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EDITORIAL

The content of this issue of JITA consists of eight papers.

The first paper, entitled "Computer control systems with critical safety applications: problems and some solutions" by H.Hristov and M. Hristov, presents SCS (Safety Critical Systems) as an important class in the area of real-time control systems. Their essential distinction from the other classes within this area is the mandatory requirement not only to provide the necessary functions as intended, but also to ensure that the system is safe to operate and safe in the event of failures.

The next paper is "Encryption based on Ballot, Stack permutations and Balanced Parentheses using Catalan-keys" by M. Saračević, E Korićanin and E. Biševac. This paper examines the possibilities of applying Catalan numbers in cryptography. It also offers the application of appropriate combinatorial problems (Ballot Problem, Stack permutations and Balanced Parentheses) in encryption and decryption of files and plaintext. The paper analyzes the properties of Catalan numbers and their relation to these combined problems.

The third article entitled "The Use Of Energy Storage Devices Of Uncontrolled Type On The Moscow Metro (Theory And Practice)" by Shevlyugin Maxim Valerievich, A.N. Stadnikov, and A.E. Golitsyn describes the problem of increasing energy saving and energy efficiency in the system of traction power supply of the Moscow Metro is considered due to the use of energy storage devices of uncontrolled type. The results of simulation modeling of the operation of an energy storage device of uncontrolled type in the system of traction power supply of the subway are presented. A particular line was studied, on which experiments on the introduction of energy storage devices based on electrochemical supercapacitors were conducted.

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In the forth article "Road traffic accidents analysis using data mining techniques" by G. Janani and N. Ramya, traffic accident data of Coimbatore is collected and cleaned in order to use it to test the predictive model. The endeavor of this paper is to spot the factors behind an accident and severity of accidents. The assessment of the Classification model showed that Naive Bayes algorithm outperforms with an accuracy of 92.45 % when compared with other algorithms.

The next paper is "The application of online platforms in open innovation", R. Milutinović, B. Stošić and V. Štavljanin, presents novel approach to the innovation process in companies is presented. The open innovation model was built on the premise of expanding the network of companies and collecting new knowledge needed to create new products, services. The main driver of openness and involvement of users in the process of new product development is the development of technology, primarily internet and new web 2.0 tools.

The sixth article is "Implementation of Fog computing in IoT-based healthcare system" by M. Maksimović gives general survey of IoT health care system. Despite numerous benefits Fog computing brings in IoT-based environments, the privacy and security issues remain the main challenge for its implementation. The reasons for integrating the IoT-based healthcare system and Fog computing, benefits and challenges, as well as the proposition of simple low-cost system are presented in this paper.

The seventh article "Influence of information technologies on the company's competitive advantage on the market in conditions of the global crisis" by N. Djurić and M. Paunović analyzes the existing effects of IT at the level of competitive advantage of companies on the market in the global crisis conditions. The research was carried out on the territory of Republika Srpska, on the sample of 136 small and medium enterprises.

The last article in this issue "Web based decision support system to determine the appropriate packaging of ethnic and traditional Indonesian foods" by Latifah Nurbaiti, Kudang Boro Seminar and Nugraha Edhi Suyatma, focuses on identifying snacks, types of packaging and active packaging parameters to build a decision support system in order to determine appropriate packaging. Types of packaging are determined using fuzzy Sugeno 4 parameters: fat, water activity, shelf-life and price. Active packaging of the snacks is done using the if-else rule with parameterized types of packaging, preservatives, oxygen barriers and water vapour barriers. The end result of this research is a web based decision support system, which recommends types of packaging and active packaging for snacks.

On behalf of the Editorial Board we would like to thank the authors for their high quality contributions, and also the reviewers for the effort and time invested into the preparation of this issue of Journal of Information Technology and Applications (Banja Luka).

Editors, Gordana Radic, Editor-in-Chief, Zoran Avramović, Dušan Starcevic

Computer Control Systems With Critical Safety Applications: Problems And Some Solutions

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Abstract: Safety Critical Systems (SCS) are defined as systems controlling critical technological processes, on the proper functioning of which depends human safety. The taxonomy of concepts related to SCS is presented as a dendritic classification scheme. The emphasis is on hierarchical relationships between concepts. After studying global scientific literature, international standards and corporate materials, a classification of the scientific issues accompanying the creation of new SCSs was made.

Regarding a part of the broached issues, technical solutions are suggested based on the structural system of the system. In particular, methods and means have been developed to detect and tolerate failures and errors in building the structure and to reduce their adverse impact on the functionality and safety of the systems.

Formal models have been developed, concerning which calculations and studies have been performed. Quantitative dependencies are established between the technical and probability parameters of diversity structure on the one hand and the reliability and safety of the system on the other. Conclusions are drawn as regards the practical application of the methods and models.

Keywords: Safety Critical Systems, risk, security, safety, reliability.

Introduction. Problem Setting

Breaches of regulated functionality (normal operation) due to failures and intrusions in systems controlling Special Critical Technology Processes (*SCTP*) may cause imminence, danger to the health and/ or loss of human life, of large material and/or spiritual values and/or damage to the environment. In various spheres such as aviation, space, defense, rail transport, nuclear power, medical electronics, machine building, etc. there are numerous examples of such technological processes.

Safety Critical Systems (SCS) is a system that controls special critical technology process - SCTP. Human safety within this technological process depends on the designated functioning of the system. In addition to their functional tasks, SCSs are associated with a risk of breach of regulated functionality and are highly critical for the health and life of people, which is why they are rightfully called systems with high moral standards. [1].

Risk, as a concept, combines the assumption of an undesirable event with the magnitude of the foreseeable adverse consequences it entails (threat to life, property damage, loss of natural assets, etc.) and is defined as a probabilistic observation. There are *allowable values* from zero (zero risk) to *limit values - border, accepted risk* (Fig.1). According to the MIL-STD-882D standard, feasibility is determined by the upper limit of the acceptable risk level [2].

The borderline risk in SCS is determined depending on the purpose and application of the system. For the various aforementioned areas, there are

specific standards that define the limit values. In some of them limit values are assigned by groups depending on the size of the supposed losses. For instance, the RAMS [3] standard for tolerable risk in railway safety systems is determined in 4-degrees with probabilities 1.10^{-9}, 1.10^{-8}, 1.10^{-7} and 1.10^{-6}, as for the smaller predictable adverse consequences a higher limit value is set.

Safety is a system property that is measured by its probability of allowing a risk occurrence (both in normal operation and in faults), lesser than the borderline risk.
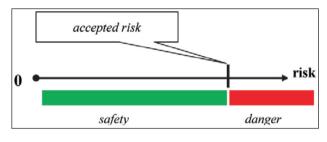

Figure 1. *Safety and accepted risk*

Nowadays, all SCSs are *computer-based*. Hardware, software, and communications are subject to increased requirements for the reliability and inadmissibility of wrong controlling actions. The system must be so designed that, any hazards, if occurring, can be detected and removed before causing an accident. SCS's failures, often due to software errors, lead to airspace crashes, failed space missions, land transport accidents, inadequate control and accidents in nuclear power plants, military incidents, improper dosage of radiation therapy for patients, significant economic losses, etc.

This publication aims to structure, *within the provided volume, the taxonomy of concepts, to define the main issues in the scientific research of Safety Critical Systems and to propose some solutions.*

TAXONOMY

Taxonomy in general

This is a study of the principles of classification and systematics of complexly organized areas with a hierarchical structure, a "hierarchically structured set of terms that is used for classification and navigation"[6]. It consists of rules, methods and their application. The methodology includes the study of text corpora to identify and annotate the most common concepts, and to define hierarchical relations between classes. The elements and groups of objects and subsystems selected for studying are called taxa. The classification is illustrated graphically with two schemes: dendritic, known in logic as classification, or as circles inserted in each other, representing taxa.

Taxonomy of SCS

Figure 2 shows the taxonomy of concepts suggested by the authors in relation to SCS. A structural classification scheme has been used. At baseline level the terms are: *errors, faults* and *objective external influences.* Three critical features of the systems are accepted as taxa, namely: *safety, security and reliability.*

Error is a deviation from an accepted and validated fidelity (regularity) criterion. It may occur both in the terms of reference (specification) of the system, and in its design, elaboration and programming.

Fault is a condition in which the object under consideration does not comply with the regulatory and technical documentation (terms of reference). It occurs in the course of the work (time or volume of work) and under the influence of external (meteorological, physical, chemical, electrical) and other objective impacts. The object ages, wears out, deteriorates, becomes a subject of impacts and this results in a breach causing at least one parameter to be inconsistent with the system's regulatory and technical documentation.

Security is the ability of the system to defend itself against, resist, counteract to any external destabilizing factors and impacts, as well as internal changes that may lead to danger.

In Figure 2, the hierarchical relationships between the concepts can be traced. Here are some of them.

Errors in the system elaboration and maintenance are subjective: accidental and unintended and non-accidental (ill-) intentioned.
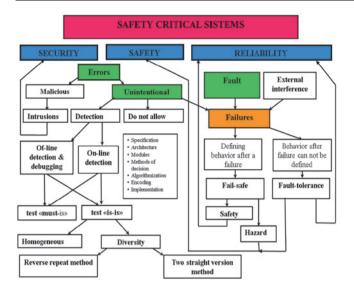
Figure 2. *Taxonomy of concepts in Safety Critical Systems*

Accidental errors (due to lack of qualification and experience of the persons developing and maintaining the system, incompetence, inattention, distraction, negligence, etc.) affect reliability and safety.

Intrusions by outsiders - errors with malicious intent - are unauthorized intrusions into the system in order to block its operation, retrieve and/or change the information in it. Intrusions are concepts of information and network *security* and are related to highly evolving methods and means of detecting external intervention and protecting SCS from malicious impacts.

To prevent accidental unintentional errors, a *perfection strategy* is implemented: a risk-based specification and a set of approaches, specific methods and tools for hardware and software development and structuring of the system.

The detection and correction of faults and errors (in design and technology, algorithmization and programming) is carried out *off-* and/or *on-line*. Off-line testing involves some approaches, methods and tools, most of which are related to the pre-launch phase. And yet, regardless of their efficiency, in a complex system there are many workspaces that may remain untested. It enters into operation with residual errors. Testing in the course of operation (on-line) serves to detect residual errors and/or any emerging faults as well as to provide timely response after identifying these (see below).

Various methods (on/off-line) are used to detect faults and errors, but diversity is the most efficient among them.

Diversity [5, 6, 7] is a method of solving a problem (mathematical, logical, technical, programming, etc.) in two (A and B) different ways (methods, programmes, channels) with one and the same input data. When the two compared solutions are relevant (including identical), there are no breaches of normal operation.

If the two channels are independent, their irregularities are detected because in the case of a breach their outputs differ. Normal operation is deliberately stopped for the purpose of removing the causes or switching to a reserve.

- When the two programs are identical (two copies of one program), their errors are the same, the channels work in the same manner, albeit incorrectly, their outputs are corresponding and the errors are undetectable.
- When the two hardware channels are homogeneous (identical in terms of hardware and software), only the hardware irregularities are identified because they are independent.
- When working on different programs in completely independent (A and B) channels, both errors and faults are detected. This is the genuine diversity method.

The most frequently applied are the two versions that deal with one and the same problem by following different methods, algorithms, and programs developed by different teams in order to be independent.

Accidental unintentional errors, along with hardware malfunctions and external, cause *failures*. Failures are events that lead to a violation of system performance. System responses to failures should be of two types: stopping until the irregularities are removed or switching to a reserve, if any.

When the nature of the SCTP technological process allows, after a failure, the SCS control system may switch to a predefined safe state or a desired fail-safe behaviour. Then, the failures are *safe* and *dangerous (hazard).* If the behaviour of the system contradicts the defined criterion, the failure is hazardous, and if it complies with it – it is safe. Such are the cases in railway signalling, locks, security technological equipment and many others.

When on the other hand SCTP is of such nature that a safe state or behaviour can not be defined (in air transport, life support systems, medicine, etc.),

any failure of the control system thereof is danger-ous. For this class of systems, the only approach to achieving safety is fault tolerance. Regardless of its nature, the failure is masked, evasive, tolerated. But the degree of fault tolerance and hence dependabili-ty, depend on the presence of redundancy - structur-al, functional, temporal, etc. When the redundancy due to the failures is exhausted, the system begins to fail and the nature of the failure starts re-emerging. The redundancy exhaustion depends on its depth, and it has functional and economic dimensions.

Scientific Issues Regarding SCS

Based on researching global scientific literature, specialized publications, reports of international scientific forums, international standards, corporate materials, etc., an attempt has been made to classify the scientific issues regarding SCS. It is constantly up to date and can be derived from the following hy-pothesis:

A *risk-based specification,* relevant to the ac-tual SCS application conditions, needs to be estab-lished. For this purpose, the potential dangers that may arise from operation/failures of SCS should be studied and examined. Next, a comparative analysis of the principles and structures on which SCS can be based should be performed in order to select a research-based method of developing the designed system.

Optimal technical solutions for individual struc-tural units should be found. A suitable programming language for SCS programming should be selected [5].

No errors should be made at any stage and at any level of SCS development. For this purpose, a class of scientifically sound methods and tools is used. And yet, despite their implementation, errors in complex systems certainly do exist. They must be detected and removed before the commissioning of the sys-tem. To that end, another class of scientific methods and tools is applied.

However, some errors still remain undetected and may cause dangerous accidents or may result in limiting functionality. The dangerous impact of the former, and the adverse impact of the latter may be limited if errors are detected in the course of op-eration (on-line). Then, their consequences are sus-pended, and the errors are removed or tolerated, so as to avoid their re-emergence. For this purpose, a third class of methods and mechanisms is applied.

Based on this hypothesis, the classification giv-en below is elaborated. Scientific issues of SCS are placed in two areas:

In terms of functionality. The functions and structure of the systems with various intended use are described and formalized in their specifications and other accompanying documents, which must comply with the relevant standards. Scientists, re-searchers, designers and programmers in the rel-evant sphere (transport, aviation, energy, medicine, etc.) elaborate specialized SCSs harmonized with these standards. If the authors did not comply with the principles and rules, if not all safety conditions were taken into account, if the correct failure re-sponses were not found, the system may be danger-ous also in the course of its normal operation as it has been set. That is, functionality is safety related.

In terms of reliability and safety. It means that we assume that the hypothesis that the specifica-tion (terms of reference) as per which the system operates is perfect. If the system functions, it is safe. Functionality is not safety related. Dangers are cre-ated when the system becomes incapacitated, ie. af-ter failures only. Problems in this area are related to fail-safe and fault-tolerance principles for structur-ing and developing SCS, methods to achieve flawless software, methods ensuring the reduction of haz-ardous operation can be reduced, etc.

Based on the studies and conclusions made so far, a structure and summaries of SCS's scientific is-sues can be made:

1. Creating a *risk-based specification* that is com-plied with the potential dangers under actual application conditions

2. *Principles for developing and structuring* SCSs relevant to the field of application and safety standards;

3. Selection of *SCS programming language and development software* that not only provides the necessary functions but also ensures that the system is safe to operate and safe in the event of failures

4. Methods and tools for *detecting faults and er-rors* in SCS.

5. Methods and algorithms to *tolerate SCS fail-*

ures and errors and to reduce their impact on the functionality and safety of the systems.

6. Quantitative *assessment of the impact of failures* on the reliability and safety of SCS and comparison with the default values.

SOME SOLUTIONS PROPOSED

Here are some proposed solutions stated under i.4, i.5 and i.6 of the SCS problem area defined as such.

Error detection through diversity in dual channel control systems

Dual channel structures 2Ú2 *are studied* [7]. The entered input vector *X* is processed in two channels 1 and 2 (Fig.3), and the output vectors *Y1* ($y_1, y_2..., y_v$) and *Y2* ($y_1, y_2..., y_v$) with identical length are compared following the principle "is – is". Their correspondence is an availability criterion, whereupon the comparator gives OK for execution of the impact *Y1* on the controlled object CO.
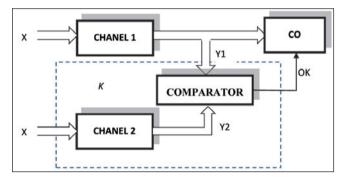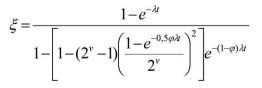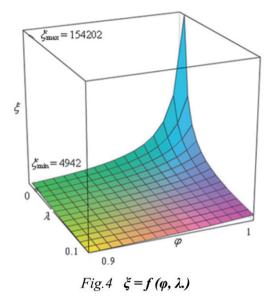

Figure 3. Dual channel diversity control system

A metric is proposed to measure the difference ɸ (0 ÷ 1) between the channels. Formulas for quantification of the effect ξ of diversity on the two channels are determined by this metric [6]. In this authored publication the effect is determined upon exponential distribution of the system until failure (λ = const.): where *t* is work (aging) and *v* is the length of the compared vectors in bits.

$$\xi = \frac{1 - e^{-\lambda t}}{1 - \left[1 - (2^v - 1)\left(\frac{1 - e^{-0.5\varphi \lambda t}}{2^v} \right)^2 \right] e^{-(1-\varphi)\lambda t}}$$

It is calculated at different ɸ values and at different values of the parameters involved in the derived formulas. Graphical results are shown in Fig. 4.

Fig. 4 $\xi = f(\varphi, \lambda.)$

It is established that:

- The maximum probability of non-identification of errors and faults, and hence the lowest safety, occurs in the absence of diversity which is equivalent to a one-channel system.
- The safety of the system is the greatest at a minimum probability of non-identification of errors and malfunctions. It is attained in the presence of full diversity when the two channels are absolutely independent. Then, the probability of safe operation is reduced to several orders of magnitude (hundreds of thousands of times) as compared to a one-channel system.
- The effect of diversity is more significant proportionally to the greater intensity of failures resulting from errors, and the fewer number of failures due to faults.
- The probability of dangerous failures is very sensitive to the intensity of failures caused by software errors. By reducing software errors, the danger is reduced by almost two orders of magnitude.

Error detection using the reverse iteration method

One of the problems of the error-detection method outlined above is that the structure still implies the existence of at least two independent, effective methods for solution (hardware and programming), which is often not the case. In addition, in order to achieve complete independence of the A and B pro-

grammes, they must be designed by different teams, which renders the decision more expensive.

These considerations stimulate the search for an approach that uses principally different methods for solution, but the distinction must be obtained by compulsion on a mandatory basis. As such, a *reverse iteration method - RIM* is proposed [8]. The application of this method spares the necessity to search for principally different algorithms. This option is embedded in the very nature of the method itself.

A prerequisite for RIM is the ability to solve "straight" and "reverse" problems (Fig.5). As per the input data X by the "straight" algorithm, problem A is solved, the output result which controls the controlled object CO. But under condition: available permit (OK) by the comparator, which compares input data X to the result of the reverse problem B. In turn, it has as input the result Y and by the algorithm that is „reverse" to A it has to calculate the input data x.

A simple example illustrates the idea. A solution to the algebraic problem $y = x^2 + 1$. The reverse problem is $x = \sqrt{y - 1}$. If we set an input value $x = 2$ for the straight task the output result will be $y = 5$. The input data $x = 2$ are memorized and submitted for execution to programme A. The solution result $y = 5$ is memorized and submitted as input data for the reverse problem B. The result obtained by the processing of B given these data should be the same as for the input data of A. If the compared vectors (2 ↔2) coincide, an OK permission is obtained. If not, then an error has occurred. "OK" is cancelled.

Certainly, in large systems solving complex problems it is not that simple.

In digital circuits such as microprocessors, code vectors $X (x1\ x2 ..., x_w)$ are entered at the input A of the circuit with a length of w bits. After processing the information flow by the programme, a vector comes out in the form of combinations of ones and zeros $Y (y_1\ y_2 ..., y_v)$ with a length of v bits (Fig.6).
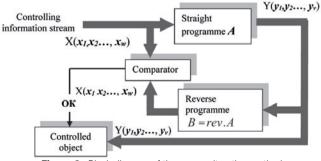

Figure 6. *Block diagram of the reverse iteration method*

$Y (y_1\ y_2 ..., y_v)$ is a control signal to the process (object), but it is given with the condition of having a match in the comparison after the solution of the reverse task. In the case of equivalence, the comparator (comparison device) gives OK. The controlled object obtains the right to accept the Y signal ($y_1\ y_2 ..., y_v$) and perform the command.

The advantages of the reverse iteration method are that the reverse programme naturally creates an algorithmic diversity by overcoming the difficulty of finding two independent effective methods for solving the problem. The safety of the *reverse iteration method* is based on the following: the error activation in programme A will trigger the wrong output vector A ,to result, which will entail incorrect end result B'. When comparing A ↔B ,the error is detected. A failure in the reverse programme, despite the correct B result, will result in an incorrect end result B. These are effective methods for solving the problem, and that means that it can be solved by a single programmer.

Error tolerance

Now the problem is the opposite. No identification is sought, but just the opposite - suppression, tolerance of errors.

As per the algorithm shown in Fig. 7, the two programmes are connected in a reliable way in parallel - it is sufficient for one of them to function in order to attain operability of the system.

In dynamic programme redundancy, only the main program B functions normally. The backup R is switched on when a failure occurs causing its activation. When B is activated by an error and an incorrect result is obtained, the backup program tolerates it. The system will not operate only if hardware faults or software errors are activated in both programs. The system's quick response under this method is greater because the backup programme is switched on only when needed.

In order to establish graphical dependencies of reliability from the depth $\boldsymbol{\varphi}$ of the diversity, formulas are derived in which the time is marked by t, and the intensity of the failures by $\boldsymbol{\lambda = const}$. The diversity depth is determined by the degree of independence of the two programs, that is, by the degree to which they generate independent failures. When $\boldsymbol{\varphi = 0}$ failures are common, and when $\boldsymbol{\varphi = 1}$ failures of each
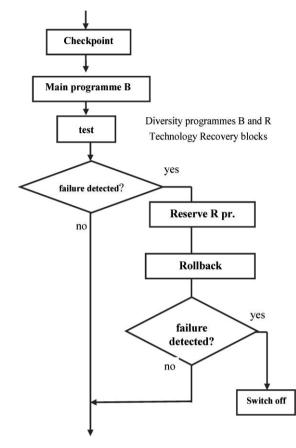
Figure 7. *Software fail safe through dynamic software redundancy*

programme are separate and independent from each other.

Let us assume that the two programmes, albeit being diversity programmes, have equal reliability, i.e., that as a result of errors each of them generates one and the same flow of failures. The following may be written about the reliability of a diversity programme:

$$P_s(t)_{\lambda=const} = e^{-(1-\varphi)\lambda t}\left[1-(1-e^{-\varphi\lambda t})^2\right]..$$

It is obvious that when diversity is maximal, upon full independence of both programmes (φ=1), the reliability of the programme system is the highest:

$$P_s(t) = 1-(1-e^{-\lambda t})^2 = 2e^{-\lambda t}-e^{-2\lambda t}$$

When the two programmes **B** and **R** are identical, i.e., there is the absence of diversity (φ = 0)

$$P_s(t) = e^{-\lambda t},$$

which should have been expected.

For **$\lambda t = 0,1$** in the same programmes a probability of failure Qs = 0,0952 may be expected, in fully independent Qs = 0,0091, i.e., reliability increases 10.5 times.

Calculations for the two-channel cases are made. Some results are graphically illustrated in Fig. 8. From the curves it can be seen that with the increase of the depth of diversity the reliability of the system Ps (λt) improves considerably. For example, with λt = 0,1 and depth φ = 1,0, the probability of failure $Qs(\lambda t) = 1-Ps(\lambda t)$ decreases as a result of diversity from 0,1 to 0,01, that is, by 10 times. Based on the models so derived and the performed research as shown above, the following important summaries can be presented:
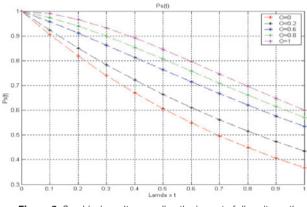

Figure 8. *Graphical results regarding the impact of diversity on the reliability of a dual programme system*

The deeper the software diversity is, the greater the reliability will be. By varying the depth of diversity from 0 to 1, the reliability changes as in a transition from a coherent to a parallel in terms of reliability system.

In order to determine the factors on which the depth of diversity depends, it is necessary to examine the particular scheme for the particular case by searching for the general and local causes of failures and their intensity.

CONCLUSION

Safety Critical Systems are an important class in the area of real-time control systems. Their essential distinction from the other classes within this area is the mandatory requirement not only to provide the necessary functions as intended, but also to ensure that the system is safe to operate and safe in the event of failures.

In order to resolve SCS-related issues, it is necessary to strictly define the concepts and dimensions involved in the study of this class. On this basis, a structure and classification of the scientific problems is provided herein, a main part of which is related to the errors in the development and maintenance of the system.

Some diversity-based solutions are proposed, through which timely detection can be attained. Formal models are derived and calculations are made allowing for the provision of recommendations for their practical application.

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Encryption based on Ballot, Stack permutations and Balanced Parentheses using Catalan-keys

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Abstract: This paper examines the possibilities of applying Catalan numbers in cryptography. It also offers the application of appropriate combinatorial problems (Ballot Problem, Stack permutations and Balanced Parentheses) in encryption and decryption of files and plaintext. The paper analyzes the properties of Catalan numbers and their relation to these combined problems. Applied copyright method is related to the decomposition of Catalan numbers in the process of efficient keys generating. Java software solution which enables key generating with the properties of the Catalan numbers is presented at the end of the paper. Java application allows encryption and decryption of plaintext based on the generated key and combinatorial problems.

Keywords: Cryptography, Catalan numbers, Ballot notation, Stack permutations, Balanced Parentheses.

Introduction

Catalan numbers have found widespread use in solving many combinatorial problems. In references [7,15] are given concrete applications of these numbers with possible solutions when it comes to representation of certain combinatorial problems. All the aforementioned combinatorial problems can be solved on the basis of values which have the Catalan numbers properties. In short, the number of combinations and the manner of Catalan numbers generating represent a solution for certain combinatorial problems. Some can be enumerated: a binary tree, the triangulation of polygons, steak permutations, paired brackets problem, Ballot problem, the problem of motion through an integer grid, etc. All the aforementioned combinatorial problems can be solved on the basis of values which have the properties of the Catalan numbers, namely the solution of these combinatorial problems lies in the application of these numbers.

Combinatorial schemes based on permutations are used in the most symmetric cryptographic methods. The important place in these procedures, particularly in keys generating, have the pseudo-random numbers. In this paper we will try to determine the important place the number theory has in cryptology, primarily in the development of algorithms for generating pseudo-random numbers that are necessary for keys generating. Number theory with asymmetric systems has the main place not only in generating keys, but also in the design of the cryptographic algorithm itself, and in the cryptographic analysis [5,8].

In this paper, our aim was to give our proposal of Catalan numbers application in keys generating, or more precisely, that these numbers can be used as generators of pseudo-random numbers. By using Catalan numbers the basic idea is realized, and this is generated from a long and unpredictable sequence of symbols from an alphabet (e.g. Binary) on

the basis of short key selected in a random manner (basis *n*).

Encryption can be realized in a combination with various combinatorial problems that are based and whose solution is hiding within these numbers. In this way, a successful system performance for encryption has been achieved. The subject of the research refers to the testing of Catalan numbers and the possibility of their use in cryptography. Beside that, the subject of this research is also the application of appropriate combinatorial problems, which are based on the properties of the Catalan numbers, for encryption and decryption of files and plaintext. The idea arose based on our previous research in the field of number theory, combinatorial problems and Catalan numbers.

Related works

On the basis of many scientific and expert papers which were published in reputable international journals, we have come to the knowledge that many combinatorial problems are used both in cryptography and as well as in the process of cryptanalysis. Among the most commonly used combinatorial problems are the problems of balanced or paired parentheses, application of stack permutations, voting problem (Ballot) etc. In paper [6] are given concrete applications of combinatorial problems in cryptography and cryptanalysis. Applied number theory has many applications in cryptography, especially the integer sequences. Previous cryptographic algorithms were designed by using the integer sequences of Fibonacci sequence and Lucas numbers.

In paper [1] were proposed cryptographic algorithms based on integer sequences of Catalan numbers, where new methods of encryption were proposed. In the proposed method of encryption, by using the Catalan numbers, a large random number "*n*" is set as a secret key of the communicating parties. Binary values in Catalan number C_n corresponding to the agreed secret key (i.e. the basis *n*) are used for encryption/decryption of the message.

In paper [16] is presented an advanced technique for encryption based on Catalan numbers. This technique combines the characteristics of substitution and transposition. In this paper, the displacement technique of each bit to the left is proposed and the displaced data is supplemented so that every gener-

ating bit of ciphertext is changed. Catalan numbers have the property of recursiveness and their generating can be efficiently implemented with the dynamical programming. Dynamical programming is a method that reduces the runtime of those problems that require finding an optimal substructure and having subproblems that are repetitive.

In paper [3], the fact that combinatorial Ballot problem or voting problem is widely used in cryptography is stated. This paper describes the theory and implementation of the electronic voting system with emphasis on the practical scheme of voting based on the so-called Gomomorf encryption.

In paper [10], a new voting method based on paper with interesting security properties is presented. The authors have attempted to examine whether the same safety features of proposed cryptographic protocols of voting can be achieved, but without the use of any cryptography.

Properties and space of *Catalan-keys*

Catalan numbers represent a sequence of numbers which were primarily used in geometry and in solving many combinatorial problems. Catalan numbers C_n, *n > 0*, present a series of natural numbers, which appear as a solution to a large number of known combinatorial problems (number of possible entries in form of *n*-balanced parenthesis, stack permutations, Ballot problem, binary trees, triangulation of polygons, etc.).

Property of Catalan-keys: Number can be labeled as Catalan number when its binary form consists of numbers equal to "1" and "0" and start with "1". If binary notation of Catalan number is conected with another mode of writing, most often with the mode of balanced parentheses, then "1" represents an open parenthesis and "0" represents closed parenthesis, and it can be said that each opened parenthesis closes, or every bit 1 has its couple and that is bit 0. Also, the binary record of the Catalan number can be presented in the form of a stack permutation or *Ballot* record. Representation using Stack permutation treats bit 1 as a *PUSH* command and bit 0 as a POP command. More in the following sections.

Space of Catalan-keys: Catalan numbers are defined as [7]:

$$C_n = \frac{(2n)!}{(n+1)!\,n!} \tag{1}$$

The given formula is also an expression for the calculation of space of Catalan-keys.

Table 1. shows the Catalan base numbers n ∈ {1,2,…,30}, which are calculated by the formula (1).

Table 1. *List of Catalan numbers*

n	C_n	n	C_n	n	C_n
1	1	11	58,786	21	24,466,267,020
2	2	12	208,012	22	91,482,563,640
3	5	13	742,900	23	343,059,613,650
4	14	14	2,674,440	24	1,289,904,147,324
5	42	15	9,694,845	25	4,861,946,401,452
6	132	16	35,357,670	26	18,367,353,072,152
7	429	17	129,644,790	27	69,533,550,916,004
8	1,430	18	477,638,700	28	263,747,951,750,360
9	4,862	19	1,767,263,190	29	1,002,242,216,651,368
10	16,796	20	6,564,120,420	30	3,814,986,502,092,304

In this paper, we will use Catalan numbers as keys generator for encryption and decryption. From Table 1., it can be seen that *n* is a basis for keys generating and C_n determines the number of valid keys, i.e. those values that satisfy the characterstic of the Catalan number (space of keys). For example, for basis *n=30* we have space of keys C_{30}=3,814,986,502,092,304, i.e. the values that satisfy the property of the Catalan number. Increasing *n* basis, the space of keys is also drastically increasing. Table 1. shows the values for the first 30 Catalan numbers. In order to provide stronger, i.e. more resistant mechanism of cryptanalysis encryption, it is neccesary to choose keys whose value base is mainly greater than 30. Now we are going to analyze the values which are generated in the C_n set. For the purposes of Catalan number validity verification we will use the binary notation. The basic feature that must be fullfiled is bit property balance in binary form for a certain number from the C_n set (we will refere to this property as *bit-balance* property).

Cryptanalysis of Catalan-keys: From the last notation it follows that, if *n* is a basis for keys generating, then C_n is the total number of different binary formats which meet the Catalan numbers property. For example, for the basis *n=30, C_{30} = 3.814.986.502.092.304* is calculated according to the formula for calculating the Catalan number.

So, for 60-bit keys there are *3.814.986.502.092.304* valid values that satisfy the condition of balance, i.e. Catalan number property. In an attempt to find all of these Catalan numbers and to perform their writing on a disk, the necessary space for this is *30.519.892.016.738.432* bytes or *28.423.864* GB or *27.757* TB. It means, that this process is very demanding when it comes to memory resources. On the other hand, if we want to find out all the 60-bit Catalan numbers and if for access to every element from the C_n set is needed 1 ms, the execution time would take *120972* years. The average time will be *120972 / 2 = 60486* years. It means, this process is very demanding when it comes to time as well.

Example 1: For n=3, based on the formula (1), we have a set of C_3=5 values that appease Catalan number property. These are the numbers *C[3]={42, 44, 50, 52, 56}*, or, based on their binary format *101010, 101100, 110010, 110100, 111000*. We determine their property which corresponds to the Catalan's number, which is the bit- balance property. Observing the binary records of the Catalan numbers, we can see that the number of 1's and 0's is equal, which means that the bit balanace of 0's and 1's is the main feature of each Catalan number. Beside that, we can conclude that *n* basis shows the number of pairs of "1" and "0". In this way we can know the length of the key on the basis of a given base. In this example, the basis is 3, which means that the length of key will be 6 bits, i.e. it will have three pairs of "1" and "0", that satisfy the balancing property.

Example 2: Now we will analyze one record that does not match the balance property. Examples of numbers from the C_3 set which have balance property are 42, 44. Now we will check what is the situation with the number between them, and that is 43. Its binary record is *101011*. We can immediately notice that there is balance property violation and this happens in the sixth bit. The same case is with number 45. Its binary record is *101101*. We can notice that here balance property violation is in the fourth bit. These numbers cannot be used for encryption of the text on basis of a combinatorial problem which is based on the Catalan number property. More about this in the following sections.

Example 3: We will analyze Catalan number *(1142920503054772802)₁₀ = (11111101110001111 0000010010001011111000101110010101001 0000*

$10)_2$. From this record we can conclude that the condition of the bit-balance is met, which means that the value 1142920503054772802 has the property of the Catalan number. The next step is to determine the basis for generating this value. The lenght of the binary record of this value is 60 bits, which means that there are 30 pairs of "1" and "0" in this record. Based on this, we can determine the basis, which is n=30.

The record of the Catalan number, in addition to the binary form, can be presented in other manners, that is, it can be represented through many combinatorial problems. It can be represented in the form of paired brackets "( ) ( ) (( ))" or in the form of *Ballot* record "ABABAABB" or via Stack permutations. In our authors' papers [9,11,12,13,14] we have performed generating testing of all numbers for a given basis *n*, which fullfill the above mentioned Catalan numbers properties.

The application of Ballot, Stack permutations and Balanced Parentheses

In this section, we will consider the application of some other combinatorial problems within the encryption process. We will implement a key that has Catalan number property on the problems such as *Ballot* (voting problem), *stack permutation* and *Balanced Parentheses*.

The general case of the *Ballot* problem is [17]: " *How many combinations there are to put the 2n votes in such way that in each adding a new vote, the number of votes that has been won by candidate A is greater than or equal to the number of the votes that candidate B has received".* This general case is related to the rule *a=b=n*, where *a* is a number of votes for candidate *A*, and *b* a number of votes for *B*, and where for each iteration applies $a_i \geq b_i$.

Since each combination begins with the first voice for candidate *A* (because for each iteration applies the rule: $a_i \geq b_i$, and so, for the first), then all the combinations of records that start with *B* are listed. In the last iteration the condition $a_i = b_i$ must be satisfied.

Example 4: The order of voting can be displayed in a tabular or matrix form for all the combinations. For example, for the order of voting *AABABB*, the following table is formed:

Candidate	i_1	i_2	i_3	i_4	i_5	i_6
	A	A	B	A	B	B
A	1	2	2	3	3	3
B	0	0	1	1	2	3

Based on the voting order table for both candidates, matrices can be formed for candidates A and B, where the matrix elements are recorded as ordinal numbers of votes at the time of adding each vote. For case *a=b=3*, where applies that $a_i \geq b_i$ for C_3 there are 5 such combinations.

$$A = \begin{bmatrix} 1 & 2 & 3 & 3 & 3 & 3 \\ 1 & 2 & 2 & 3 & 3 & 3 \\ 1 & 1 & 2 & 3 & 3 & 3 \\ 1 & 1 & 2 & 2 & 3 & 3 \\ 1 & 2 & 2 & 2 & 3 & 3 \end{bmatrix} \quad B = \begin{bmatrix} 0 & 0 & 0 & 1 & 2 & 3 \\ 0 & 0 & 1 & 1 & 2 & 3 \\ 0 & 1 & 1 & 1 & 2 & 3 \\ 0 & 1 & 1 & 2 & 2 & 3 \\ 0 & 0 & 1 & 2 & 2 & 3 \end{bmatrix}$$

Example 5: In the matrices A and B, the example of 6 voters is given, of which 3 are voting for candidate A and 3 for candidate B. These matrices can be represented in the form of a matrix with Ballot records. If we respect the condition that candidate A got the first vote, and the balance of the appearance of another candidate is respected, where it applies that always in a given voting moment we have $a_i \geq b_i$, then we have 5 such permissible combinations:

A A A B B B
A A B A B B
A A B B A B
A B A A B B
A B A B A B

As we can see, once again we got 5 key values that possess the balance property, only in this case they were not presented in binary form, instead they are presented in the form of *Ballot record*. Precisely, in papers [3,10] is stated the fact that combinatorial Ballot problem or voting lists problem is widely used in cryptography and in the method of recording and encryption.

Example 6: For the given key *K=877268*, for which we have already established that has Catalan number property and the given plaintext *P="SINGIDUNUM"*. If we present the key in a form of Ballot notation, then bit 1 is a vote for the first candidate A and it represents character reading operation from the message *P*, and bit 0 is a vote for

message	S	I	N	G	I	D	U	N	U	M										
voting key	1	1	0	1	0	1	1	0	0	0	1	0	1	1	0	1	0	1	0	0
voting phases	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
candidate A	1	2	2	3	3	4	5	5	5	5	6	6	7	8	8	9	9	10	10	10
candidate B	0	0	1	1	2	2	2	3	4	5	5	6	6	6	7	7	8	8	9	10
divergence (index)	1	2	2	3	3	4	5	5	/4/	/1/	6	6	7	8	8	9	9	10	10	/7/
ciphertext		I		N			I	G	S		D		N		U			M	U

Figure 1. Encryption on the principle of the voting order (Ballot problem)

the second candidate B and represents operation of writing in the ciphertext *C*. The resulting ciphertext is *C="INIGSDNUMU"*.

Now we will introduce the possibility of applying the stack structure in the encryption process. The stack is an abstract type and data structure that is based on the *LIFO* principle *(last in, first out),* with two basic operations: *push and pop*.

It is also possible to generate stack permutations based on the Catalan number properties; by making the connection between the operation over the stack and the characters that appear in binary notation of a key that has Catalan number property:

1. If the current character in a record is 1, then the *push* operation is invoked and the number of appearances of this bit is located in a record on the left side.
2. When the value 0 appears, then the *pop* operation is invoked and the bit from the stack is pushed out to the exit.

In our paper [11], the number of permutations used in the stack corresponds to the Catalan number. Therefore, applying a stack can only map each binary record (or equivalent ballot record) of 2n length on one permutation of the set {1,2, ..., n}. A binary record is expected at the input, and since the push operation records only the number of occurrences of value 1, a two-time output is obtained twice (figure shows the relationship between the in-
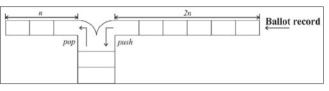
put and the output of the stack).

Figure 2. The processing of input data through stack structure

For the decryption procedure, it is necessary to allow, on the basis of output values obtained using the stack, the corresponding binary or *Ballot* record (reverse process). Output values obtained from the stack are determined by the sequence of operations over the stack. In our paper [11], the values obtained from the stack structure we have named SVB (*stack value based binary/ballot notation*). Below, an algorithm for mapping SVB records to the *Ballot* record is proposed.

Algorithm 1. Mapping SVB records in *Ballot* record [11]

Input: Stream P_i, i = *1, . . . , n* contains a set of permutation {1, . . . , n} using stack.
1: for i = 1 to n do
1.1: If P_i > 0 send P_i characters A to the output..
1.2: Send one character B to the output..
1.3: If P_i > 0 for j = i + 1 all the way to n reduce P_j for P_i.
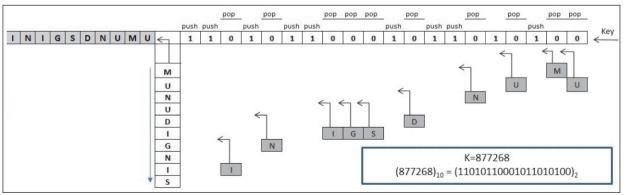Output: The appropriate ballot record.

Figure 3. Encryption based on the stack permutation principle

Example 7: For the given key *K=877268*, for which we have already established that it has Catalan number property and the given plaintext *P="SINGIDUNUM"*. Bit 1 in the binary key record represents the *push* operation or the character reading from the message P, and the bit 0 represents the *pop* operation or writing in the ciphertext C. The resulting ciphertext is *C="INIGSDNUMU"*.

A similar example of encryption, based on the sequences of the stack operations is given in the case study [2]. Equivalent to the stack permutations and the *Ballot* notation can only be the *Balanced Parentheses* notation, i.e., a record in a form of balanced parenthesis [4]. In our paper [9] thoroughly are considered the possibilities of representation of the Catalan numbers based on combinatorial problems of the *Balanced Parentheses*. In that paper we have provided a method for alphanumeric notation of paired brackets which is exactly based on the Catalan numbers properties.

We will display an example of text encryption based on *Balanced Parentheses* combinatorial problems, which is performed in a similar manner as with the stack permutations or Ballot problems.

Example 8: For the given key *K=877268*, for which we have already established that it has Catalan number property and the given plaintext *P="SINGIDUNUM"*. If the key is presented in the form of paired parentheses, then bit 1 is opened parenthesis and presents reading operation of the characters from the message, and bit 0 is closed parenthesis and presents writing operation in the ciphertext. The last opened parenthesis must be closed first (LIFO). The resulting ciphertext is *C="INIGSDNUMU"*.

Java software solution for encryption based on Ballot notation and Catalan-keys

Java application for encryption based on Ballot notation consists of three phases. The first phase involves finding Catalan numbers (keys) based on the given *n* basis. This phase involves the next steps:

- On the input *n* is assigned,
- On the basis of *n*, the set C_n (space of keys) is calculated,
- Selecting one Catalan number (key) from the C_n set,
- The selected key is converted from decimal to Ballot record (notation).

The second phase is the encryption process based on a key that has the Catalan number property. This phase includes the following steps:
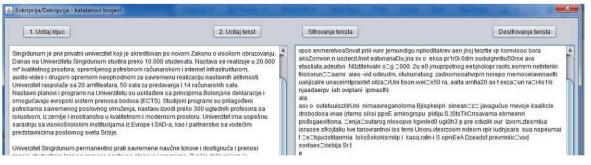
- Loading the message (plaintext),
- Converting the message *(ASCII Text to Binary)* into binary sequence,
- The binary sequence is divided into *X* segments whose length corresponds to the *n* basis,
- By using the binary key record and reading it, starting from the first bit and ending with the last bit in the key (the occurrence of bit 1 denotes an open pair and 0 a closed pair), the sequence of bits permutation $X_1....X_n$ is performed,
- The process of mixing the bits is performed according to the described principle of Ballot record (notation).
- The obtained permutations of the bits are converted - *Binary to ASCII Text,* and in this way the cipher text is obtained.

The third phase is a decryption process based on a key that has the Catalan number property. This phase includes the following steps:

- Loading the cipher text (textual record)
- Converting the cipher text *(ASCII Text to Binary)* into binary sequence,
- The binary sequence is divided into X segments whose length corresponds to the *n* basis
- By using the binary key record and reading it in reverse order, starting from the last bit and ending with the first bit in the key (the occurrence of bit 0 denotes an open pair and 1 a closed pair), the sequence of bits permutation $X_1.... X_n$ is performed.

Key (bin)	1	1	0	1	0	1	1	0	0	0	1	0	1	1	0	1	0	1	0	0
Balanced parentheses	(	(	)	(	)	(	(	)	)	)	(	)	(	(	)	(	)	(	)	)
message	S	I		N		G	I				D		U	N		U		M		
ciphertext			I		N			I	G	S		D			N		U		M	U

Figure 4. Encryption in the form of balanced parentheses

Figure 5. *Encryption of plaintext and displaying the ciphertext in the right panel*
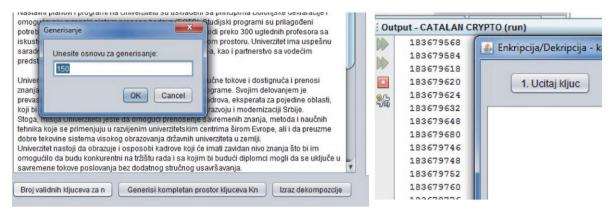

Figure 6. *Generating all valid keys for a given n basis*

- The process of mixing the bits is performed according to the described principle of Ballot record (notation), in reverse order,
- The obtained permutations of the bits are converted - *Binary to ASCII Text,* and in this way the source message is obtained.

For the implementation of Java software solution, it is important to note that we did not use a ready-made Java classes from the two standard APIs (JCA, JCE). The classes for working with files (*File, File-Writer, FileReader, BigInteger, Vector, logging.Logger...)* were used*.* In addition, we used the *Swing* and *AWT* package for programming the GUI application. The project consists of three classes: *CatalanCrypto, CatalanNumbers and CatalanDecomposition.*

I) Within the *CatalanCrypto* class, the following methods are given:

- File encryptionCatalanBallot (File file, String key)
- File decryptionCatalanBallot (File file, String key)
- public String loadKey (File file).

II) The second class in our Java project is *Catalan-Numbers* with a method for finding Catalan number: *find_catalan(File file).*

The main form of the *Java GUI application* has the following functionalities: Loading a key, Loading a file, Encryption of plaintext, Decryption of ciphertext, Checking the number of valid keys for given *n* (spaces of keys), Generating the keys that have the Catalan number properties, Dynamic generating of binary keys records. When starting the Java application, the first step is loading the key from an external file. In the application, there is an algorithm for generating a complete space of keys for a specific *n* basis. We use the method of manual taking of one of those values and storing them in the *KEY.TXT* file. After that, we include the specified file as the current active key. In this way, we can create multiple keys, but in one process we have to determine which key is active for the current encryption or decryption process.

After loading the key, the next step is loading the file with plaintext. File with the extension .txt, .doc can be loaded. After successful loading of the key and the message, the "*text encryption*" button becomes enabled. Otherwise, it is disabled before this. After getting the ciphertext, the "*text decryption*" button becomes enabled. Otherwise, before that this button was disabled.

Figure 7. *The content of the plaintext (message)*

Figure 8. *Content of the encrypted text based on the 60-bit Catalan number-key K=1142920503054772772, Ballot key record (((((0(((0))((((0)))))0)0))0(((((0))0 ((0)000))0)0)*

By clicking the button "*text decryption*", we can decrypt ciphertext and compare it to the original message.

In Figure 6, a method for generating keys for a given *n* base is given. The condition to start generating the entire space of keys for particualar *n* basis is to determine the file in which the entire space of keys will be recorded. After that, generating and recording of keys starts. This process may take a time, depending on the input of *n* basis.

Conculsion

In this paper, we investigated and presented how Catalan numbers are widely used in solving many combinatorial problems, such as stack permutations, paired parentheses problem, *Ballot* problem etc. Having in regard the fact that cryptography is very dinamic field, that it is up to date and very widespread, this paper covers only some of its mathematical concepts and gives a contribution when it comes to the application of number theory in the field of cryptography.

Also, we mentioned the theoretical basis of the research where the basic Catalan numbers properties were tested, and the focus was placed on the bit balance property in binary notation of the Catalan number. After that, we gave a few suggestions and examples of combinatorial problem application in encrypting files. We put the emphasis on the application of stack permutation in text encryption, where also the equivalent combinatorial problems in encoding were displayed, such as the *Ballot* problem, stack permutations and *Balanced Parentheses*.

Our theoretical basis of the research was related to the method of keys generating based on the bit balance property of Catalan number and the encryption based on Ballot notation. Specifically, a case study is given that includes specific algorithms for encryption and decryption, which are implemented in the Java programming language. The implemented GUI application has all necessary elements for easy and efficient files encrypt and decrypt, keys loading, displaying the content of ciphertext and messages, keys generating, etc.

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THE USE OF ENERGY STORAGE DEVICES OF UNCONTROLLED TYPE ON THE MOSCOW METRO (THEORY AND PRACTICE)

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Abstract: The problem of increasing energy saving and energy efficiency in the system of traction power supply of the Moscow Metro is considered due to the use of energy storage devices of uncontrolled type. The results of simulation modeling of the operation of an energy storage device of uncontrolled type in the system of traction power supply of the subway are presented. A particular line of the Moscow Metro, Filevskaya, was studied, on which experiments on the introduction of energy storage devices based on electrochemical super capacitors were conducted.

With the help of experimental measurements, the electric power indicators of the operation of a stationary energy storage device had been obtained at regular service on the traction substation of the Filevskaya line of the Moscow Metro for several months. The maximum levels of the converted energies, the cyclicity, the efficiency of the plant operation, and the amount of the energy economy are determined.

By statistical processing of the instantaneous values of the performance of the traction substation with the accumulator and the analysis of the data of the energy monitoring of the Moscow metro, an important parameter of reducing the installed capacity was investigated. The similarity of the data of theoretical calculations and experimental measurements is shown.

Keywords: modeling of the operation, energy storage devices, capacitive energy storage, regeneration of braking energy, traction power supply, underground.

INTRODUCTION

The system of traction power supply (STPS) of the Moscow Metro is one of the most powerful electricity consumers of the megapolis. The main part of the metro energy consumption is the consumption of train traction. In addition, the STPS has the most uneven energy consumption schedule - within a few minutes or even seconds, the power consumption of one of the four feeders of the traction substation (TS) can range from 0 to 10 MW. Such fluctuations in the load have a very negative effect on all electrical equipment. It should also be noted that, due to the lack of reliable receivers of the braking energy of the

rolling stock (BERS) in the STPS of the underground, from 5 to 25% of the recovery energy is excessive and is lost in the braking rheostats in the form of heat.

METHODS FOR SOLVING THE PROBLEM

One of the most complex methods for solving the stated problems is the local buffering of electricity at various stages of its delivery to the consumer, that is, the introduction of energy storage devices (ESD) in the STPS of the underground, capable of reducing capital investments in the main traction electric equipment, saving 30% of the electricity used
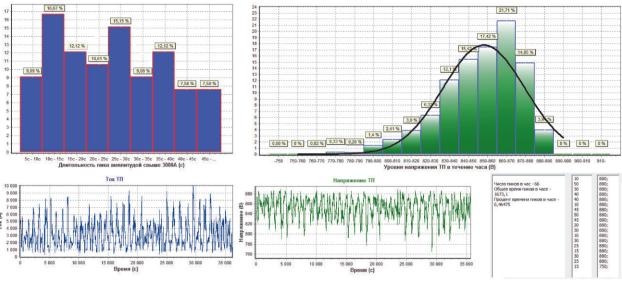
Figure 1. *The interface of the program for statistical processing of experimentally measured data*

for traction, and increasing the energy efficiency of STPS as a whole [4-7].

For assessing the efficiency of the use of ESD in STPS of the underground, in this paper has been developed a software-measuring complex (SMC) intended to solve a wide range of objectives of designing, operating and electric power processes in STPS, both the undergrounds and electrified railways. The main features of SMC include the functions of probabilistic modeling of the track profile for a given category of complexity, modeling the movement of the train, the automatic formation of deterministic and probabilistic train traffic schedule, the calculation of the parameters of the substitution circuit for the TS and the traction network, configurations and simulation of its operation, calculation of current loads of transformers and semiconductor converters of TS and comparison with permissible norms, calculation of current loads of feeders, determination of minimum and maximum stresses on current collectors, calculation of parameters of ESD, indicators and the choice of mode of operation, and so on. It should be noted that it is possible to use in SMC data of experimental measurements of the performance of electric power facilities of the underground.

To improve the accuracy of theoretical calculations, along with purely imitation modeling, the methods of statistical modeling were also used to estimate the characteristics of ESD, based on the processing of the results of the experimentally measured data on the operation of TS and BERS of the underground. In this case, the processing of TS operation (feeder and traction aggregate currents, as well as bus bar voltage) is performed as a function of time for several days with a small time sampling step (about 1 ms) - determination of the duty cycle of the starting currents and braking energy regeneration currents of BERS, currents of TS, their peak and average values for different periods of time, as well as the parameters of the laws of distribution of the investigated quantities.

Figure 1 shows an example of the processing of data on the performance of the TS-917 (*Rimskaya* station) of the Moscow Metro – the dependence of the current and voltage on the TS time for an hour during the intensive traffic period, the probability distribution of the peaks of the traction currents, the probability distribution diagram voltage levels of TS, selection of the laws of probability the density distribution.

With the help of the presented program of statistical processing and modeling (Fig. 1), experimental data on the performance of several TS at various hours of the day and under different Moscow metro power supply systems (centralized and decentralized) were investigated and the necessary dependencies were constructed.

A similar statistical analysis was performed from the given measurements of the performance of BERS. As a result, experimental data on the starting energies (As) and the deceleration energies (Ad) per one BERS car were obtained (Fig. 2).
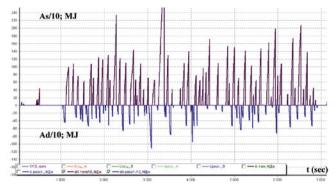
Figure 2. *The energetic indicators of BERS operation of the underground*

Further statistical modeling made it possible to combine experimental data on TS and BERS performance indicators, as a result of which it was possible to estimate the order of excess energy of recovery in STPS, as well as the power capacity and the power of the stationary ESD needed for its adoption at TS.

In this case, the theory of processing systems of random functions was used, on the basis of the "Normal" (*Gaussian*) distribution law, and the required two-parameter dependence obtained the following form:

$$f(A,P) = \frac{1}{2\pi\sigma_A\sigma_P\sqrt{1-r_{AP}^2}} \cdot$$

$$\cdot \exp\left[-\frac{1}{2\sqrt{1-r_{AP}^2}} \cdot \left[\frac{(A-m_A)^2}{\sigma_A^2} - \frac{2r\cdot(A-m_A)\cdot(P-m_P)}{\sigma_A\sigma_P} + \frac{(P-m_P)^2}{\sigma_P^2}\right]\right]$$

$$r_{AP} = \frac{K_{AP}}{\sigma_A\sigma_P}; \quad K_{AP} = \sum_i\sum_j(A_i-m_A)\cdot(P_j-m_P)\cdot p_{ij} \quad (1)$$

Where:
- $m_{A,P}$ и $\sigma_{A,P}$ – are the mathematical expectation and the standard deviation of the energy intensity and power of ESD;
- rAP is the correlation coefficient;
- KAP is the correlation moment;
- pij is the probability that the system (A, P) takes the values Ai and Pj, and the summation extends over all possible values of the random values A, P.

The proposed method and model of statistical processing, based on pre-measured or modeled distribution laws, allows using the original metro line data (profile, location of stations and TS, type of BERS, dimensions of motion, etc.) and experimental measurement data to determine energy and capacity of storage facilities, as well as assess the preliminary technical and economic effect.

Figure 3 shows the spatial surface of the probability distribution density (p;%) of the excess energy recovery as a function of the energy capacity (A; MJ) and the power (P; MW) of the ESD for TP of the underground. In this case, the simulation was made for TS-917 *Rimskaya* station of the *Lublinskaya* line of the Moscow Metro. It is clearly seen from the schedule that for a given substation the energy intensity of the ESD for taking almost all the excess energy of recuperation should be about 70 MJ, and its power should be about 2.5 MW.

Preliminary statistical modeling (Fig. 3) made it possible to determine the parameters of ESD for its use at the TS of the *Filevskaya* line of the Moscow metro. Figure 4 presents the results of simulation of the ESD operation during the day, which were subsequently used for comparison with the experimental data.

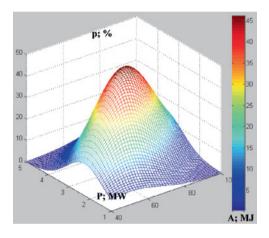**Figure 3.** *The surface of the distribution of the probability density of accepting excess energy of recuperation in the dependence on the energy intensity and power of the ESD for the TS of the underground*
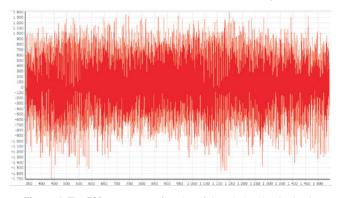

Figure 4. *The ESD current as a function of time during the day by the results of simulation*

Thus, SMC with ESD and additional applied programs make it possible to carry out the whole range

of research and design work related to the calculation of all the performance indicators of the STPS, and the SMC modules that are part of the SMC and individual ESD modeling application programs at any points of the STPS allow to investigate their operation modes and the processes of energy exchange in the network, that makes it possible to estimate the necessary parameters of ESD and the technical and economic efficiency of their use accurately enough.

EVALUATION OF THE RESULTS IN PRACTICE

After lengthy studies on the basis of experimental measurements and simulation experiments, it was decided to install two ESD of an uncontrolled type on traction substations T-23 and T-24 of a low-loaded *Filevskaya* line of the Moscow underground of an open type [1-3]. Energy accumulators of an uncontrolled type are those ESD, the accumulating element of which is connected directly to the TS buses, and the modes of charge or discharge of ESD are determined by the conditions of circulating energy in the traction network.

The accumulating element of each ESD consists of electrochemical capacitors of the Russian company *OOO EKE (Elton)*. Each of the storage units consists of 14 cabinets manufactured by the Russian company *JSC Zavod konvertor*. Each cabinet contains 11 storage modules connected in series. The total capacity of ESD (14 cabinets) is 187 F, and the maximum operating voltage is 990 V.

Energy storage devices were included in the regular operation in January 2014. With the purpose of analyzing the functioning of ESD, the work of the new device was monitored, namely, for many days continuously measured and recorded the currents of charge and discharge of ESD, voltages on its buses, followed by statistical processing of the received data.

Figure 5 shows the dependence of the TS, ESD current and their positive sum, i.e. the current that goes to the traction network for powering the trains, in the function of time for 2 minutes.
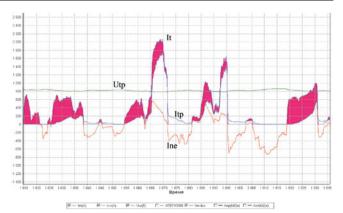

Figure 5. *Currents TS, ESD and their sum (access to the traction network for powering trains) as a function of time for 2 minutes based on the results of the full-scale experiment*

The processing of the results of experimental measurements showed that the reduction of the consumed peak power of TS (for a specific measurement period) was about 13.4%. At the same time, the maximum value of the consumed current from TS, due to feeding of the storage device, decreased from 7 kA without ESD to 5.5 kA in the presence of ESD (that is, by 27%).

Figure 6 shows a continuous diagram of the consumption of electricity (power) for meters on traction units of the T-23 substation at half-hour intervals for two days. From the diagram, the fact of a decrease in power consumption is shown visually when alternating days with disconnected and switched on ESD are alternating.
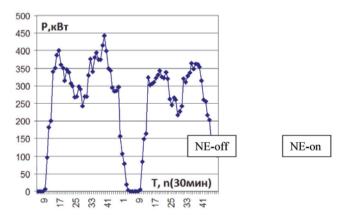

Figure 6. *Power on metering devices at substation T-23*

The indicator of TS power reduction due to ESD is very important, as it affects the reduction of power losses, the increase in the efficiency of traction aggregates, the reduction of power consumption and the reduction of capital costs for the main traction

equipment of TS, as well as the reduction of fare for paying for electricity at an average power level .

The average power level of the TS for a certain period of time, usually 30 minutes, taking into account the work of ESD ($P_S^{(30)}$) can be estimated by the following formula:

$$P_S^{(30)} = \frac{A_T^{(30)}}{T^{(30)}} = \frac{A_{TP}^{(30)} + A_{NE}^{(30)}}{T^{(30)}} \qquad (2)$$

$$P_S^{(30)} = \frac{1}{T^{(30)}} \left(\int_0^{T^{(30)}} p_{TP}(t)dt + \int_0^{T^{(30)}} p_{NE}(t)dt \right) = \frac{1}{T^{(30)}} \left(\int_0^{T^{(30)}} i_{TP}(t)u_{TP}(t)dt + \int_0^{T^{(30)}} i_{NE}(t)u_{NE}(t)dt \right)$$
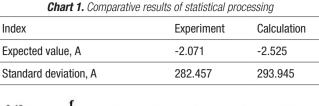
Where:
- $A_T^{(30)}$ - is the energy that goes to BERS traction;
- $A_{TP}^{(30)}$ - is the energy from TS;
- $A_{NE}^{(30)}$ - is the energy from ESD;
- $T^{(30)}$ - integration time;
- P_{TP} и P_{NE} –instantaneous power of TS and ESD;
- i_{TP} и u_{TP} – instantaneous current and voltage values of the TS;
- i_{NE} и u_{NE} –instantaneous values of current and voltage ESD.

During the operation of ESD, the integrated performance of the drive was also evaluated, namely, energy characteristics and efficiency - the charge and discharge energies of ESD can reach values of the order of 10-12 MJ per charge-charge cycle, and the mean daily efficiency of ESD was about 0.95. The saving of power consumption by feeder network tractors reached about 0.5-2.5% in the winter and 5.6% in the spring period of the underground operation.

To assess the adequacy of the simulation results of the ESD operation on the TS, the calculated data (Fig. 4) were compared with the experimental measurements. Figure 7 shows the current ESD diagram during the day and the selected law of probability density distribution of ESD current. Studies have shown that the distribution of the value of the ESD current in the experiment and in the simulation is in accordance with the normal law. The hypothesis about the "Normal" (*Gaussian*) distribution was tested using the *Pearson* agreement criterion.

It should be separately noted that a comparison of the experimentally obtained results and the results of simulation showed good convergence in the selected statistical characteristics. The table presents comparative data of statistical processing of results of simulation and experimental measurements.
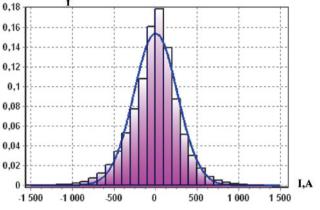
Chart 1. *Comparative results of statistical processing*

Index	Experiment	Calculation
Expected value, A	-2.071	-2.525
Standard deviation, A	282.457	293.945

Figure 7. *Distribution of the probability density of the current ESD*

CONCLUSION

Thus, the ESD performance indicators in the regular mode reflect a high correlation with the calculated data and have the following values:
- the maximum charge currents were about 1800A;
- the maximum discharge currents amounted to about 2300A;
- the maximum received energy per one recharge cycle was 10.5 MJ;
- the maximum energy given for one recharge cycle was 11 MJ;
- the average daily efficiency of the ESD was 95.5%;
- energy savings amounted to 0.5-2.5% in the winter period and 5.6% in the spring period;
- reduction of the peak power consumption of the transformer substation was 13.4%.

Monitoring of initial operation showed that the installation of ESD on the T-23 allowed to partially smooth out the schedule of TS power consumption, to reduce the voltage drop on the TS buses and to increase the overall energy reliability of the traction power supply of the Moscow Metro.

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Road Traffic Accidents Analysis Using Data Mining Techniques

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Abstract: Road Traffic Accidents (RTAs) are a major public concern, resulting in an estimated 1.2 million deaths and 50 million injuries worldwide each year. In the developing world, RTAs are among the leading cause of death and injury. Most of the analysis of road accident uses data mining techniques which provide productive results. The analysis of the accident locations can help in identifying certain road accident features that make a road accident to occur frequently in the locations. Association rule mining is one of the popular data mining techniques that identify the correlation in various attributes of road accident. Data analysis has the capability to identify different reasons behind road accidents. In the existing system, k-means algorithm is applied to group the accident locations into three clusters. Then the association rule mining is used to characterize the locations. Most state of the art traffic management and information systems focus on data analysis and very few have been done in the sense of classification. So, the proposed system uses classification technique to predict the severity of the accident which will bring out the factors behind road accidents that occurred and a predictive model is constructed using fuzzy logic to predict the location wise accident frequency.

Keywords: Road Traffic Accident (RTA), Data Mining, k-means, Association Rule Mining (ASM), Classification, Prediction.

Introduction

Road and traffic accidents are the major causes of fatality and disability in Coimbatore. A RTA not only causes property damage but it may lead to partial or full disability and sometimes can be fatal for human being. Increasing ratio of RTA is not a good sign for the transportation safety. The analysis of traffic accident data provides solution to identify different causes of road accidents and undertaking preventive measures. Various types of research have been done on road accident data from different countries. Significant help in this situation represents an identification of the key factors causing road traffic accidents [1]. Application of suitable data mining methods on the collected datasets representing different situations on the roads and occurred accidents can help understand the most significant factors or often repeating patterns. The success of such analysis depends strongly on the quality of the data available for the experiments. An interesting source of data in this domain is continually created by Department of Police, Coimbatore. All available data files provide detailed road safety data about the circumstances of personal injury road accidents involved and the consequential casualties. The statistics relate only to the accidents that are occurred on public roads, and are reported to the police and subsequently recorded using the RADMS (Road Accident Database Management System) accident reporting form (completed by police).

This paper consists of four main sections: the section 1 discusses about the Literature review. The proposed methodology is discussed in section 2. The section 3 describes the simulation results and

the section 4 describes the conclusion, that is summarizes extracted knowledge in respect with other relevant work.

REFERENCES SURVEY

Sachin Kumar. [2] Discussed about the various data mining techniques in order to cluster the data into various categories and to identify the correlation between the attributes in the dataset. Lee et al. [3] stated that statistical models were a good choice to analyze road accidents in order to identify the correlation between accident and other traffic and geometric factors. However, Chen and Jovanis [4] stated that analyzing large dimensional datasets using traditional statistical techniques may result in certain problems such as sparse data in large contingency tables and also the statistical models have their own model with specific assumptions and violation of these can lead to some erroneous results. Due to these limitations of statistical methods, data mining techniques are being used to analyze road accidents. Data mining techniques are used to extract novel, implicit and hidden information from large data. Barai [5] discussed that there are variety of applications in transportation engineering such as road roughness analysis, pavement analysis and road accident analysis which uses data mining. Various data mining techniques [6] such as ASM, classification and clustering are widely used for the analysis of road accidents. Accident cases in India are usually recorded by police officer of the region in which the accident has occurred and also the area covered by a police station is limited and they keep record of accidents that are occurred in the regions under their control. Abellan et al. [7] developed various decision trees to extract different decision rules to analyze two-lane rural highway data of Spain. It is found that bad light conditions and safety barriers badly affect the crash severity. Geurts et al. [8] used ASM technique to analyze the various circumstances that occur at high-frequency accident locations on Belgium road networks. Tesema et al. [9] used adaptive regression tree model to build a decision support system for the road accidents in Ethiopia. Kashani et al. [10] used the Classification and Regression Tree (CART) to analyze road accidents data of Iran and found that not using seat belt, improper overtaking and over speed affect the severity of accidents.

Kwon et al. [11] used classification algorithm to analyze factor dependencies related to road safety. Accident severity is directly concerned with the victim involved in accidents and it only targets the type of severity and shows the circumstances that affect the injury severity of accidents. Most of the accidents are concerned with certain location characteristics which make them to occur frequently at these locations. Hence, identification of these locations where accident frequencies are high and further analyzing them is very much beneficial to identify the factors that affect the accident frequency at these locations. Depaire et al. [12] discussed that cluster analysis of road accident data can extract better information rather than analyzing data without clustering. Preeti Mulay [13] discussed that the RTA involved fatal crashes data is directly concerned with nutritional health survey data to analysis of the association of dietary habit of a motor vehicle driver's to road traffic accident by applying Association rule mining algorithms. So the previous work focuses mainly on the driver characteristics and dietary habits, where aforementioned was analysed using ASM, and this paper focused on the contribution of various road-related factors such as the role of environment, place where the accident occurred and cause of the accident in order to classify the severity of the accident.

In this paper, the data mining techniques are used to identify accident locations which are more prone to risk and further analyzing them to identify various factors that affect road accidents at those locations. Initially, the dataset is divided into k groups based on their locations using k-means clustering algorithm. Then, the association rule mining algorithm is applied on those to reveal the correlation between different attributes in the accident data and understand the characteristics of these locations. Then, the Classification algorithm (Naive Bayes) is applied to classify the severity of the accident.

METHODOLOGY

The proposed methodology consists of four phases, namely the Preprocessing, Clustering of data, Association Rule Mining, and Classification. Figure 3.1 represents the system architecture of the project.

Data Preprocessing

Data preprocessing is the initial step in data mining techniques which involves mainly transforming the raw data into an understandable format. Generally Real-world data is incomplete, inconsistent and is likely to contain many errors. Data preprocessing is a method of resolving such issues and it prepares the raw data for further processing. In this paper the Data preprocessing techniques such as Data Cleaning and Data Transformation is used.
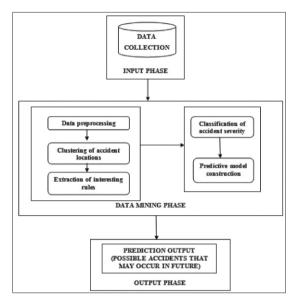

Figure 3.1. *System Architecture*

Clustering

Clustering is an unsupervised data mining technique which is used to group the data objects into different clusters in such way that objects within a group are more similar than the objects in other clusters. K-means algorithm [14] is very popular clustering technique for numerical data. It groups the data objects into k clusters. There are various clustering algorithms existing but selection of suitable clustering algorithm depends on the type and nature of data. Our prime motive of this paper is to discriminate data into different clusters based on the accident location.

Association Rule Mining

Association rule mining is a very popular data mining technique based on market basket analysis that extracts interesting rules between various attributes in a large data set [18]. Association rule mining produces a set of rules that define the underlying patterns in the data set. Given a data set D of n transactions where each transaction is TID. Let $I = \{I1, I2,..., In\}$ be a set of items. An item set A will occur in T if and only if $A \subseteq T$. $A \rightarrow B$ is an association rule, provided that $A \subset I$, $B \subset I$ and $A \cap B = \emptyset$. In case of road accident data, an association rule can identify the various attribute values which are responsible for an accident occurrence. In association rule mining, various interesting measures are there to assess the quality of a rule. These interesting measures for the rule $A \rightarrow B$ are discussed as follows:

Support

The support of the rule $A \rightarrow B$ defines the percentage how often A and B occur together in a data set and can be calculated using the Equation (1). Support is also known as frequency constraint. A set of items satisfying certain support threshold is known as frequent item set. These frequent item sets are further used to generate association rules based on other measures.

$$\text{Support} = \frac{P(A \cap B)}{N} \tag{1}$$

Where N is the total number of accident records.

Confidence

Confidence of the rule $A \rightarrow B$ defines the ratio of the occurrence of A and B together with the occurrence of A only and can be calculated by using the Equation (2). Higher the confidence values of the rule A B, higher the chances of occurrence of B with the occurrence of A. Sometimes, only confidence values are not sufficient enough to evaluate the descriptive interest of a rule.

$$\text{Confidence} = \frac{P(A \cap B)}{P(A)} \tag{2}$$

Lift

Lift for the rule $A \rightarrow B$ measures the occurrence of A and B together more than expected. In other words, lift is the ratio of

the Confidence and the expected confidence of a rule. Expected confidence can be defined as the occurrence of A and B together with the occurrence of B. A lift value ranges from 0 to ∞. Lift values greater

than 1 make a rule potentially useful for predicting the consequent in future data sets. Lift determines how far from independence are A and B. Lift measures co-occurrence only and is also symmetric with respect to A and B. Lift can be calculated using Equation (3).

$$\text{Lift} = \frac{P(A \cap B)}{P(A)*P(B)} \tag{3}$$

Apriori Algorithm

Apriori Algorithm [14] is used to generate the frequent item-sets and the strong association rules. The input of the algorithm will be the transaction Database of Accident data and the output will be the frequent item-sets and Association rules which satisfy the minimum threshold of Lift.

Classification

Classification is the process of finding a derived model which describes the data classes. The main purpose is to be able to use the model to predict the class of objects whose labels are unknown. The derived model is based on the analysis set of training data.

Naive Bayes Classifier

Naive Bayes classifier [14] uses the probabilistic method to predict a class for every instance of data set. The input of the algorithm is Test data and the output will be the predicted severity level. The specific working process of the Naive Bayes is as follows:

Let T be the training sample set. Each sample has category labels. Sample set has a total of m classes: C1, C2,...Cm. Each sample is represented by an n-dimensional vector System designX={x1, x2, ..., xn}, and each vector describes n attributes A1, A2,...,An. Different ways in calculating the probability of the class are explained below.

1. Given a simple X, the classifier will predict that X belongs to the highest posterior probability of class. If and only if $P(C_i|X) > P(C_j|X)$, 1<=i, j<=m, X is predicted to belong to class C_i. According to the Bayes' theorem, the probability is calculated as in equation (4).

$$P(C\_i/X)=(P(X/C\_i)*P(C\_i))/(P(X) \tag{4}$$

Because P(X) is the same for all classes, it only need to find the largest $P(X|C_i)P(C_i)$. The prior probability of class C_i can be calculated. $P(C_i)=s_i/s$, s_i is the number of training samples of class C_i, and s is the total number of training samples. If the prior probability of class C_i is unknown, it is usually assumed that the probability of these classes are equal, then P(C1)= P(C2)= ...= P(Cm), therefore the problem is transformed into how to get maximum $P(X| C_i)$.

2. If the data set has many attributes, the workload of calculating $P(X| C_i)$ is very high. In order to reduce the computational overhead of $P(X|C_i)$, simple assumptions are used that under certain condition attribute characteristic value is independent of each other. $P(X| C_i)$ is calculated as in equation (5)

$$P\left(\frac{X}{C_i}\right) = \prod_{k=1}^{n} P(\frac{x_k}{C_i}) \tag{5}$$

3. Probability $P(x_1|C_i), P(x_2|C_i), ..., P(x_n|C_i)$ can be calculated from the training set. Here x_k refer to the attribute A_k of sample X.

4. For each class, calculating $P(X|C_i)P(C_i)$. If and only if $P(X|C_i)P(C_i)$ is maximum, the classifier prediction sample X belongs to class C_i. Bayes' theorem is used for classification as the past information about a parameter can be incorporated and form a prior distribution for future analysis.

Performance Evaluation

Classification performance is evaluated in terms of three commonly used metrics: accuracy, recall and precision as defined in equation (6) – (8). Table 3.1 is a confusion matrix whose entries are given as a function of two typical classes in severity classification.

- Accuracy is the percentage of test set samples that are correctly classified by the model.

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FN+FP} \tag{6}$$

- Precision is the fraction of retrieved instances which are relevant.

$$\text{Precision} = \frac{\text{Number of TP}}{\text{Number of TP+FP}} \tag{7}$$

- Recall is the fraction of relevant instances which are retrieved.

$$\text{Recall} = \frac{\text{Number of TP}}{\text{Number of TP+FN}} \tag{8}$$

Where
TP= True Positive   FP= False Positive
TN= True Negative   FN= False Negative

Table 3.1. Confusion Matrix

	Predicted Slight	Predicted Severe
Actual Slight	TP	TN
Actual Severe	FP	FN

Simulation Results

The proposed methodology is implemented using the Java language and executed in NetBeans IDE.

Data Set

In Coimbatore, all accident related details are collected and maintained by the Department of Police using software called Road Accident Database Management System (RADMS) and the information is stored at the central server which is located at one particular place in TamilNadu. Hence, these data provide information about accidents that have happened in the road network of entire city. The data for this study is obtained from the Commissioner office, Coimbatore. The data consists of 570 accident details for 3 years from 2013 to 2015 in Coimbatore. After pre-processing, 542 accident records were considered for this study. A description about the data set is provided in the table 4.1. Sample dataset is provided in the table 4.2.

Table 4.1. Data set Description

Attribute Name	Type
Date & Time of Accident	Nominal
Road name	Nominal
Road No	Nominal
Municipality	Nominal
Fatal	Nominal
Grievous	Nominal
Injury	Nominal
Property Damage	Nominal
Nature of Accident	Nominal
Reason as in FIR	Nominal
Place	Nominal
Lightning	Binary

Table 4.2. Sample Data set

Road name	Road no	Municipality	fatal	Grievous	Nature
1	1	1	1	0	1
2	1	2	0	1	2
2	1	2	1	1	3
3	2	1	0	1	1

Categorization of accident locations

K-means clustering technique was applied on the accident data to get three clusters based on the accident locations. The clusters are renamed as the Area under city, Area beyond city limit and Area under Highways. There are 52 locations where accidents happened in Coimbatore.

Association rule mining

Apriori algorithm is used to generate the rules. To find the strong association rules minimum support of 5% is set. Association rules provide the correlation between the different attributes when an accident happens. Based on the lift value the interesting rules have been chosen in this paper. The rules for various clusters are discussed below:

Association rules for Cluster 1

The association rules of Cluster 1 shows that most of the accidents that happened in these locations are mainly due to over speed and careless driving. These locations are highly sensitive to Hit and Run. Most of the accidents happened here led to injuries & some led to property damage. If the nature of the accident is RTA then the area comes under the road type CH. Strong rules with high lift value show that the accidents are happening mostly near the junction areas and due to poor lightning and road surface.

Association Rules for Cluster 2

The association rules of Cluster 2 show that most of the accident happened in these locations are mainly due to self accident. Most of the accidents happened in these locations are due to negligence and some are due to the intersection road feature. The accidents that happened in these areas belong to the road type SH. When compared to Cluster 1, the fatal and injury levels are less in this cluster. Most of the vehicles involved in the accidents have crossed the minimum speed limit.

Association Rules for Cluster 3

The association rules of Cluster 3 show that most of the accidents happened in these locations are mainly due to rash driving. Most of the accidents' nature is RTA. Most fatal accidents happen due to rash driving and few self accidents also happened. The rules suggest that highways are more prone to accidents. When compared to the other areas, Cluster 3 areas are more prone to severe fatal accidents. Most of the accidents happened in the highways areas.

The association rules for the various clusters show the factors behind the accident and they reveal the correlation between different attributes. Some of the rules in all clusters are similar to each other. Similar rules such as: if the nature of the accident is RTA and the FIR is Rash, and few other rules are also similar, we come to the conclusion that rash driving leads to fatalities and injuries. If the road lightening is poor, then accident is likely to occur in those locations.

Classification

Naïve Bayes algorithm is used to classify the severity of accidents. The severity of an accident is directly concerned with the victims involved in the accident. Based on the affected victims, the severity level of an accident is classified. To train, the Model 70% of data is taken and to test the model 30% of data is used. Based on the attribute such as Fatal, Grievous, Injury and Damage the class label is created. The class label represents the severity level of the accident happened. Class 0 represents the low severity and class 1 represents the high severity. Naïve Bayes performs well in terms of accuracy when compared with other classification algorithms such as Decision tree J48, Random forest. The outcome of this phase is the severity level of the accidents occurred. In Coimbatore, 40% of accident happened belong to the severity level high and 60% of accident happened belong to the severity level slight. To measure the performance of the classifier, the classification accuracy is computed from the test set.

Prediction

In the proposed system, the Prediction model using fuzzy logic is built in order to predict the probability of accident occurrence in Coimbatore. Fuzzy rule based systems are an extension of classical rule based systems. Fuzzy rules are linguistic IF-THEN constructions that have the general form "IF A, THEN B" where A and B are propositions containing linguistic variables. In effect, the use of linguistic variables and fuzzy IF-THEN rules exploits the tolerance for imprecision and uncertainty. In this respect, fuzzy logic mimics the crucial ability of the human mind to summarize data and focus on decision-relevant information.

A fuzzy rule based system consists of four major modules: fuzzification, inference engine, knowledge base and defuzzification module [18]. The fuzzification module transforms the crisp input(s) into fuzzy values. These values are then processed in fuzzy domain by inference engine based on the knowledge base supplied by the domain expert(s). The knowledge base is composed of the Rule Base (RB), which characterizes the control goals and control policy of the domain expert by a set of linguistic control rules, and of the Data Base (DB), containing the term sets and the membership functions defining their semantics. Finally, the processed output is transformed from fuzzy domain to crisp domain by defuzzification module.

The structure of a rule base can be stated as follows:

R_i : if X_i is A_{i1} ... X_n is Ain then Y is B_j

Where A_{in} and B_j are fuzzy sets defined on the input and output domains respectively. $X_1...X_n$ and Y are input and output linguistic variables, respectively, and A_{i1} ... A_{in} and B_j linguistic labels, each one of them having associated a fuzzy set defining its meaning.

Figure 4.1 represents the yearly distribution of accidents happened in Coimbatore. In the year 2013, 207 accidents occurred, in the year 2014, 229 accidents occurred and in the year 2015, 218 accidents occurred.

Figure 4.2 represents the monthly distribution of accidents happened in the various clusters.

Figure 4.3 represents the rate of accidents that occurred in the various locations of Coimbatore.

Figure 4.4, Figure 4.5 and Figure 4.6 represent the comparison of performance metrics of different classification algorithms.

Figure 4.7 and Figure 4.8 represent the comparison of the Prediction results and Location wise prediction results respectively.
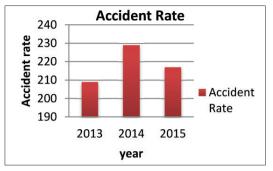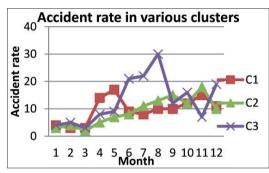
Figure 4.1. *Yearly Distribution of Accident rate*
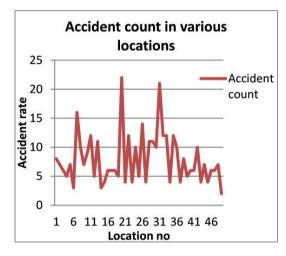

Figure 4.2. *Month wise Accident rate in various clusters*

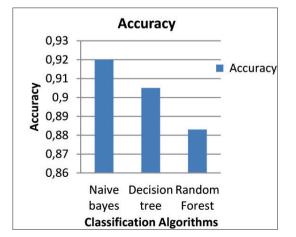**Figure 4.3.** *Location wise accident rate*

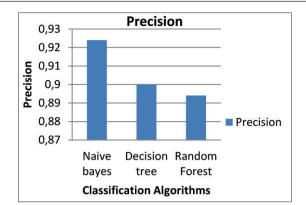**Figure 4.4.** *Performance Evaluation of Classifier in terms of accuracy*

Figure 4.5. *Performance Evaluation of Classifier in terms of Precision*

Figure 4.6. *Performance Evaluation of Classifier in terms of Recall*

Figure 4.7. *Comparison of prediction results*

Figure 4.8. *Location wise prediction results*

Conclusion And Future Work

In this paper, traffic accident data of Coimbatore is collected and cleaned in order to use it to test the predictive model. The endeavour of this paper is to spot the factors behind an accident and severity

of accidents. The assessment of the Classification model showed that Naive Bayes algorithm outperforms with an accuracy of 92.45 % when compared with other algorithms. In contrast with the previously published work of authors, which focused on driver characteristics and dietary habits, this paper focused on the contribution of various road-related factors such as the role of environment, place where the accident occurred and cause of the accident that have impact on the accident severity. The results of this study could be used by the respective authorities to promote road safety and create awareness about risk factors. Thus, this work could have tremendous impact on the well-being of Coimbatore civilians and a predictive model is constructed in order to predict the probability of accident occurrence which helps the Coimbatore civilians to have awareness about the accident prone zones in advance.

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The Application Of Online Platforms In Open Innovation

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Abstract: It is well known that innovation has been recognized as a crucial success factor for companies. The development of information technologies enabled integration of innovators (suppliers, customers, institutes) into innovation process by the use of IT-based tools. This facilitated the access to a large pool of ideas that can grow into innovation as new product/service, process. The connection of open innovation concept and information systems resulted in platforms for open innovation that enabled easier access, not only to customers, but also to other potential participants, who are willing to independently contribute in solving the specific problems of the company. Having in mind the importance of this contemporary approach, the main goal of the paper is the systematization of platforms for open innovation. Moreover, we presented platform classification, key elements of existed platforms design, as well as various examples of best practice of platforms for open innovation with recognized design elements.

Keywords: Open innovation, Innovation platforms, Customer involvement.

Introduction

Nowadays users have admission to a wide range of products and services, accordingly, companies are forced to find new ways to create and maintain competitive advantage. Cooperation with partners, even competitors, which have become a strategic imperative, has been used as one of the ways to solve this problem. Researchers in the field of strategy and marketing are increasingly focusing on cooperation with users in order to co-create the value. Collaboration with users can be realized in different parts of the business process, but one of the most important is the one which results in the value creation in the form of innovation [18].

The innovation process has changed significantly in the last decades and continues to change. It used to mean that companies are creating innovations by carrying out research activities within the company, solely with available resources - the principle of closed innovation ("not invented here"). With the development of industry, there are new factors that influence the changes in the innovation process, such as increased mobility of employees, increased quality and importance of university research, availability of different research, and the growth of venture capital investment [6]. The impact of these factors led to a change in the logic of existing models of innovation, which resulted in the emergence of a new model known as the open innovation model. Open innovation involves the use of both internal and external ideas, in terms of inputs for the innovation process, as well as the use of internal and external pathways for placement on the market. Thus, companies open their traditional internal innovation processes by including suppliers, users and other external relations [7][20].

Open innovation is of strategic importance to both large companies and SMEs [21], and represents

a very important issue for higher levels of management [9]. Hence, companies are increasingly experimenting with the introduction of new approaches that involve inclusion of a large number of different external participants and cooperation, aiming at information and knowledge exchange [8]. The open innovation model was built on the premise of expanding the network of companies and collecting new knowledge needed to create new products, services. The main driver of openness and involvement of users in the process of new product development is the development of technology, primarily internet and new web 2.0 tools. Online collaborations stimulate the development of new ideas and approaches that can lead to completely new solutions [2].

Over the past few years, there has been an increase in the number of online open innovation platforms, also known as collective intelligence systems [14]. The main reason is fast technological changes and the expansion of application fields of open innovation [19]. Moreover, internet enabled larger groups of users to access information that was previously exclusively available to companies themselves, as well as the ability to share their achievements with others. For manufacturers, internet technology allowed direct interaction with its customers, overcoming mediation through traders or organizations dealing with market research [17].

DEFINING OPEN INNOVATION PLATFORMS

The literature recognizes two overlapping streams in the field of open innovation [13]. The focus of the first stream, represented by Henry Chesbrough, is based on chances and opportunities such as: the acquisition of external experts and intellectual property rights, the achievement of strategic advantages, as well as many other ways to overcome the problems arising from the "not invented here" syndrome. The second stream, represented by Eric von Hippel, takes into consideration user and tool perspective. This stream is based on users' motivation to voluntarily contribute to the defined problem; the identification and the attraction of the appropriate participants; and the ways to design tools for open innovation.

Both of the aforementioned streams can be integrated into one approach known as a platform for open innovation. All types of open innovation

platforms, that is, IT-based tools for open innovation, share a common topical (Open innovation) and technical (Platform) foundation.

From the topical perspective, the open innovation platforms include IT-based tools that facilitate the application of open innovation. They enable the inclusion of potential participants, so-called innovators, into the innovation process. In accordance with the definition presented by Neyer et al. (2009), innovators can be internal (employees of R&D department), peripherals (other employees in the organization) and external (users, suppliers, experts). Open innovation platforms are based on voluntary participation of these three types of innovators, who can take part in different stages of the innovation process defined by the organizer, primarily in the search, selection and implementation of ideas.

The first step is to collect existing or new suggestions. The goal is to collect as many creative solutions as possible. The proposed solutions can be presented as short descriptions but, also, as solutions that can be implemented as such [1].

Next step is selection of the appropriate solution which can be done both by the experts and the community [4]. A typical approach to assessment in which community participates is done by using mechanisms (1) *summation* - number of votes for a solution; (2) *averaging* - using different scales (e.g. Likert's scale) (the platform of Threadless.com); (3) *consensus* - using qualitative estimates, that is, comments (for example, Osram LED - Emotionalize Your Light). Platforms that use a combination of previous mechanisms can also be found [11].

Finally, implementation is carried out. It involves transforming accepted solutions into products or services and their launching on the market. The pathway from suggestions to a final product or service can be expensive, so in practice companies often create prototypes before final implementation. In context of open innovation, prototypes are partly being created by the innovators [5].

From a technical point of view, the open innovation platforms represent a virtual environment that serves as an information exchange infrastructure. Most of them are in the form of a web platform with an interface to interact with users. Platforms provide interaction regardless of time or location constraints. Aiming at proper platform functioning, it is

necessary to provide appropriate hardware (servers), software (source code of a platform or web server) and services (internet connection). In accordance with the previous, open innovation platform can be defined as virtual environment that provides digital service, with the intention of creating innovations, enabling incentives to innovators in terms of time and location independence.

In the broadest sense, platforms for open innovation are the socio-technical systems that consist of social and technical subsystem. These two subsystems convert the input to the corresponding output within the environment in which the platform operates (Figure 1).
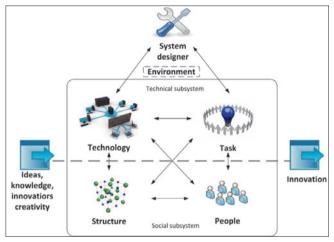

Figure 1. *Open innovation platform design*

The purpose of the technical subsystem (technology and task) is to define the challenges to be solved and how these challenges will be solved. The social subsystem implies people who participate and their structure, namely necessary knowledge, skills, reward system and structure of authority [13].

Types Of Open Innovation Platforms

There are different IT-based tools used for open innovation. According to Moeslein and Neyer (2009), there are five classes: *Innovation competitions*, *Innovation communities*, *Innovation market places*, *Innovation toolkits* and *Innovation technologies*. This classification does not imply that classes exclude each other. Quite the opposite, there is often overlapping, namely, one platform can permeate different classes [13].

Innovation contests

Innovation contests in their basic structure have a long tradition and have influenced the development of both industry and society. Back in 1896, Napoleon III Bonaparte offered a reward for the one who invent the appropriate substitute for butter, in a way that it could be used by soldiers. In recent decades, this form of contest has become an integral part of modern business. One of the early examples of this kind of business was organized by the Fredkin Prize for Computer Chess 1997, which awarded a $100,000 prize to the one who makes a computer program that would be able to defeat Gary Kasparov - chess grandmaster at the time [3][13].

The application of innovation contests is experiencing an upswing with the development of information technologies, primarily internet, which enabled online competitions. Nowadays, high speed internet flow allows individuals, companies, public companies, and non-governmental organizations to organize this form of contests [17]. The contest starts when the organizer posts an open challenge/problem on the platform. Participants then develop and submit their contributions for a predetermined period. After that, a group of experts or other innovators makes an evaluation of the contributions. Evaluation results are used to determine the winning idea, which receives the award [12]. Thus, the focus of the innovation contest is reflected in the competitive challenges, moreover, in the opportunity to generate a large number of innovative ideas.

An example of this platform is Aufbruch Bayern, organized by the Government of Bavaria, with the aim of identifying the most innovative solutions for families, education and technological innovations. Citizens are asked to suggest ideas, existing projects, and best practices. The best suggestions have been implemented. A similar idea can also be found in the Go London Social Innovation Competition platform, where ideas are proposed on the question of how to increase the physical activity of London residents [3].

Innovation communities

Unlike the competitive approach to the innovation contest, the innovation community is gathering their members in order to jointly create innovation. Although innovation communities differ in structure, thematic focus and scope of social connections,

they are mostly based on common enthusiasm and knowledge related to a particular domain. Community members discuss new ideas for products and services, that is, on how to improve them. The interest in being a member of a community depends on the very characteristics of the community, such as language, netiquette, norms and individual motivation. Furthermore, communities can implement the characteristics of an innovation competition by setting challenges within the community. In that case, the challenge carries a smaller reward or even no reward, so as not to disturb the spirit of cooperation among community members [13].

Members of the online community can participate in all stages of an innovation project, from ideation, through prototyping to the development of a final solution. An example of including the online community in the innovation process is Audi and the development of the Audi Infotainment system. These systems represent the integration of modern communication technologies and entertainment in the domain of audio, video, navigation, telematics and user interfaces into the infotainment system of cars. Audi is a well-known automobile manufacturing company that gathers its fans and enthusiasts in the form of social communities around its brand. The company has a great community brand and organizes virtual meetings that everyone can access through the company's official website, non-commercial websites such as Audi clubs, forums, and other virtual communities dedicated to car enthusiasts [10].

Innovation market place

The innovation market place provides the opportunity to set the challenge for which innovators can give their solution proposals, or vice versa, innovators are setting up solutions to certain problems with the goal of finding someone who needs this solution. In this case, the innovation platform is the mediator between the organizer, who posts the challenges on the platform, and the community (innovators) that provides solutions to defined challenges. The organizer guarantees the innovator that he will pay the prize. The intermediary (platform), also, takes a percentage. The innovation market place ensures generating innovation by combining existing knowledge or approach (innovators) with

new areas of application (organizer challenges). A single project, within the innovation market, can be seen as an innovation contest [13].

The InnoCentive platform is one of the most renowned innovation market places, which serves as an outsourcer of scientific and technological solutions. The concept is very simple and clear. It is presented as a virtual innovation network for cooperation between companies, research organizations, university labs and free scientists. Companies that seek solutions to a particular problem post a challenge for which they are willing to give a certain prize. InnoCentive has the role of a broker that facilitates cooperation; defines intellectual property rights arising from cooperation; and guarantees the payment of the prize. A platform of this type should provide co-operation between party that can be called a seeker, and on the other hand, party that can be called the solver. Currently, there are over 380,000 registered inventors from over 200 different countries and over 2 thousand challenges. The prizes range from 0 to 1 million dollars (https://www.innocentive.com/).

Innovation toolkits

The innovation toolkit provides a virtual environment with limited space in which innovators can create innovative solutions for the defined process. By setting a limited space for the solution, the feasibility of the solution is ensured, bearing in mind that innovators, in this case, do not need to have specific knowledge in the field. On the one hand, the innovation toolkit limits the creativity of the innovator by setting a boundary, while, on the other hand, encourages creativity by giving the impulse in the direction where the contribution is expected [13]. The innovation toolkit helps the knowledge transfer that the innovators possess. The contributions given by innovators can be also considered as prototypes. Therefore, the search for ideas and their implementation is the main focus of this type of platform. A good example for these platforms is the Miadidas platform, which allows users to design customized snickers.

Innovation technologies

Innovation technology platforms represent a specific platform that enables the implementation

of ideas. They represent a platform or interface for transferring certain designs to rapid prototyping devices, such as 3D printers, 3D scanners, or lasers. Innovators are able to generate tangible prototypes from their crafted design. These prototypes have multiple uses in the innovation process. Compared to the innovation toolkit, the specifics and results of innovation technology go one step further, bearing in mind that virtual prototypes are transformed into the physical by using innovation technologies. Therefore, the main focus of these platforms is implementation. Good examples of these platforms are: Ponoko, which offers the ability to create and distribute a customized design using a configurator; eMachineShop for producing metal prototypes from CAD data; ShapeWays for the production of prototypes using different materials [5].

DESIGN ELEMENTS AND ATTRIBUTES OF OPEN INNOVATION PLATFORMS

With the advent of internet technology, new concepts of communication and user interaction have developed, such as forums, blogs, wiki, social networks. This group also covers innovation platforms that enable a wide range of applications. As already mentioned in the text, different types of platforms can be identified. Accordingly, different attributes and design elements can be recognized, with even more diverse characteristics and values that they can obtain.

Malone et al. (2010) have identified the basic elements or genomes, which can be used to describe the online platform dedicated to collective intelligence (innovation platform). For the classification of these elements, four questions are used: *What is being done? Who is doing it? Why are they doing it? and How is it being done?*. Consequently, to build a system of collective intelligence that should meet the expectations of the organizers, managers must ask these questions and give answers to them.

Question What? The first question to be answered is *What is being done?* In traditional organizations, the answer to this question is grounded on a mission or goal of the organization. In the case of innovation platforms, the answer to this question comprises two basic elements: *Create* and *Decide*. Participants in the process create a new solu-

tion (part of the software, a new design for a T-shirt, new taste), but also evaluate and select alternatives (decide whether to install a new module in Linux; choose the best design that will be printed on the T-shirt). By identifying the underlying goal it is determined which of these two basic elements should be started and mainly, in order to perform the work it is necessary to select at least one. The *Create* element almost always requires a *Decide* element to determine which of the created alternatives should be selected. A *Decide* element usually requires a *Create* item in order to generate the choices being considered.

Question Who? The next question is *Who is doing it?*. In this case, two basic elements are set: *Hierarchy* and *Crowd*. In a traditional hierarchical organization, the answer to this problem is answered when someone in authority delegates to employees or group of employees to perform a specific task. The *Crowd* element implies that the activity can be performed by anyone in the group. At the beginning, the crowd was used only for voting when choosing an alternative. Now everyone can submit a new article or update existing ones on Wikipedia. Anyone can suggest a new design that will be printed on the T-shirts, or participate in a voting for the best design (Threadless).

The main reason for using a *Crowd* element is to involve more people in the process. This means that the *Crowd* is useful in situations where (1) many people have the skills necessary to perform certain activities or (2) we do not know in advance who possesses the appropriate resources and skills. On the InnoCentive platform, companies often find people who will solve a particular problem with a reward for which the company has no solution. When the conditions for using the *Crowd* are not met, the *Hierarchy* is used. In cases where only a few people have the appropriate skills and when they know who these people are, they are simply assigned to execute these activities.

Question Why? This question is closely related to the question *Who?*. Also, closely related questions are *Why do people participate in activities? What motivates them to participate? What are the incentives?* This element includes a number of possible elements that can encourage people to participate in collective intelligence systems. Some of them

Table 1. Attributes of open innovation platforms

QUESTION [13]	DESIGN ELEMENTS [3]	ATTRIBUTES [3]						
What?	Issue specification: solution space for contribution	Low (L) (open topic)		Defined (D)			High (H) (specific topic)	
	Degree of elaboration: required level of contribution	Idea (I)	Sketch (S)	Concept (C)	Prototype (P)	Solution (S)	Evolving (E)	Mixed (M)
Who?	Media	Online (On)		Mixed (M)		Offline (Of)		
	Target group: description of participants	Specified (S)			Unspecified (US)			
	Organizer: platform operator	Company (C)		Public organization (PO)		Non-profit organization (NpO)		Individual (I)
	Participation: number of persons participating	Individual (I)		Team (T)		Both (B)		
Why?	Motivation: incentives for participation	Monetary (Mo)		Non-monetary (NM)		Mixed (M)		
How?	Runtime: task duration	Very short (VS)		Short (S)	Long (L)		Very long (VL)	
	Tool for interaction	Innovation contest (IC)	Innovation community (ICm)	Innovation market place (IMP)		Innovation toolkit (IT)	Mixed (M)	
	Evaluation: method for contribution ranking	Jury Evaluation (JE)		Peer review (PR)	Self-assessment (SA)		Mixed (M)	

are *Money, Love, Glory*. Lately, most of the organizations rely on *Love* and *Glory* as motivational factors in comparison with traditional companies that rely mainly on *Money*.

Question How? The last element concerns the question *How is something done?*. In traditional organizations, the answer to this question is given by defining the organizational structure and process. The key determinant of the answer to this question is whether members of the crowd give their contributions and decisions independently or are they strictly related. Based on this connection, four elements are defined: *Collection, Collaboration, Individual Decision* and *Group Decision*. The first two elements are related to the *Create* item from the *What?*, while the other two are linked to the *Decide* element. Question *How?* is connected to the type of innovation platforms.

Unlike the previous approach to defining design elements by responding to the defined questions that Malone et al. (2010) recognized, Bullinger and Moeslein (2010) identified a framework of ten design elements, that is, attributes that characterize innovation platforms (Table 1).

Table 1 demonstrates the attributes specific to innovation platforms associated with design elements, identified in the work of Malone et al. (2010).

ANALYSIS OF SELECTED INNOVATION PLATFORMS BY IDENTIFIED ATTRIBUTES

For the analysis of different cases of open innovation platforms we selected some of the previously identified attributes. Each table field contains one or more values of the design elements/attribute, obtained from the set of values that a certain attribute can take (values in Table 1).

Table 2. An overview of different open innovation platforms based on design elements

Innovation platforms	Design elements/attributes:									
	Media	Tool for interaction	Evaluation	Issue specification	Degree of elaboration	Target group	Organizer	Participation	Motivation	Runtime
InnoCentive	On	IMP, IC	JE	L	M	S,US	C, PO, NpO	I, T	M	S, L
Yet2.com	On	IMP, IC	JE	L	M	S,US	C, PO, NpO	I, T	M	S, L
P&G - C + D	On	IC	JE	D	M	S,US	C	I, T	M	L
Dell - IdeaStorm	On	ICm	M	D	M	S	C	I, T	NM	L
Ninesigma	On	IMP, IC	JE	L	M	S,US	C, PO, NpO	I, T	M	S, L
Quirky	On	IC	M	D	I, S, C	S,US	C	I, T	M	L
MyStarbucks Idea	On	ICm	M	D	M	S,US	C	I, T	NM	L
Miadidas	On	IT	SA	D	I	S	C	I	NM	L
Lego Idea	On	IT, ICm	JE	L	I, S, C	S	C	I, T	M, NM	L
BMW's Co-Creation Lab	On	IC, ICm	JE	D	I, S, C	S	C	I, T	M	S, L
Go London Social Innovation Competition	On	IC	M	D	I	S	PO	I, T	M, NM	S, L
Doritos: Crash the Superbowl	On	IC	M	D	I	US	C	I, T	M	S, L
Shell GameChanger	On	IC, ICm	JE	D	I	S,US	C	I, T	M	L

It is very important to carry out such analysis of innovation platform cases both from the aspect of the organizer and from the aspect of the innovator (participant). From the organizers perspective, the analysis can serve as a foundation for good/bad examples that can be implemented in the same or similar way. The database (knowledge base) provides the opportunity to recognize the right elements of design in different cases, the type of innovation platform, the need for engaging mediators (innovation market place), the scope of stages from the innovation process in which innovators can engage, how innovators are motivated, and many other issues which can contribute to the success of one platform implementation. From the aspect of the innovator, it is also important to recognize the elements of the design, primarily the type of platform and the motivation elements.

It has to be acknowledged that this overview has limitations and that it does not explain the entire space for participation and collaboration related to open innovation. It is focused only on freely accessible online open innovation platforms. Wider view would add notably more aspects and potential attributes to be considered which would be difficult to handle in a single article.

Conclusion

With the development of information technologies, opportunities for developing open innovation platforms are growing. The number of collective intelligence cases is likely to grow in the future. In order to fully define the platforms, a lot of effort is required toward identification of all the elements that can be an integral part of the design of innovation platforms, the conditions in which they are useful, and the constraints in which these elements can be combined. For now, there is no well-defined framework that can guarantee success, but what can be found in literature and practice can serve as a good starting point. Having this in mind, the paper presents some of the design elements proposed by different authors, and different cases of the platforms for open innovation that apply recognized elements. The proposed systematization of

a number of platforms can significantly contribute to the future organizers in terms of the best practice, as well as the participants (innovators), to better understand on which platforms they could take part.

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IMPLEMENTATION OF FOG COMPUTING IN IOT-BASED HEALTHCARE SYSTEM

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Abstract: INowhere do the technology advancements bring improvements than in the healthcare sector, constantly creating new healthcare applications and systems which completely revolutionize the healthcare domain. The appearance of Internet of Things (IoT) based healthcare systems has immensely improved quality and delivery of care, and significantly reduced the costs. At the same time, these systems generate the enormous amount of health-associated data which has to be properly gathered, analyzed and shared. The smart devices, as the components of IoT-driven healthcare systems, are not able to deal with IoT-produced data, neither data posting to the Cloud is the appropriate solution. To overcome smart devices' and Cloud's limitations the new paradigm, known as Fog computing, has appeared, where an additional layer processes the data and sends the results to the Cloud. Despite numerous benefits Fog computing brings into IoT-based environments, the privacy and security issues remain the main challenge for its implementation. The reasons for integrating the IoT-based healthcare system and Fog computing, benefits and challenges, as well as the proposition of simple low-cost system are presented in this paper.

Keywords: Fog computing, Cloud computing, healthcare, Raspberry Pi.

INTRODUCTION

The explosion of advances in Information and Communication Technologies (ICTs) has completely revolutionized the healthcare sector. The evolution of the Internet of Things (IoT) defined as an ecosystem of smart devices in which applications and services are driven by sensed, collected and exchanged information between devices, as well as with the environment, with or without human intervention, makes it highly prominent in the healthcare sector. The incorporation of the IoT into healthcare sector contributes to immense improvements in healthcare by radically changing the way of healthcare delivery, driving better outcomes, increasing efficiency, and making healthcare affordable, acceptable, and available to anyone and anywhere at any time [31].

The IoT-based healthcare system appears as an adequate approach to ensure the appropriate (effec-tive and proactive) healthcare delivery based on parameters monitoring and useful medical knowledge obtained on the gathered and analyzed health-related data [9, 19]. Its omnipresence in peoples' lives has resulted in the increasing number of diverse, smart medical devices and sensors, which more than ever before generate and transmit data. On a daily basis, these devices and sensors generate a prodigious amount of health-related data. There are estimates that healthcare data produced by IoT-based systems will be 25000 petabytes in 2020 [14]. Managing this data, collecting, analyzing, interpreting, and sharing is quite challenging.

Putting escalating volumes of rapidly growing, and mostly unstructured health-associated data to the Cloud and transmitting response data back requires a larger bandwidth, a considerable amount of time and can suffer from latency issues. This is not

tolerable in time-sensitive and emergency response applications, such as healthcare. Scientific efforts to deal with these challenges have resulted in the realization of Fog computing vision. Fog computing creates an additional layer of computing power between the devices and the Cloud. Fog infrastructure enables splitting big data to sub data, and managing smaller and time-sensitive data at miniature data analysis centers. In this way, decentralized and intelligent processing closer to where the data originates, without the need to send every piece of information to the Cloud, is realized, what frees up time and storage space in the Cloud [7]. This approach is far better when dealing with the requirements of IoT communication framework in healthcare applications.

This paper represents a study of the importance, opportunities, benefits and challenges of Fog computing and the IoT-based healthcare system integration. The rest of the paper is structured as follows: the fundamentals of IoT-based healthcare systems are discussed in the second section, while the third section emphasizes the main principles of Fog computing as well as the justification of its implementation in an IoT-driven healthcare system. The way of creating a simple IoT-powered, low-cost healthcare system based on Fog computing principles is proposed in the fourth section, while section five discusses privacy and security issues in Fog computing paradigm. The last section contains concluding remarks.

THE IoT-BASED HEALTHCARE SYSTEM

The proliferation and widespread adoption of new technologies, particularly IoT and smart devices, have created new ways of healthcare delivery, thus improving human health and well-being. The powering healthcare systems with the IoT vision lead to numerous advantages, such as the availability and accessibility, an ability to provide a more "personalized" system, and high-quality cost-effective healthcare [21]. Hence, IoT is considered as promising solutions for the healthcare sector, since it places the patient in the center of the treatment process, enables self-managing their own disease, gives health professionals faster and secure access to all information they need to care for the patient, enables remote care and assistance through associated networked-monitoring equipment [2].

To realize the IoT-based healthcare system, following elements are essential: a variety of sensors (consumer-based, wearable devices, internally embedded devices and stationary devices), microcontrollers, microprocessors, healthcare-specific gateways and the Cloud [25]. In other words, there is a three-layer architecture of IoT-powered healthcare system that consists of:

- Sensing/perception layer which main functions are sensing and collecting data as well as some communications and controlling actions.
- Network layer which is responsible for communication, connectivity, routing, etc.
- Application layer made of functional modules for application systems and users. At this level the sensed and collected data is being used for analysis, computations, visualizations, etc.

In other words, the IoT-driven e-health solution enables [21]:

- Sensing and collecting patient health-related data from a diversity of sensors in remote, secure, and safe manners.
- The appliance of a variety of data mining techniques and algorithms in order to discover hidden patterns and detect any anomalies, and based on obtained valuable knowledge make predictions and actionable decisions.
- Sharing the data through wireless connectivity with those who can make adequate and timely feedback.

An increasing number of smart medical devices and sensors used in IoT-driven healthcare vision implies the fast generation of large amounts of diverse data. In order to successfully deal with growing amounts of great variety of data and high speed of data generation and processing it is necessary to deal with technical and security issues [16]. From the technical perspective, the sensor and smart devices used in IoT-driven healthcare system for monitoring patients' current healthcare status have limited computation and storage capabilities, and hence they are not able to deal with the large amount of fast generated diverse medical data [2]. Posting these data to the Cloud for processing and storage and transmitting response data back also is not the right solutions, because it requires a larger bandwidth, a considerable amount of time and can suf-

fer from latency issues. Regarding privacy and security issues, all data related to a patient's health and medical history are especially sensitive and need to be protected in the appropriate way [21]. Having in mind the estimations regarding an astonishing number of IoT smart devices that will be in operation in the following period and expected data traffic [8], as well as security and privacy requirements, it is obvious that Cloud is not capable of dealing with these challenges. The solution for faster computing and connectivity is seen in the realization of an additional layer, which will be placed between end devices and Cloud (Fig. 1). This layer refers to Fog computing and based on its advantages has a potential to revolutionize various domains, especially time sensitive such as healthcare.

However, Fog infrastructure will show its full potential only by successfully overcoming numerous challenges for its implementation [11].

Figure 1. *The role of computing layers in an IoT system [12]*

Fog computing in IoT-based healthcare system

Fog computing is a novel trend in computing established by Cisco [5] that extends the Cloud computing paradigm at the edge of the network, processing data near data source (Fig. 1). Enabling data analytics and knowledge generation to occur at the data source, Fog computing significantly decreases the data volume that must be moved between end devices and Cloud [22].

While in Cloud computing, data and applications are processed in Cloud, which is a time-consuming task for voluminous data, Fog computing operating on the edge of network consume considerably less time. Furthermore, sending the large quantities of high-velocity and high-variety of IoT-generated data to the Cloud creates problems regarding bandwidth

issues. High latency and scalability problems caused by servers' remote locations are additional drawbacks of Cloud computing [4]. The main differences between Fog and Cloud computing are presented in Table 1.

However, it is necessary to keep in mind that Fog computing is not a replacement for Cloud computing. Instead, Fog computing is the solution to Cloud's limitations. Reducing amounts of data and its movement across the network, and performing processing at the edge of the network, Fog infrastructure reduces congestion, eliminates bottlenecks, and enhances security [27].

These benefits make the Fog computing far more beneficial for many applications as compared to the Cloud, especially for [6, 17, 23]:

- Applications that require very low and predictable latency like health-monitoring and various emergency response applications;
- Geographically distributed sensor/actuator networks - applications in which thousands or millions of things across a large geographic area are generating data (e.g. smart cities, environmental monitoring);
- Fast mobile applications such as smart connected vehicle or connected rail; and
- Large-scale distributed control systems (e.g. smart grid).

The IoT applications which generate large volumes of data, produced by diverse IoT devices and generated at high speed, especially benefit from Fog computing. In IoT-powered healthcare applications, real-time processing and event response are crucial. Fog computing enables real-time and online analytic even when connectivity is poor or lost with the Cloud, and implies less congestion and faster real-time interaction and optimizations for IoT devices what makes it perfect for utilization in IoT-based healthcare systems. With supported heterogeneity, improved interoperability, and enhanced privacy issues, IoT-based healthcare system using Fog computing has potential to become reliable, simpler, scalable, and exceptionally high performance than ever before.

Table 1. Fog computing vs. Cloud computing [4, 15]

Requirement	Fog computing	Cloud computing
Hardware	Limited storage/compute resources	Scalable storage/compute resources
Data storage	Temporary	Permanent
Latency	Low	High
Delay jitter	Very Low	High
Bandwidth	Low	High
Response time	Seconds to minute	Minutes, days or weeks
Location of server nodes	At the edge of local network	Within the Internet
Distance between client and server	One hop	Multiple hops
Security	Can be defined	Undefined
Attack on data *enroute*	Very low probability	High probability
Location awareness	Yes	No
Geo-distribution	Distributed	Centralized
Number of server nodes	Very large	Few
Support for Mobility	Supported	Limited
Flexibility	High	Limited
Agility	High	Limited
Type of last mile connectivity	Wireless	Leased line

The major benefits of IoT-powered healthcare system where Fog computing principles are implemented can be summarized as follows:

- Enhanced quality of care based on accurate and on-time diagnoses and treatments, and decreased incidence of medical mistakes.
- Convenient, efficient, patient-tailored, and cost-effective healthcare delivery accompanied with more satisfied patients' and healthcare providers' experience.
- Improved preventive care and monitoring and treatments of rural residents' health conditions through online healthcare services.
- Saving time and reducing costs together with improved efficiency and coordination.

The development of a simple, low-cost IoT-based healthcare system using Fog computing

The success of Fog computing is based on the implemented Fog devices that must be capable to perform successful processing at the very early stage. In other words, Fog devices must be able to deal successfully with fast generated voluminous data, and to filter and transmit the important data to the Cloud. There is a variety of Fog nodes, with various hardware and software capabilities. In order to present the creation of a simple, low-cost IoT-based healthcare system that uses Fog computing (Fig. 2), the Raspberry Pi (RPi) is chosen as a key building element based on its performances: small, cheap, powerful, and fully customizable. RPi is a programmable small computer board, which has built-in support for a large number of input and output peripherals and network communication [19]. Some of its 26-pins GPIO (General Purpose Input and Output) port can be used as digital input/output signals and can be programmed directly on RPi through high-level programming languages (e.g. C++, Python, and Java.), while others can be used as interfaces for embedded protocols for controlling a set of electronic circuit (sensors, analog to digital converters (ADC), relay, status button, etc.). Hence, the GPIO port represents the main way of connecting RPi with other electronic boards as well as the communication link with other computing devices using a variety of different protocols, including Serial Peripheral Interface (SPI) and Inter-Integrated Circuit (I^2C) [19, 20]. To measure the patient's vital parameters, three sensors were chosen in the realization of custom IoT-based healthcare solution [20]:

- Temperature sensor (TTC05) – detection of body temperature and its changes;
- Heart rate sensor (Pulse sensor module) – detection of body's heart rate or pulse; and
- Blood pressure sensor (US9111) – used to detect blood pressure.

Electronic circuit scheme of Raspberry Pi as a sensing unit for measuring vital parameters and details about delivering measurement information complying IoT ideology is presented in previous works [19, 20].

However, compared to previous manners of realization, instead of sending all raw data to the Cloud, RPi can be used as a sink node (Fog node). Collected medical data (temperature, heart rate, and blood pressure) from the RPi (Fog node) are sent to the gateway (Fog server) for processing and storage. In other words, embedding some of the data mining techniques, fuzzy logic approaches or some other

type of artificial intelligence into the Fog server (e.g. laptop or PC), raw data can be processed intelligently and in real-time without sending it to the Cloud (Fig. 2). It is important to note that, based on its performances, RPi can also serve as a gateway.

In this way, computations are performed only where the data originates, instantly alerting health-care providers in a case of detected abnormal values and enabling faster real-time reaction. By implementing Fog infrastructure, there is no need to post large amounts of measured values of vital parameters to the Cloud because the most of the data processing is done at Fog layer. The aggregated results, in the sense of some kind of analysis over some period (e.g. historic and predictive analysis, machine learning, and virtualized data) can be sent to the Cloud for further processing, knowledge discovering, advanced decision making, and storage, whenever it is permitted by the network conditions. When the data is uploaded to the Cloud, the Fog storage is being released. Hence, Cloud computing layer aggregates data summaries from multiple Fog nodes/servers, performs deeper analysis and based on achieved insights performs rule and pattern updates at the Fog level.

SECURITY AND PRIVACY ISSUES IN FOG COMPUTING

The rapid development of IoT-based health-care systems is followed with the privacy and security risks. Since private data regarding health are especially sensitive, they must be protected in appropriate manners. The necessity of generation, processing, and sharing health-related data with the appropriate level of security and privacy is an important goal that must be accomplished. Therefore, the security and privacy issues of IoT-driven health-care systems

must be threatened on many levels, with security and privacy framework and mechanisms built into the whole health-care ecosystem, from the device, to the network, to the data center, in order to fulfill following aspects of privacy and security [21, 24]:

- Confidentiality – the data is only available to authorized users,
- Data integrity – the data cannot be modified without detection,
- Accountability – the identification of the creator of an event or data is enabled,
- Availability of services, and
- Access control - the functionality and data are only available to authorized users.

Since Fog can be looked as an extension of the cloud, evidently some of the existing security and privacy challenges remain. However, because of Fog computing distinct characteristic (mobility support, location awareness, and low latency), it introduces novel security and privacy challenges, what may influence the Fog computing implementation into the IoT system. From the other side, the Fog computing could offer an ideal platform to deal successfully with many security and privacy issues in the IoT [32]. Fog computing potential to address security and privacy issues in IoT applications is as follows:

- Privacy – Fog nodes at the edge of network usually gather sensitive data generated by sensors and end devices, in health-care applications particularly. Fog computing enables the analyzing and processing data at the edge, and thus minimize the transmission of sensitive data to the Cloud, what contributes to the privacy preservation. Storing data in the Fog layer contributes to better protection of data. In order to protect data privacy, sensitive data
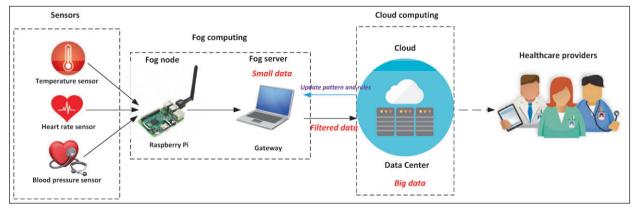

Figure 2. Prototype of Fog-assisted and IoT-based health-care system architecture

from end users have to be encrypted before outsourcing it to the Fog node [32]. There are various privacy-preserving techniques (e.g., differential privacy, homomorphic encryption) that can be applied between the Fog and the Cloud to preserve data privacy [1]. Among data privacy, usage privacy, and location privacy are also important challenges that must be considered and accomplished.

- Authentication – The Fog level holds the potential to enable authentication in IoT devices or appliance of light-weight encryption algorithms between Fog nodes and IoT devices to improve the authentication [1]. The authentication at different levels of Fog nodes is discussed in [29].
- Networking security – Fog nodes, deployed at the edge of network, bring numerous challenges regarding the network management. The solution for overcoming challenges related to the implementation and management, alongside increased network scalability and decreased costs can be found in the employment of SDN (Software Defined Networks). Authors of [32] discuss new challenges and opportunities connected to network security during appliance of SDN techniques in Fog computing: network monitoring and intrusion detection system, traffic isolation and prioritization, network resource access control, and network sharing. However, the Fog vision contributes to necessary security updates of IoT devices [1].
- Attack detection – Fog computing enables the improved detection of unusual behavior or malicious attacks, on both the IoT device and the Cloud sides [1]. Attack detection on the Fog node side can be performed by monitoring and analyzing log file, access control policies and user login data. In this way, Fog nodes are able to identify threats or attacks faster and mitigate them before they are passed through to the system [26]. At the Fog network side, malicious attacks such as denial-of-service (DoS), port scanning, etc. can be detected. Even Fog level holds the potential to monitor the security status of distributed systems in a scalable and trustworthy manner, it is very

challenging to implement attack detection in geo-distributed, large-scale, high-mobility Fog computing environment and at the same time fulfill the low-latency requirement [32].

- Access control – Fog level facilitates the adoption of many standard access control models and creates an opportunity for designing new access control models [24]. A policy-based resource access control in Fog computing, to support secure collaboration and interoperability between heterogeneous resources is presented in [11]. However, the access control design spanning end user-Fog-Cloud, satisfying designing goals and resource constraints is challenging [32].

Despite the numerous benefits of Fog computing implementation in IoT systems, there are numerous challenges that must be considered. Even there are works that discuss privacy and security issues in Fog computing [1, 3, 11, 13, 18, 26, 28-30, 32], these aspects still can be considered as understudied. The development of novel security and privacy mechanism according to the Fog computing paradigm and their implementation will enable Fog computing vision to show its full potential in IoT systems.

CONCLUDING REMARKS

The current IoT solutions, powered by an army of smart devices, cause dramatic changes in every aspect of our lives. Health-care sector did not remain immune to technology advancements. In contrary, the health-care field is seen as the domain where the IoT is able to show its full potential. IoT-driven health-care systems and applications lead to enhanced availability, accessibility, quality, and cost-effective health-care delivery. However, these systems pose numerous challenges regarding data exchange, interoperability, and availability of resources, security and privacy. In order to deal with these challenges, integration of Fog computing and IoT-based health-care systems, appears as the appropriate solution. Fog computing, as the result of a constant need for better, faster and more secure computing, with its features (low latency, low bandwidth, heterogeneity, interoperability, scalability, increased level of security and privacy, real-time processing and actions) is perfect for implementing into IoT-based health-care approaches. The Fog comput-

ing principles are demonstrated in proposed simple, low-cost IoT-based health-care system, where data receiving, sending, and manipulating is done in the localized environment. Applying technology based on IoT and Fog computing in proposed solution makes possible handling and overcoming existing challenges and constraints and significantly contributes to decreasing costs of health-care delivery.

Authorship statement

Author(s) confirms that the above named article is an original work, did not previously published or is currently under consideration for any other publication.

Conflicts of interest

We declare that we have no conflicts of interest

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INFLUENCE OF INFORMATION TECHNOLOGIES ON THE COMPANY'S COMPETITIVE ADVANTAGE ON THE MARKET IN CONDITIONS OF THE GLOBAL CRISIS

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Abstract: In the recent decades, there has been recorded a great expansion in the computing and communication field and all the predictions are pointing to the further technological progress when using information technologies (IT) in the companies' business. The appearance of IT in business offers certain advantages, has an influence on the business quality, cost control and also on achieving and maintaining competitive advantage of companies in conditions of the global crisis. The research was carried out on the teritory of Republika Srpska, on the sample of 136 small and medium enterprises. The key goal of this research work was to analyze the existing effects of IT at the level of competitive advantage of companies on the market in the global crisis conditions. The research results confirmed a big importance of IT in the company business for the purpose of achieving and maintaining competitive advantage on the market in conditions of the global crisis.

Keywords: information technologies, competitive advantage, market, global crisis.

INTRODUCTION

Information technologies have a very important role in developing innovations in the company, both in big corporations and micro, small and medium enterprises, and therefore, they facilitate the growth and development of organizations of this century. Modern way of life demands from managers of business organizations to improve themselves constantly and to introduce innovations in the managing process. Nowadays, one of the key elements for achieving it is the application of IT.

In the last twenty years, information technologies have found their place in all segments of business life and therefore have become an inevitable part of the modern society. By development of IT and structural reform, small and medium enterprises have been encouraged to introduce new technologies in their business.

Apart from the uncertainty in business, when the market is more and more globalized and highly competitive, the thing which is characteristic for this century, among other factors, is that organizations are making significant changes in business strategies, in order to harmonize them with demands of the new competitive environment [14].

Modern information technologies are constantly getting more and more important, while they are also causing changes in the way of managing companies, as well as in their competitive advantage in the global crisis conditions. The appearance of electronic business defines the role of certain companies on the market, but it also offers some advantages and benefits. The application of IT has an influence on

more efficient business, more successful information flow, cost control, as well as on the competitive advantage of companies on the market [15].

Improving old and introducing new information technologies in the company business represents a crucial role in achieving competitive advantage of companies on the market in conditions of the global crisis.

Market globalization, availability of acess to competitive enterprises and great dynamism of the market created a space for introducing new technologies in the company.

One of the key elements of survival and competitive advantage of companies on the market in conditions of the global crisis is the application of IT. Modern business, in time of great expansions, would be almost unimaginable without using modern technologies. In order to increase the level of competitiveness and business quality and to make the operation more efficient, operative, successful and according to the global criteria and standards, the companies are resorting to using IT on a daily level [21].

Competitive Advantage of the Company

The conditions in which the companies operate today are very different from the ones that were present some years ago. Nowadays, the business environment is uncertain and turbulent, so the companies are constantly exposed to sudden, unexpected and unpredictable changes. Only the most successful companies can survive these everyday changes, because it is necessary for an enterprise to permanently respond to the demands of the fastidious market in order to survive and this could only be achieved by constantly improving all business activities [11].

Successful companies are extremely innovative, technologically advanced and adaptable in every sense. In order to achieve that, it is necessary for them to possess valuable resources and their own abilities which enable them to perform business activities better than the competition. The competitive advantage of companies is at the heart of their business on competitive markets and it is the only guarantee of their future operation and survival in the global environment. In the time of quick changes, many companies are losing the race for a competitive position on the market. That is why it is necessary to create and maintain (develop and apply) the appropriate strategies in companies and every one of them should be based on building and maintaining competitive advantage which is very important for the company, so managers are creating it by using different business strategies.

The goal of every company is to provide above-average profit, constant growth and development, as well as to achieve and maintain the advantage over competitors. The competitive environment has a direct influence on business results and on abilities for development, survival and growth of the company. It includes constant confrontation of companies with the situation on the market [1]. The environment challenges represent good opportunities for some activities, while for some they represent danger and only for the rare ones they are not influential at all.

In time when quality is becoming a general category and goods with the higher price are a constant mean of the competitive advantage, the question is how to produce and survive on the market. The turnovers in their own available means are being sought increasingly, through the optimal structure of the engaged funds and their consumption and all that in order to maximize the company's income.

Competitiveness is the base that defines success or failure of the company [18]. In the era of constant development, the term competitiveness has taken a very important place. Competition between business rivals has been significantly intensified lately, in order to achieve the goal of the company's existence on the market.

Competitive advantage [18] is defined by several factors: production conditions, human, knowledge, capital and infrastrucural resources. Countries that have the most dynamic process of interaction of all these factors achieve success in the competitive advantage [18].

In order to achieve competitive advantage efficiently, it is important to integrate information technologies, harmonize IT and business strategy, gain IT managing skills and to achieve IT competence. Managers can expect that the competitive advantage from their investments in IT will start to show when the its implementation is higher than average, regarding the competition.

Management Strategy as Competitive Advantage in the Company Business

The imperative for companies' survival and prosperity on the market in conditions of modern economy is the competitiveness. Competitive advantage is a decisive factor of the strategic operation of the company and its existence is the base for distinguishing a successful from an unsuccessful enterprise. Every strategy is based on building and maintaining it [7].

Competitive advantage is an organizational ability which enables the company to create significantly higher values for the customer, in regard to its competitors. In order to achieve and maintain competitive advantage on the market, the company needs to conduct constant changes which are manifested by the emergence of frequent innovations [10]. The company's survival on the market implies a successful battle with the competition, which demands from the company's managers to estimate realistically the situation in the environment, potential possibilities of the company, real possibilities of the competition, while reducing costs and ensuring positive business results. Nowadays, modern information technologies have a strategic importance for companies' functioning. The influence of IT on the company business is based on their introduction to the development of products and services, on the introduction of electronic business, on the contribution to cost reduction, etc. [8].

Greater focus of IT in the company can improve its competitive advantage on the market a lot. Introducing and applying IT can be successful only if the development of the information system is compliant with the development strategy of the business system [2].

The significant application of modern information technologies in all segments of company business brought new opportunities for competing on the market and it also forced companies to question their business strategies, so the competitive advantage would survive on the market in conditions of the global economic crisis [19]. Everyday development of the competition, as well as the current global crisis, demands from companies to carry out more frequent analysis of business processes.

Achieving company's competitive advantage on the market implies the analysis of business processes, as well as daily following of world business trends on the market. The competitive advantage is not a permanent category, but it is sustainable [9]. The main goal of every company is to accomplish, but also maintain competitive advantage on the market, which is achieved by innovation of the product or service. Most companies became aware of the fact that customers' satisfaction is not enough for them to be competitive on the market, but they also need to surpass the expectations, as it is the only way to convince the customers that they are the best. In conditions of tougher competition, only the companies that are looking for solutions for the highest quality products with minimum costs in their strategic vision can survive, as well as the ones that are performing business processes in the shortest amount of time.

The most important thing for company's management regarding the strategic planning is to place the IT properly and recognize their influence on the companies' business on the market while achieving the competitive position [12]. Measuring performances became a main component in the development strategy of the company in conditions of the global crisis, together with sustainable growth and high position of the company on the market.

Managers can expect results of the investments in the information technologies, regarding the competitive advantage, when the application of IT in their company is higher than the average application of the competition [13].

The information technologies are defining the efforts dedicated to the improvement, including not only a dedication to the resources, such as the budget, equipment and staff, but also the managerial dedications, like introducing top management [6].

The companies in modern business conditions have to recognize the importance of harmonization of IT and business strategy, so they could adjust the whole business to it. If the company does not recognize all possibilities that the information technologies are offering, or they do not want to adjust its business to the new trends, it is certain that they will face a quick dissapearance from the market.

The most well-known dimension of the competitiveness analysis is the model of competitive forces [17]. This model recognizes five main strategies which can lead company to danger, and they are:
- Entrance of new competitiors,
- Threat of the appearance of alternative prod-

ucts/services,
- Negotiating power of the customer,
- Negotiating power of the supplier,
- Rivalry between existing competitors.

The Porter's model of competitive forces is one of the most common and most practical tools used for defining the company's business strategy. According to him, the choice of strategies is based on the competitive advantage and span. He defines two types of achieving competitive advantage: based on the low costs or on differentiation [21].

The size and duration of the company's competitive advantage are caused by the level of marketing dynamics and other activities on the market [4]. While defining the competitive strategies, companies have to pay attention to the market width, competition areas and to the way of gaining competitive advantage on the chosen market.

The Role of Information Technologies in the Process of Creating Competitive Advantage in Global Frameworks

In modern life, different interests appear every day, as well as different expertise in people who are managing business systems and organizations, then the levels of organizational complexity and therefore, different system types. One system can never provide all the information that is necessary to some organization or business system [5]. Company's business activities take place by sectors which have an appropriate information system in their business scope. All those systems need to be bound in one unique system which unifies the information about the company's business. Information systems are created as application packages which, depending on the sector they are used in, possess formed functions [3]. They should be strategic, i.e. they should fulfill the main goals of the company's business.

The influence of modern information technologies on the competitive position of the company on the market is reflected in the sense that they change the activity structure and nature of the competition, shape the competitive advantage and start completely new business processes and operations within the existing ones [18].

Company managers are aware of the fact that the company's competitive ability nowadays depends greatly on how much the observed company's activity and product or business activity realization is covered by modern IT and special databases [3].

New tendencies in the IT development are keeping up with the development of new business activities of the company, new production and information technologies, which demand a continuous adaptation to the whole of the company's management instruments, on the line of the set goal realization [7].

Using information technologies has an increasing role in forming new products and services [3]. Its main role in companies is re-engineering business relations, improving business activities and also achieving competitive advantage on the market.

New forms of using information services inside companies are enabling the implementation of qualitative business policy of the company. By using electronic trade, distance shopping and other information services, the customer constantly takes on a more important role in communication, and in that way, »classic« producers are becoming multimedia information representatives, by using the Internet on their own [20].

The influence of IT on companies in Republika Srpska in conditions of the global crisis has also a lot of other advantages, which are reflected in modernizing business activities with a decrease in the number of employees, better financial business of the company, more rational use of resource capacities, as well as with more qualitative distribution of materials and goods.

The research about the influence of IT on the company's competitive advantage on the market has been carried out on a representative sample of 136 business entities on the territory of Republika Srpska.

The goal of this research is getting data in order to define the influence of IT on the company's competitive advantage on the market in conditions of the global crisis. In Republika Srpska, 93% of the surveyed business entities confirmed that they are using modern information technologies in their business.

In addition to the above-mentioned, other research goals were defined, regarding the influence of IT on reducing costs in the company, reducing work force and increasing work productivity of servicemen.

According to the results received from the respondents, regarding the jobs they do, it can be concluded that the sample structure is satisfactory, because of the level of deviation from the ideal values and the conditions within which the mentioned research has been carried out. The research is directed to defining the role of IT in the process of achieving and maintaining company's competitive advantage on the market in conditions of the global crisis.

The set scientific goal of this work, relevance of assumptions and foundation of hypothesis, with the support of methods applied within this research, confirms a dominant influence of IT on the pace of achieving and maintaining competitive advantage of the company on the market. The research also ensured an appropriate theoretical framework and basis for studying and defining the adequate development strategy of information systems in the company.

Apart from the above-mentioned, other research goals were defined and they refer to the influence of IT on decrease of needs for employing accounting officers, automatization and faster recording of business events, improving and developing accounting analysis, increasing work productivity of accounting officers, developing accounting business in the near future, preparing accounting information for management needs and so on.

Individual results of the empiric research confirmed an extremely important influence of IT on the company's competitive advantage on the market in conditions of the global crisis. Out of 136 examinees, more than half (55%) confirmed that information technologies affect the competitive advantage of the company significantly.

Figure 1. *Influence of information technologies on the competitive advantage of the company (Đalić, 2017)*

Modern information technologies tend to improve all business activities in the company really fast. Modernization of the company's business activities with the goal of increasing its competitiveness on the market is achieved by decreasing the number

of employees and, at the same time, decreasing the costs related to them. A part of the research carried out for that purpose confirmed that the application of IT has a significant influence on the number of employees, as well as on the labor saving, so the employees' work standard is becoming more complex in the process of achieving competitive position on the market. On the basis of very fast development of information technologies, the collected research results, regarding the contribution of IT to the decrease in the number of the company's employees, confirmed their significant influence on the decrease in the manpower needs – almost 75,55% of the respondents confirmed that the introduction of IT causes a need for decreasing the number of employees in the company.
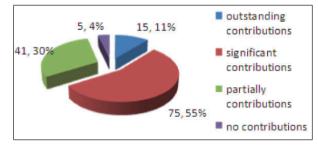

Figure 2. *Influence of information technologies on the decrease in needs for manpower (Đalić, 2017)*

The empirical research which refers to the influence of IT on the company's competitive advantage on the market in conditions of the global crisis confirmed their significant impact on the maintenance of competitive position on the market. The conducted research is shown in the Figure 3, where it can clearly be seen that the majority of respondents, almost 66%, agrees that information technologies contribute exceptionally to the achievement and maintenance of the company's competitive position on the market.
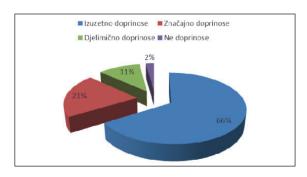

Figure 3. *Influence of information technologies on achieving and maintaining company's competitive advantage (Đalić, 2017)*

The research showed that over 70% of respondents in Republika Srpska have access to the Internet and they also confirmed an exceptional awareness that IT could have a significant role in their training to connect to the international business chains.

The conducted research showed that the companies' management in Republika Srpska is aware of the role and importance of IT in improving business results and achieving competitive position on the market. At the same time, introducing IT to the company is considered as a long-term investment.

Important segment of the research are the attitudes of the information systems' users, who think that the application of IT is extremely important and necessary in the everyday work of the company. The users also believe that their application would help overcoming business issues, meeting habits, needs and expectations of customers, as well as achieving company's competitive position on the market in conditions of crisis.

Using information technologies in every segment of the modern company business accelerates the cost-effectiveness of the organization significantly. Intensive application of IT enables collecting up-to-date information and their analysis, quick and easy spreading of business on new markets, while reducing distance between business entities, which has an indirect influence on the companies' competitiveness forcing them to be more adaptable.

The competitiveness of these companies depends on the value of used technology, while their sustainability on the market is connected to the speed and applicability of innovations, where the human factor, i.e. knowledge, has a decisive role.

Conclusion

Everyday competitive conditions and state of the market demand a fast and continious change of organizational behaviour inside the company, in order to satisfy the needs for successful companies' business on the market, as well as to maintain competitive position. According to the conducted research, it can be concluded that all stated activities should be directed to creating a more favorable economic environment for companies' operation on the world market, while providing companies with conditions for daily modernization by using information technologies.

Compared to the traditional way of doing business, companies that are using IT in their strategies, in order to achieve a competitive advantage, are accomplishing an increased volume of work, higher profit, they are more dedicated to the consumers, and all this results in increasing their competitive ability on the market in conditions of the global crisis.

In order to maintain its competitive advantage, the company has to outperform its business rivals all the time. The conducted researches show that more and more small and medium enterprises are recognizing the value of using new technologies, as well as the advantage over the competition, which they could therefore acquire. The most important thing is that managers ought to place IT in the company properly and recognize their influence on the business and structure of the company.

According to the research carried out in this work, it is obvious that managers of the companies in Republika Srpska are aware of the role and significance of IT in improving business results, in order to achieve a competitive position on the market, but at the same time, they believe that introducing IT to companies represents a long-term investment.

An important segment of the conducted research are attitudes of the surveyed users of information systems, who believe that the application of information technologies is very important and necessary in everyday work of the company. They said that the application of IT would help in overcoming some business problems, but also answering to the habits, needs and expectations of customers in a right way, which leads to the accomplishment of the company's competitive position on the market in conditions of crisis. Companies in Republika Srpska, which have chosen the application of IT as their strategy, in order to achieve competitive advantage, are gaining higher profits and are more focused on the consumers and their needs, in comparison with the traditional way of doing business.

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Web Based Decision Support System yo Determine yhe Appropriate Packaging of Ethnic and Traditional Indonesian Foods

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Abstract: Culinary efforts, especially ethnic and traditional snacks attract many people to Indonesia. Maintaining the quality of snacks for consumers requires a good packaging technique. Food packaging consists of a wide variety of packaging options that match the characteristics of each snack; this is no easy task. Decision support systems can help to facilitate decisions made regarding selection of the right packaging. This paper focuses on identifying snacks, types of packaging and active packaging parameters to build a decision support system in order to determine appropriate packaging. Types of packaging are determined using fuzzy Sugeno 4 parameters: fat, water activity, shelf-life and price. Active packaging of the snacks is done using the if-else rule with parameterised types of packaging, preservatives, oxygen barriers and water vapour barriers. The end result of this research is a web-based decision support system, which recommends types of packaging and active packaging for snacks.

Keywords: active packaging; snacks; fuzzy logic.

Introduction

Food and beverage industries in Indonesia should be able to compete in the era of ASEAN Economic Nation (AEC). Nevertheless, some challenges were found; one is to train workers in the logistic sectors as they need to treat the products well. Therefore, consumers can receive products in good condition. The challenge can be overcome with packaging methods; besides, packaging can also serve as a search feature and maintain the quality of freshness. It also extends the shelf-life during the distribution process [14]. One growing food industry in Indonesia is the ethnic and traditional snacks industry.

There are two kinds of ethnic and traditional snacks, cake and cookie. Cake tends to be perishable, while cookies can last several days without becoming foul [12]. According to Jay [6], there are two factors that influence food spoilage, namely intrinsic and extrinsic factors. The intrinsic factor consists of acidity (pH), water activity (a_w), potential of oxidation-reduction (Eh), nutrient content, antimicrobial content and biological structure.

One problem that arises is the difficulty in determining the type of packaging and active packaging that is suitable for the food to be packaged. The decision supporting-system can be used as a specific tool describing the computerised-system to support the decision-making in an organization [13]. According to Marimin and Maghfiroh [7], decision-making often faces various unique, uncertain and dynamic conditions, which lead to time-consuming and complex outcomes. A decision supporting-system is required to help determine the right packaging and active packaging for ethnic and traditional snacks in Indonesia.

Previous research about the selection of meat product packaging was conducted by Ahsyar et al. [1]. Within the research, Ahsyar et al., [1] stated that the parameters that determine the type of packaging for meat products are pH, temperature, a_w, preservatives and shelf-life target. Besides, Guillard et al., [5] in another research about decision supporting-system for designing MAP packaging in fresh product noted that the method used to build the system was Fuzzy logic and the Bipolar querying approach.

This paper discusses the identification of snacks' parameters and the types of packaging and active packaging required to build a decision supporting-system in order to determine the right packaging. The Fuzzy logic method is used to build this web-based decision support system. Fuzzy logic is a logic underlying the model of expected reasoning of actual circumstances. Its importance is derived from the fact that most models of human reasoning are estimates of natural events [15].

CHARACTERISTICS OF SNACKS, TYPES OF PACKAGING OND ACTIVE PACKAGING

Indonesian ethnic and traditional snacks generally consist of two major categories: moist food and dry food. The main parameter that distinguishes between moist food and dry food is a_w. Generally, the main ingredient in Indonesian ethnic and traditional snacks is coconut milk. Indonesian snacks can be processed in various ways, namely steamed, baked or fried [2]. Various preparation processes and main ingredients cause different water and oil content in different foods. Indonesian ethnic and traditional snacks' characteristics are summarised in the value of fat, a_w, and barrier parameters. The parameter of barrier is described with its nature when exposed to oxygen or water vapour within the package. Different characteristics of snacks result in different natures of various foods under the same condition. Some foods become perishable when exposed to oxygen or water vapour, while some do not.

Peter Fellows and Ann Hampton [4] declared that packaging materials composed of various types including glass, metal, plastic and paper. There are many different kinds of packaging types as shown in Table 1. Plastic has many sub packs and each sub package has different properties. This type of pack-

aging will be tailored to the characteristics of the snacks.

Table 1. Packaging type and character

Packaging type	Sub-package	Character
Glass	Jar cake	Easy to crack and if broken, will be harmful to the food it protects
Plastic	Polypropylene (PP), polyester (PET) and vinylidene	Has a high resistance to moisture and glue
Plastic	Polyethylene (PE) and polystyrene	resistance against moisture and fat
Plastic	Cellophane	Has a low resistance to moisture and fat
Metal	Aluminium foil (AF) and tinplate	Low on gas permeable, moisture and light
Paper	Greaseproof paper and glassine paper	Oil resistant

Robertson [9] defines active packaging as packaging that is deliberately inserted by other materials to improve the packaging itself. Anti-microbial packaging and antioxidants are two main applications of active packaging. The basic concept in the packaging antioxidant is the ability to control lipid oxidation, pigments and vitamins in order to be maintained in the desired products [8]. Active packaging is composed of several kinds of them such as oxygen absorbers, antimicrobial and moisture absorber films. An oxygen absorber is able to absorb the oxygen, by absorbing water vapour produced by packaging. Film antimicrobial properties prevent microbes that can cause food to rot quickly.

DESIGN OF FUZZY LOGIC AND RULE ACTIVE PACKAGING

Fuzzy logic is used to determine the decision-making process of Indonesian ethnic and traditional snacks' packaging. There are three main stages in the decision decision-making process when using the fuzzy method, namely to formulate membership function and to make the inference rule and defuzzification.
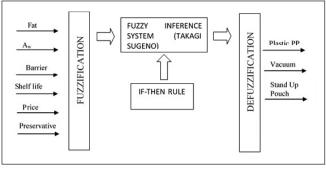
Figure 1. *Fuzzy logic process steps*

Figure 2. *Membership function of fat parameter*

In this study, the inference method used is fuzzy Sugeno [11] by the equation:

If x_1 is A_1 and $\cdots$ and x_k is A_k then $y = p$ $\qquad$ (1)

x_i : parameter for-i $\qquad$ A_i : fuzzy set for-i

y : output $\qquad$ p : constants

Defuzzification produces non fuzzy control action that best represents the membership function of how fuzzy control actions are concluded [3]. The defuzzification process with Sugeno method by finding the average value:

$$z = \frac{\alpha pred_1 * z_1 + \alpha pred_2 * z_2 + \cdots + \alpha pred_N * z_N}{\alpha pred_1 + \alpha pred_2 + \cdots + \alpha pred_N}$$ $\qquad$ (2)

$\alpha pred_i$ = membership degree rule for-i

z_i = rule limiting for-i

The parameters used to determine the type of packaging is fat, a_w, shelf-life and price. These parameters will be made fuzzy membership functions respectively. Fat parameters have a range of about 0.4 to 18 (Figure 2). The low membership value is about 0.4 to 6.7, moderate value of about 2.8 to 15.5 and a height about 11.6 to 18. a_w parameter has a membership range of about 0.12 to 0.9. a_w value range of membership and fat is taken from the studies on Indonesian ethnic and traditional snacks. Shelf-life parameters have a range between 7 to 180 days. Membership pricing parameters have a range of about IDR 30,000 to IDR 200,000. These prices are taken from the price per 1 kg pack. The rule for fuzzy inference according to equation 1 shown in picture 4 is that in matlab, defuzzification calculation results is like equation 2 shown in picture 3.

Figure 3. *The results of calculations' defuzzification*

Figure 4. *Rule of fuzzy inference*

Limiting one to six, where each has a value of 0.1, 0.2, 0.4, 0.6, 0.8 and 1; limiting one, two, three, four, five, six each are a group type of packaging one, two, three, four, five and six. Packaging type 'one' is made of PP. Packaging type 'two' is made of AF and PET mixture at a low price. Packaging type 'three' is made of AF and PET mixes at moderate prices. Packaging type 'four' is made of AF mix, PE and PET at a bargain price. Packaging type 'five' is made of AF mix, PE and PET with expensive prices. Packaging type 'six' is vacuum packaging. Packs in-

cluded in types of packaging one to six are called sub-packaging.

The next step is seeing if we have input-output value of fat, a_w, shelf-life and price. Figure 5b shows the divider (Z) which is worth 0.245 the input value of 0.4 fat; a_w 0.52; shelf-life of 60 days and a price of IDR. 75,000. A limited value of the fuzzy calculation will be the benchmark for approval of the type of packaging. Type one package on the limiting values is about 0 and 0.169. As for the types of packaging-two, three, four, five and six, each is between 0.17 and 0.329, 0.33 and 0.489, 0.49 and 0.649, 0.65 and 0.799 and 0.8 and 1. In picture 3, worth 0.245 means limiting the decision about the type of packaging to pack two.

Determining the active packaging requires three additional parameters, namely preservatives, oxygen barrier and water vapour barrier. The determination of the active packaging rule totalled 48.

Table 2. Examples of active packaging determination rule

No	Types of packaging	Preservative	Oxygen barrier	Vapour barrier	Active packaging
1	Two	No	Yes	No	Oxygen absorber
2	Three	No	No	Yes	Moisture absorber
3	Four	No	Yes	Yes	Antimicrobial films
4	Six	No	Yes	No	Oxygen absorber
5	Five	Yes	Yes	Yes	Nothing

SYSTEM DESIGN AND IMPLEMENTATION

System design

The Traditional approach model system is used at the stage of system requirements analysis [10]. An analysis conducted consists of system flow analysis and database analysis. Analysis of the flow system includes a context diagram (context diagram) and a data flow diagram (data flow diagram). A context diagram describes the overall activity and interactions in the system in the form of an abstract. The activity and the interactions are described in the input-output relationship process. The right of access to the system is divided into two levels, namely the administrator and the user. The administrators have the authority to manage user data, packaging data, attribute data, parameters, snacks products and comments from users. On the other hand, the user can fill in the parameters of snacks' products to see a suggestion of packaging options, change the profile data and provide suggestions or comments.

DFD on the level 1 is the decomposition of a context diagram. DFD on the level 1 that exists in Figure 6 illustrates the details of a major process in the context diagram. The description of the processes that exist in the DFD on the level 1 can be seen in Table 3, while table 4 contains the names in the database that will be used in the system design.
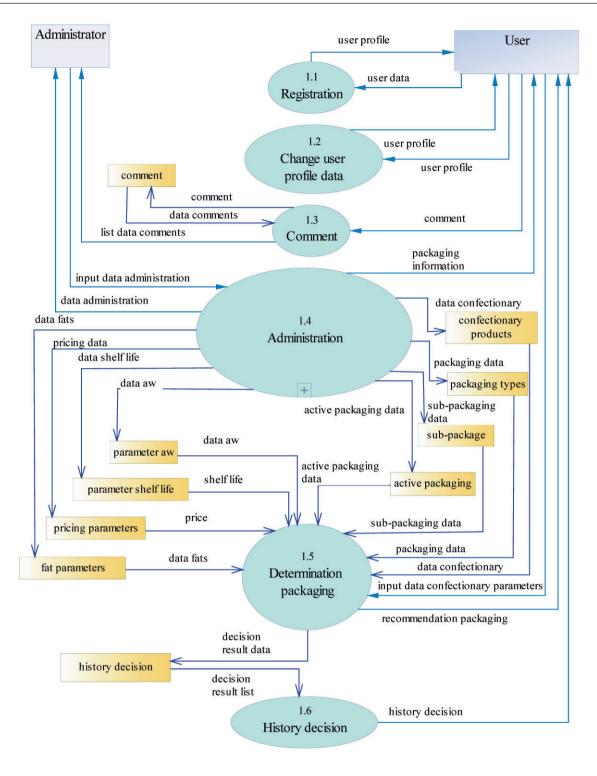

Figure 5. Context diagram

Figure 6. *DFD level 1*

Table 3. Description of the process in the DFD level 1

Name of the process	Incoming data flow	Outgoing data flow	Description
Registration	User profiles	User data	The registration process performed by a new user to fill out a user profile to gain access rights as a user.
Changing the user profile	User Profiles	User profile	The process change of user profiles by users who have user access rights. Profiles that have been changed will be viewable by the user.
Comments	Feedback, Data commentary	Commentary a list of comments	Process comments by users with user access rights. The comments will be entered into a database table in the comments. A list of the users' comments will be visible to the administrator.
Admin	All data administration (User, Packaging, Product snacks regional specialties Indonesia, Rule), comments	Info of pack, user data, the list of administrative data	Process of view, fill, modify and delete the entire administrative data consisting of user data, packaging, snacks products and rule by the administrator.
The determination of pack	Data of snacks, types of packaging, active packaging, expire date, the price, the rule limiting, rule, a_w, fat, selection of criteria	The solution decisions, the result data judgment	Process of determining the type of packaging and active packaging system that involves data from the system and user input data.
History of decision	The judgment of results list	History of made	Display the history made process of packing and active determination by each user.

Database analysis using the entity relational diagram (ERD) is a model to define requirements in the basis data. Basis data requirements consist of entity data, attribute and relationship with the entity. Entity data consists of tables that are needed in the system for saving information.

Relation to entity is described in Table 4.

Table 4 Specification relationship ERD

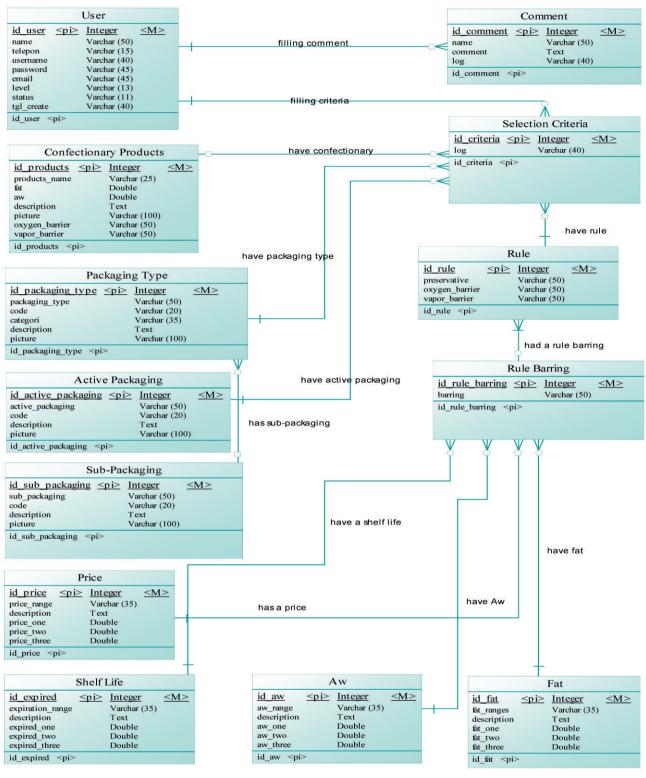| Relationships	Relationship Description
Filling	The relationship between the user entity to entity comment and the relationship between the user entity to entity selection criteria.
Own	The relationship between entity types of packaging with the entity sub-packaging; the relationship between the entity type of packaging with selection criteria; the relationship between the entities of snacks' products with entity selection criteria; the relationship between entity lipid parameters with rule limiting; the relationship between entity parameter a_w with the entity rule limiting; the relationship between entity parameters of shelf-life by limiting rule entity; the relationship between price parameter entity to entity limiting rule; the relationship between the rule limiting entity to entity rule and the relationship between entity to entity selection of the criteria rule.

Figure 7. Entity relational diagram

Table 5. *This is the name of the tables in the database.*

Name Table	The description
Users	Table serves to store user data and give access rights to each user. This table is used to authenticate users who will use the system.
The snacks of products	Table serves to store data in the local specialty of snacks in Indonesia. In this table, there is a value of each parameter related to the snacks that will be used as input to determine the type of packaging and active packaging accordingly.
Fat	This table serve to store membership function of lipid parameters. This table is used for fuzzy calculation.
a_w	This table serves to store the membership function of the parameter a_w. This table is used for fuzzy calculation.
Shelf-life	This table serves to store the membership function of the shelf life parameters. This table is used for fuzzy calculation.
Price	This table serves to store the membership function of the parameter price. This table is used for fuzzy calculation.
Rule of the limit	This table serves to store fuzzy rule for calculations.
The Rule	This tables serves to store the rule for determining the type of packaging and active packaging of unpredicted calculation results.
The type of packaging	This table serves to store other types of packaging that will be used in determining the type of package.
Sub of packing	This table serves to store the sub-packaging of each type of packaging.
Active packaging	This table serves to store other types of active packaging that will be used in the determination of active packaging.
History-made	This table serves to store data decisions for determining types of packaging and active packaging in accordance with the result of the rule.
Comments	Table serves to store the comments given by the user of this system that can later be critiqued and used to garner suggestions about the system.

SYSTEM IMPLEMENTATION

The Decision support system determines Indonesian ethnic and traditional food packaging, starting from the beginning display system. The display system consists of the home menu, packaging and active packaging. After logging in, users who have access rights will be entered on the user page. The Menu on the user page consists of a profile specifying the packaging, commentary, history and contacts. In the profile menu, users can view the profile data themselves. On the specified packaging menu, the user can enter comestible criteria that will determine the types of active packaging. After completing these, the process gives rise to the determination on the result page regarding the recommended packaging and active packaging. As in Figure 8, examples are given of comestible names the user enters, with criteria such as Semprit cookies, do not use preservatives, the shelf-life of 100 days, as well as the price per kilograms packing, IDR 160.000,00.

Figure 8. *Page determination packaging*

The Menu on the administrator page has the profile, users, packaging with sub menu types of packaging, sub packaging and active packaging, as well as the parameters with sub menus' fat, a_w, price and shelf-life; it will also include Indonesian ethnic and traditional snacks' products and comments. On the profile menu, administrators can see the data themselves. In the user menu (picture 9), administrators can see, add, modify and delete user data list that is already registered on the system. On the menu package, the admin can see, add, modify and delete the list of data types of packaging, sub-packaging and active packaging. On the menu parameter, the admin can see, add, change and delete the data register fat, a_w, price and shelf life. On the Indonesian ethnic and traditional snacks' products menu, admin can see, add, modify and delete

the data snacks list. On the comment menu, administrators can view a list of comments that have been

entered by the user who has user access rights.

Figure 9. *Administer users*

CONCLUSIONS AND RECOMMENDATIONS

To further develop this system, research starts from identifying the parameters that will determine the type of snacks packaging and active packaging. There are seven parameters that have been identified, namely fat, aw, shelf-life, price, preservatives, oxygen barrier and water vapour barrier. The main parameters, however, to determine the type of packaging include fat, aw, shelf-life and price, while the

additional parameters to specify the active packaging are a preservative, oxygen barrier and water vapour barrier. The main parameters are used as input for the calculation of fuzzy method with Sugeno inference to obtain recommended packaging types. Additional parameters are added to the rule to build decision support systems using the traditional methods system. The results of the implementation of the system analysis and design in the form of a

web can provide a solution on types of packaging and active packaging for Indonesian ethnic and traditional food.

This decision support system is limited to the type of packaging and active packaging. The expected future improvement of the system is the expansion in terms of more detailed sub-packaging and packaging techniques with more diverse parameters. This will generate the best decision of packaging for Indonesian ethnic and traditional food.

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