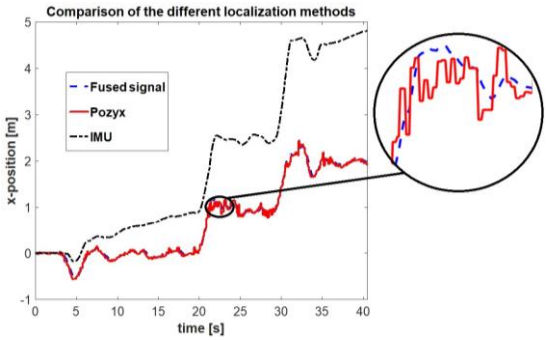


Figure 4
The comparison of the different localization methods

3 Obstacle Detection and Landing

Obstacle detection is one of the key functionalities of a fully autonomous drone. For autonomous landing applications, both static obstacles and moving obstacles should be detected.

3.1 The Static Obstacle Detection

In order to detect static obstacles, a solution based on distance measurement is proposed. The algorithm uses the difference between absolute height (the distance to the ground level h_a) and relative height (the distance to the nearest obstacle h_r) to detect an obstacle. A graphical representation of the heights can be found in Figure 5.

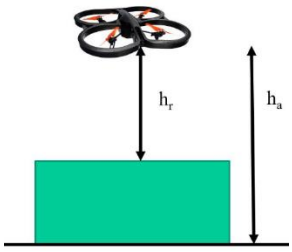


Figure 5
The static obstacle detection based on the absolute and relative heights

3.2 The Moving Obstacle Detection

The idea behind the detection of moving obstacles is to interpret complex situations and to make appropriate decisions of the UAV based on this additional information. In the experiment, a Lego Mindstorms EV3 was used to represent a moving obstacle. The moving obstacle is marked with red paper. Based on color detection, it is possible to extract the coordinates of the obstacle in the image frame. These coordinates need to be converted to real-world coordinates to obtain the obstacle's position/velocity information. Figure 6 presents moving obstacle detection using color segmentation. The images were acquired by using the bottom camera of the drone.

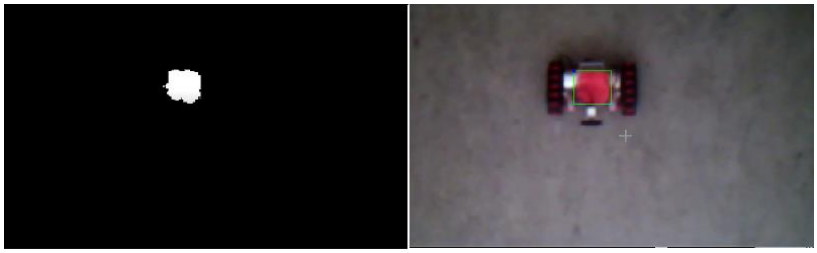


Figure 6
Color-based tracking moving obstacle

In order to convert obstacle positions from an image coordinate to a world coordinate, the calculation is implemented based on the diagram as shown in Figure 7. In which, *M* is the center point of the received image. *P* is the position of the Lego robot in the image frame. AOV_x is the angle of field of view and *D* presents the bottom camera of the AR.Drone 2.0. *O* is the projection point of *D* in the horizontal plane. *W* is the intersection point between *DP* and the horizontal plane. The following formulas are applied.

$$|DM| = \frac{|KM|}{\tan(AOV_x/2)} \tag{11}$$

$$\alpha = \frac{|PM|}{|DM|} \tag{12}$$

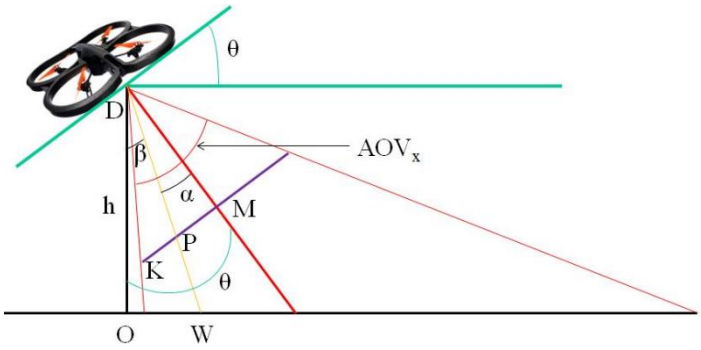


Figure 7
The conversion from the image coordinates to the real-world coordinates

$$\beta = \begin{cases} \theta + \alpha \text{ if } X_P > X_M \\ \theta - \alpha \text{ if } X_P < X_M \end{cases} \quad (13)$$

We define α' as:

$$\alpha' = artan(\frac{X_P - X_M}{|DM|}) \quad (14)$$

We have:

$$\beta = \theta + \alpha' \quad (15)$$

$$x_W = \tan(\beta)\, h \quad (16)$$

With $DO = h$

The absolute world x-coordinate of the object is:

$$x_{obj} = x_{drone} + \cos(\gamma)\,.\,x_W - \sin(\gamma) y_W \quad (17)$$

Where:

x_W, y_W: the world coordinates in x and y directions of point W;

x_{obj} : the absolute world x-coordinate of the object;

x_{drone}: the absolute world x-coordinate of the drone;

γ: the yaw angle of the drone.

In a similar approach, the y-coordinate of the object (the moving obstacle) is:

$$y_{obj} = y_{drone} + \cos(\gamma)\,.\,y_W + \sin(\gamma) x_W \quad (18)$$

where:

y_{obj} : the absolute world y-coordinate of the object;

y_{drone}: the absolute world y-coordinate of the drone;

The moving obstacle's velocity is estimated as follows:

$$v_{obj}(t) = \sqrt{\left(\frac{x_{obj}(t) - x_{obj}(t-1)}{\Delta t}\right)^2 + \left(\frac{y_{obj}(t) - y_{obj}(t-1)}{\Delta t}\right)^2} \tag{19}$$

3.3 Landing Algorithm

In our approach, the landing algorithm based on the above obstacle detection method is presented in Figure 8. In which, depending on specific situations, the drone decides the best location for the landing task.

Figure 9 presents an example of a UAV landing application for victim rescue purposes [28]. Assume the map of the horizontal landing plane is presented as in Figure 9a with the purple area occupied by obstacles and the green area free for landing. Take into account the dimension of the drone, the area that is marked as "obstacle" should be extended by the drone's (rounded up) radius. Therefore, the real possible landing spot is the green locations as shown in Figure 9b. As the landing map is a binary matrix, the optimal landing spot can quickly be found by checking for every possible landing point the distance to the target location. The optimal landing spot is then the one with the smallest distance to the victim's location. Figure 9c presented an optimal landing spot in terms of the distance to the target location (victim's position).

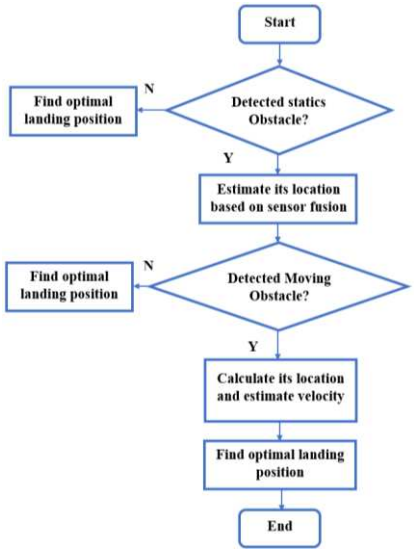


Figure 8
Landing algorithm flowchart

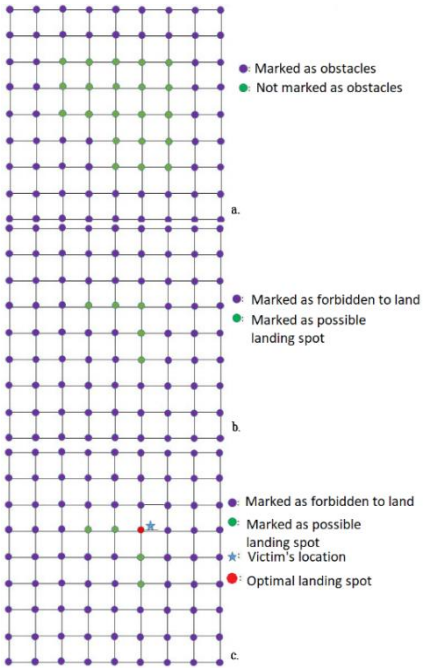


Figure 9
Landing mapped protocol

4 Control Design Based on an Accelerated Particle Swarm Optimization Algorithm

In this section, the control approach for the drone is presented. The cascade control includes an outer loop and an inner loop. For more details about the main characteristics of the Ar.Drone 2.0, please refer [29]. The outer loop transforms the landing commands into the AR.Drone 2.0. The high layer consists of a C++ application in Visual Studio, which allows accessing all drone's communication channels, therefore, enabling functions to send commands or set configurations, receive and store data from sensors and videostream. The inner loop is considered a black-box. The identification method is used to identify the transfer functions of this black-box as shown in Figure 10.

As the drone is complicated to control as it is a multiple-inputs and multiple-outputs system (MIMO). However, it can be considered as a Linear Time-Invariant (LTI) System. Therefore, it is decomposed into multiple single input and single output (SISO) systems.

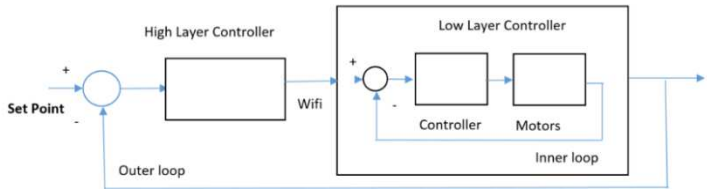


Figure 10

Quadrotor layers: the low layer represents the electronic assistance and the embedded operative system on the AR.Drone; the high layer represents the pilot

The parametric identification using the prediction error method (PEM) and Pseudo-Random Binary Signal (PRBS) input signals is used to identify the system. The results are:

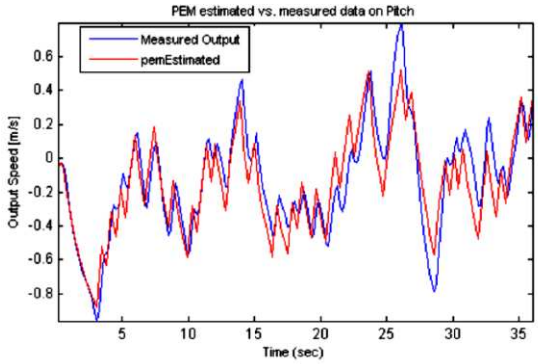
$$H_x(s) = \frac{V_{out}^x(s)}{V_{in}^x(s)} = \frac{7.27}{(1.05s+1)}$$
$$H_x(s) = \frac{V_{out}^x(s)}{V_{in}^x(s)} = \frac{7.27}{(1.05s+1)} \tag{8}$$
$$H_{altitude}(s) = \frac{\dot{\varsigma}_{out}(s)}{\dot{\varsigma}_{in}(s)} = \frac{0.72}{(0.23s+1)}$$

For the outer loop controller, the inputs are the setpoints for speed $(V_{in}^x(s), V_{in}^y(s), \dot{\varsigma}_{in}(s))$ and the outputs are the response of the internal control to follow those setpoints $(V_{out}^x(s), V_{out}^y(s), \dot{\varsigma}_{out}(s))$. The drone provides an estimation by using its equipped sensors, making it also possible to obtain the position by integrating the relative speeds.

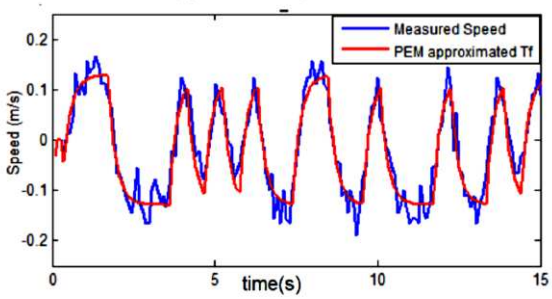
For each drone, specific transfer functions are archived. The validation of the AR.Drone 2.0's transfer functions is shown in Figure 11. The results prove that drone movements are properly approximated.

In this study, the controllers of the AR.Drone 2.0 are designed based on a multi-objective particle swarm optimization (MOPSO) [33]. This method is implemented to facilitate convergence to an optimal set of PID. In the traditional PSO, the particle's positions are found based on two values: (1) the current global best *Gb* and (2) the personal best Pb_i [32].

In our approach, only the global best is used to accelerate the convergence of the algorithm. The diversity of each particle is simulated by using randomness.



(a) The validation of the pitch/roll transfer function response and measurement (speed in m/s).



(b) The validation of the altitude transfer function response and the measurement(speed in m/s).

Figure 11
The comparison of pitch/roll (a), altitude (b) transfer function

The velocity and position vectors are designed as:

$$V_i(t+1) = V_i(t) + c_1 r + c_2(Gb(t) - X_i(t)) \quad (10)$$

$$X_i(t+1) = X_i(t) + V_i(t+1)\Delta t \quad (11)$$

where:

$c_1 \in [0.1\ 0.5]$*(UB-LB);*

$c_2 \in [0.1\ 0.7]$;

r: a random number in [0,1].

$Gb(t)$: the global best position of iteration t;

$V_i(t)$; $V_i(t+1)$: the velocities of the particles i of iteration t, $t+1$;

$X_i(t)$;$X_i(t+1)$: the positions of the particles i of iteration t, $t+1$;

LB, UB: the lower and upper bounds of X.

The value of c_1 can be designed as the following formula to reduce the randomness.

$$c_1 = c_0 \xi^t (UB - LB) \tag{12}$$

Where:

$c_1 \in [0.1\ 0.5]$ is the initial value of the randomness parameter while t is the number of the iterations and $\xi \in (0\ 1)$ is a control parameter. For more detail, please refer [33] for more detail.

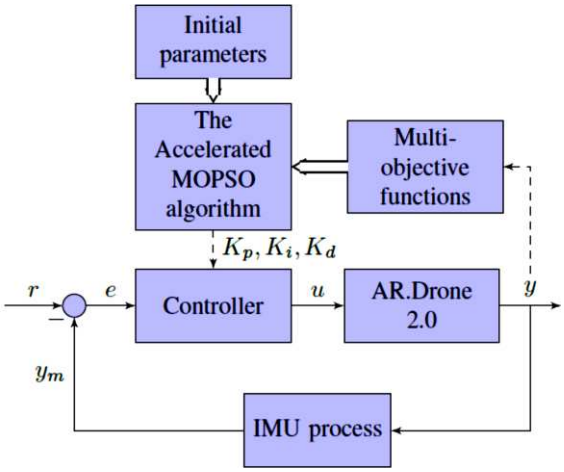


Figure 12
The block diagram of the accelerated MPSO-based PID controller

In this study, the controller parameters K_p; K_i; K_d are considered as an optimal set of MPSO algorithm. They are chosen to satisfy prescribed performance criteria regarding the settling times (T_s), the overshoot (OS), and the steady-state error (SSE). The objective functions are designed as:

$$\begin{aligned} J_1(X) &= |SSE| \\ J_2(X) &= OS \\ J_3(X) &= T_s \end{aligned} \tag{13}$$

where:

X is a set of parameters that is optimized, $X = (K_p;K_i;K_d)$.

Figure 12 depicts the block diagram of the controller approach based on MPSO. In this study, the dimension of the particle is 3. In the beginning, the algorithm generates arbitrary values of $K_p;K_i;\ K_d$ and calculates the objectives function. It continuously updates the set of parameters until it reaches the optimal set.

The composited objective optimization is designed as follows.

$$J(X) = \beta_1 J_1(X) + \beta_2 J_2(X) + \beta_3 J_3(X) \quad (14)$$

Where: $\beta_1, \beta_2, \beta_3$ are positive values, in this study, those values are set as $\beta_1 = 0.3$, $\beta_2 = 0.25$, $\beta_3 = 0.45$. The swarm size $N = 50$. The maximum number of iterations $T_{max} = 50$; $c_0 = 0.2$; $c_2 = 0.7$; $\xi = 0.97$.

The results of the *x, y, z* position controllers for the drone are presented in Figure 13, Figure 14, Figure 15 respectively. It can be observed that the measured position accurately follows the simulated one which correctly tracks the reference without overshoot. The control efforts are reasonable. The position errors between real and desired positions in *x; y; z* coordinates are presented in Figure 16.

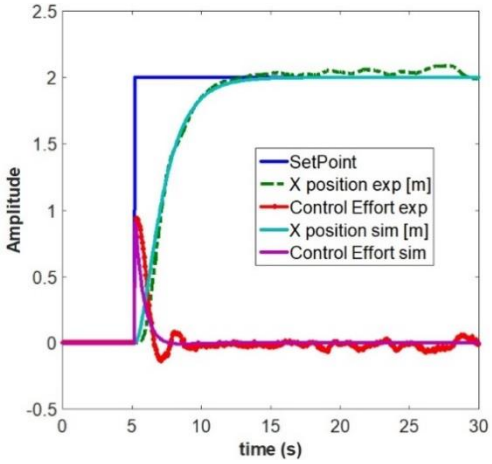


Figure 13
PID controlled *X* position (m)

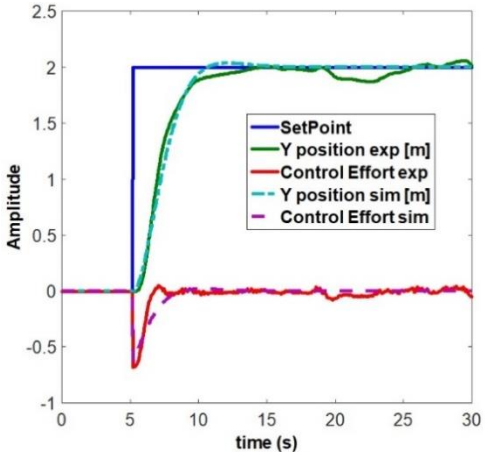


Figure 14
PID controlled *Y* position (m)

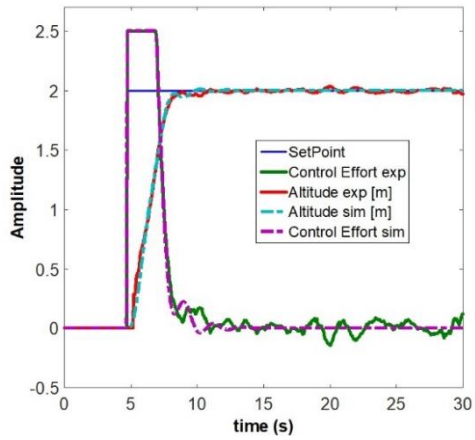


Figure 15
PID controlled Altitude (*Z*) position (m)

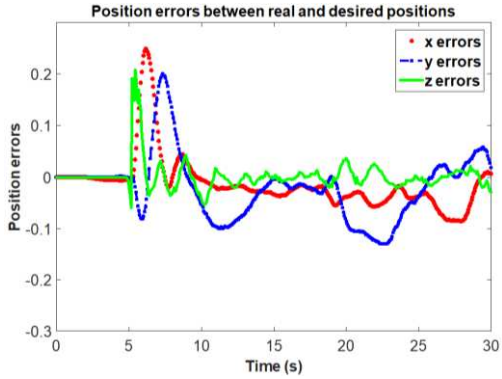


Figure 16
Position errors (m) between real and desired positions in *x; y; z* coordinates

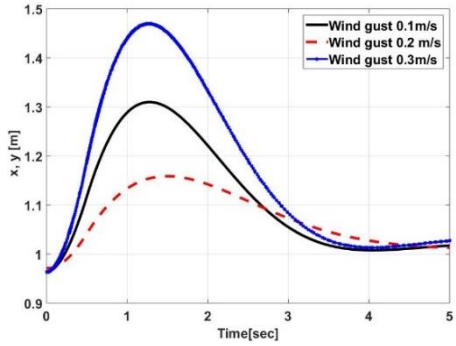


Figure 17
Wind disturbance X(Y) response comparison

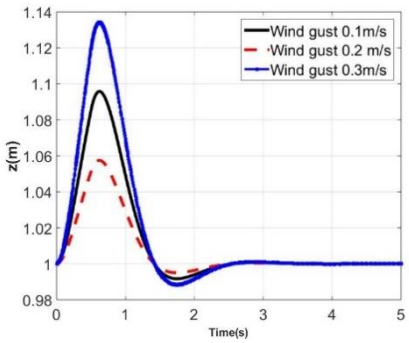


Figure 18
Wind disturbance Z response comparison

In this study, the stabilization of the drone underwind gust conditions is considered. The UAV's controller should handle the disturbance rejection problem approximately. Figure 17 and Figure 18 illustrate the wind disturbance to the step response where wind gusts are 0.1m/s; 0.2 m/s; 0.3 m/s during 5s respectively. The results show that the designed controllers are stable with wind gust disturbance.

5 Experiment Results

In this section, the results of moving obstacle velocity estimation of the AR.Drone 2.0 are illustrated. In addition, the landing processes in environments with the presence of unknown static/dynamic obstacles are validated.

5.1 Velocity Estimation of Moving Obstacles Results

For safe landing in a dynamic environment, an essential requirement is the perception of the moving object's velocity. To validate our approach, the velocity estimation system setup consists of a Lego Mindstorm that is driving with a constant speed of 0.2 m/s and an AR.Drone 2.0 that estimates the velocity of the robot using its bottom camera. To obtain a proper velocity estimation, a cumulative moving average filter is applied in this application. The result shows that the measurement is reasonable at the first stage as shown in Figure 19. After that, the velocity estimation is quite accurate as shown in Figure 20.

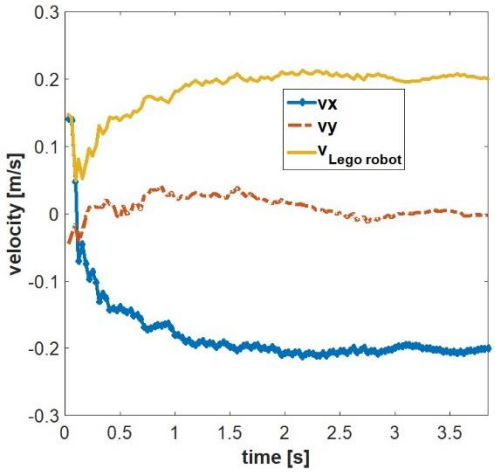


Figure 19
The cumulative moving average filter that is applied to the velocity measurements of the moving obstacle (first stage)

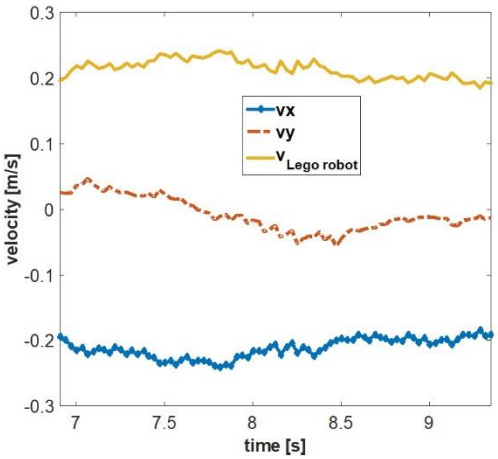


Figure 20
The cumulative moving average filter that is applied to the velocity measurements of the moving obstacle (second stage)

The experiment shows that velocity estimation based on a vision system is feasible from a drone. Even considering delays, accurate velocity estimations of moving obstacles are possible. This speed information can help autonomous UAV to interpret complex situations to find a suitable position for its landing.

5.2 Autonomous Landing Results

The idea for autonomous landing task of the drone is to find the position in the environment at which there are no static/potential moving obstacles and has the shortest distance to the target. As soon as the drone detects a static obstacle by its ultrasonic sensor, the position of that obstacle is provided by the sensor fusion method. The drone's velocity information is provided as stated in the previous subsection.

Case I: Landing in presence of static obstacles

The experiment for the landing process in presence of static obstacles is conducted in a room with full furniture such as sofa, chair, table, etc.; the target (victim) location is marked as a blue rectangle on the ground (see Figure 21). The outcomes prove that the drone is able to avoid all obstacles on its path and autonomous landing on the optimal position (victim's position).

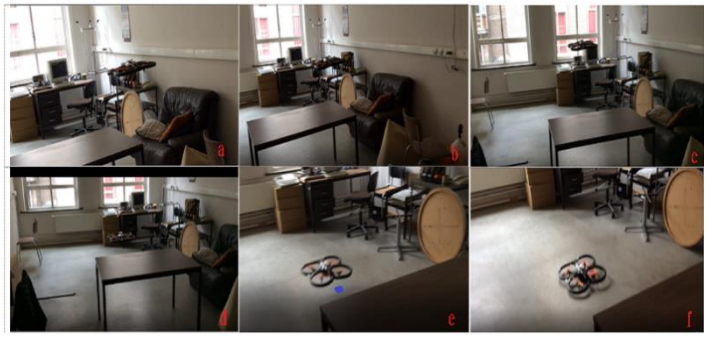


Figure 21

Landing in presence of static obstacles results in the sequence of time. a) fly over a static obstacle (sofa); b) fly over a static obstacle (table); c) fly to the target position; d) closer to the target; e) prepare to land; f) landing

Case II: Landing in presence of moving obstacles

In this experiment, a Lego Mindstorms EV3 was used to represent a moving obstacle. The moving obstacle is marked with a red marker and the target (victim's position) location is marked as the blue area on the ground as shown in Figure 22. Based on the color detection algorithm, it is possible to extract the obstacle's position in the image frame. In Figure 22a, the drone detects the Lego robot as a moving obstacle. As the target position on the robot path, the UAV stills follow the robot and flies to the position near the target. However, it did not decide to land immediately. The drone hovers and waits until the robot passes the target position then it lands safely.

The conducted experiments prove that the proposed approach allows the UAV to land on the optimal position safely in GPS denied environments with the presence of uncertain obstacles.

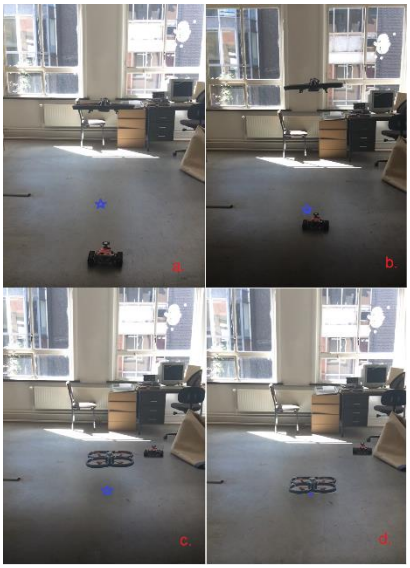


Figure 22
Landing in presence of dynamics obstacle results in the sequence of time

Conclusions

This paper presents a novel autonomous landing approach of a commercial AR.Drone 2.0 in presence of uncertain obstacles with GPS denied environment. The main achievements are: (*i*) the development of an autonomous navigation system to assistant landing for UAV in term of avoiding unknown and dynamic obstacles; (*ii*) the proposed unknown static obstacle and dynamic obstacle detection approach; (*iii*) the effective estimation of moving obstacle's velocity based on the drone's vision system; (*iv*) the development of cascade control based on an accelerated particle swarm optimization algorithm which allows the drone to land safely. The results show that the obtained model fits well with the measured data. Furthermore, the designed control strategy is capable of controlling the drone properly. In addition, the proposed autonomous landing strategy can guide the UAV to avoid static/dynamic obstacles and land on the optimal position. However, only considering moving obstacles with constant speed is the limitation of this work. Future work includes an extension of the proposed approach to multiple UAVs and a combination of multiple ground vehicles moving with variable speeds.

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Impact of Tax Benefits and Earnings Management on Capital structures Across V4 Countries

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Abstract: The issue of capital structure is among the most commonly discussed fields within Corporate Finance Theory. By optimizing the capital structure, it is possible to achieve an increase in the company value and increase the company flexibility and competitiveness. Economists have, for more than half a century, seen tax benefits (tax shields) as a capital structure determinant. Nonetheless, leverage is also influenced by earnings management, which can significantly reduce information asymmetry, between stakeholders when used correctly. This paper examines the influence of the tax shield and earnings management on a corporate capital structure, in V4 countries. In order to determine the influence of the tax shield and earnings management, panel data model was used. Net sample consisted of 10627 companies from the V4 countries from 2014-2017. The results of the model indicate that corporate behavior in the area of capital structure follows Pecking order; short-term trade credit is the most commonly used liability. The interest tax shield is of little importance for deciding between debt and equity, while the non-debt tax shield is negatively correlated with debt. Furthermore, an inverse correlation between debt and earnings management, as measured by the modified Jones model, indicates that debt monitoring, reduces agent costs and reduces the application of earnings management techniques.

Keywords: tax advantage; earnings management; emerging economies; capital structure determinants; Visegrad countries

1 Introduction

Capital Structure is believed to be one of the most discussed topics of corporate finance theory. Too high a level of debt may lead to increased credit risk, the low credibility of the company, increase the cost of capital (WACC) and risk of the company failure as reported by Siekelova et al. [1], Kovacova and Kliestik [2], Valaskova et al. [3] or Durica et al. [4]. Conversely, a conservative approach to indebtedness may reduce corporate competitiveness, ultimately reducing the benefit of equity holders. A balanced debt-to-equity ratio is a win-win strategy, as both sides (debt holders and equity holders) make the most of capital. Moreover, there is growth in both indicators of profitability (return on assets - ROA, return on equity - ROE) and improvement in indicators of financial condition of the company [5, 6].

Capital structure theories have been developed mainly in advanced economies, especially in the US. First, it is the theory of Modigliani and Miller [7], which was developed by Myers [8] and called the Trade-off theory. The balance between the tax advantage of debt and the cost of financial distress forms an optimal capital structure. The tax benefit of debt, called the tax shield, is the main motive of this theory and should explain the growth in corporate debt. The Pecking order theory developed by Myers and Majluf [9] is the second dominant theory of capital structure, which in turn states that the company's internal resources, as retained earnings, are the first source of funds, regardless of the relatively higher capital cost and no tax advantage. These theories of capital structure take into account only marginally the third entity of stakeholders: managers who are responsible for the key financial decisions of the company. Jensen and Meckling [10] built up the Agency cost theory that clarifies the position of managers in deciding on the capital structure so as to achieve the highest benefit at a given debt-to-equity ratio. Holthausen [11] states that debt holders, equity holders and business managers are rational and use all available means to achieve their goals, including earnings management. McKee [12] states that earnings management is a legal choice and reporting management to achieve stable, predictable outcome. Under accounting regulations in national form or international GAAP (IFRS), financial statements are influenced in order to achieve a positive image of the business and to achieve the set objectives of the business. The existence of earnings management may be a reason for the continuous growth of corporate debt. The tax shield enables to reduce the company tax burden by reducing the pre-tax profit and represents one of the earnings management techniques.

In this context we tried to investigate the impact of the tax shield and earnings management on the corporate capital structure in the V4 countries. Traditional capital structure determinants such as tangibility, liquidity, profitability, business growth, risk or enterprise size are investigated in many studies from developed countries [13-16]. On the other hand, studies on the capital structure are represented to a lesser extent than the previous ones and are mainly assessed by

SMEs [17-21]. Earnings management as a determinant of the capital structure has been analyzed in only a few studies primarily focused on publicly traded companies such as An et al. [22], Nikoomaran et al. [23] or Naz et al. [24]. As Sundvik [25] states, earnings management is not only used by public companies to increase the market value of the stock, but also by non-traded companies to increase profits through tax planning. This study examines the influence of both different types of tax benefits and earnings management on the capital structure of enterprises regardless of the type of ownership structure (listed or non-listed company).

This study has the following structure: The paper begins with a look at the investigated theories of capital structure from the point of view of developed and developing countries with regard to the Visegrad countries. The literature review also provides a critical assessment of the interrelationship between earnings management and tax benefits (tax shields), together with an overview of earnings management research in the Central European region. The description of the methods used (longitudinal data model) together with the data description is the content of the third section. The discussion is focused on comparing the results of the model with the prevailing approaches to capital structure on a Central European scale. The last section clarifies the possible shortcomings of this approach, including proposals for future research in the field of capital structure and earnings management.

2 Theoretical Background

2.1 Capital Structure in Developed and Emerging Countries

This sub-chapter summarizes theoretical and empirical knowledge of the capital structure in developed countries. These findings are compared with results in emerging countries, especially in the V4 economies.

As mentioned in the Introduction, there are two basic capital structure theories that are frequently studied in the financial literature: Trade-off theory developed by Myers [8] and Pecking order theory proposed by Myers and Majluf [9]. Both these theories have been tested since their inception, but empirical results do not provide unambiguous confirmation of which of the theories is correct, i.e. how the capital structure determinants relate to the debt value. Schwarz and Aronson [26] were one of the first to confirm the Trade-off theory based on the assumption of a constant optimal debt, which was confirmed, for example, by the Czech Republic. Graham et al. [14] confirmed the validity of the theory through the negative relationship of the non-interest tax shield and the interest tax shield. Anderson and Caverhill [16] confirm the validity of Trade-off theory based on a direct correlation between debt and liquidity due to lower default risk and lower

bankruptcy costs. Kamath [27] states that more than 80% of quoted companies use internal resources as retained earnings, for 75% of companies, debt is the second best option, and for 80% of companies, the least preferred option is to issue shares. Pecking-order theory has also been confirmed by Titman and Wessels [28], Bancel and Mittoo [29] or Rajan and Zingales [13].

However, several studies have produced ambiguous results. Antoniou et al. [30] used panel data for analysis; their results indicate the application of both theories in deciding on the capital structure, as debt is positively correlated with tangibility and size, but also inverse correlated with profitability or business growth. Eldomiaty and Ismail [15] show that businesses are influenced by external conditions when deciding on the capital structure. At low tax rates, an enterprise cannot reach a high tax shield and opts for internal resources; on the contrary, the high tax burden makes the debt more attractive.

The capital structure in Central European countries, together with other emerging economies, was investigated mainly, over the last thirty years, after the transition to a market economy. Booth et al. [18] compared the capital structure in both types of economies (developed and developing); they argue that there are no different firm-specific determinants, the different capital structure is given by country-specific factors (GDP, inflation). Nivorozkin [17], based on an analysis of five emerging countries, reports that debt in these countries is lower than in developed economies, but the effect of business factors may also be different in countries with the same institutional and legal roots (for example, Slovakia and the Czech Republic). Delacoure [31] has developed a modified Pecking order theory based on an examination of the capital structure in Russia, Poland, the Czech Republic and Slovakia. Equity is perceived as a free source of capital; cost of equity is not taken into account.

Bauer [32] used a sample of quoted enterprises from the V4 countries. The results indicate that managers prefer internal resources and Pecking order theory, which was also confirmed by the author's analysis of Czech companies [33]. Reznakova et al. [19] used panel data from more than a thousand Slovak enterprises for the period 2002-2007. The main results are inconsistent with the Trade-off theory, but the authors stress that none of the theories can fully explain the capital structure. Koralun-Bereznicka [34] used a sample of enterprises from 11 European countries, including Poland, the Czech Republic and Slovakia. This proves that Pecking order theory is supported by several determinants in regard to long-term debt, while short-term debt better explains Trade-off theory. Moreover, in addition to firm-specific factors, the industry along with the country have an important position.

Hernadi and Ormos [21] investigated the choice between equity and debt on a sample of Central and Eastern European countries, taking into account the V4. They note that, in terms of long-term indebtedness, company-specific factors are more important, while country-specific factors are more important for short-term

indebtedness, which should mean that financial decisions in developed and emerging countries are increasingly converging. Qualitative research by the authors [35] confirms the significant role of Pecking order theory in the region; the frequency of responses supporting Trade-off theory was low which signaled minimal role of this theory. Hartwell and Malinowska [20] results support the findings of previous studies: Pecking order theory fully explains the behavior of similar companies. Companies quoted on the Warsaw Stock Exchange prefer and trade credit and short-term debt over long-term debt and bank loans, which give rise to the partial tax benefits of interest.

Recent research on capital structure in Central and Eastern European countries suggests that the corporate capital structure is not uniform despite similar macroeconomic conditions and / or economic developments. Stradowski and Schmidt [36] examining Czech, Polish, Hungarian and Greek companies note that while Hungarian and Greek companies prefer debt based on trade-off theory; the Czech market is more inclined to the conclusions of the pecking order approach. Polish companies have undecided behavior regarding debt or equity preferences; none of the investigated theories clearly describes the behavior of these companies. However, the authors note that the Hungarian market evidenced significant anomalies that distinguish it from the financial structure of other Central European countries. Ruckova and Stavarek [37] outlined the differences in debt preferences in different sizes of enterprises. Focusing on the region of Central and Eastern Europe, they pointed out that while large companies prefer equity in the first place and the Pecking-order approach, the financial policy of medium-sized companies does not show a clear preference for either capital structure policy.

Profitable farms in V4 from the sample by Fenyves et al. [38] do not rely on debt, which corresponds to the pecking order approach, with the exception of Slovakia, whose corporate behavior in this sector can be explained not only by the pecking order approach, but also by another theory with greater explanatory power. Similar results as [36] were achieved by Skulanova [39] in the mining sector. Moreover, she notes that the high debt ratio in the past tends to negatively affect future debt; this effect is low, but not negligible. The study by Kedzior et al. [40] refuted the widespread acceptance of the pecking order approach in Central European countries. Polish technology companies prefer debt (trade-off theory) in terms of external technology acquisition. On the other hand, companies with significant R&D activities are to a greater extent financed by internal resources in the order of retained earnings, share capital and debt. These conclusions do not support the pecking order theory, but its modification according to [31].

Building companies in Central Europe do not show a homogeneous dependence of debt use on return on equity [41]. Slovak companies have an indirect dependence of debt on the return of debt in the examined sector. However, the magnitude of the effect of debt on profitability is smaller than for the reverse relationship. Horvathova et al. [42], tested the impact of capital structure on corporate

performance. A high share of equity (90%) minimizes EVA entities; the increase in debt has a positive effect on this indicator as well as EVA equity. The optimal debt-to-equity ratio should be 20:80 in favor of equity, taking into account maximum performance and existing financial and credit risks. The risk of default increases with the growth of debt; The interconnectedness of both areas of corporate finance is reflected in the similarity between the explanatory variables of bankruptcy models and the determinants of capital structure. Kovacova et al. [43] notes that Slovak and Czech bankruptcy models prefer similar predictors, Hungarian and Polish models differ significantly from them (e.g. in the first two mentioned countries ROA and current ratio is more used, in Hungary ROE and quick ratio).

Czech companies consider the lack of internal funds as retained earnings to be the most important factor in debt policy [44]. Financial flexibility is more important for retail companies, manufacturing companies considered earnings and cash flow volatility more important. Campbell and Rogers [45] note that the high volatility of operating and investment cash flow also causes instability in the capital structure, and the capital structure is formed with respect to other variables (earnings volatility). In relation to cash flow volatility and debt policy, corporate governance has an indispensable role to play as investigated by [46]. Taking into account the theory of capital, market indebtedness is significantly more affected by the level of corporate governance than the book value of debt. Poor corporate governance was associated with high indebtedness in the surveyed companies in Eastern Europe, which confirms the results of further studies in this area [47] [48].

The studies mentioned above, show that there are systematic differences in capital structures not only in terms of industries, countries and their macroeconomic factors (tax policy), but also less researched factors of capital structure such as corporate governance and related earnings management.

2.2 Earnings Management, Tax Shield and Sources of Tax Shield

Earnings management is a complex issue dealing with the management and manipulation of profits with a view to show the company financial performance according to the ideas of the company management. Walker [49], unlike McKee [12], defines earnings management in a broader sense as: the use of managerial discretion over (within GAAP) accounting choices, earnings reporting choices, and real economic decisions to influence how underlying economic events are reflected in one or more measures of earnings. There may be several motives for earnings management. One of the most important reasons is income smoothing to create a consistent view of a financially efficient business. The value of the company can be optimized through earnings management, which means growth of shareholder returns and motivation of future shareholders. As Dopuch and Pincus [50] states, one of the motives is the tax advantage. An enterprise may use some

tax-based profit management methods, such as the choice of capital structure, inventory management methods, asset depreciation method, or extending the use of R&D costs [51]. These methods are part of earnings management but also represent different forms of non-interest and interest tax shields.

The main source of the tax shield is the interest paid as described in Modigliani and Miller [7]. Due to the growth of corporate debt, especially in international companies, thin capitalization has been introduced. Buettner et al. [52] states that an enterprise is thin capitalized if the established debt-to-equity ratio is exceeded. When this threshold is exceeded, further interest paid is not tax deductible. The aim of these measures is to reduce tax evasion, in particular in the context of lending between related parties which cause base erosion and profit shifting. Bachman et al. [53] examined the impact of thin-capitalized rules on the tax shield and noted that highly indebted companies have significantly reduced the tax shield as a result of the rules on limiting the tax deductibility of interest. A non-interest tax shield arises from the existence of different types of tax relief and incentives. The most widespread source is the depreciation reported by McKee [12] as one of the most popular earnings management techniques. Keating and Zimmerman [54] have shown that managers are changing the depreciation policy due to changes in tax laws, poor performance or new investment opportunities. Greater flexibility in the choice of depreciation method (e.g. straight-line vs. accelerated depreciation) or depreciation periods extends the earnings management options and hence, the value of the tax shield.

Research and development costs are another source of the tax shield as well as earnings management. A study by Guidara and Boujelbene [55] evidences that high R&D businesses have discretionary accruals significantly different from zero, unlike businesses with no R&D and zero discretionary accruals. High R&D indicates the existence of profit manipulation. Tahinakis [56], analyzing European businesses in times of recession, found that businesses are manipulating R&D to avoid reporting losses or declining returns, regardless of whether the economy is in recession or not.

Tax loss carry forward significantly affects the value of the tax shield as identified by Velez-Pareja [57]. Chludek [58] argues that there is a negative relationship between loss carry forward and market value in the case of loss-making companies. Huxley and Sidaoui [59] examined the effect of volatility on the value of investment portfolios in Peru. They note that adopting a more liberal net carry forward in the tax code could bring an increase in returns on the stock market. Herborn et al. [60] states that the value of tax loss carry forward may be influenced by earnings management. Loss carry forward is a tool of earnings management and provides investors with information about future profitability.

Desai and Dharmpala [61] argue that tax reductions can give business management justification for opportunistic behavior and misleading corporate investors. Hanlon and Slemrod [62] found investors worried about the

interconnectivity between tax shields, misuse of management positions and profit manipulation. The result of their study is to reveal the negative market reaction (fall in stock prices) to the publication of a wide application of tax optimization in the company. Dhaliwal et al. [63] examined the interaction of earnings management and effective tax rate. The study states that corporations are lowering the effective interest rate forecast for the fourth quarter, which is explained by lowering tax-deductible costs by business management to meet analysts' forecasts and expectations of business shareholders. Guenther [64] states that businesses can increase profits through the deductibility of interest expense. There is an inverse relationship between the company's debt and profit, i.e. a large debt implies a low company profit and vice versa. In connection with corporate income tax, this means an increase in the tax liability in connection with the increase in profit before tax. Given these assumptions, an enterprise will manipulate profits in an effort to reduce its tax liability. Therefore, an increasing debt ratio indicates profit manipulation.

Research on earnings management in Central European countries suggests that the reasons for the application of these techniques are several, including more favorable debt financing conditions, growth in corporate value or bias in tax charges [65]. Kramarova [66], focusing on transfer pricing, notes that Slovak companies manage their profits downwards, but it is not possible to confirm a linear link between earnings management and tax avoidance, or between controlled transactions and tax avoidance. Downward earnings management in order to reduce tax liability is not only typical in Slovak economic conditions, but also in other V4 countries [67]. Kliestik et al. [68] emphasizes that accounting manipulations with profit are not random, but have a growing trend. Earnings management in Czech companies reached a break-even point in 2013, other Central European countries have the same trend in earnings management, but their break-even point was not until 2014.

In addition to tax avoidance, initial public offering is a common reason for applying profit manipulation techniques. Sosnowski [69] examining Polish listed companies found that earnings management is not aggressively applied before IPOs, but the conservative form is widespread in the examined sample. Slight accounting manipulations reduce the probability of issuing new shares and the sale of secondary shares is more frequent, especially if the company reports negative discretionary accruals. In another study [70], the author focused on IPOs related to private equity funds. There is no evidence that the level of discretionary accruals in PE-backed and other listed companies is different; these companies do not show a lower level of accounting manipulation than other companies. However, no significant differences in the level of earnings management were found even compared to other Central and Eastern European countries [71] [72]. Sajnog [73] also researched Polish listed companies focusing on another phenomenon of earnings management, namely executive compensation. Although a strong relationship between corporate performance and executive compensation is

presented [74] [73] shows a positive but insignificant relationship between ROE and executive compensation, and an inverse relationship between ROS and the variable under study.

Another area of earnings management research in developing Central European countries is earnings management detection methods. There is no consensus as to which of the models is most suitable for detection. Callao, et al. [67] evaluated models of accrual earnings management from the perspective of developing Eastern European countries (Visegrad Four). Although, the modified Jones model [75] is one of the most widely used models, it does not provide sufficiently reliable results in the studied countries; other models should be more appropriate, e.g. [76] [77]. Kliestik et al. [78], on the other hand, recommend the modified Jones model as the most suitable in Central European countries. Polish companies manipulate profit the most, while Slovak companies the least. However, none of the forms of accrual earnings management (downward and upward) prevail. Strakova [79] investigated the conditions of use of more than 20 models of earnings management and notes that only seven models, including the modified Jones model, are suitable for application in the conditions of Central European economies.

3 Research Methodology and Data

The purpose of the study is to examine the influence of earnings management and tax shields on the corporate capital structure of V4 economies and to determine which of the capital structure theories explains more appropriate behavior of these companies. In view of the subject matter of this study, we have chosen to use Leverage as a dependent variable quantified as a debt to asset ratio called Total leverage (TLEV). Studies mentioned in the previous chapter show that there are several major determinants of capital structure in particular tangibility, liquidity, profitability along with others. Eight explanatory variables were selected to quantify the leverage of businesses, the effective tax rate as a tax shield proxy, discretionary accruals as proxy earnings management, and six traditional determinants of the capital structure. The algorithms for calculating variables, as a predicted correlation according to capital structure theories, are presented in Table 1.

Earnings management can be detected by Discretionary Accruals (DA), part of Total Accruals (TA) influenced by corporate managers. We chose a model created by Dechow et al. [75], usually called modified Jones model, which belongs to the most widely used earnings management models. To estimate Discretionary accruals, it is necessary to run a regression with dependent variable - Total accruals. The total accrual is estimated using the formula listed in Hoglund [80]. This model can be applied to both cross-sectional data and time series.

Table 1
Formulae and predicted correlation of independent variables

Variable	Label	Formula	Predicted correlation	
			Trade-off theory	**Pecking order theory**
Tangibility	TANG	Tangible Fixed Assets / Total Assets	positive	negative
Liquidity	LIQ	Current Assets/Current Liabilities	positive	negative
Profitability	PROF	EBITDA/Total Assets	positive	negative
Size	SIZE	ln (Turnover)	positive	negative
Growth	GROWTH	(Total Assets$_t$ - Total Assets$_{t-1}$) / Total Assets$_{t-1}$	negative	positive
Tax shield	TAX	Taxation/EBT	positive	unknown
Business risk	RISK	(EBITDA$_t$ - EBITDA$_{t-1}$)/EBITDA$_{t-1}$	negative	negative
Earnings management	EM	Discretionary accruals quantified by the modified Jones model	unknown	positive

The modified Jones model estimate Non-discretionary accruals (NDA), residuals are Discretionary accruals. In summary, DA estimate is given in Equations (1)-(3).

$$\mathrm{TA} = \Delta\mathrm{CA} - \Delta\mathrm{CL} - \Delta\mathrm{Cash} + \Delta\mathrm{STD} - \mathrm{Dep} \tag{1}$$

$$\frac{\mathrm{TA_{it}}}{\mathrm{A_{it-1}}} = \alpha_0 \frac{1}{\mathrm{A_{it-1}}} + \alpha_1 \frac{\Delta\mathrm{REV_{it}} - \Delta\mathrm{REC_{it}}}{\mathrm{A_{it-1}}} + \alpha_2 \frac{\mathrm{PPE_{it}}}{\mathrm{A_{it-1}}} + \varepsilon_{\mathrm{it}} \tag{2}$$

$$\mathrm{TA} = \mathrm{NDA} + \mathrm{DA} \tag{3}$$

Where ΔCA - change in Current assets, ΔCL - change in Current liabilities, $\Delta Cash$ is change in Cash, ΔSTD - change in Short-term debt, Dep - Depreciation, TA_{it} - Total accruals in year *t*, $A_{\mathrm{it-1}}$ - Assets in year *t-1*, ΔREV_{it} - change in Revenues, ΔREC_{it} is change in Receivables; PPE_{it} - Property, Plant and Equipment in year *t*.

Due to data that is cross-sectional and time-series, the longitudinal data model is appropriated to estimate the influence of these factors on leverage. There are two basic types of panel data models; random effect model and fixed effect model. Using the notation given in Greene [81], the fixed effect panel model is given, as follows:

$$y_{it} = z_i^{'}\alpha + x_{it}^{'}\beta + \varepsilon_{it} \tag{4}$$

Where: $i = 1, \ldots, n$ and $t = 1, \ldots, T$

In addition to the x_{it} variables, the fixed effect model contains dummy variables z_i expressing the subject to a dependent variable. For this reason, the *LSDV* model was used to model fixed effects. On the other hand, the random effect model,

which is estimated by *FGLS* model, assumes that the selected subjects represent the entire population and the results of the model can be generalized to the whole population. One of the key and necessary assumptions is zero correlation between intercept (unobserved effects) and independent variables. To determine which model is appropriate, *Hausman test* is applied. The null hypothesis suggests that independent variables are uncorrelated with random effects (a random effect model is preferred). The fixed effect model is preferred as said by alternative hypothesis.

SAS Enterprise Guide (Regression Analysis of Panel Data task) was used to provide a panel data model. We have examined the overall significance by F-test, as the significance of the regression coefficients by t-test was examined. Variables were non-significant if their p-value was greater than 0.05 (significance level). As mentioned above, very low collinearity is in panel data models; yet we have verified collinearity by correlation matrix and the auxiliary regression method proposed by Gujarati and Porter [82].

Amadeus database supplied data for the paper. Sampling criteria were adapted to the goal of this study, the company registered office in the one of V4 countries, the value of pre-tax profit of more than 100000 EUR and assets of more than 2000000 EUR in 2014-2017. We assume that in such enterprises tax shield is obtained and managers use earnings management techniques. These criteria were met by 19910 companies of V4. Data covers 2014-2017. The sample were checked for extreme values by Mahalanobis distance as the outliers may distort the results.

4 Results and Discussion

The analyze of a sample of business was the first step in creating a capital structure model. The Amadeus database provides information on more than fifty data from financial statements and more than thirty financial indicators and ratios. However, the sample contained many incomplete financial statements and unspecified financial ratios, so these data points had to be removed. Subsequently, 1033 outliers were removed according to the Mahalanobis distance procedure. Data cover years 2014-2017; based on the formulas in Table 1, the variables were quantified in only three years. The sample included 10627 enterprises (1608 Slovak, 4163 Czech, 2662 Polish and 2192 Hungarian enterprises) and 31881 observations. Summary statistics are listed in Table 2.

Slovak corporate total leverage is in average higher in than in other countries, but it does not exceed two thirds of the assets value, which is the limit value of the golden rule of risk compensation for riskier sectors.

Table 2
Descriptive statistics of V4 company's financial indicators

	Slovakia		**The Czech Republic**	
Variable	**Mean**	**Std Dev**	**Mean**	**Std Dev**
TLEV	0.5262	0.2543	0.3938	0.2352
TANG	0.3714	0.2866	0.3852	0.2634
LIQ	2.4568	3.2086	3.7732	4.4773
PROF	0.1703	0.1160	0.1627	0.0949
SIZE	9.2647	1.4233	9.3790	1.3597
GROWTH	0.0638	0.1727	0.0932	0.1509
TAX	0.2411	0.1234	0.2056	0.1082
RISK	0.1212	0.5452	0.1325	0.4405
EM	0.0027	0.1342	0.0019	0.1127
	Poland		**Hungary**	
Variable	**Mean**	**Std Dev**	**Mean**	**Std Dev**
TLEV	0.4711	0.2143	0.4522	0.2247
TANG	0.3920	0.2765	0.3318	0.2513
LIQ	2.0684	1.9129	2.5352	2.8283
PROF	0.1430	0.0889	0.1562	0.0970
SIZE	9.6346	1.2175	9.5803	1.2511
GROWTH	0.1062	0.1708	0.1010	0.1915
TAX	0.2176	0.1253	0.0844	0.0649
RISK	0.1337	0.4369	0.1538	0.5248
EM	0.0042	0.1062	0.0065	0.1435

All countries show a high level of liquidity, above the recommended values (1.5-2), indicating that the companies are financially sound and able to meet their obligations. It also indicates a higher percentage of the company's internal resources that can be used for financing. This assumption is also confirmed by the high average profitability.

In terms of business growth, Hungary shows more than 10% of average growth. On the other hand, this growth is highly volatile, which is demonstrated in Risk variable. Significant profit volatility was reflected in the positive value of the proxy for Earnings management. The average enterprise in this sample uses profit manipulation to increase reported profit and overestimate the enterprise. Managers try to smooth the income to create a better view of the business. The comparison between the countries shows that the increase in the risk of changes in operating profit increases earnings management indicator. The tax shield quantified by the effective tax rate describes the individual corporate tax rate. Average values in Slovakia, the Czech Republic and Poland are similar, much lower effective tax rate is reported in Hungarian companies. This indicator is derived from the statutory tax rate; in Hungary, the tax rate has been reduced to 9% since 2017. In other countries, the statutory tax rate ranges from 19 to 22%.

First of all, we checked the existence of multi-colinearity in the model. Gujarati and Porter [82] suggest 0.5 in absolute terms. We have created correlation matrices with explanatory variables for each country. All correlation coefficients are in all cases lower than 0.4 in absolute numbers, which means that there is a low degree of multi-colinearity in the sample that does not bias the model results. To confirm these findings, we also applied an auxiliary regression procedure that confirmed the previous conclusions. Subsequently, we formed econometric models of panel data, the results of the fixed effect models are reported in Table 3.

Table 3
Results of one-way fixed effect models

Parameter estimates	**Slovakia**		**The Czech Republic**	
Variable	**Estimate**	**Pr > |t|**	**Estimate**	**Pr > |t|**
TANG	0.0261	0.2677	0.0500	0.0003
LIQ	-0.0113	<0.0001	-0.0068	<0.0001
PROF	-0.3892	<0.0001	-0.2816	<0.0001
SIZE	0.0316	<0.0001	-0.0032	0.4701
GROWTH	0.0623	<0.0001	0.1012	<0.0001
TAX	-0.0100	0.3320	-0.0491	<0.0001
RISK	0.0095	<0.0001	0.0125	<0.0001
EM	-0.0662	<0.0001	-0.0623	<0.0001
F test		54.0951		62.3999
Pr > F		<0.0001		<0.0001
R-Square		0.965		0.969
Adj. R-Square		0.947		0.953
Parameter estimates	**Poland**		**Hungary**	
Variable	**Estimate**	**Pr > |t|**	**Estimate**	**Pr > |t|**
TANG	0.0072	0.6055	-0.0709	0.0029
LIQ	-0.0245	<0.0001	-0.0193	<0.0001
PROF	-0.3733	<0.0001	-0.2088	<0.0001
SIZE	0.0048	0.2649	-0.0481	<0.0001
GROWTH	0.0804	<0.0001	0.0897	<0.0001
TAX	-0.0140	0.0174	-0.0261	0.3039
RISK	0.0088	<0.0001	0.0121	<0.0001
EM	-0.0188	0.0012	-0.1082	<0.0001
F test		70.8584		29.4523
Pr > F		<0.0001		<0.0001
R-Square		0.973		0.937
Adj. R-Square		0.959		0.905

All models are significant at 0.05, with a coefficient of determination greater than 90%. These values prove that the explanatory variables correctly describe the capital structure in the V4 countries. The model specification was verified by the *Hausman* specification test, for which we quantified the one-way random model. The p-values of the *Hausman* test were lower than 0.0001, therefore the null hypothesis (random model is correct) is rejected.

According to the results in Table 3, we can conclude that Slovak, Czech and Polish companies follow both above stated theories (Pecking-Order and Trade-off) with the predominant influence of Pecking order theory. Hungarian companies provide results confirming the use of internal resources as a first choice in asset financing. The prevailing influence of the Pecking order is along the line with the qualitative survey of Hernadi and Ormos [35]. Our other findings are most consistent with the results of Hernadi and Ormos [21] and Nivorozhkin [17]. Other studies gave the same results only in some indicators (mainly Profitability, Size, Tangibility): Reznakova, et al. [19], Bauer [32], Harwell and Malinowska [20], Rajan and Zingales [13] or Titman and Wessels [28]. On the contrary, the research of Koralun - Bereznicka [34] brings completely different results. One reason for the different results is the use of aggregated data, which can distort the results as the author notes.

Tax shield indicator is positively correlated with debt, which does not satisfy any of the theories examined. The reason for this relationship between variables is given by the liabilities structure of the companies in the sample. A detailed examination of liabilities revealed that the predominant component of liabilities (debt) is trade credit, which is not interest-bearing and is short-term. This substantiates previous results of Rahman et al. [83] who investigated the mutual substitution between bank financing and trade credit. If businesses have bank overdrafts, they also use trade credit to a greater extent, confirming the complementary theory of trade credit and bank credit. This implies that the tax shield indicator is largely made up of a non-interest tax shield. Debt and non-interest tax shield are inversely related confirming DeAngelo and Masulis [84] hypothesis that both types of tax shield are mutually substituting. In terms of the non-debt tax shield, the results concurred with the most of the existing studies [28] [32]. For this reason, we can agree with the results of the Delacoure [31] study. The importance of the interest tax shield in the V4 countries is low and businesses use mainly their own created resources or trade credit to finance the company because it is conspired as free source of financing.

Business risk is significantly direct correlated with the debt-to-assets. This result significantly differs from most of the previous findings about risk and capital structure. As the volatility of profit increases, so does the cost of debt, which should be reflected in lower future debt [58]. The positive relationship between debt and risk is due to the high percentage of short-term debt in corporations. There is a limited availability of the long-term debt in V4 economies because the banks are the predominant providers of long-term debt, which have high

requirements on borrowers and capital adequacy [85]. As reported by Hudakova et al. [87], financial together with economic risk do not depend on the business size in Slovakia, although financial risk is a key risk factor for SMEs. Enterprises with volatile profits offset the need for capital by short-term debt. A negative correlation between corporate risk and debt was observed, for example, by Nivorozhkin [17].

Earnings management estimated by the discretionary accruals is negatively correlated with the company's debt. This result confirms the debt monitoring hypothesis. Agent costs can be reduced by debt monitoring, as confirmed by Fung and Goodwin [88] who analyzed the relationship between earnings management and short-term debt. Similar results were obtained by Naz et al. [24] or Tahir et al. [89]. Conversely, An et al. [22] or Nikoomaran et al. [23] found a positive relationship between them. With reference to the direct correlation between debt and risk, we can note that the volatility of profit increases the risk of financial distress likewise the cost of capital. Businesses acquire each additional unit of capital under stricter creditors' conditions. Such a situation reduces the possibility of applying earnings management because the financial statements are more analyzed and audited.

Conclusions

Choosing the correct balance of debt and equity is one of the key choices, for any business. This decision can substantially affect a company's future financial performance, as well as, the benefits for all of the stakeholders (creditors, equity holders and business managers). Through earnings management techniques, an enterprise can improve its financial standing, which should enable it to raise more debt, raise its tax shield and increase share values.

This paper investigated the impact of the tax shield and earnings management on the corporate capital structure of V4 economies. A panel data regression model was created using financial information on 19910 businesses from 2014-2017 regardless, of their listing status. Eight (8), firm-specific factors were used; 7 traditional indicators (tangibility, liquidity, profitability, size, growth, business risk and tax shield) and earnings management indicator. The results of the model suggest that CEE firms primarily use internal resources to finance capital, which is mainly indicated by the negative correlations between leverage and profitability and leverage and liquidity. The preference of short-term debt and trade credit can be viewed as a relevant capital structure factor. The interest tax shield does not create sufficient debt preference since managers make greater use of non-debt tax benefits. Earnings management is negatively correlated with debt, which is supported by the debt monitoring hypothesis.

Finally, it can be emphasized, that the model results contributed to addressing the shortcomings in the field of capital structure, as well as, earnings management. The findings of the model can be taken into account when developing the model for detecting earnings management. However, the limitations of this study are

given by the variables used; another earnings management detection model may be used, earnings management in the view of capital structure at different stages of the life-cycle may be investigated, or a SME model may be developed in which profit manipulation techniques should be applied. The findings and limitations of the study suggest further directions and possibilities for future research, such as testing the modified pecking order theory [31] in CEE, investigating the impact of trade credit on capital structure risk, focus on more detailed research of the impact of earnings management on capital structure in risk sectors such as tourism and/or at different stages of the life-cycle.

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Sensory Integration in Deep Neural Networks

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Abstract: Two unimodal deep networks and one multimodal deep network are created to test for possible mechanisms of sensory integration that may shed more light on how sensory integration is carried out in biological organisms. One unimodal network is provided with pictures and the other with mel-spectrograms created from sounds. Adapted pre-trained VGG16 network was used for unimodal networks. After training consisting of 30 epochs and repeated for 100 runs the unimodal networks achieved an average accuracy of 0.57 and 0.73 respectively. The multimodal network received processed features from both unimodal networks and after training consisting of 30 epochs and repeated for 100 runs outperformed both unimodal networks with the average accuracy of 0.79. Next, noise was applied to the test data to see how unimodal and multimodal networks compare in noisy environments. Unimodal networks achieved an average accuracy of 0.63 and 0.69 respectively. Again, the multimodal network outperformed both unimodal networks with an average accuracy of 0.73. Pre-trained networks were used and limited training data were provided to the networks to simulate conditions similar to animal brains.

Keywords: sensory integration; deep learning; neural network

1 Introduction

Biological organisms evolved to make use of different modalities – types of stimuli that they react to – such as visual, audio, chemical and others. Sensory integration in living organisms is an important tool that enables animals to better differentiate between objects and get information in noisy environments [1]. Though many studies have been done on neurophysiology of multimodal integration, mostly in invertebrates such as Drosophila [2] or wolf spider [3], we still do not know precisely how such integration is done on a neuronal level, not even in simple organisms like C. Elegans [4]. Computational modelling may provide insights into these processes as it allows for experiments that are not possible with living brains either because they are not feasible or ethically viable [5].

Deep neural networks thank, in part, their popularity because they are able to identify patterns in a way similar to how human brains do. They are successful in recognising pictures, sounds, and other data [6]. However, most applications are in the domain of one modality (visual, audio, or other). When two or more unimodal networks are to be combined into a multimodal network to improve classification results there are more approaches that can be used. Probably the simplest approach is to do a weighted average of network results [7]. Most deep neural networks used for classification have a top softmax layer that represents probabilities that the object provided to the network belongs to a certain class. Probabilities from unimodal networks are then weighted and averaged to provide final probabilities. While this approach can improve classification it does not use all the advantages that multimodal integration has over unimodal classification. The power of multimodal integration using deep neural networks lies in the fact that data that were not used in one modality can be useful when combined over more modalities. Features that have not been used in simple classification tasks can be utilised in connection with features from other networks [7]. A more effective approach seems to lay in building a multimodal deep network that takes as its inputs features produced by unimodal networks [7]. This network is then trained on the multimodal data and should classify the objects more precisely. Typically a dense layer is used for integrating the inputs [8], although other approaches are tested such as using lateral connections and self-organisation [9], fully convolutional neural networks [10], or sequential late fusion [11].

In this study, we aim to explore how two unimodal networks can be fused into a multimodal network using deep neural networks and compare the performance of unimodal and multimodal networks. We would like to bring new evidence to how these networks perform in comparison with one another and how do they respond to noisy stimuli. In this study, in contrast with other studies mentioned above, we use pre-trained deep neural networks. Such a setup has two similarities to the neural systems of living organisms. First, living organisms have pre-wired neural systems that evolved during their phylogenesis. Second, pre-wired (or pre-trained) networks are able to learn even from a few examples as in natural settings it would be very disadvantageous to be able to learn only from thousands of examples.

2 Methodology

2.1 Architecture

Keras toolbox (keras.io) running under TensorFlow (tensorflow.org) in Python environment has been used for simulation experiments.

As was mentioned in the introduction, the aim is to inspect how a multimodal network working with two sets of features from unimodal networks perform in

comparison to unimodal networks. The model consists of two unimodal deep neural networks and one multimodal deep neural network. The first unimodal network is designed for the classification of visual data and the second unimodal network is designed for the classification of audio data converted to mel-spectrograms. To allow for faster training and lower the need for large samples we use Imagenet network [12] embedded into Keras environment as VGG16 for both unimodal networks. The embedding allows us to use the network directly and modify it easily for our purposes. The top classification layer was removed and substituted with a set of dense, dropout and dense layer with softmax activation to allow it to adapt to our data. The layers were frozen for training except for the top three layers to allow transfer learning on our dataset. As inputs we use 150*150*3 RGB images and each network outputs a vector of length 8192 that represents high-level features of the input image.

We concatenate the output vectors into a 16384 vector to represent both modalities and feed this vector into a multimodal network. The architecture of the multimodal network consists of an input layer, a dense layer with 1024 fully connected neurons, a drop-out layer, and a softmax classification layer. A block diagram is shown in Figure 1.

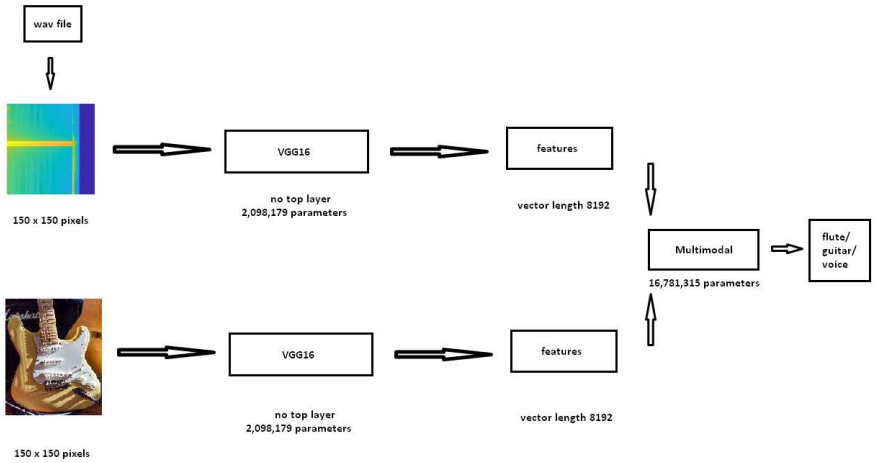

Figure 1
Block diagram of used architecture

2.2 Data

We use two modalities of data and three categories that are the same in each modality. We use data from two public databases. For visual data we use photographs from UnSplash (unsplash.com) and for audio data, we use audio samples from NSynth [13] that are converted into mel-spectrograms. We use three categories – voice – with a sound sample of singing and a photograph of a singing

person/s; guitar – with a sound sample of a guitar sound and a photograph of a guitar and flute – with a sound sample of a flute and a photograph of flute/s. The distribution of data is shown in Table 1.

Table 1
Distribution of data

	Flute	Flute	Guitar	Guitar	Voice	Voice
	Sound	Picture	Sound	Picture	Sound	Picture
training	6	6	14	14	11	11
test	6	6	14	14	11	11
validation	3	3	3	3	3	3

Sample picture and sample mel-spectrogram are found in Figure 2a and 2b. 31 samples of every modality are used for training and 31 samples for testing. For an experiment with noisy data, we use the same samples with added Gaussian noise (zero-mean white noise with variance 0.01). For an example of a noisy picture and noisy mel-spectrogram, see Figure 2c and 2d.

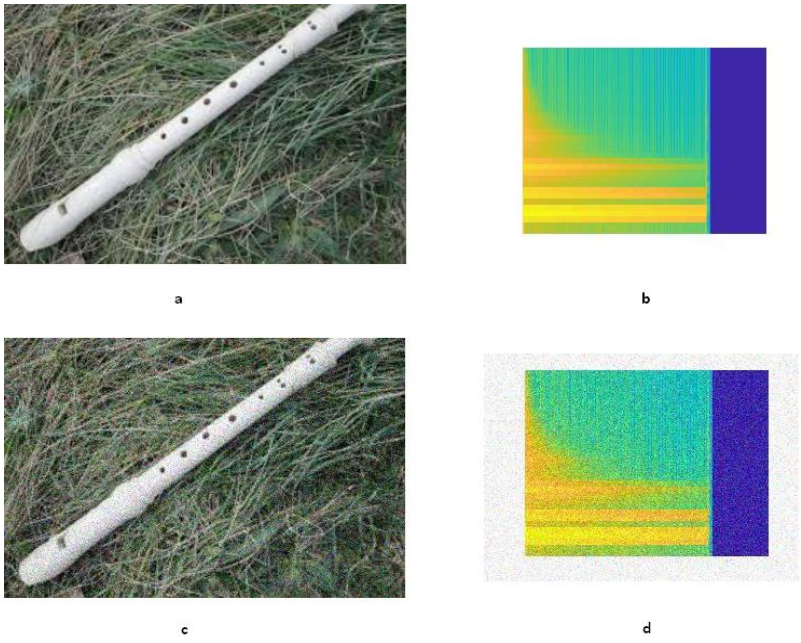

Figure 2
Sample data. a) picture, b) mel-spectrogram, c) noisy picture, d) noisy mel-spectrogram

2.3 Training

Unimodal and multimodal networks are trained using RMSprop optimizer, for loss we use sparse categorical crossentropy, the number of epochs is 30. Figure 3 shows the development of averaged training accuracy (acc; https://github.com/keras-team/keras/blob/68dc181a5e34d1f20edabe531176b3bfb50001f9/keras/engine/training.py#L375) and training loss (sparse categorical crossentropy; keras.io/api/losses/) across 100 runs.

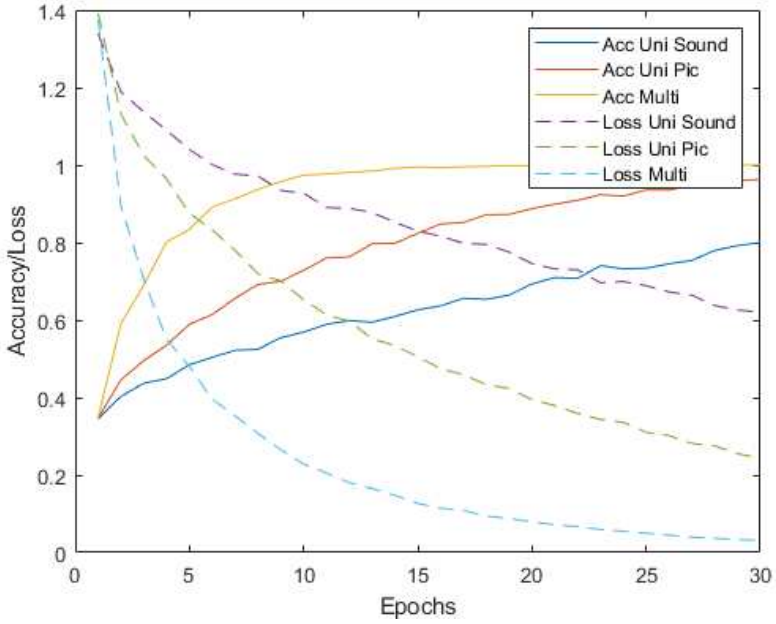

Figure 3
Average training accuracy and training loss

Training graph shows that multimodal network achieves better accuracy and lower loss over time and outperforms both unimodal networks.

3 Results

First, we tested both unimodal and multimodal networks to see whether multimodal network outperforms the unimodal networks. As deep neural networks use stochastic processes we repeated training and measured accuracy for 100 runs. We found the average accuracy for the first unimodal network (audio) to be 0.57, for the second unimodal network (visual) 0.73, and for the multimodal network

0.79. Graph of individual runs is shown in Figure 5. Multimodal network performed better than any single unimodal network.

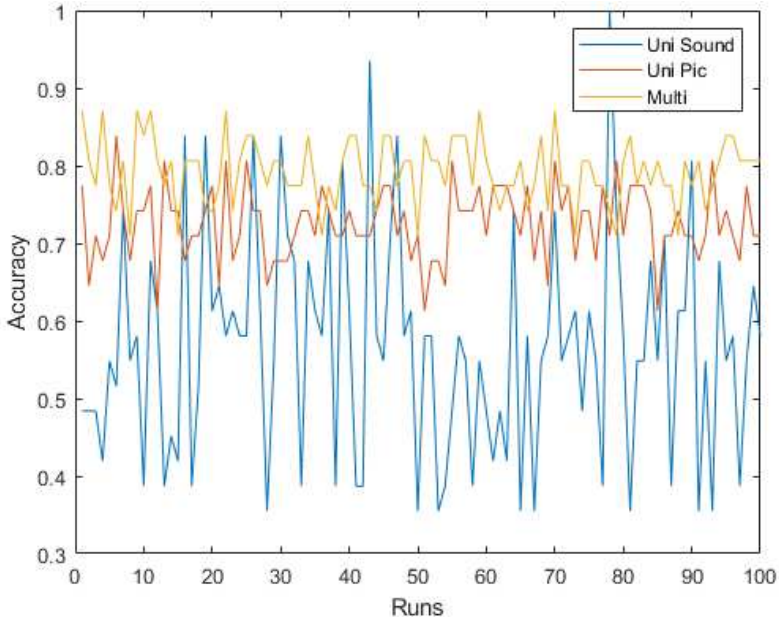

Figure 4

Accuracy of unimodal and multimodal networks over 100 runs. First unimodal network - blue, second unimodal network - red, multimodal network - orange

Next, we were curious about how the network behaved under noisy inputs. As we mentioned in the Introduction, multimodal networks should enhance recognition when inputs are noisy.

We used the same networks, parameters, and training data as in the previous experiment. Before testing the networks we added Gaussian noise to the inputs. We used zero-mean white noise with a variance 0.01. Again, we repeated training and testing for 100 runs and measured the accuracy of the networks. We found the average accuracy for the first unimodal network (audio) to be 0.63, for the second unimodal network (visual) 0.69, and for the multimodal network 0.73. Graph of individual runs is shown in Figure 5. Again, the multimodal network outperformed both unimodal networks although its performance was not as good as on the data without noise. The accuracy for the second unimodal network (visual) also decreased. Unexpected was a slightly better performance of the first unimodal network (audio) for noisy inputs. This may be due to stochastic fluctuation or to some, yet unknown, aspect of the interaction of deep neural networks with spectrogram data.

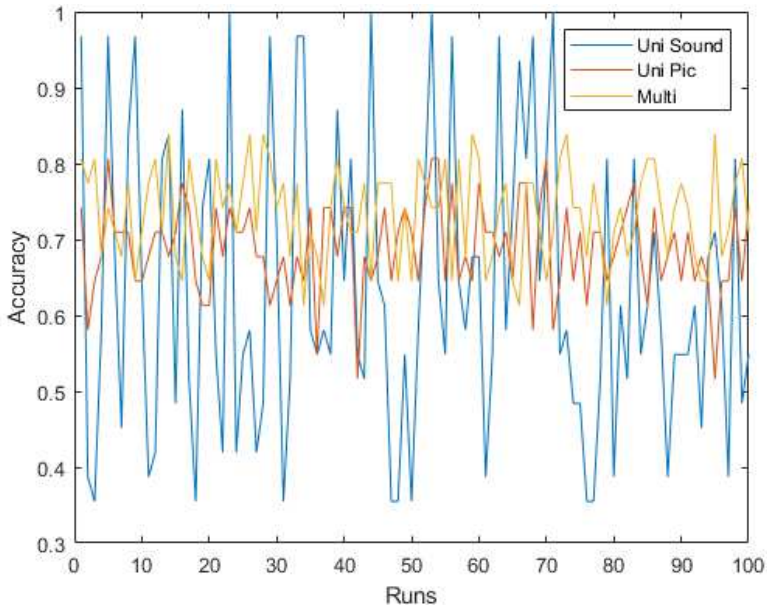

Figure 5
Accuracy of unimodal and multimodal networks with noisy test data over 100 runs. First unimodal network - blue, second unimodal network - red, multimodal network - orange

We created the confusion matrices for both unimodal and multimodal networks and for both not-noisy and noisy test data. In the tables, we summed the classification results for 100 runs. The results are shown in Table 2.

Table 2
Confusion matrices

Unimodal network - sound; not-noisy			
Input/Prediction	Flute	Guitar	Voice
Flute	32	16	12
Guitar	0	19	121
Voice	0	0	110
Unimodal network - picture; not-noisy			
Input/Prediction	Flute	Guitar	Voice
Flute	26	32	2
Guitar	4	102	34
Voice	0	13	97
Multimodal network; not-noisy			
Input/Prediction	Flute	Guitar	Voice
Flute	47	13	0
Guitar	7	93	40
Voice	0	0	110

Unimodal network - sound; noisy			
Input/Prediction	Flute	Guitar	Voice
Flute	42	8	10
Guitar	0	62	78
Voice	0	2	108
Unimodal network - picture; noisy			
Input/Prediction	Flute	Guitar	Voice
Flute	26	30	4
Guitar	2	91	47
Voice	0	14	96
Multimodal network; noisy			
Input/Prediction	Flute	Guitar	Voice
Flute	46	14	0
Guitar	2	72	66
Voice	0	1	109

Confusion matrices confirm our previous results. A multimodal network shows better classification results than any of unimodal networks using both not noisy and noisy test data. Upon closer inspection, we see that the worse performance of the unimodal network for sounds was primarily caused by misclassification of class Guitar in a not-noisy situation. We may only speculate that the classification of mel-spectrograms is a more complex task and adding the noise somehow tipped the algorithm towards better performance. This issue remains open for further research. On the other hand, this result underscores the fact that the advantage of multimodal networks is the fact that even if some of the unimodal networks do not work perfectly, their drawbacks are compensated using data from other unimodal networks when integrated into a multimodal network.

Conclusions

Sensory integration is an advantage for living organisms as it enables them to better classify objects and extract data from noisy environments. Deep neural networks are in many respects similar to biological ones and thus can help us to obtain insights using experiments that would otherwise be not feasible. In this study, we wanted to test whether a multimodal network integrating inputs from two unimodal networks representing two modalities can outperform these networks. Besides, we wanted to test whether such performance is possible using only a limited number of stimuli as is the norm in living systems. We also feel that it is important that our study has been done using open-platform software and data and we described the details of architecture and training parameters so that this study can be used for inspiration and subsequent research for other scientists.

Our results show, that the multimodal network outperformed both unimodal networks. Furthermore, it outperformed them also when tested on noisy data.

Our simulations show that the superior performance of the multimodal network does not have to hold for every single run. One may argue that this would make the multimodal network unusable in natural settings. We, however, think that it may well be possible that biological networks may also work this way – the robustness of the network does not lay in how it performs every single run, but the research indicates that brains operate in a statistical fashion [14]. When an animal sees an image or hears a sound, the activity of visual/audio neurons does not stop immediately, but reverberates and thus enables the animal to make use of the statistical properties of neural signal [15].

We feel that such interconnections between neuroscience and computational modeling may be fruitful for both research fields and may bring further insights into how animal (and human) brains work.

Acknowledgement

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