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# Artificial Intelligence in Engineering Management

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## INTRODUCTION

In the last years and in the last centuries the soft computing methods ant the artificial intelligence has undergone a complex evolution. Since ancient times people have been trying to understand the human thining and/or copy the operation method of the human brain and intelligence. [6]

In the 20$^{th}$ and 21$^{st}$ centuries when the military industry and other industrial members use more and more precise and complex machines, production lines, processes and computers the artificial intelligence, soft computing methods and neural networks are achieving a higher level than ever. [6]

This work provides an overview of the development and evolution of the artificial intelligence and the most important mathematical methods of artificial intelligence. The reader can get basic information about the definition of artificilai intelligence and some basic skills about the mathematical background of fuzzy logic and support vector machine method. [6]

The book describes the importance of the artificial intelligence, the history of AI, the history of fuzzy logic, the most important defuzzification methods, the theoretical background of support vector machine (SVM) and the book ends with some case studies. The fuzzy logic can help the engineers to solve different technical, maintenance problems or analyse parameter deviations in the daily routine. The modern lean manufacturing principles like customer demand and ‘just in time’ and suppliear evauliation systems also increased the importance of artificial intelligence. [6]

The book contains 9 chapters and several sub-chapters. The chapter before the last contains different case studies from the daily life and laboratories, these case studies come from the following areas: diesel engine operation, fleet management and electric vehicles. These case studies help to the engineers of the future to implement and improve their skills and methods in the practice. [6]

The main purpose of this book on Artificial Intelligence is to introduce the main definitions and tools for fuzzy logic and support vector machine. I hope students and engineers will use this book with satisfaction during their study or work. [6]

## 1. HISTORY OF ARTIFICIAL INTELLIGENCE

Engineers, scientists and philosophers have been trying for long time ago to understand and resolve two big questions of the universe: how does a human mind work, and can machines have minds? These questions are still unanswered in nowodays (2018). We know a computitional approach what we can accept. This approach originated by computer scientist and engineers. The of this idea is that the machines can do everything that humans can do. This idea or approach can be works but we have to think about a lot of other important skills and habits what machines can do, like love, creative discovery and moral choice will always be beyond the scope of any machine. Independetly from these facts the engineers and scientists have already built machines that we can call „intelligent". *„So what does the word 'intelligence' mean? Let us look at a dictionary definition."* (Essential English Dictionary, Collins, London, 1990) [7] [11]:

1. *„Someone's intelligence is their ability to understand and learn things."*
2. *„Intelligence is the ability to think and understand instead of doing things by instinct or automatically."* [7] [11]

Thus, according to the first definition, intelligence is the quality possessed by humans. But the secon deiniton can give some flexibility. It is a not give a strict way to specify wehether it is someone or something that has the abilit to understand, feell or think. Another point of view of thinking means [7] [11]:

*„Thinking is the activity of using your brain to consider a problem or to create an idea."* (Essential English Dictionary, Collins, London, 1990) [7] [11]

*„So, in order to think, someone or something has to have a brain, or in other words, an organ that enables someone or something to learn and understand things, to solve problems and to make decisions. So we can define intelligence as the ability to learn and understand, to solve problems and to make decisions."* The question about the machine intelligence came from the 'dark ages' of artificial intelligence, these dark ages are the late 1940s. The artificial intelligenc or AI is the one of the most important science field. The goal of this area to make machines, processes or software to do things that would require intelligence if done by humans. The basic question is: *„Can machines think?"* The answer is not a simple 'YES' or 'NO', but rather a vague or fuzzy one. The everyday

life, experience and felleings can give an impression about it. [7]

[11]Some people are smarter in some ways than others. Sometimes people can make a very intelligent decisions but sometimes they are can not make and they are making a very very silly mistakes during their work or their life. Some people have a such a good skills on mathematical and engineering fiel but they are in philosophy and history. Some people are good at making money, while others are better at spending it. As humans, we all have a skill to learn and understand contexts, solve porblems and make decisions (in this case the quality of the decision is not important, good or not good). Important to know the human abilities are not equal and we can find differences in defferent areas. [7] [11]

The earliest and most significant paper has the following title: 'Computing machinery and intelligence'. This work was written by the British mathematician Alan Turing over fifty years ago. *„However, it has stood up well to the test of time, and Turing's approach remains universal. Alan Turing began his scientific career in the early 1930s by rediscovering the Central Limit Theorem. In 1937 he wrote a paper on computable numbers, in which he proposed the concept of a universal machine. Later, during the Second World War, he was a key player in deciphering Enigma code system, the German military encoding machine. After the war, Turing designed the 'Automatic Computing Engine'. He also wrote the first program capable of playing a complete chess game; it was later implemented on the Manchester University computer."* [7] [11]

Turing had a high level concept of the universal computar an he had also a good experience in building code braking system. These properties helped him to worked on the fundamental question of artificial intelligence. He asked: *„Is there thought without experience? Is there mind without communication? Is there language without living? Is there intelligence without life?"* [7] [11]

These questions are a fundamental question of artificial intelligence: Can machines think? Turing try to avoided sematic argument by inventing a game, this is what we call Turing imitation game. *„Instead of asking, 'Can machines think?', Turing said we should ask, 'Can machines pass a behaviour test for intelligence?'"* [7] [11]

Turing predicted an important thing to the future. The prediction is the following: „*by the year 2000, a computer could be programmed to have a conversation with a human interrogator for five minutes and would have a 30 percent chance of deceiving the interrogator that it was a human.*" Turing made the base of the intelligent behaviour of computer. [7] [11]

## 1.1 Basic background of knowledge based intelligent systems

In another point of view the computer can passes the test if the integrators cannot distunguish the machine from a human on the basis of the answers to their questions. This imitation game developed by turing and it has two phases. During the first phase the integrator, a man and a woman are each placed in separate rooms and can communicate only wit neutral equioments like remote terminal. The target is the following: the integrator has to find out who is the woman and who is the man. During this game the participants hav to try to deceive the interviewee that he is the woman, and/or she is the man. [7] [11]

In the second phase we change the man and we replaced by a computer. This computer programmed to device the interrogator as the man did. It is possible to make programs and sub programs into this computer to make mistakes, failures and provide fuzzy answers. If the computer can fool the interrogator as often the real human did, we may say this computer has passed the intelligen behaviour test, because the computer gave a similar answer what real man can. Physical simulation of a human is not important for intelligence. It is a very important detail in the Turing test! During the test the interrogator and the other participants can not see each other, can not touch and hear. Therefor, these things can not make an affect on the interrogator! Honestly, the interrogator can ask provocateur questions to identify the machine. [7] [11]

An easy example for a provocateur question: complex mathematical tasks and/or calculations. The computers will make a correct solution and the compuer will do it faster than the human ever can. The computer gas to know when to make a mistake or when to give an answer with a delay. Other good questions can be when the interrogator try to dicover the emotional nature and behaviours of the human. In this case the interrogator can ask to examine a short novel or poem or describe a painting. At this point the

computer has to simulate a human's emotional understanding of the work, art or other situations. [7] [11]

The Turing test has two remarkable qualities that make it really universal. The Turing test can gie an objective standard view on intelligence: the communication between the human and machine with a terminal. This communication method can avoid the human nature of intelligence and it can elliminate any other human habits and properties. As we can see the test itself is independent from the details of the experiment. The interrogator can ask everything and he or she has to concentrate on the content of the answers provided. Turing believed that by the end of the 20$^{th}$ century it would be possible to program a digital computer to play the imitation game. Good to know the computers of nowodays still can not pass the Turing test. The computers can be intelligent on some field. [7] [11]

Our brain stores the equivalent of over 1018 bits and can process information at the equivalent of about 1015 bits per second. The new research projects can give a new way to develope our brain. After 2020 the human brain can modelled by a chip. The size of a chip is a sugar cube and perhaps by then there will be a computer that will be play the Turing imitation game. [7] [11]

Do we truly need the machine to perform scientific estimates as gradually and erroneously as people do? From a pragmatic perspective, a savvy machine should help people to decide, to look for data, to control complex articles, lastly to comprehend the importance of words. There is most likely no reason for attempting to accomplish the conceptual and tricky objective of creating machines with human-like insight. To construct an astute PC framework, we need to catch, arrange and utilize human master information in some tight specialized topic. [7] [11]

The history of artificial intelligence is full of interesting events. The first chapter of the history is the 'Dark Ages' of artificial intelligence wich is the main period of the knowledge – basesd system science. During the next part of the book the reader will get some information about the most important milestones of the artifical intelligence. [7] [11]

## 1.2 THE ‘DARK AGES’, OR THE BIRTH OF ARTIFICIAL INTELLIGENCE (1943–56)

The main work in the field of artificial intelligence was publisheb by Warren McCulloch and Walter Pitts in 1943. McCulloch had degrees in philosophy and medicine from Columbia University and became the Director of the Basic Research Laboratory in the Department of Psychiatry at the University of Illinois. He made a resarch on the central nervous system resulted in the first major contribution to AI: a model of neurons of the brain. Later (and nowodays too) the neural networks will be very important! Walter Pitts was a young matgematican who proposed a model of artifical neural networks, and he was the co-author of McCulloch. They showed that their neural network demonstrate was, indeed, identical to the Turing machine, and demonstrated that any processable function could be calculated by some network of connected neurons. [7] [11]

McCulloch and Pitts also showed that simple network structures could learn. The neural network demonstrates empowered both theoretical and experimental work to display or model the human brain in the research facility. In any case, analyzes plainly showed that the binary model of neurons was not right. Truth be told, a neuron has highly non-linear characteristics and cannot be considered as a simple two-state device. McCulloch, the second 'establishing father' of AI after Alan Turing, had made the foundation of neural computing and artificial neural networks (ANN). After a decrease in the 1970s, the field of ANN was restored in the late 1980s. The third founder of AI was John von Neumann (János Neumann, Budapest, Hungar, 1903 – Washington, USA, 1957), the brilliant Hungarianborn mathematician. Neumann joinet to the Princeton University to lecturing mathematical physics in 1930. He was a colleague and a good friend of Alan Turing. Neuman was one of the most important key figure in the Manhattan Project during Second World War. He worked on a nuclear bomb. He was an a dviser for the Electronic Numerical Integrator and Calculator (ENIAC) project at the University of Pennsylvania and helped to design the Electronic Discrete Variable Automatic Computer (EDVAC). In 1951 two graduated students Marvin Minsky and Dean Edmonds built the first neural network computer in the Princeton mathematics department. Neumann checked their work and later he gave a support for them. [7] [11]

Another pioneer of the first-generation researchers was Claude Shannon. He graduated from Massachusetts Institute of Technology (MIT, Boston, United States) and joined Bell Telephone Laboratories in 1941. If the new Neumann-type computer could examine one move per microsecond, it would take a lot of years to make its first move. Thus Shannon demonstrated the need to use heuristics in the search for the solution. [7] [11]

The next pioneer is John McCarthy who was another founder of artificial intelligence, he also worked at Princeton University. McCarthy organized a workshop with Martin Minsky and Claude Shannon to the summer at Dartmouth College, where McCarthy worked after graduating from Princeton. They invited researchers and engineer who were interested in the sutdy of machine intelligence, artificial neural nets and automata theory. It happened in 1956 and the workshop was sponsored by the IBM Company. [7] [11]

Good to know: only ten researchers were on this workshop. They gave a birth of a new sciencific way of era what we call artificial intelligence. In the next twenty years the field of AI would be dominated by the participants at the Dartmouth workshop and their students. [7] [11]

## 1.3 THE GOLDEN AGE OF ARTIFICIAL INTELLIGENCE (1956 – 1960S)

In the early period of artificial intelligence was full with great ideas and this period contains a very limited success for the engineers. Few years before the computers only used to made routine mathematical calculations, but nowodays the AI researchers demonstrating that the computers could do more than before. This period was the time of the great expectations. In these times John McCarhy moved from Dartmouth to MIT. *„He defined the high-level language LISP – one of the oldest programming languages (FORTRAN is just two years older), which is still in current use. In 1958, McCarthy presented a paper, 'Programs with Common Sense', in which he proposed a program called the Advice Taker to search for solutions to general problems of the world."* McCarthy presented hos his program works and generate a plan to drive to the airport, this codes based on some simple axioms. [7] [11]

Another important researcher from the group of Darmouth workshop was Marvin Minsky. Minsky also moved to MIT. McCarthys' focus were on the formal logic, Minsky Minsky developed an anti - logical outlook on knowledge representation and reasoning. Minsky developed the theory of frames. This theory was the base of knowledge engineering. The neural computing and artificial neural networks developed by McCulloch and Pitts continued it. *„Learning methods were improved and Frank Rosenblatt proved the perceptron convergence theorem, demonstrating that his learning algorithm could adjust the connection strengths of a perceptron."* [7] [11]

The one of the most ambitious projects os these years was the General Problem Solver (GPS) project. Allen Newll and Herbert Simon were the pioneers of this project, they worked at the Canekie Mellon University in the United States. The developed a general prupose program to simulate human problem solving methods. The General Problem Solver was the first method which can separate the problem solving technique from the datas. It was based on the technique now referred to as means-ends analysis. [7] [11]

*„Newell and Simon postulated that a problem to be solved could be defined in terms of states. The means-ends analysis was used to determine a difference between the current state and the desirable state or the goal state of the problem, and to choose and apply operators to reach the goal state. If the goal state could not be immediately reached from the current state, a new state closer to the goal would be established and the procedure repeated until the goal state was reached. The set of operators determined the solution plan. However, GPS failed to solve complicated problems. The program was based on formal logic and therefore could generate an infinite number of possible operators, which is inherently inefficient. The amount of computer time and memory that GPS required to solve real-world problems led to the project being abandoned."* [7] [11]

In the 1960s the researchers and scientists simulate and investigate the complex thinking process and developed general methods for solving broad classes of different types of problems. During their work they used the general purpose serch mechanism to find a solution to the problems. [7] [11]

Such approaches, now referred to as weak methods, applied weak information about the problem domain; this resulted in weak performance of the programs developed.

In these years a lot of new ideas came from the research institutes,
these were the following: knowledge representation, learning algorithms, neural computing and computing with words. These ideas could not be implemented in these years. The reasons were the performance of the computers. These old computers had limited capabilities. But twenty years later the computers undergone a big development and it used to make a real life practical application. [7] [11]

The another important resercher is Lofti Zadeh professor from the University of California at Berkeley. He publsihed the one of the most important and famous paper, it is the 'Fuzzy sets', he published it in 1965. This work is the base of the fuzzy set theory. Nowodays a lot of machines all around us full with smart solutions and intelligent systems which are based on fuzzy set theory. [7] [11]

In the 1970s the artificial intelligence lost a lot from its populatirity and a lot of government cancelled AI projects. In these years the AI was still a new scientific field with just a few practical applications. The other bad thins is: the applications were games. The outsiders can think that the AI is just a toy and nothing more. They could not seen any practical solutions of artificial intelligence. [7] [11]

### 1.4 The second chapter or some bad years, the late 1960s - early 1970s

In the middle of the 1950s the researchers were full with dreams and plans. They were making dozens promises to build intelligent machines on a human-scale knowledge base by the 1980s and exceed the human intelligence until 2000. In the 1970s the whole world see these ideas and dream were too optimistic. In these years just some AI programs could demonstrate some possibilities of artrificial intelligence. The AI solutions and programs could not solve any difficult real-world problems. [7] [11]

In the history of artrificial intelligence we can see that the most diffucult years were the late 1960s. In this period the AI researchers were developing a lot of general methods frod broad classes of problem. Thes early programs contains a lot of 'bugs' or even no knowledre about a problem domain. For a right efficiency the programs applied a search stretegy by trying out different combinations of small steps, until they found the best solution. [7] [11]

This method only used for small problems not a real one. It looked
lie if the researchers could scaled up to solve the large problem the method can works. But this approach was failed. A lot of problems can be solved in a polynomial time. In another poin of view the hard or intactable problems require times that are exponential function of the problem size. Now we can see the polynomial time algorith can be efficient but an eyponential time algorith still has a probelm. If the execution time increases then the problem size also increases. In the early 1970s the theory of NP competeness developed by Cook and Karp. This method or theory can show the existence ot large classes of nondeterministic polynomial problems. „*A problem is called NP if its solution (if one exists) can be guessed and verified in polynomial time; non - deterministic means that no particular algorithm is followed to make the guess."* The NP complete is the most difficult pborlem in this class. These problems are very difficult to solve with faster CPUs and with bigger computer memories too. The problems in these period were very difficult to solve. The artificial intelligence methods were used to translation tasks. In 1957 is an important year in the space exploration, in this year the Soviet Union launched the Sputnik satellite. The United States National Research Council started to use artificial intelligence to translate russian scientific articles. In the beginning of this project the method worked on a simple way. The team tried to replacing the russion word with english. They used an electronic dictionary. We can think that this method can works but in the real life not. The translation requires need to understant the subject of the translation. If the tranlsators have a deep knowledge in the subject of the translataion they can choose the right word in the text. As we can this task is very difficult because the translators were not a rocket os space scientist and they had not got a detailed informations about technical specifications of the satellit. The US govenment cancelled this translation project. [7] [11]

The British government also started artrificial intelligent research projects. The leader of these projects was Sir James Lighthill who commissioned by the Science Research Council of Great Britain. „*He did not find any major or even significant results from AI research, and therefore saw no need to have a separate science called 'artificial intelligence'."* [7] [11]

## 1.5 THE NEW ERA OF SRTIFICIAL INTELLIGENE – EXPRT SYSTEMS, 1970-1980

The realisation of the problem domain for intelligent machines was the most important development sthep in the 1970s. The point of view of the artificial intelligence researchers were that the clever search algorithms and the different types of reeasoning techniques could be generate a human like problem solving methods for the machines. The general purpose was the following: the elementary reasoning steps could use a weak knowledge. But weak methods failed in the practice. The reasearchers and engineers realised that the only possibilities to deliver a real pratical resutls wa to solve typical cases in narrow areas of expertise by making large reasoning steps. [7] [11]

The Dendral project made the base of the new technology and solutions. The Dendral project developed at the Stanford University in the United States to analyse chemicals and chemical components in 1969. The project was in a highlight by the NASA. In these years the NAS worked on a unmanned spacecraft was to be launched to the Mars. The Dendral project was an important key for this Mars project. The research results were important for the NASA. The results required to determine te molecular structure os Martrian soil. These methodology based on the mass spectral data provided by a mass spectrometer. „*Edward Feigenbaum (a former student of Herbert Simon), Bruce Buchanan (a computer scientist) and Joshua Lederberg (a Nobel prize winner in genetics) formed a team to solve this challenging problem. The traditional method of solving such problems relies on a generateand test technique: all possible molecular structures consistent with the mass spectrogram are generated first, and then the mass spectrum is determined or predicted for each structure and tested against the actual spectrum."* In the practice this method can not works. Why? In the real life millions of possible structures can generated. The method failed. [7] [11]

In this time there were not any scientific algorithms for mapping the mass spectrum into its molecular structure. Lederberg was one of the scientist who solved this issue with his big experience. He reduced the number of the possible structures by looking for well-known patterns of peaks in the spectrum. Thanks for thes technique he provided jus a few possible solutions for the examination. Feigenbaums built this experetise into a computer program to make it perform az a human expert level. These program will be the expert

systems in the future. Feigenbaum had to learn and unerstand the basic knowledge, terminology and iedas in chemistry and spectral analysis. *„However, it became apparent that Feigenbaum used not only rules of chemistry but also his own heuristics, or rules-of-thumb, based on his experience, and even guesswork. Soon Feigenbaum identified one of the major difficulties in the project, which he called the 'knowledge acquisition bottleneck' – how to extract knowledge from human experts to apply to computers."* The another important aspect: Lederbert had to study the basics in programmin and computing. [7] [11]

Feigenbaum, Buchanan and Ledeberg were the pioneers and project members of the Dendral project. The Dendral project is the first successful knowledge – based system. What was their key for the success? They mepped all the relevant and important theoretical knowledge. It was a cookbook! The Dendral made a paradigm shift in the research field of artificial intelligence. The Dendral erased the generalpurpose, knowledge-sparse, weak methods to domain-specific, knowledgeintensive techniques from the artificial intelligence field. [7] [11]

The scope of the Dendral to developed a computer program to reach the human perfromance and knowledge on chemist. The Dendral project team could investigate an important fact: the computers could equal with a human in a narrow, (sticht) defined areas. The Dendral project put the bases of the nem methodology of expert systems. The Dendral was a such a good analytical tool for chemists. It was marketed commercially in the United States. It was an important step in the history of artificial intelligence. [7] [11]

After the field of chemistry the research projects taked a new way. The next project undertaken by Feigenbaum and others at Stanford University was in the area of medical diagnosis. The proect name was MYCIN which started in 1972. This project was a PhD thesis of Edward Shortliffe in 1976. MYCIN was a rule-based expert system for the diagnosis of infectious blood diseases. The program could give a therapeutic advices to the doctors with a user friendly method. MYCIN had various qualities normal to early master frameworks, counting: MYCIN could perform at a level proportionate to human specialists in the field and impressively superior to anything junior specialists. The MYCIN used about 450 independent ruel os IF- THEN rules. t camed from the human knowledge in a narro w domain through extensive interviewing of experts. Important to

see the following fact: the knowledge which build in like a rules
was clearly separated from the reasoing mechanism. What does it mean? The researchers and the engineer could manipulate the knowledge system if the modified rules, put in nuew rules or delete some of them. An empty version of MYCIN was developed and produced by the Stanford University in 1979. The name of the empty version is EMYCIN. It had all the features of the MYCIN system except the knowledge of infectious blood diseases. The EMYCIN made the basics of other diagnostic application in the field of medicine. The programmers and developers just had to add new rules and/or knowledge in the applications. During the development of MYCIN the program introduces some new features. The rules in the MYCIN system reflected an important thing: it is the uncertainty associated with knowledge, or we can call it to medical diagnostic. It means that the system has az uncertainty! [7] [11]

The next step in this fantastic evolution was the Prostector. It is a sepcial expert system for mineral exploration. This project developed by the Stanford Research Instituta in 1979. This project developed around 10 years (1974 – 1983). The project team were build up from nine experts. The Prospector used a combined structure which contained incorporated rules and sematic networks. The Prospector had more than thousand rules to represent extensive domain knowledge. It also had a sophisticated support package including a knowledge acquisition system. „*Prospector: operates as follows. The user, an exploration geologist, is asked to input the characteristics of a suspected deposit: the geological setting, structures, kinds of rocks and minerals. Then the program compares these characteristics with models of ore deposits and, if necessary, queries the user to obtain additional information. Finally, Prospector makes an assessment of the suspected mineral deposit and presents its conclusion. It can also explain the steps it used to reach the conclusion."* The inaccuracy is an impoartant fact of exploration geology, from the point of view of artificial intelligence the analyzed thing is incomplete or fuzzy. The Prospector used Bayes's rules to propogate uncertainties through the system. The Prospector reach the level of an geologist and proved itself in the practice. The prospector found a molybdenum deposit near to Mount Tolman ins Washington State in 1980. Subsequent drilling by a mining company confirmed the deposit was worth over $100

million. It is the best justification for the expert systems! These experts system now become classisc. [7] [11]

These expert systems were used with a high efficiency in the practice. Thanks for these success the the artificial intelligecen get a higher prior than ever. In his period most of the expert systems based and developed by the following programmin languages: LISP, PROLOG, OPS etc, but these programs need a powerfull workstation. These facts generated a problam. The expensive hardware and the difficult programming languages made a gate for the evolution of the artificial intelligence. The development of the experts system was left in the hands of a few research groups at Stanford University, Massachusetts Institute of Technology (MIT), Stanford Research Institute and Carnegie-Mellon University. As you can see, these institutes and universitis are in the United States. The changes came in the 1980, when a lot of cheap personal computers came to the market and in these year we can found/buy a lot of easy to use development tools. Thanks for these tools the researschers and engineers got a new possibilities to develope expert systems. [7] [11]

The first important report about expert system applications made in 1986. This report contained a different fields: chemistry, electronics, engineering, geology, management, medicine, process control and military science. Most of these apllications usesd on the field of medicine, but seven years later a similar report contained more 2500 expert systems! The new possibilities for the expert systems were the following: business and manufacturing. These two fields accounted for the 60% of the applications. These numbers and new fields showd the justification of the expert systems and artificial intelligence. These were a great success! It would be a mistake to overestimate the expert systems ability. [7] [11]

The tasks and problems are comoplex, we can find some disadvantages point also at the technical and also at the sociological fields. „*These are the following: Expert systems are limited to very narrow areas of expertise. because such as MYCIN, which has been developed for the diagnosis of infectious blood diseases, there is no real knowledge of human physiology. If a patient has more than one like a disease, we can not rely on MYCIN. In fact, therapy is prescribed blood disorders may be harmful even for the other disease."* In the practice or in the real life the expert system are not so flexible. The

systems hd a difficultied domain boundaries. In that case if we get
a different task than the original task problems, the expert system can try to solve it and it is rather inadequate unpredictable ways. [7] [11]

The experet systems have a limited explanation skill. The knowlwdge systems can find the sequences of the rules, they can find the solution to the problem but can not relate accumulated and/or heuristic knowledge to any deeper understanding the situations or the problems. [7] [11]

The expert system alsa have another problem: it is the verifiing and validating. Nowodays we have not know any method or technique to analyse the completeness ans cosistency. Heuristic rules represent knowledge in abstract form and lack even basic understanding of the domain area. It makes the task of identifying incorrect, incomplete or inconsistent knowledge very difficult. The first generation of the expert system had a little or they had not any ability to learn from thei experience. All of these expert systems are made individually and the development porcesses were verey slow. We have to wait 10 years to build an expert system which can solva a difficult problem. The systems what you can find above (DENDRAL, MYCIN, PROSPECTOR) need 30 years to made. The expert systems gave a big push to make any other important applications later. [7] [11]

## 1.6 FROM 1980S UNTIL TODAY

As you can read in the previous chapter the expert systems gave a breakthrought for artificial intelligence. In the middle of the 1980s hundreds of researchers and engineers started to work on different artificial intelligence project. In these years the scientcific works found a new era of artificial intelligence this is what we call neural networks. Until the end of the 1960s the most important and basic rules had already been taken. As w ered before only the years of the 1980s made a breakthrought in the world of computers. The main reason of this breakthrough van be find in psychological and on financial field. *"For example, in 1969, Minsky and Papert had mathematically demonstrated the fundamental computational limitations of one-layer perceptrons."* The researchers opinion was the following: there is not any available reason to expect more complex multilayer perceptrons would represent much. This fact did not encourage anybody to

make a research project on this field. Until the end of the 1970s a
lot of researcher and engineer left this field or scarried about the failure. [7] [11]

In the 1980s the brain like information processing came into the focus again. The human brain can work with a lot of information in the same time with a high speed. The researchers and engineer try to make a modell of the human brain. These research topics gave again a big push for the neural networks. The development of neural networks started on two ways. Grossberg made a new principle about self organization (this is the adaptive resonance theory). This work made the basic principles for the new class of neural networks. Hopfield works define the neural networks with feedback. This work published in the 1980s. Kohnen published a work about self oranised maps in 1982. Barto, Sutton and Anderson published their work on reinforcement learning and its application in control. The breakthrough what everybody wants came in 1986 when the back propagation learning algorithm work published by Bryson and Ho in 1969. This method was redesigned by Rumelhart and McCelland in Paralell Distributed Processing. Explorations in the Microstructures of Cognition At the same time, back-propagation learning was also discovered by Parker (1987) and LeCun (988), and since then has become the most popular technique for training multilayer perceptrons. Broomhead and Lowe found a new way, it was the layered feedforward networks what they used with radial basis function like an alternativel to multilayer perceptrons. They published their work in 1988. The artificial neural networks walked a long way from the early versions. The root of these tools can be find in neuroscience, psychology, mathematics and engineering. [7] [11]

As we can see the researchers and engineers try to made a model about the human brain or the natural brain. For these researches the biological simulations were necessary. With these models we could discover how livingy systems or the human body (brain) works and we can understand deeper the definition of tinelligence. Important to know: the natural or biological systems are not told how they can work in a specific environment. The most important thing for these system is: to survive. The fittest species have a better chance to reproduce, and thereby to pass their genetic material (or maybe experience) to the next generation. "*The evolutionary approach to artificial intelligence is based on the computational models of natural selection and genetics. Evolutionary computation works*

*by simulating a population of individuals, evaluating their performance, generating a new population, and repeating this process a number of times. Evolutionary computation combines three main techniques: genetic algorithms, evolutionary strategies, and genetic programming."* [7] [11]

John Holland was the publisher who wrote about the concept ot the geneteic algorithms in 1975. Holland developed a special algorithm which helped to manipulate artificial chromosomes. This algorithm used genetic operations as selection, crossover and mutations. The geneteic algorithms are based on a solid theoretical foundation of the Schema Theorem. Ingo Rechenberg and Hans-Paul Schwefel, students of the Technical University of Berlin, developed a brand new optimisation method called evolutionary strategies int the 1960s. They developed the evolutionary strategies to solv parameter optimization problems in engineering field. The suggestion or Rechenberg and Schwefel were the random changes in the parameters like in a real life or in ta natural mutation. These evolutionary strategies approach can be considered as an alternative way to the engineer's intuition. The evolutionary strategis use a numerical optimization procedure, same as or similar what we can find at Monte Carlo simulaton. The genetic algorithms and the evolutionary strategies also can use a wide range of science or engineering problems. They provide robust and reliable solutions for highly complex, nonlinear search and optimisation problems that previously could not be solved at all. [7] [11]

The application of the genetic model of learning to programmingrepresented by genetic programming. The goal of this method to give a computer code to solve a problem. So, the genetic programming can generate a solution for the computer programs. One of the most important pioneer of the genetic programming was John Koza in the 1990s. He used genetic operations to manipulate symbolic code representing LISP programs. "*Genetic programming offers a solution to the main challenge of computer science – making computers solve problems without being explicitly programmed. Genetic algorithms, evolutionary strategies and genetic programming represent rapidly growing areas of AI, and have great potential."* [7] [11]

The neural networks opened a new way to make a connection with the real world than do systems based on symbolic reasoning. The neural networks have a lot of important properties which can give a lot of advantages for the system. The neural networks can

leadn, adopt the canges in the system, establish patterns in situations where rules are not known, and deal with fuzzy or incomplete information. But the neural networks often work as a balck box. Important to know these systems also have some disadvantages, for example: process of training neural networks with current technologies is slow, and frequent retraining can cause serious difficulties. [7] [11]

The ANNs can solve problems better than expert systems especially in knowledge poor situations. The two methods are not independent from each other. They rather nicely complement each other. The classic expert systems are easy to use for closed system applications with precise inputs and logical outputs. These systems use expert knowledge in the form of rules and it is necessary, the system can interact with the user. A major drawback is that human experts cannot always express their knowledge in terms of rules or explain the line of their reasoning. This fact can prevent the expert system from accumulating the necessary knowledge, and consequently lead to its failure. *"To overcome this limitation, neural computing can be used for extracting hidden knowledge in large data sets to obtain rules for expert systems. ANNs can also be used for correcting rules in traditional rule-based expert systems."* In another point of view, where acquired knowledge is incomplete, neural networks can refine the knowledge, and where the knowledge is inconsistent with some given data, neural networks can revise the rules. [7] [11]

Another important method which is help for researchers and engineer to checnk an analyze the imprecise and uncertain knowledge for example parameter deviation, and analyze big datas is the fuzzy logic. The handling imprecision in classic expert systems are based on the probability concept. The MYCIN uses certainty factors, the Prospector used Bayes rules. The experts do no think in changing or probability values but in such terms as often, generally, sometimes, occasionally and rarely. The fuzzy logic is an ideal tool to understand the meaning of words, human reasoning or decision meaning with mathematical formulas. To understand and work with the human knowledge we have to use fuzzy logic. During the fuzzy analyzes we have to understand the experts opinion, complex problem and the not clear differences between problems or sets. During the fuzzy investigation or operiaton we have to use a linguistic variable. This variables are

words not really numbers. The fuzzy systems use IF – THEN rules ike the other expert systems. For example [7] [11]:

- *"IF speed is high THEN stopping_distance is long;"*
- *"IF speed is low THEN stopping_distance is short."*

The pioneer of the fuzzy logig was Professor Lotfi Zadeh who was the chairman if the electrical engineering department at University of Berkeley. He published his most important work in fuzzy logic in 1965. He made the rules of computer programming with words. During his work he hit into a lot of walls, the acceptance of fuzzy logic was very slow and it was not so easy. On of the problems was the name of the method. The 'fuzzy' name looked like 'light' to be taken seriously. Later the fuzzy logic get a high prior in Japan and just some years later became important again int the estern world. It has been used successfully since 1987 in Japanese designed dishwashers, washing machines, air conditioners, television sets, copiers, cars, robots etc. [7] [11]

*"The introduction of fuzzy products gave rise to tremendous interest in this apparently 'new' technology first proposed over 30 years ago. Hundreds of books and thousands of technical papers have been written on this topic. Some of the classics are: Fuzzy Sets, Neural Networks and Soft Computing (Yager and Zadeh, eds, 1994); The Fuzzy Systems Handbook (Cox, 1999); Fuzzy Engineering (Kosko, 1997); Expert Systems and Fuzzy Systems (Negoita, 1985); and also, the best-seller science book, Fuzzy Thinking (Kosko, 1993), which popularised the field of fuzzy logic."* [7] [11]

The most of the fuzzy logic applications contain into the field of contor engineering. Important to know the fuzzy control system use just a small part of fuzzy logic's properties. "*Benefits derived from the application of fuzzy logic models in knowledge-based and decision-support systems can be summarised as follows (Cox, 1999; Turban and Aronson, 2000): Improved computational power: Fuzzy rule-based systems perform faster than conventional expert systems and require fewer rules."* The fuzzy expert system can merges the rules. Zadehs theory was the following: he thinked that in the next few years most expeert systems will use fuzzy logic to solve nonlinear and computationally difficult problems. [7] [11]

The fuzzy logic has a developed cognitive modelling property.

The fuzzy system can encode the knowledge which can reflect the think of the experts about the complex problem. During a problem solving process the experts often use a lof of imprecise words like: high and low, fast and slow, heavy and light, and they also use such terms as very often and almost never, usually and hardly ever, frequently and occasionally. If we would like to use the fuzzy logic correctly we have to define the crisp boundaries between the fuzzy sets. It means that we have to breking down the experetise into small fregments. But this fragmentation has a negative effect on the expert system. When we would like to analyze a complex problem, the expert system will have a bad efficiency. The fuzzy expert systems contain imprecise informations, represent the expert mind much better and improve the cognitive modelling process of the problem. [7] [11]

## 2. THE BASICS OF FUZZY LOGIC

The first references to fuzzy logic can be found in the works of Lofti Zadeh who achieved outstanding results in this topic in 1965. He examined the blurred boundaries of the truth values of different colloquial concepts from a mathematical approach (calculation with words). He assigned a value between [0;1] (closed interval) to every logical statement during the modelling process. Figure 1 presents the difference between non - fuzzy and fuzzy logic. [3] [4] [5] [9]

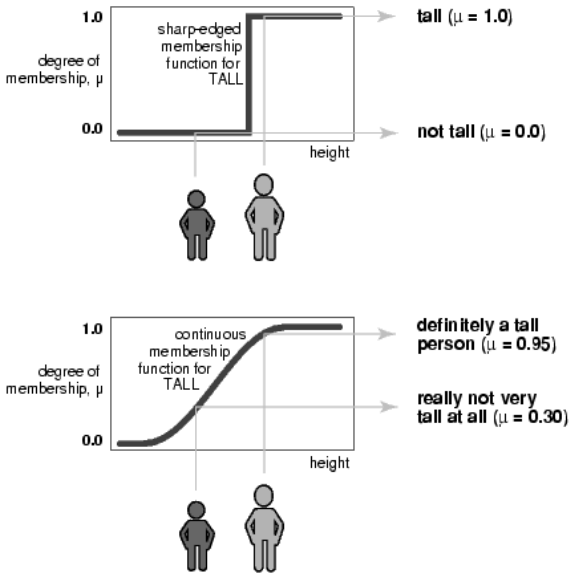


*Figure 1.: Non - Fuzzy and Fuzzy logic* [5]

We talk about nice weather, high speed, and good restaurants with a blurred meaning in our everyday life. If we were surrounded by exact definitions, verbal communication would become impossible so the lack of precision in the vernacular is necessary in our life. If mathematics is used to describe the complexity of the real world, we have to do it in a numerical form. The Fuzzy is the only way to describe human knowledge, expertise and experience in a mathematical form. [3] [4] [5] [9]

If we happen to read the measuring results incorrectly from the gauges in practice, this mistake can lead to inaccuracy during our work. This is the reason why we can use Fuzzy logic when such problems occur. This inaccuracy can be represented by so-called

membership functions. The process in fuzzy systems is illustrated in Figure 1. [3] [4] [5] [9]

The first step is fuzzification, which is in fact (about) giving production values to the system. We have to define the categories and the membership functions for the model. The main factors need to be examined. It is important to select an appropriate number of categories. If the number of the categories is increased, we can get an exact picture of the system but it can lead to unnecessary calculations. Having too much information can be as dangerous as having too little. [3] [4] [5] [9]

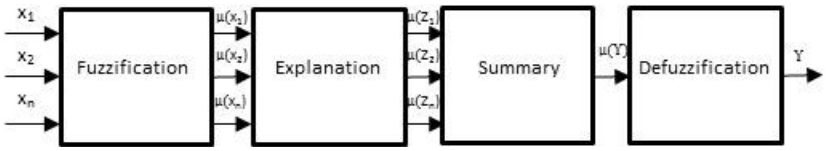


*Figure 2.: The fuzzy system and process [9]*

Every category has to use a membership function, we know several ways to define the categories. The μ(x;a) membership function gives the rate of feature x in set A. Another important step is scale definition. It is practical to use it in the following scales: 0-10, 1-10, 0-100, 1-100. The target of the scale is to find the simplest possible way to compare and evaluate the examined values. [3] [4] [5] [9]

It is essential that the system uses the right rule in the explanation stage. The rules come from the defined categories. If the rules work well, the system can interpret the values. This is how the rules of a fuzzy model are created. [3] [4] [5] [9]

In the final step, we link the values - which we got from the explanation - which differ form 0 in the light of the features of the controlled process, the fuzzy process. The result of this is a fuzzy set. As this is a preconlcusion, this result is not relevant in practical usage. It can be interpreted in the next step called defuzzification. [3] [4] [5] [9]

The defuzzification is the last step of the process. In this step, we have to choose the exact value based on the fuzzy conclusion and this value - depending on the application and the model - is the most representative of the set. The meaning of the defuzzification can be different depending on the usage. We can use different types of defuzzification methods to get the right results. [3] [4] [5] [9]

The most important ones among them are[3] [4] [5] [9]:

- Center of Gravity (COG);

- Center of Area (COA);

- Weighted Mean of Maximum.

The Center of Gravity method is one of the most commonly used defuzzification methods. The main advantages of COG are that it is easy to use with triangular and trapezoidal rules and it can show continuous behavior during direct navigating. The COG in general form [3] [4] [5] [9]:

$$Y_{COG} = \frac{\sum_{i=1}^{n} \int_{-\infty}^{+\infty} \mu_i(z) z dz}{\sum_{i=1}^{n} \int_{-\infty}^{+\infty} \mu_i(z) dz} \quad (1)$$

The Center of Area method is very similar to the Center of Gravity. The difference between the two methods is in the calculation. The COG uses areas which are covered by part conclusion while the COA uses only the cumulative consequences. The form of COA [3] [4] [5] [9]:

$$Y_{COA} = \frac{\int_{-\infty}^{+\infty} \mu_{\sum}(z) z dz}{\int_{-\infty}^{+\infty} \mu_{\sum}(z) dz} \quad (2)$$

The Weighted Mean of Maximum is the most frequently used method for defuzzification. The method's result shows the biggest membership value. If it reaches the highest result in one interval, then we have to calculate the mean value of this stage. Its form is [3] [4] [5] [9]:

$$Y_{WMM} = \frac{\sum_{i=1}^{n} \mu_i z_i}{\sum_{i=1}^{n} \mu_i} \quad (3)$$

Menyhárt and Pokorádi have used Fuzzy logic to examine battery parameter deviations and operation condition monitoring in their previous research.

# 3. GENERAL OVERVIEW OF SIGMOID FUNCTION

The sigmoid function is an important mathematical function which hasn an S shaped curve or in another name it has a sigmoid curve. Often the sigmoid functions are not other like a special variant of the logistic function. We can define a sigmoid function with the following formula [3] [10]:

$$S(x) = \frac{1}{1+e^{-x}} = \frac{e^x}{e^x+1} \quad (4)$$

The Gompertz curve has a similas shapes, it is an important tool in modeling systems that that saturate at large values of x. The another similar funticon is the ogee curve which used in the spillway of some dams. *"Sigmoid functions have domain of all real numbers, with return value monotonically increasing most often from 0 to 1 or alternatively from −1 to 1, depending on convention. The sigmoid functions have a wide variation. Recearchers and engineers use it as an activation function of artificial neurons. Sigmoid curves are also common in statistics as cumulative distribution functions (which go from 0 to 1), such as the integrals of the logistic distribution, the normal distribution, and Student's t probability density functions."* [3] [10]

The sigmoid function has the following important properties [3] [10]:

- bounded;
- differentiable;
- real valued;
- monotonic;
- differentiable having a non-negative first derivative which is bell shaped;
- it is constrainged by a pair of horizontal asymptotes.

The following formulas show some example about functions [3] [10]:

- Logistic function:

$$f(x) = \frac{1}{1+e^{-x}} \tag{5}$$

- Hyperbolic tangent:

$$f(x) = tanhx = \frac{e^{x}-e^{-x}}{e^{x}+e^{-x}} \tag{6}$$

- Arctangent function:

$$f(x) = arctanx \tag{7}$$

- Gudermannian function:

$$f(x) = gd(x) = \int_0^x \frac{1}{cosht} dt \tag{8}$$

- Error function

$$f(x) = erf(x) = \frac{2}{\sqrt{\pi}} \int_0^{\pi} e^{-t^2} dt \tag{9}$$

- Generalised logistic function:

$$f(x) = (1 + e^{-x})^{-\alpha}, \alpha > 0 \tag{10}$$

- Smoothstep function:

$$f(x) = \begin{cases} \left(\int_0^1 (1-u^2)^N du\right)^{-1} \int_0^x (1-u^2)^N du & |x| \leq 1 \\ sgn(x) & |x| \geq 1 \end{cases} \quad N \geq 1 \tag{11}$$

- Specific alebraic functions:

$$f(x) = \frac{x}{\sqrt{1+x^2}} \tag{12}$$

# 4. FUZZY LOGIC AND MATLAB

Nowodays the importance of the fuzzy logic can get a higher prior than ever. We use this artificial intelligence tool in our daily life too not only in high tech equioments. We can find it in washingmachines, cameras, ovens, microwaves etc. But we do not have to forget the other important fields of artificial intelligence, these are the industrial solutions and health care or medical services. [2] [3]

In science or engineering life the MatLAB® software is very popular to make codes or simulations. If we would like to use MatLAB® mathematical software to analyze fuzzy logic we have to use Fuzzy Logic Toolbox™. This toolbox can help for the users to use fuzzy logic with special rules system and to simulate the functions. The toolbos is base on the foundation of fuzzy logic. As we know from the previous chapters the fuzzy logic may be viewed as a methodology for computing with words rather than numbers. Important to know the accuracy of the words is not so good, the numbers are more precise. In another point of view the computing with worlds can exploits the tolerance for imprecision and it can lowers the cost of solution. [2] [3]

The second concept of the fuzzy logic, when the users work with the IF – THEN rule or simply fuzzy rule. The rule based systems have a long story what we can read in the first chapters, what is missing in such systems is a mechanism for dealing with fuzzy consequents and fuzzy antecedents. This mechanism is based on the calculus of fuzzy rules. *"The calculus of fuzzy rules serves as a basis for what might be called the Fuzzy Dependency and Command Language (FDCL)."* Important to know the Fuzzy Dependency and Command Language is not used in the MatLAB® Fuzzy Logic Toolbox™. It is the one of its principal consistituents. Another point of view the fuzzy logic is not other like a a translation of a hman solution into the Fuzzy Dependency and Command Language. [2] [3]

In the new researchfield we can find a lot of projects about fuzzy logic combination with a neurocomputing and fenetic algorithms. The fuzzy logic, neurocomputing and the genetic algorithsm are a member of a group what we can call soft computing methods. Unlike the traditional, hard computing, soft computing accommodates the imprecision of the real world. "*The guiding principle of soft computing is: Exploit the tolerance for*

*imprecision, uncertainty, and partial truth to achieve tractability, robustness, and low solution cost."* In the not far future the soft computing methods will be a very important part of a new conception of Machine IQ (MIQ) systems. These new methods will have some much higher possibilities than the old or traditional methods. [2] [3]

In the set of the soft computing methdos the fuzzy logic and the neurocimputing system combinations have the best properties in the practice. These kinds of systems have a high role in the set up of the fuzzy rule base. One of the most usefull method is the Adaptive Neuro Fuzzy Inference System (ANFIS) by Dr. Roger Jang. This method is an important component of the MatLAB® toolbox. *"Fuzzy logic is all about the relative importance of precision: How important is it to be exactly right when a rough answer will do?"* [2] [3]

You can use Fuzzy Logic Toolbox software with MATLAB® technical computing software as a tool for solving problems with fuzzy logic. The fuzzy logic can be the key to work with significance and precision what humans have been managing for a very long time. Important to know: the fuzzy logic new and old in the same time. The methodical science of fuzzy logic is still young, but the concepts of fuzzy logic is based on an old skill of human reasoning. The fuzzy logic is a good way to make an output space for an input space. Mapping input to output is the starting point for everything. [2] [3]

Fuzzy logic examples [2] [3]:

- *"With information about how good your service was at a restaurant; a fuzzy logic system can tell you what the tip should be."[2]*
- *"With your specification of how hot you want the water; a fuzzy logic system can adjust the faucet valve to the right setting." [2]*
- *"With information about how far away the subject of your photograph is, a fuzzy logic system can focus the lens for you." [2]*
- *"With information about how fast the car is going and how hard the motor is working, a fuzzy logic system can shift gears for you." [2]*

If we would like to determine the appropriate amount of the tips requires mapping inputs to the appropriate outputs. Between the input and the output, the preceding figure shows a black box that can contain any number of things: fuzzy systems, linear systems, expert systems, neural networks, differential equations, interpolated multidimensional lookup tables, or even a spiritual advisor, just to name a few of the possible options. Important to know this list is not full. [2] [3]

We can make a lot of black box methods to work, during the research works we can see that the fuzzy logic is the best way. Lofti Zadeh said the following about this: *"In almost every case you can build the same product without fuzzy logic, but fuzzy is faster and cheaper."* [2] [3]

In the following list we can find a lot of benefit of fuzzy logic [2] [3]:

- *"Fuzzy logic is conceptually easy to understand."*
    - *"The mathematical concepts behind fuzzy reasoning are very simple. Fuzzy logic is a more intuitive approach without the far-reaching complexity."* [2]
- *"Fuzzy logic is flexible."*
    - *"With any given system, it is easy to layer on more functionality without starting again from scratch."* [2]
- *"Fuzzy logic is tolerant of imprecise data."*
    - *"Everything is imprecise if you look closely enough, but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end."* [2]
- *"Fuzzy logic can model nonlinear functions of arbitrary complexity."*
    - *"You can create a fuzzy system to match any set of input-output data. This process is made particularly easy by adaptive techniques like*

*Adaptive Neuro-Fuzzy Inference Systems (ANFIS), which are available in Fuzzy Logic Toolbox software."* [2]

- *"Fuzzy logic can be built on top of the experience of experts."*
    - *"In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, fuzzy logic lets you rely on the experience of people who already understand your system."* [2]
- *"Fuzzy logic can be blended with conventional control techniques."*
    - *"Fuzzy systems don't necessarily replace conventional control methods. In many cases fuzzy systems augment them and simplify their implementation."* [2]
- *"Fuzzy logic is based on natural language."*
    - *"The basis for fuzzy logic is the basis for human communication. This observation underpins many of the other statements about fuzzy logic. Because fuzzy logic is built on the structures of qualitative description used in everyday language, fuzzy logic is easy to use."* [2]

The last point of this list is very important. It is the natural language. The natural language is not other like the daily language which used by ordinary people. It has an evolution from thousand of years of human history. The sentences written in ordinary language represent a triumph of efficient communication in our life. [2] [3]

As we can see the fuzzy logic has a lot of benefits, but in some cases we can not use fuzzy logic. [2] [3]

Important to know: the fuzzy logic is not a magic tool. The fuzzy logis is not else like a convenient way to map an input space to an output space. If the user feel that it is can not works or not easy to use, try something else. If you can find simpler solution already exists, use it. The fuzzy logic is an ideal tool to codification of the common sense. If you try to use common sense when you would like to implement it and you will make the right decision. Many controllers, for example, do a fine job without using fuzzy logic. If you work a lot with fuzzy logic and if you will get enough experience you will see the

fuzzy logic is a very good tool for dealing quckly and efficiently with imprecision and nonlinearity. [2] [3]

The MatLAB® Fuzzy Logic Toolbox™ is usefull to create and edit fuzzy inference systems. With this software you can create these system with graphical tools and/or command line functions. Other way is when you generate them automatically with apative neuro fuzzy or clustering techniqes. [2] [3]

The Simulink® software is helps to test the fuzzy system in a block diagram simulation environment. The toolbox gives a way to use your own stand alone 'C' program(s). You can customize the stand-alone engine to build fuzzy inference into your own code. All provided code is ANSI® compliant. [2] [3]

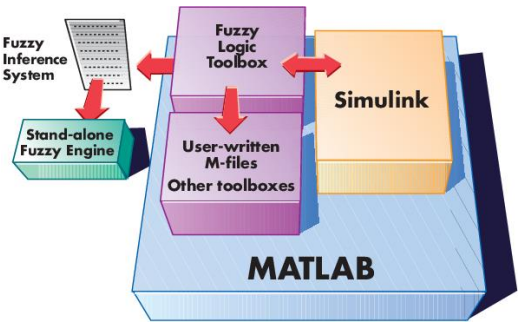


*Figure 3.: MatLAB Simulink and Fuzzy Logic Toolbox [2]*

# 5. SUPPORT VECTOR MACHINE – SVM

## 5.1 Theoretical background of SVM method

With the progress of informatics, we enter an era of a growing demand for real mathematical, computer modelling but these techniques have to check repetitive and similar schemes, and there is a need for the classification of these schemes during their operation. The fastest growing area of artificial intelligence is the statistical learning algorithms. In other words, we can call it the theory of machine learning, which enables us to draw conclusions and make generalizations from the learning sets and the sample sets (which means real time observations). The most important method is the Support Vector (SV) method which works on statistical base. The Support Vector group is made up from different variants of Support Vector Machine (classification) and Support Vector Regression (regression). Their names refer to the fact that not all the elements of the available training set are used for the statistical model. [3] [5]

The SVM is nothing more than a special neural network or a statistical learning theory in some cases.

The SVM formation and development have taken place in the last 30-40 years. V.N. Vapnik has done significant work in this topic.

The SVM method can be used for approximating functions, classifications, but its main task is to find the optimal solution. The SVM is applied in different areas like character recognition, image processing, bioinformatics, data mining etc. The SVM can take decisions very quickly, this is the reason why we can use it in real time applications. Its advantage is that it can make and implement decisions very quickly, so the SVM proves applicable to real time applications as well. [3] [5]

## 5.2 SVM for classification

Suppose the following [3] [5]:

$$(x_1, y_1) \ldots (x_n, y_n);\ x_i \in R^d;\ y_i \in \{-1,1\} \qquad (13)$$

The elements of the samples derived from two classes. The elements of $x_i \epsilon R^d$ from class $A_1$ then use $y_i = 1$, if from class $A_2$ then use $y_i = -1$. The training set is linearly

separable if we know a hyperplane one side of which contains only the elements of class $A_1$, while the other side contains the elements of class $A_2$.

So

$$\langle x, \varphi \rangle = c \tag{14}$$

is linearly separable with a hyperplane, if

$$\langle x_i, \varphi \rangle > c, \text{ if } y_i = 1, \tag{15}$$

$$\langle x_i, \varphi \rangle < c, \text{if } y_i = -1, \tag{16}$$

where $\varphi \epsilon R^d$ unit vector is an inner product between a and b where $c \in R \ \langle a, b \rangle$. The SVM always looks for the most optimal hyperplane. Figure 1. shows two non - optimal separator lines and another one, which was made by SVM method. [3] [5]

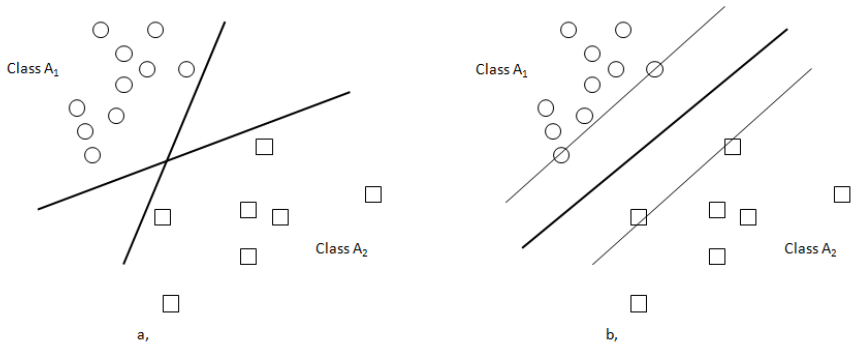


*Figure 4.: Separation with a hyperplane, two not optimal separations in case a, while case b contains a separation with maximum edge* [3] [5]

The thin lines on Figure 1. in case b are edges or margins. The thick line in the middle is called the band limit. The points which fit on the margins are the support vectors. The separating hyperplane is as far away as possible from the sample points. The support vectors are the closest to the optimum hyperplane. [3] [5]

### 5.3 SVM for regression

The Support vector based statistical classification and regression methods belong to the statistical learning algorithms group. The Support Vector Machine (SVM) algorithm was the first method for classification, later the first form of the Support Vector Regression appeared in 1997. The SVM can rank an optional number of vectors into classes in the case of binary classification where the model is based on learning vectors (Figure 5.) [3] [5]

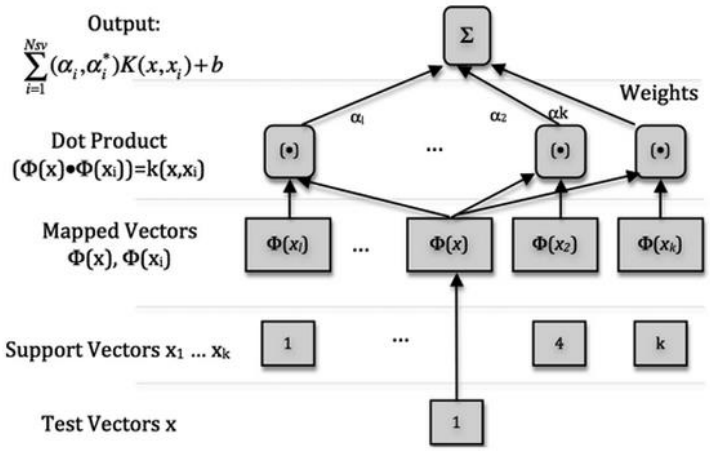


*Figure 5.: Support Vector Regression process* [3] [5]

The square of the distance is widely used in the classical areas of mathematics. We can find it in the case of L2 and I2 spaces and in the smallest square methodology of numerical mathematics. The variance can be found in probability theory, the classical regression analysis also use this. [3] [5]

Form:

$$\left(y - f(x,\alpha)\right)^2, \tag{17}$$

Where x is the input and y is the output. We use loss functions (like those used in robust mathematics) in the case of SVM, such as the ε-insensitive loss function. [3] [5]

The ε-insensitive loss function means that the system is not sensitive to deviations which are smaller than ε. Higher deviations than ε are not used quadratically, we use them linearly. [3] [5]

That is

$$L_\varepsilon\big(y - f(x,\alpha)\big) = |y - f(x,\alpha)|_\varepsilon \tag{18}$$

a linear ε-insensitive loss function, where

$$|y - f(x,\alpha)|_\varepsilon = \begin{cases} 0, & \text{if } |f(x,\alpha)| \le \varepsilon, \\ |f(x,\alpha) - y| - \varepsilon, & \text{if } |f(x,\alpha)| > \varepsilon, \end{cases} \tag{19}$$

It is shown by Figure 6. [3] [5]

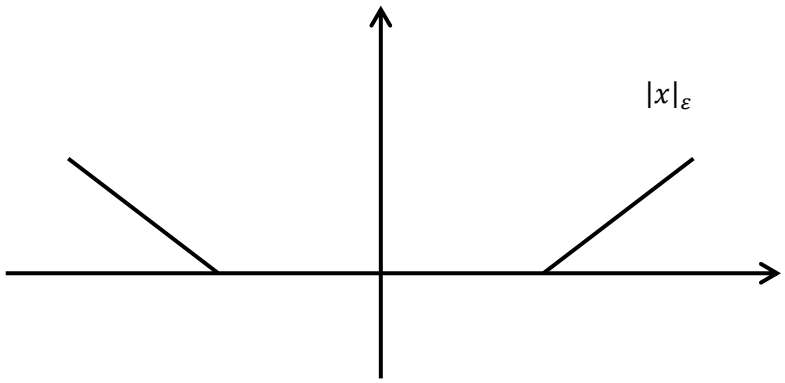


*Figure 6.: The ε – insensitive loss function* [3] [5]

## 5.4 Fuzzy logic and SVM applications

The SVM is one type of machine learning techniques, this technique is based on statistical methods. The SVM can be used for classification or regression analysis. The target of SVM is to find the most optimal hyperplane. Thanks to this feature, it is different from other neural networks. [3] [5]

The variables of Fuzzy systems are based on fuzzy sets. It is possible to give a numerical description of empirical and linguistic skills with the help of these features.

They cannot support independent machine learning and adaptation At first glance (it seems as if) the two machine learning methods cannot be used and combined at the same time. The paper presents how the two methods can work together in different applications in everyday life/ use. [3] [5]

The proposed network combines the characteristics of SVM and Fuzzy systems. It is high general performance, even if the dimension of the input space is very high, structured and it gives a numerical representation of knowledge and ability using linguistic fuzzy rules, in order to bridge the semantic gap between the low-level descriptors and the high-level semantics of an image. The authors checked different types of images with this special Fuzzy-SVM network. The main focus was on urban and beach pictures. [3] [5]

In order to avoid the scale effect, every feature should contain more or less the same numerical values. In this case the MPEG-7 descriptors are already scaled into integer values of equivalent magnitude. The authors used the Personal Content Services database for their work. It is contains 767 high quality color images which are divided into two classes (beach and urban) (figure 6.). They used 40 images from the beach category and 20 from the urban during the system training. The remaining 707 were used for the evaluation. [3] [5]

*Figure 7.: Beach and urban pictures* [3] [5]

The Fuzzy SVM network made it possible to extract linguistic fizzy rules during the classification. An extracted fuzzy rule for the case of the Edge Histogram descriptor [3] [5]:

IF the number of 0 ± edges on the upper part of the image is low AND the number of 45 ± edges on the upper part of the image is medium AND . . . AND the number of non-directional edges on the lower part of the image is high, THEN the image belongs to class Beach. [3] [5]

The proposed network was successfully applied to the problem of image classification. The fusion of the two methods was very useful as it can provide a lingusitic description of the underlying classification mechanism. The authors write some words about their future works: they would like use more MPEG-7 descriptors and more classes. [3] [5]

Yixin Chen and his co-author James Z. Wang start their work with a description of Fuzzy logic: this research topic has been very popular for a long time. They mention the Support Vector Machine method, it has a good generalization ability but what is even more important: SVM works well in multidimensional spaces. They describe the connection between fuzzy classification and kernel machines and they look for a link between fuzzy rules and kernel functions and present an algorithm for classification. [3] [5]

Takuya Inoue and his colleague Shigeo Abe at Kobe University in Japan also did a similar research. They carried out a research about classification problems.

Boumediene Allaoua and Abdellad Laoufi - unlike the previous examples – used the methods mentioned above in vehicle industry. They present a new sliding mode fuzzy

control scheme for torque control of induction motors. The control
principle which they developed is based on sliding mode fuzzy control combined with SVM. The sliding mode fuzzy control contributes to the robustness of induction motor wheel drives and the space vector modulation improves the torque, flux, and current steady performance by reducing the ripple. They used the Lyapunov direct method with fuzzy logic. Figure 7. shows their system. [3] [5]

Compared with the classical PI control method, the conventional SMC method and SMFC with SVM technique, this new scheme has low torque ripple, low current distortion, and high performance dynamic characteristics. This new control scheme can achieve high accuracy in torque tracking to various reference torque signals and shows robustness to external load disturbances. In summary, their system is simple, accurate and it has high reliability. [3] [5]

# 6. CASE STUDIES

## 6.1 BMW X3 Oil change time analysis with Fuzzy Logic

The oil service period of modern vehicles gets high priority in technological research and development, the vehicles use different types of alternative oil sources because of the changing environmental requirements. [1]

*Figure 8.: Analyzed vehicle* [1]

The following table contains the main parameters of the investigated BMW vehicle:

*Table 1.: BMW X3 basic informations* [1]

| | |
|---|---|
| Vehicle Type | BMW X3 |
| Chase Number | WBAPBMOODWE49110 |
| First date in traffic | 2006.02.23 |
| Engine | Diesel, 2000 cm |
| Oil service km limit | 30000 km |
| Oil service time period limit | 24 months |

The fuel is used not only by autonomous vehicles, but now we can meet it in industrial applications and in daily traffic, It is a well-known fact that to reach the highest efficiency we have to maintain the car change the oil on time and look after the car parts. [1]

The main purpose about this research is checking the details and parameter tolerance of car fuel distance and time period of oil change with fuzzy logic concept; with the help of

fuzzy logic datawe candevelopsuch report which will helpus to determine the use of oil and thecorrect time period. [1]

To get the result we need some parameters for this process, and the main parameters are [1]:

- Distance [km]
- Time period

All information and data which I got are based on practical in daily useand expert's opinion about it,Particles shows that the car diesel engine can work forlong period, if we see the data from the company which give usthat the engine can work up to 100% and lower range is almost 76%but in actual daily lifeand after what I checked thatthe engine oilworks on 61% as well with full safety and regular performance,Well thedistance it depends on many things like the type of the oil and also on other parts and engine load, there is another factor what we should add that is the outsideatmosphere, the road, and the weather, temperature, humidity, So the limit ofdistance which vehicles have in Europe is differentfrom the limit in Asia like Pakistan or India. [1]

The data is given below in the table:

*Table 2.: Empirical datas* [1]

| | | Empirical value |
|---|---|---|
| Distance [%] | Min | 100,00% |
| | Max | 117,11% |
| | Average | 84,49% |
| Time period [%] | Min | 20,83% |
| | Max | 100% |
| | Average | 54% |

*Table 3.: The functions coefficients*

| Parameter (i) | a | $b_i$ |
|---|---|---|
| Distance | 0,8901 | 107,5415 |
| Time period | 0,1884 | 56,993 |

Calculation of the coefficients:

Distance [1]:

$$\left.\begin{aligned} 0{,}9998 &= \frac{1}{1+e^{a(b-117.11)}} \\ 0{,}0012 &= \frac{1}{1+e^{a(b-100)}} \end{aligned}\right\}$$

$$\left.\begin{aligned} 0{,}9998 + 0{,}9998 * e^{a(b-117.11)} &= 1 \\ 0{,}0012 + 0{,}0012 * e^{a(b-100)} &= 1 \end{aligned}\right\}$$

$$\left.\begin{aligned} 0{,}9998 * e^{a(b-117.11)} &= 2 * 10^{-4} \\ 0{,}0012 * e^{a(b-100)} &= 0{,}9988 \end{aligned}\right\}$$

$$\left.\begin{aligned} e^{a(b-117.11)} &= 2.0004 * 10^{-4} \\ e^{a(b-100)} &= 832.33 \end{aligned}\right\}$$

$$\left.\begin{aligned} a(b-117.11) &= -8.5169 \\ a(b-100) &= 6.7133 \end{aligned}\right\}$$

$$\left.\begin{aligned} ab - 117.11a &= -8.5169 \\ ab - 100a &= 6.7133 \end{aligned}\right\}$$

$$-17.11a = -15{,}2302$$

$$a = 0.8901$$

$$0.8901(b-117.11) = -8.5169$$

$$0.8901b - 104.2396 = -8.5169$$

$$0.8901b = 95.7227$$

$$b = 107.5415$$

Time period [1]:

$$\left.\begin{aligned} 0{,}9997 &= \frac{1}{1+e^{a(b-100)}} \\ 0{,}0011 &= \frac{1}{1+e^{a(b-20.83)}} \end{aligned}\right\}$$

$$\left.\begin{aligned} 0{,}9997 + 0{,}9997 * e^{a(b-100)} &= 1 \\ 0{,}0011 + 0{,}0011 * e^{a(b-20.83)} &= 1 \end{aligned}\right\}$$

$$\left.\begin{aligned} 0{,}9997 * e^{a(b-100)} &= 3 * 10^{-4} \\ 0{,}0011 * e^{a(b-20.83)} &= 0.9989 \end{aligned}\right\}$$

$$\left.\begin{aligned} e^{a(b-100)} &= 3.0009 * 10^{-4} \\ e^{a(b-20.83)} &= 908.09 \end{aligned}\right\}$$

$$\left.\begin{aligned} a(b-100) &= -8.1114 \\ a(b-20.83) &= 6.8113 \end{aligned}\right\}$$

$$\left.\begin{aligned} ab - 100a &= -8.1114 \\ ab - 20.83a &= 6.8113 \end{aligned}\right\}$$

$$-79.17a = -14.9227$$

$$a = 0.1884$$

$$0.1884(b-100) = -8.1114$$

$$0.1884b - 18.8489 = -8.1114$$

$$0.1884b = 10.7375$$

$$b = 56.993$$

Based on the statistical data mentioned above, the fuzzy membership function of parameter tolerances is given by the [1]:

$$\mu_i(x) = \frac{1}{1 + e^{a_i(b_i - x)}} \tag{20}$$

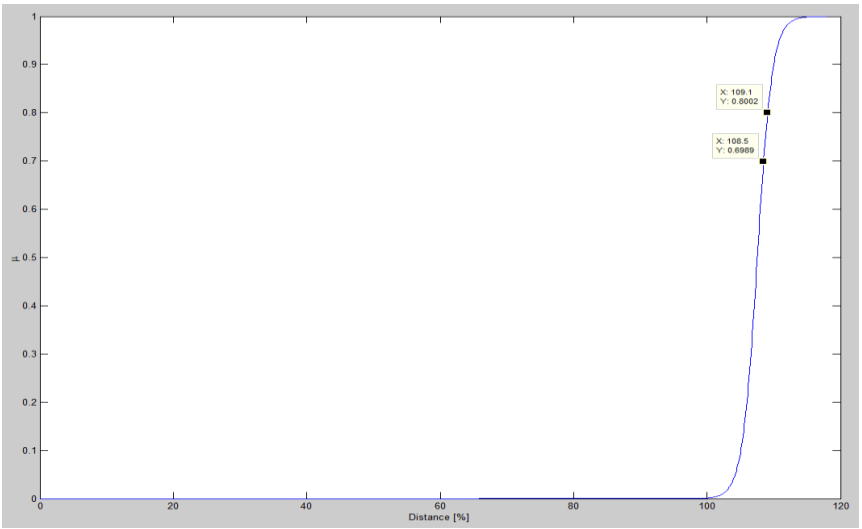


*Figure 9.: Distance % and membership* [1]

In this figure there is relation between distance and membershipand in next figure the membership iswith time period

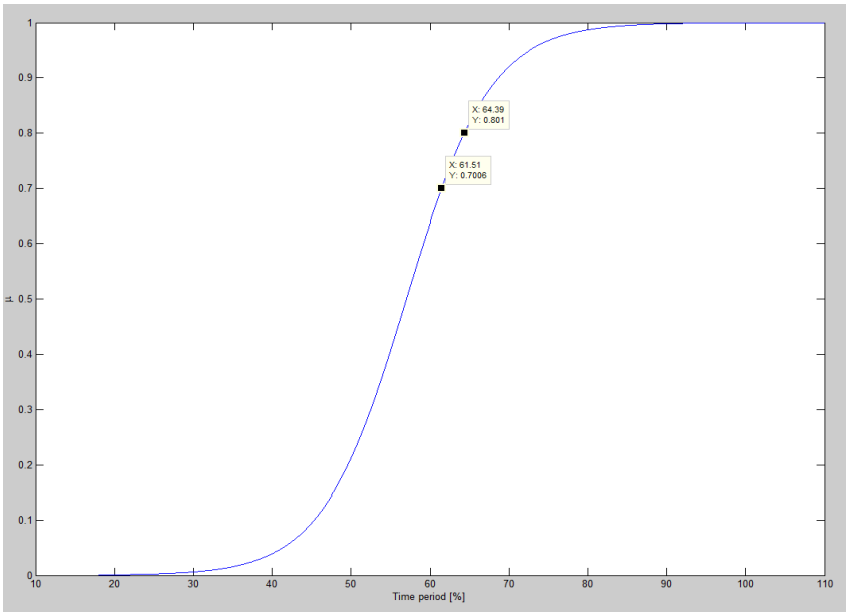


*Figure 10.: Time period and membership* [1]

During this process we have seen one main thing that is the incorrect timing and distance which we got from control system, well this uncertainty can cause big harm to our vehicles, change oil before or after the correct time can be harmful, That's why we control the system by logical rules and membership function (1) – (2). [1]

## 6.2 Calculations

Below in the table I have the ideal values for distance and time period, the distance is 100% at 30000KM so it means the ranges of 0,7 and 0,8 are more than the company safety measurements so this is the difference between imaginary and practical data.
The next table is calculation and data from 2006 to 2016 which shows clearly that the oil change time is different every year and is exceeding the ideal or the time which is given by the company. [1]

*Table 4.: The functions coefficients* [1]

| Distance [%] | | Time period [%] | |
|---|---|---|---|
| μ=0,7 | μ=0,8 | μ=0,7 | μ=0,8 |
| 108,5 [%] | 109,1 [%] | 61,51 [%] | 64,39 [%] |

*Table 5.: Calculation* [1]

| Distance | Percentage [%] |
|---|---|
| 30000 Km | 100% |
| 32400 Km | 108% |
| 32700 Km | 109% |
| Result 1: 108%=2400 | |
| Result 2: 109%=2700 | |

This calculations show that the range of distance can be more than 100% which means not only the level changes but also the level of distance are changing with time period, due to these change there is improvement in efficiency of the vehicle, with minor changes as we see in the above in the table that if we reach 108% we can earn 2400KM, and by making 109% we can get 2700Km, which is too much if we seeit after 5 years, for a big company who have some number of cars he can earn alot of money, the mileage of the

car can increases in just oneoil change and it can be improved just

if we select right tolerance, Not only the engine performance but also the amount of maintenance can be less than past, If we succeed to drive our car with longer oil timing then this can reduce our annual cost by huge margin, with these calculations I can say that Fuzzy logic has really big rule in cars like X3, fuzzy logic plays huge rule and give us a lot of opportunities in this field. [1]

## 6.3 Basic datas

*Table 6.: Parameter calculations* [1]

| | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|
| Km | 31192 | 66325 | 99906 | 119826 | 143791 |
| ServiceInterval | 30000 | 60000 | 90000 | 120000 | 150000 |
| | 31192 | 35133 | 33581 | 19920 | 23965 |
| | 103,97% | 117,11% | 111,94% | 66,40% | 79,88% |
| Month | 5 | 13 | 16 | 8 | 14 |
| ServiceInterval | 24 | 24 | 24 | 24 | 24 |
| | 20,83% | 54,17% | 66,67% | 33,33% | 58,33% |
| | 2012 | 2013 | 2014 | 2015 | 2016 |
| Km | 176357 | 207934 | 233369 | | 241615 |
| ServiceInterval | 180000 | 210000 | 240000 | | 270000 |
| | 32566 | 31577 | 25435 | | 8246 |
| | 108,55% | 105,26% | 84,78% | | 27,49% |
| Month | 13 | 12 | 14 | | 22 |
| ServiceInterval | 24 | 24 | 24 | | 24 |
| | 54,17% | 50,00% | 58,33% | | 91,67% |

The first year is not important in the calculation; it was the breaking in period,

Here are some basic data about the car like model of the car and which I have used in my calculations [1]:

MatLAB codes [1]:

Distance:

```
x=0:0.1:118;
a=0.8901;
b=107.5415;
y=1./(1+exp(a*(b-x)));
Plot(x, y)
```

Time period:

```
x=18:0.1:110;
a=0.1884;
b=56.993;
y=1. / (1+exp (a*(b-x)));
Plot(x, y)
```

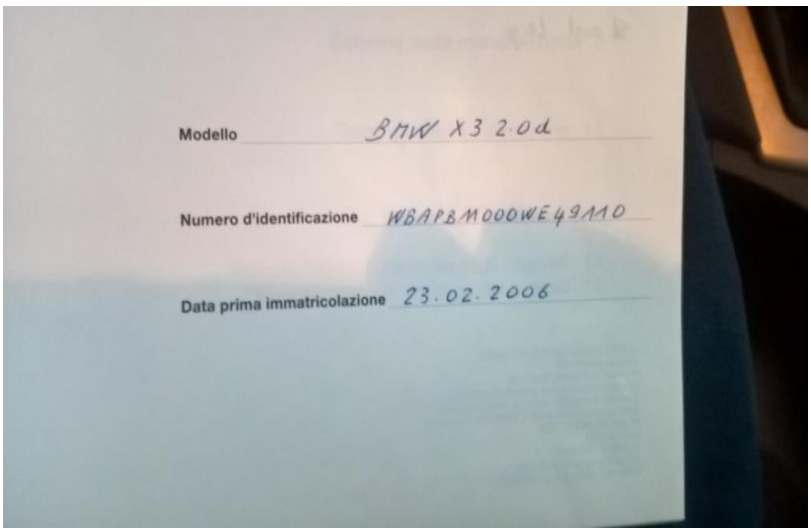


*Figure 11.: Basic Data of the car* [1]

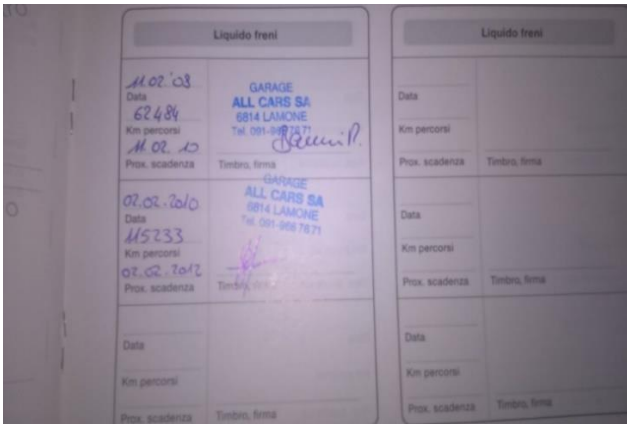


*Figure 12.: Service book 1* [1]

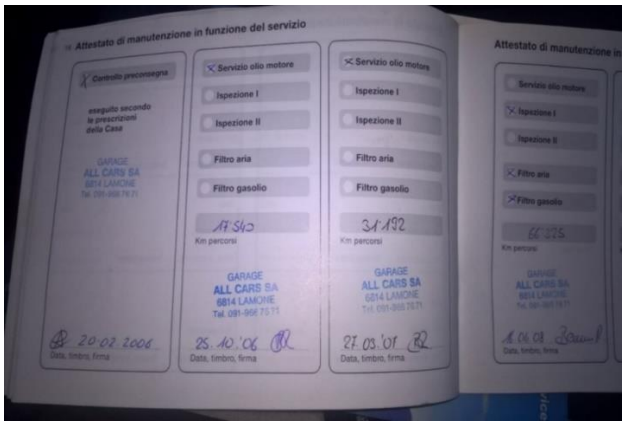


*Figure 13.: service book 2 [1]*

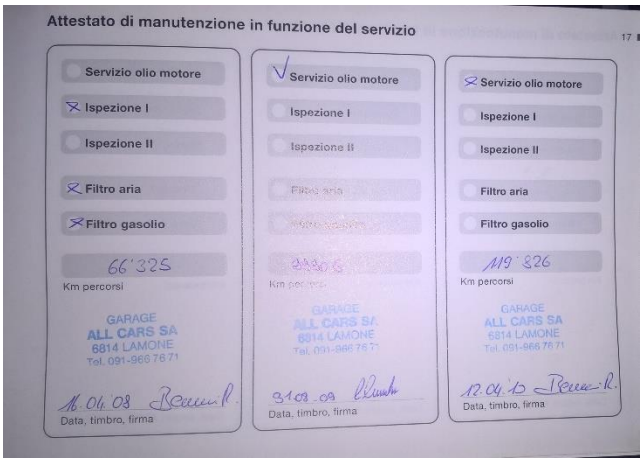


*Figure 14.: Service book 3 [1]*

# 7. ELECTRIC VEHICLES BATTERY ANALYZES WITH SIGMOID FUNCTION

The main focus of the extract of the sciencific artice is the examination of the parameter deviations of autonomous electric vehicles and/or robots' batteries. This case study would like to describe an important energetic question. What are the limits for the batteries within which we can use them with a low risk and with a high efficiency? [8]

The most important thing during the electric vehicle and/or robot development process is to choose the right battery, with the right size, weight and other parameters. According to Dr. Emődi and his co-authors, the most important parameters are the following [8]:

- self-discharge rate [%/day];
- being environmentally friendly;
- number of charge / discharge cycles;
- efficiency [%];
- purchase price;
- occurrence;
- power density [kW/l] or [kW/kg];
- energy density [kW·h/l] or [kW·h/kg].

If possible, we have to use energy storage with small dimension and small weight. It has to be able to endure the charge and discharge cycles. The vehicle's dynamism depends on the power density. [8]

*"The maximum range of the vehicle depends on the energy density. The hybrid and electric systems, the maximum range and the electric motor properties influence what kind of energy storage has to be used. Nickel based batteries are better for power density and energy density. The lead batteries are very cheap, while the performance of bipolar lead batteries is better."* [8]

The high-temperature systems like sodium nickel chloride work between 270-350ºC. This kind of battery system is used in linear hybrid vehicles. The heat loss at this kind of batteries can be restricted using a double-walled thermally insulated case, it has a safety risk. A heating system has to be used for the ideal operating temperature and the use of a temperature control system is also necessary (which are more weight for the vehicle).

This kind of battery cannot be used at sectional working systems and not easy to use at indoor systems like AGV systems. [8]

The power density and energy density of lithium-ion batteries are on a high level. The life cycle of the lithium batteries is good enough, too (just enough to think about the mobile devices like smartphones, tablest etc.). The target of the development of lithium-ion batteries is to minimize the costs. [8]

Zinc air batteries are used as primer batteries. We cannot charge this kind of batteries, if it runs down, we have to change and recycle it. It cannot be used in hybrid vehicles.

The most promising are the lithium-polymer batteries, which are used not only by hobby modellers. We can find them in industrial applications and in the daily traffic. Table 7. contains the properties of the lithium-polymer batteries. v

*Table 7.: The main propertie of lithium – polymer batteries* [8]

| Energy density | | Power density | | Life time | | Price |
|---|---|---|---|---|---|---|
| W*h/kg | W*h/l | W/kg | W/l | numbe or cycles | year | Eur/(kW*h) |
| 150 | 220 | ~ 300 | 450 | <1000 | - | <225 |

The basic question in the electric vehicle development: how much energy (energy density) can be stored in one battery and how can the vehicle use this kind of energy (power density) during their cruise or work? The first one means the range of the vehicle, the second one means the driving dynamics. [8]

*"The lithium-polymer batteries work between 60-100°C operating temperature. The batteries' power density is in the middle range, but their energy density is outstanding. Some of the most important things at the lithium-polymer batteries are overcharging and discharging to 0. In such cases the batteries can be damaged, they can be overheated, or they might explode. This is the reason why we have to handle this question as an important one when we would like to define the charge limits of the batteries."* [8]

Modern electric vehicles use an energy management system or battery monitoring system (BMS) which helps the charging system control. The batteries life time is longer with an energy management system. The distributors give a guarantee for 100000 - 200000 km depending on in which country they sell the vehicle or the betteries. If one of the batteries

is damaged, it is not necessary to change all of them because the vehicles use a battery cell system. This fact has a cos effective impact on the vehicles. [8]

## 7.1 Parameter deviation define with fuzzy logic

The analyzes parameters during the investigation are the (*V)* voltage and the *(Ah)* amperhours These two parameters are important not only for the electric engines but also for the safe operation and to the right efficiency. The upper and the lower limits clearing can cause overheating and/or blow up, it is a safety risk. The target is the parameter deviation with a right safety. [8]

We can find differences between the theoretical and practical datas in the daily routine. The practical experience shows that the vehicle batteries can work in a wider range than the original. The theoretical data define 100% for the upper limit but practice shows that the batteries can work with some overcharge (105%). The lower limit is 76% but on 61% the batteries also can work with the right efficiency and safety. We can find a lot of reasons. The batteries' life cycle is influenced by a lot of things like different types of operating conditions, temperature, humidity, engine load, vibrations etc.. Table 8. contains the main data of the empirical results. [8]

*Table 8.: Lithium – polymer betteries empirical datas*

| | | Empirical value |
|---|---|---|
| $V_{max}$ [%] | Min | 100% |
| | Max | 105,67% |
| | Average | 104,85% |
| | Median | 104,76% |
| $Ah_{max}$ [%] | Min | 100% |
| | Max | 105,57% |
| | Average | 104,75% |
| | Median | 104,67% |
| $V_{min}$ [%] | Min | 76,19% |
| | Max | 61,19% |
| | Average | 61,9% |
| | Median | 61,9% |
| $Ah_{min}$ [%] | Min | 76,2% |
| | Max | 61,37% |

| | | |
|---|---|---|
| | Average | 61,85% |
| | Median | 61,85% |

Based on the statistical data above, the parameters fuzzy sets give by the following [8]:

$$\mu_i(x) = \frac{1}{1 + e^{a_i(b_i - x)}} \tag{21}$$

general function. Table 9 contains the coefficients of the functions. The membership functions are presented in Figures 15-18.

*Table 9.: The (1) functions coefficients* [8]

| Parameter ($i$) | $a_i$ | $b_i$ |
|---|---|---|
| $V_{max}$ | 2,5 | 102,835 |
| $Ah_{max}$ | 2,0 | 101,785 |
| $V_{min}$ | 1,5 | 68,690 |
| $Ah_{min}$ | 1,8 | 67,785 |

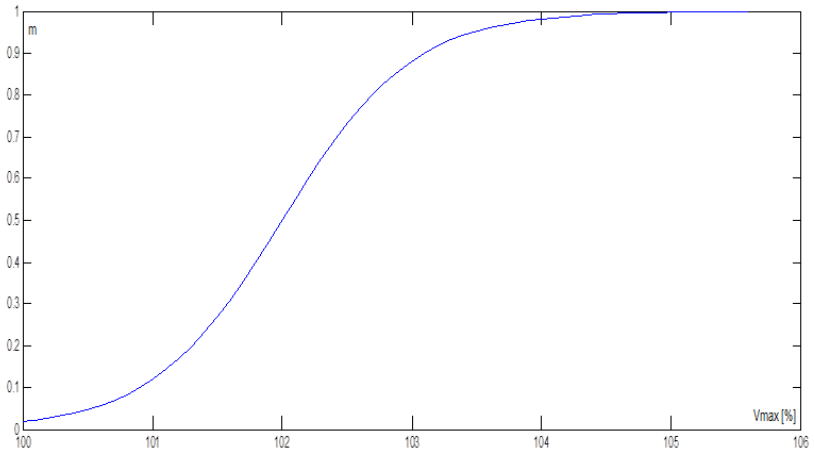


*Figure 15.: Membership function of Vmax [8]*

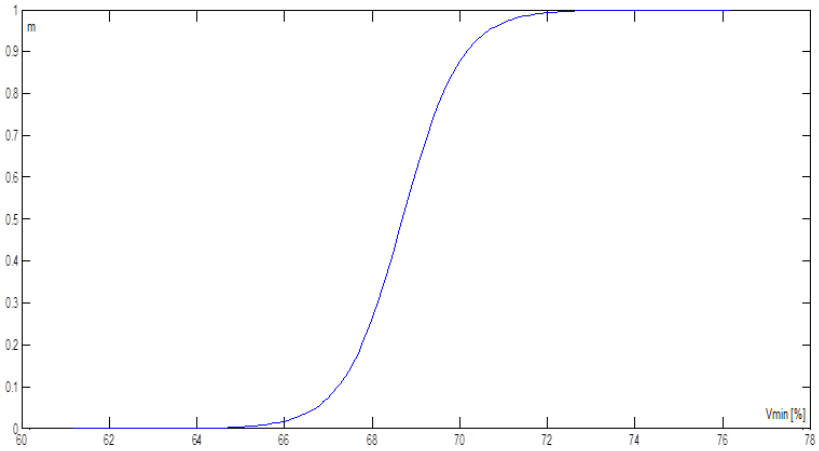


*Figure 16.: Membership function of Vmin [8]*

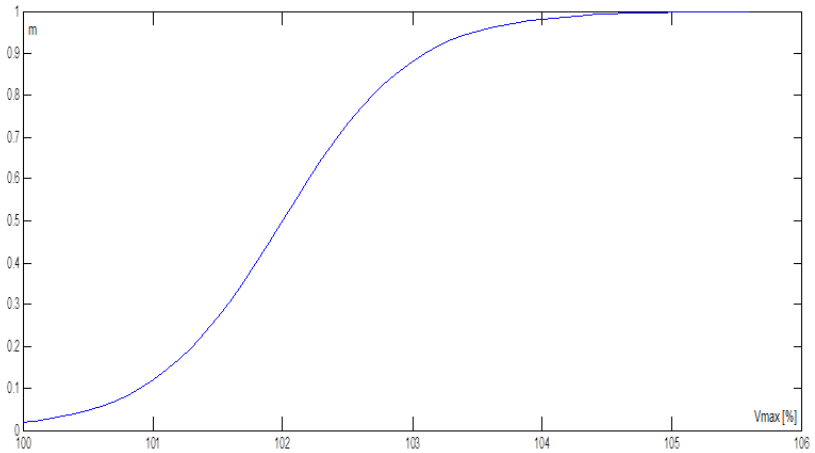


*Figure 17.: Membership function of Ahmax [8]*

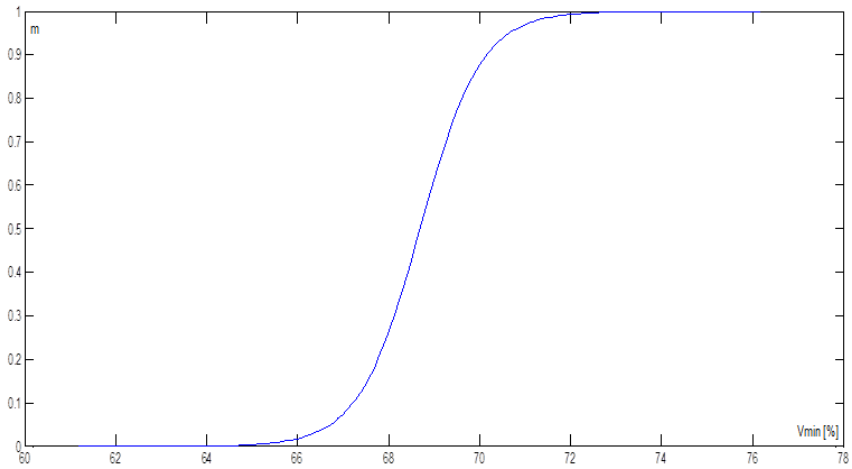


*Figure 18.: Membership function of Ahmin [8]*

## 7.2 Define of the allowable parameter deviations

Batteries have two states which are checked by the energy or the battery management system. We have to define the optimal maximum level and the optimal minimum level of the batteries. The BMS system can make an action if the batteries reach these levels. [8]

## 7.3 The rule for charge (upper limit)

If the battery is full, the system has to cancel the charging process.

$$\begin{aligned} &IF && \text{V reaches the } V_{max} \text{ limit;} \\ &OR && \text{Ah reaches the } Ah_{max} \text{ limit;} \\ &THEN && \text{cancel the charging process.} \end{aligned} \tag{22}$$

We can find the logical connection OR between the conditions so one of the conditions has to be met. This logical rule's truth value surface is [8]:

$$\mu(V_{max}; Ah_{max}) = MAX\left(\frac{1}{1+e^{a_{V\max}(b_{V\max}-V)}} \;;\; \frac{1}{1+e^{a_{Ah\max}(b_{Ah\max}-Ah)}}\right) \tag{23}$$

The surface is in the Figure 19..

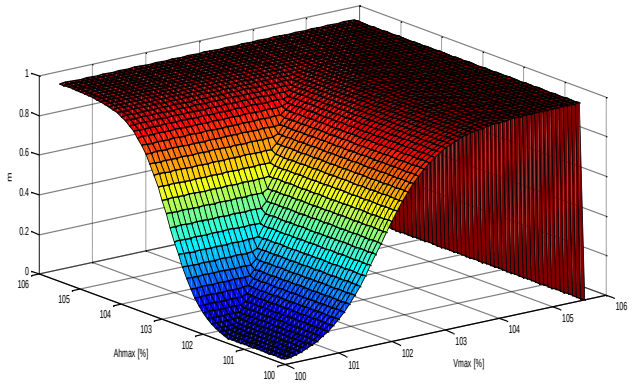


*Figure 19. The truth values surface of the battery's upcharging (24) [8]*

### 7.4 Rules of battery immersion

If the battery power is low we have to start the charging process.

In this case we have to use

$$\begin{array}{ll} IF & \text{V reaches the bottom } V_{min} \text{ limit;} \\ OR & \text{Ah reaches the bottom } Ah_{min} \text{ limit;} \\ THEN & \text{the charging process has to be started.} \end{array} \qquad (24)$$

logical rules. We again find the logical connection OR between the conditions, so the rule works the same way as before. This logical rule's truth value surface is [8]:

$$\mu(V_{\min}; Ah_{\min}) = MAX\left(\frac{1}{1+e^{a_{V\min}(b_{V\min}-V)}} \quad ; \quad \frac{1}{1+e^{a_{Ah\min}(b_{Ah\min}-Ah)}}\right) \qquad (25)$$

The surface is in the Figure 20.

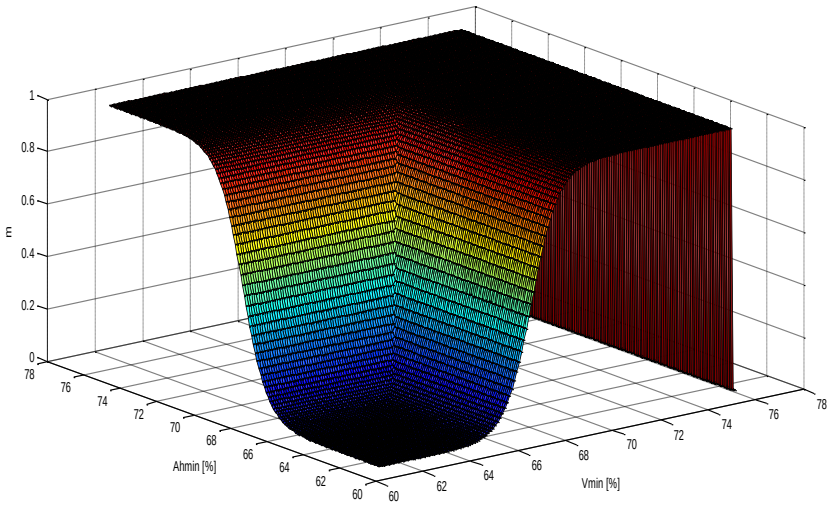


*Figure 20. The truth values surface of the battery's immersion (25) [8]*

## 7.5 Results of the parameter deviations

During this analyzes we have to think about the inaccuracy of the measuring system too. The inaccuracy depend on a lot of details in the real life, for example: noises, vibration etc. The failure or failures can make a lot of system problem what we can not avoid in the practice. This fact is why we use the following membership functions: (15) - (18) and (19) – (22). Other science and engineering results shows tha we have to choose the truth values between 0,7 – 0,8. The charging above 0,8 can be dangerous. Table 10. contains data for the up charging and the Table 11 contains data for the immersion process (for 0,7 and 0,8). [8]

*Table 10.: Vmax and Ahmax truth values* [8]

| $\delta V_{max}$ [%] | | $\delta Ah_{max}$ [%] | |
|---|---|---|---|
| μ=0,7 | μ=0,8 | μ=0,7 | μ=0,8 |
| 103,2 % | 103,4 % | 102,2 % | 102,5 % |

*Table 11.: Vmin and Ahmin truth values [8]*

| $\delta V_{min}$ [%] | | $\delta Ah_{min}$ [%] | |
|---|---|---|---|
| μ=0,7 | μ=0,8 | μ=0,7 | μ=0,8 |
| 69,26 % | 69,62 % | 68,26 % | 68,56 % |

We can find differences between the practical and the theoretical results, the tables and the pictures about the sigmoid functions are a good mirror to see the deviations. The battery immersion voltage can work on a higher level and the whole voltage field is in a wider range. [8]

These fact is useful for vehicle makers, researchers and engineers. The bigger movement possibility in the technical parameters can open a door. This door is open to a new way. The machines, not only the vehicles can work with a higher efficiency and very important with a higher safety with the same machine parts and/or liquids. During these kinds of researches and work we have to use ‘big datas’ to get a correct result. Just think about fleet management or big factories where we can find a dozen of machines which are the same. With this techniq or technology we can recalculate the maintenance strategy and save a lot of money. [3] [8]

# 8. BATTERIES' VOLTAGE ANALYSIS WITH SUPPORT VECTOR MACHINE (SVM) METHOD

## 8.1 Support Vector Machine Applied for Classification

One of the most popular methods for classification is the Support Vector Machine. This method can make an optimal hyperplane to separate data. [12]

The vehicle and its electrical system under the investigation was a prototype electric vehicle (Figure 21). The electrical energy system supplying the vehicle was based on the LiFeYPO4 batteries. The electrical system integrates two sets of 8 rechargeable batteries of the type of LiFeYPO4 serially connected in each sets to provide appropriate voltage level of 48 DC V (Figure 22). [12]


*Figure 21.: Experimental electric vehicle [12]*

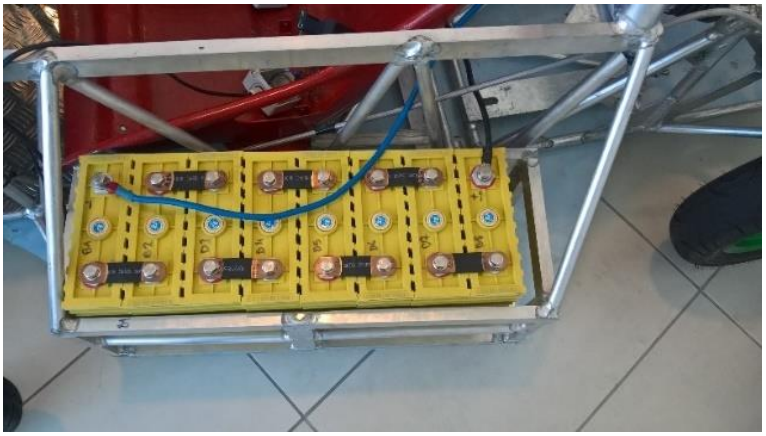

*Figure 22.: E-vehicle System of batteries [12]*

The nominal voltage of a single battery is 3,2V. The recommended maximum and minimum voltages of the batteries are 3,55V and 3V, respectively, and, these parameters are ensured by manufacturer of the batteries. The batteries were connected to a DC electric engine controller of the type of 48V/350A DC electric engine controller (Fig. 23). This controller managed the power and efficiency of the vehicle. The controller has high efficiency, good stability and a compact size. It uses PWM-technology and it can reverse the direction of the rotational motion of the electric motor. The electric motor is a DC 48V and 4kW electric motor. The vehicle uses a single DC motor to introduce mechanical energy ensuring movement of the e-machine. [12]

*Figure 23.: The electric engine controller [12]*

During research work authors made voltage measurement using an Arduino device. The Arduino device is an open source electric controller and due to its simple programming and configuration properties today it is a very popular development platform. [12]

Based on lessons learned from vehicle runs the developer team of the vehicle stated that batteries are able to work far out of their maintenance regimes ensured by manufacturers without any overheating, or, any other malfunctions threatening the energy supply system of the e-vehicle. To find the extended limits of the batteries' maintenance regimes, the developers' team agreed to involve ten full cycles of the batteries including charging and discharging processes into investigations. The results of the voltage measurement of the batteries' are tabulated in Table 12. [12]

The first finding must be done: results of the voltage measurements show a significant difference between the allowed and measured voltages. This practical data shows better efficiency in the use during competition runs. [12]

*Table 12.: Practical and prescribed values* [12]

| Measurements | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. |
|---|---|---|---|---|---|---|---|---|---|---|
| Measured Voltage (upper), V | 3,600 | 3,680 | 3,90 | 3,700 | 3,740 | 3,750 | 3,781 | 3,820 | 3,830 | 3,833 |
| Maximum Voltage Allowed (upper), V | 3,550 | | | | | | | | | |
| Measured Voltage (lower), V | 2,200 | 2,250 | 2,283 | 2,293 | 2,456 | 2,534 | 2,574 | 2,697 | 2,713 | 2,965 |
| Minimum Voltage Allowed (lower), V | 3,000 | | | | | | | | | |

The authors used and modified MATLAB script for the Support Vector Machine (SVM) analyses. Using this program the data are on a diagram which is easy to use in practice. The program is a linear classifier that is defined by a threshold value and a 2-dimensional weight vector. The MATLAB script uses the bioinformatics toolbox, which includes a svmtrain function. Figure 4 describes the new upper Voltage limit of the batteries (3.665 V). The 'x' axis is the 'Number of measurements [pcs]' the 'y' axis is the 'Voltage [V]'. The red crosses show the original or the prescribed Voltage data. The blue crosses show the tentative data. The SVM method can calculate a new optimal hyperplane, which is the new voltage limit. [12]

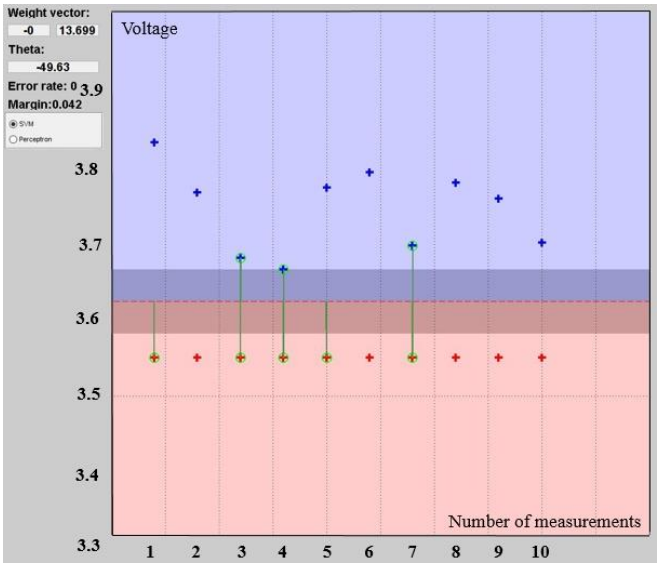


*Figure 24.: SVM margins: upper limit [12]*

Figure 24 shows the new margins of the lower voltage of the batteries (2.75V).

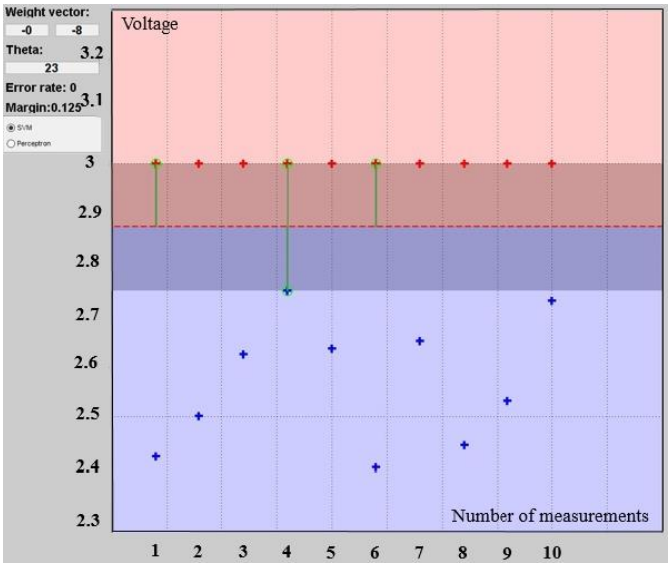


*Figure 25.: SVM margins: lower limit [12]*

In summary, these MATLAB calculations show that the batteries can work with wider limits than it is ensured by manufacturers with an appropriate level of safety. [12]

## 8.2 Data Evaluation Using Fuzzy Logic

The measured results show variance in practice. The use of fuzzy logic enabled the authors to find a precise bounds of the batteries' regimes where they can work safely. The statistical data is shown in Table 13. [12]

*Table 13.: Batteries Dataset* [12]

| | | Empirical value |
|---|---|---|
| $V_{maxSVM}$ [%] | Min | 100,00 |
| | Max | 104,5 |
| | Average | 102,13 |
| $V_{minSVM}$ [%] | Min | 75,07 |
| | Max | 65,48 |
| | Average | 68,11 |
| $V_{max}$ [%] | Min | 100,00 |
| | Max | 105,41 |
| | Average | 104,85 |
| $V_{min}$ [%] | Min | 84,05 |
| | Max | 61,97 |
| | Average | 70,32 |

The fuzzy membership functions make an imaging in the analyzed set and describe it in a 0 ÷ 1 interval. The μ membership function describes the result of the analysis in a 0 ÷ 1 interval. The μ values can take any result between 0 and 1. The general formula of determines the Fuzzy membership function of parameter tolerances in the following form [12]:

$$\mu = \frac{1}{1 + e^{a_i (b_i - x)}} \tag{26}$$

where $x$ is the input parameter, $a_i$ and $b_i$ are scalar coefficients. From (1) it is easy to see that coefficients $a_i$ and $b_i$ can change the shape of the membership function. Coefficient $a_i$ affects the slope of the membership function, whilst coefficient $b_i$ determines the midpoint of the membership function. [12]

The sigmoid function is a special mathematical function. It has an "S" shaped curve. This function has a positive derivate everywhere and it is a bounden differentiable real function. In another approach, the sigmoid function is a special case of the logical criteria. The function often takes values either on the range from 0 to 1 and/or from -1 to 1. This property always depends on the preliminary defined convention. There is

wide variety of the known sigmoid functions. The sigmoid functions have been used as an activation function or in artificial intelligence. The fuzzy logic often uses it when a detailed description is missing, in these cases the sigmoid function has an important role. [12]

The coefficients of the Fuzzy membership function defined by Eq. (1) can be found in Table 14. [12]

*Table 14.: Calculated Coefficients [12]*

| Parameter (i) | $a_i$ | $b_i$ |
|---|---|---|
| $V_{maxSVM}$ | 2,473 | 101,754 |
| $V_{minSVM}$ | 1,776 | 73,055 |
| $V_{max}$ | 2,552 | 104,995 |
| $V_{min}$ | 1,665 | 69,566 |

Figures 26 and 27 illustrate the membership functions which are calculated using coefficients tabulated in Tab. 14. [12]

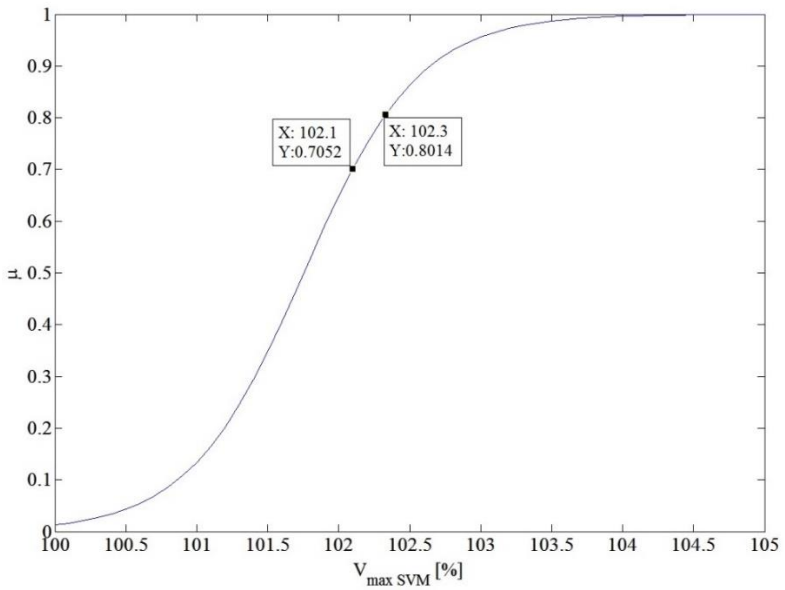


*Figure 26.: Fuzzy membership function VmaxSVM [12]*

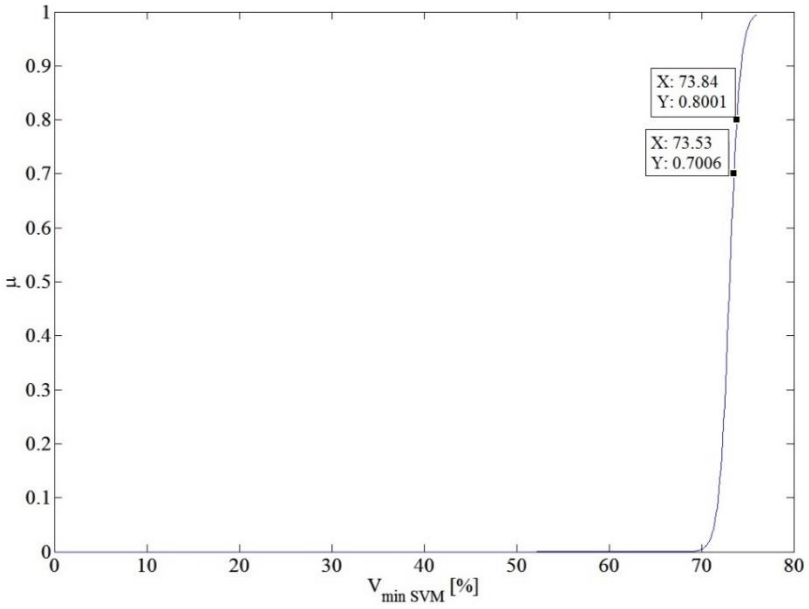


*Figure 27.: Fuzzy membership function VminSVM [12]*

## 8.3 Results of the new acceptable Voltage parameter tolerances

The maximum and minimum voltage levels are controlled by the Battery Management System (BMS) and when the batteries reach either higher or lower values of these limits, the BMS has to be activated. [12]

There are two kinds of intervention of the BMS system can provide: it has to either start the charging process or stop it. The OR logical connection must be used between the criteria. The logical rule's true value surface is [12]:

$$\mu\left(V_{\max SVM};V_{\max}\right)=MAX\left[\frac{1}{1+e^{a_{V\max SVM}\left(b_{V\max SVM}-x\right)}};\frac{1}{1+e^{a_{V\max}\left(b_{V\max}-x\right)}}\right], \quad (27)$$

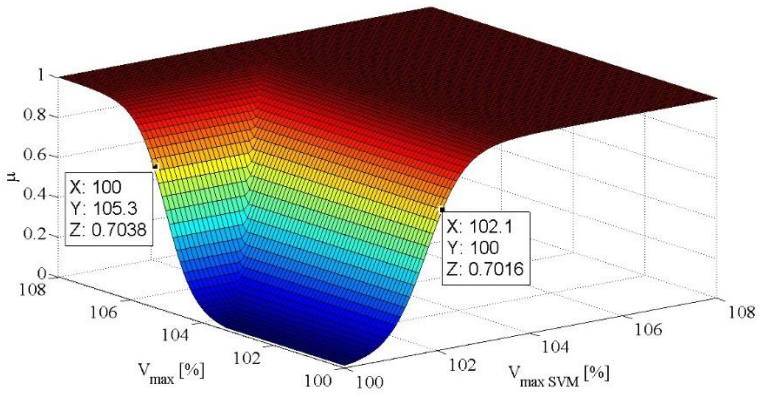


*Figure 28.: The Fuzzy membership function of VmaxSVM [12]*

The BMS needs to start the charging process if the voltage is low. In this case, the OR logical rules have to be followed again. The true value surface is [12]:

$$\mu(V_{\min SVM}; V_{\min}) = MAX\left[\frac{1}{1+e^{a_{V\min SVM}(b_{V\min SVM}-x)}}; \frac{1}{1+e^{a_{V\min}(b_{V\min}-x)}}\right], \tag{28}$$

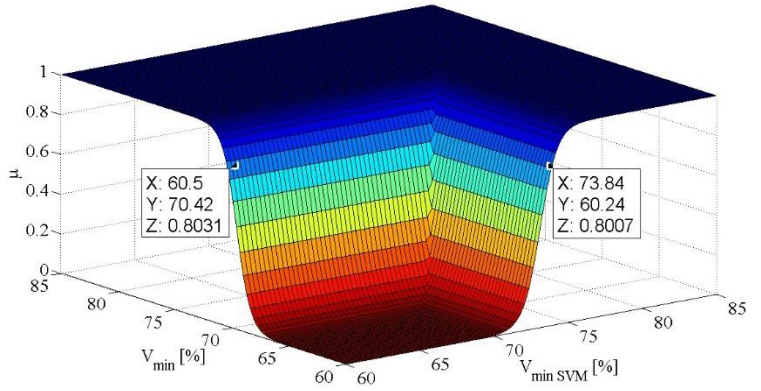


*Figure 29.: Fuzzy membership function of VminSVM [12]*

As it is shown by practical experience, the true values have been determined between 0.7 ÷ 0.8. This shows that it can be dangerous if we exceed 0.8 during the batteries' charging process and/or immersion. Tables 4 and 5 tabulate the data for 0.7 and 0.8, respectively. [12]

*Table 15.: Vmax and VmaxSVM Truth values [12]*

| | | |
|---|---|---|
| $V_{max}$ | $\mu$ = 0,7 | 102,1 % |
| | | 3,73 V |
| | $\mu$ = 0,8 | 102,3 % |
| | | 3,74 V |
| $V_{maxSVM}$ | $\mu$ = 0,7 | 105,3 % |
| | | 3,74 V |
| | $\mu$ = 0,8 | 105,5 % |
| | | 3,75 V |

*Table 16.: Vmin and VminSVM Truth values [12]*

| | | |
|---|---|---|
| $V_{min}$ | $\mu$ = 0,7 | 70,08 % |
| | | 2,49 V |
| | $\mu$ = 0,8 | 70,04 % |
| | | 2,5 V |
| $V_{minSVM}$ | $\mu$ = 0,7 | 73,53 % |
| | | 2,69 V |
| | $\mu$ = 0,8 | 73,84 % |
| | | 2,71 V |

The authors discussed the results of the technical status management of the Li-batteries using soft computing method. The conventional method of battery maintenance based on strict measurements of the voltages has been investigated. The basic hypothesis of the authors of the possible extension of upper and lower values of the voltages of the maintenance of the batteries has been proven. [12]

Authors had established new logical rules for the Battery Management System to start to recharge the batteries, or, to stop charging process using SVM method and Fuzzy logic. [12]

The authors analyzed Lithium batteries' data with MATLAB software. The Support Vector Machine simulations derived new voltage limits for the batteries both for its maximum and minimum values. These new limits ensure proper safety level during daily life. [12]

The authors checked the batteries' parameter tolerances with Fuzzy logic after the SVM calculations. Using techniques described above the authors determined a brand new

voltage limits for the batteries. The results showed that Fuzzy analysis can be effectively used if it is supported by the SVM analysis. [12]

The use of Fuzzy logic and SVM produced better efficiency for the electrical system of electric vehicle. The new voltage limits of the batteries made a new perspective for the electric vehicle. The electrical system can ensure a better electric performance due to the extended battery voltage range. The vehicle can use this performance for a longer range, for better acceleration capabilities, or for reaching higher speeds, which are important features during competition runs. [12]

# 9. BATTERIES PARAMETER ANALYZES WITH FUZZY LOGIC RULE BASE

We can find a lot of literature, article and sciencecific works about the electric vehicles battey. These resesarchworks are also contains works from university, research institute and gorvenment sides. From these works we can get a lot of information about the importance of the electric vehicles. Then batteries used for this research. The measuring results are in Table 6. At the end of the table we can find the average result of the measurements. The Ah datas can show a deviation in the practice, it is always depends on the BSM software. [4]

*Table 17.: The datas of the batteries [4]*

| | | 1. | 2. | 3. | 4. | 5. | Average |
|---|---|---|---|---|---|---|---|
| NOK | V | 4,6046 | 4,602 | 4,65 | 4,603 | 4,61 | 4,61637 |
| | Ah | 48,23867 | 48,21143 | 48,71429 | 48,2219 | 48,29524 | 48,36197 |
| OK | V | 4,201 | 4,204 | 4,209 | 4,2 | 4,205 | 4,2034 |
| | Ah | 44,01048 | 44,0419 | 44,09429 | 44 | 44,05238 | 44,03562 |
| | V | 3,6 | 3,6 | 3,609 | 3,607 | 3,603 | 3,6043 |
| | Ah | 37,71429 | 37,71429 | 37,80857 | 37,78762 | 37,74571 | 37,75933 |
| NOK | V | 3,2 | 3,201 | 3,208 | 3,207 | 3,202 | 3,2031 |
| | Ah | 33,52381 | 33,53429 | 33,60762 | 33,59714 | 33,54476 | 33,55629 |
| | | 6. | 7. | 8. | 9. | 10. | |
| NOK | V | 4,689 | 4,6021 | 4,6002 | 4,6023 | 4,6005 | |
| | Ah | 49,12286 | 48,21248 | 48,19257 | 48,21457 | 48,19571 | |
| OK | V | 4,208 | 4,206 | 4,2 | 4,201 | 4,2 | |
| | Ah | 44,08381 | 44,06286 | 44 | 44,01048 | 44 | |
| | V | 3,607 | 3,6 | 3,602 | 3,606 | 3,609 | |
| | Ah | 37,78762 | 37,71429 | 37,73524 | 37,77714 | 37,80857 | |
| NOK | V | 3,2 | 3,209 | 3,203 | 3,2 | 3,201 | |
| | Ah | 33,52381 | 33,6181 | 33,55524 | 33,52381 | 33,53429 | |

The first coloumn containt the „OK” and the „NOK” results. These fields shows those parts where the batteries work with a right efficiency and safety. The target of the investigation: how can we use the batteries between failures and anomalies. Important to know: these datas came from engineers and engineer groups experience and knowledge. [4]

- NOK: Not acceptable result
- OK: Acceptable result

From the voltage side [4]:

- Not acceptable 0 - 3,2031 V
- Acceptable: 3,6043 – 4,2034
- Not acceptable: above 4,61637 V

From the amperhours (Ah) side [4]:

- Low: 0 - 33,55629 Ah
- Right: 37,75933 – 44,03562
- High: above 48,36197

The three sets of the batteries reliability (it based on the expert knowledge) [4]:

- the reliability of the batteries is low: 0-40%
- the reliability of the batteries is right: 50-70%
- the reliability of the batteries is acceptable: 60-100%.

The membership functions analyzed by Matlab mathematical software. With this software we can get the new operation limits during the dailiy usage. In this ideal condition the batteries work with a right safety and efficiency. It means that? the voltage and the amper hour results are right, so the batteries have a right safety. In the next steps the reader can see how can w eget the membership functions [4]:

The membership functions (Figure 25.):

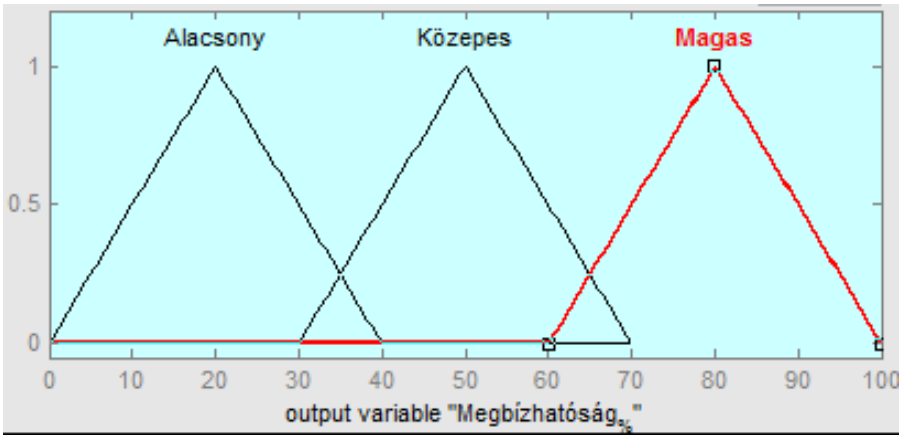


*Figure 30.: The reliablility in percentage [4]*

Membership functions of the amper hours [4]:

$$\mu(lowAh) = \begin{cases} 1, & if \quad 0 \le x \le 33{,}556 \\ \frac{37{,}7593 - x}{4{,}2033}, & if \quad 33{,}556 < x \le 37{,}7593 \\ 0, & if \quad x > 37{,}7593 \end{cases} \tag{29}$$

$$\mu(rightAh) = \begin{cases} 0, & if \quad 0 \le x \le 33{,}556 \\ \frac{x - 33{,}556}{4{,}2033}, & if \quad 33{,}556 < x \le 37{,}7593 \\ 1, & if \quad 37{,}7593 < x \le 44{,}0356 \\ \frac{48{,}36197 - x}{4{,}326}, & if \quad 44{,}0356 < x \le 48{,}36197 \\ 0, & if \quad x > 48{,}36197 \end{cases} \tag{30}$$

$$\mu(highAh) = \begin{cases} 0, & if \quad 0 \le x \le 44{,}0356 \\ \frac{x - 44{,}0356}{4{,}326}, & if \quad 44{,}0356 < x \le 48{,}36197 \\ 1, & if \quad 48{,}36197 < x \end{cases} \tag{31}$$

On Figure 31. we can see the (8), (9) and (10) functions. [4]

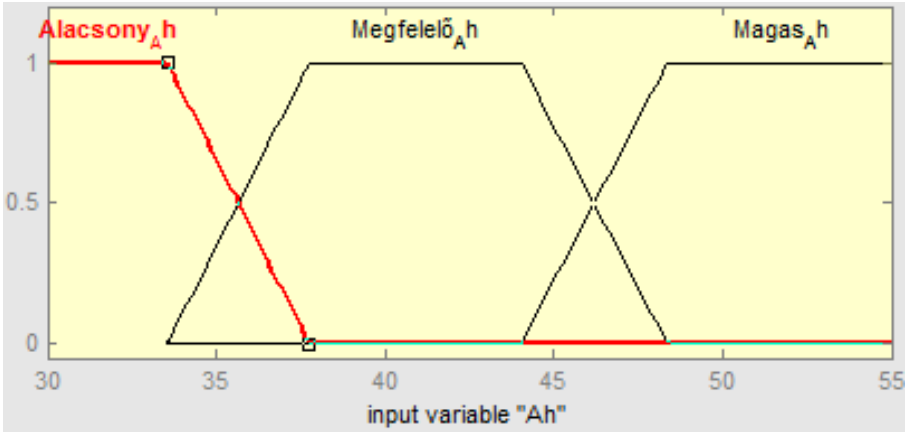


*Figure 31.: The three membership function [4]*

Membership functions of the voltage results [4]:

$$\mu(lowV) = \begin{cases} 1, & if \quad 0 \le x \le 3{,}2031 \\ \frac{3{,}6043 - x}{0{,}4012}, & if \quad 3{,}2031 < x \le 3{,}6043 \\ 0, & hif \quad x > 3{,}6043 \end{cases} \tag{32}$$

$$\mu(rightV) = \begin{cases} 0, & if \quad 0 \le x \le 3{,}2031 \\ \frac{x - 3{,}2031}{0{,}4012}, & if \quad 3{,}2031 < x \le 3{,}6043 \\ 1, & if \quad 3{,}6043 < x \le 4{,}2034 \\ \frac{4{,}61637 - x}{0{,}4129}, & if \quad 4{,}2034 < x \le 4{,}61637 \\ 0, & if \quad x > 406046 \end{cases} \tag{33}$$

$$\mu(highV) = \begin{cases} 0, & if \quad 0 \le x \le 4{,}2034 \\ \frac{x - 4{,}2034}{0{,}4129}, & if \quad 4{,}2034 < x \le 4{,}61637 \\ 1, & if \quad 4{,}61637 < x \end{cases} \tag{34}$$

On Figure 32. we can see the (11), (12) and (13) functions.

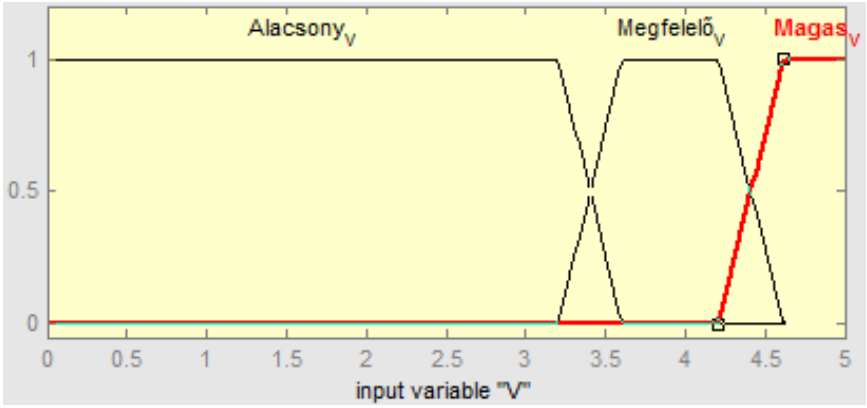


*Figure 32.: The three membership function [4]*

During the rules we have to keep in mind the followin: the high and also the low charging level will have a negative affect on the batteries efficiency, safety and lifetime. If we can find these deviations in the voltage of the batteries or the lifetime is shorter than defined, the batteris will not work with a right safety and efficiency. The safety parts of the system can be critical on the roads, but enough to think about UGV sor AGVs. Most of these robots are working with batteries. The AGV systems are very popular and important part of the supply chain system. The batteri failures can occur accidents or any other defect on the product quality. The fuzzy rule base is the following [4]:

- IF the voltage is low THEN the reliability is low;
- IF the voltage is right THEN the reliability is high;
- IF the voltage is high THEN the reliablility is low;
- IF the voltage is right AND the amperhours are low THEN the reliability is high;
- IF the voltage is right AND the amperhours are high THEN the reliability is right;
- IF the voltage is right AND the amperhours are right THEN the reliability is right.

With these rules we can get the following surface of the functions [4]:

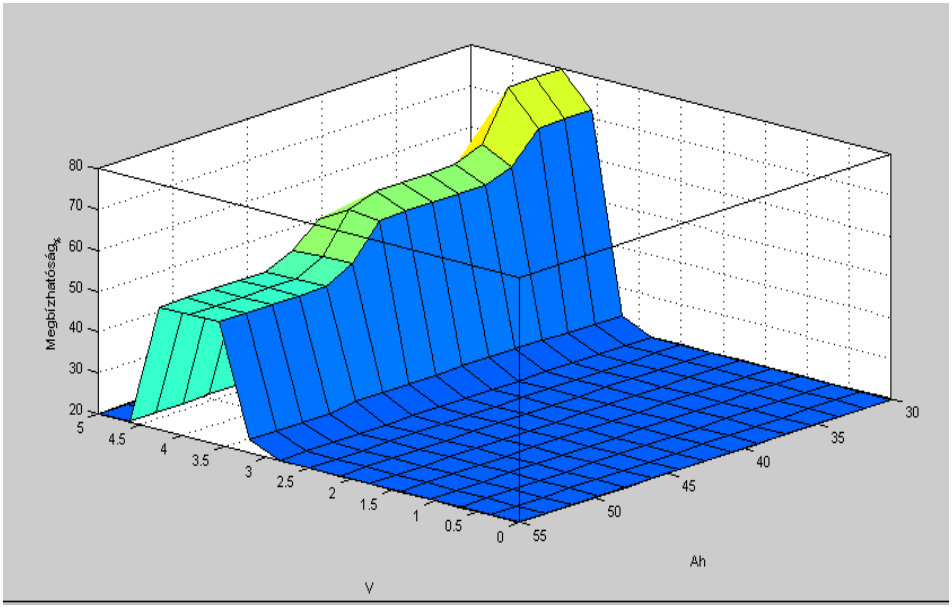


*Figure 33.: The surface of the function [4]*

The surface on the Figure 33 can define the ideal parameter intervals. In these intervals the batteries can work with a right safety and efficiency. On the ideal voltage result and with the low amper hours result the safety of the batteries are good. But it has a negative property, the charge storage capacity of the batteries is low. [4]

The batteries can work on the bottom limit of the voltage and it uses a such a high level amper hours. In this case the performance of the vehicle can be good. With this options the voltafe of the batteries min 3,7V, theamper hours result is 44Ah and the reliability is around 65%. [4]

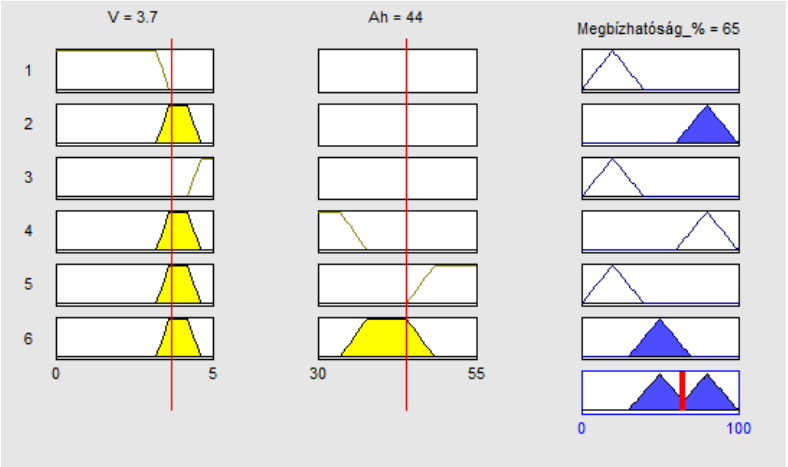


*Figure 33.: The used battery parameters [4]*

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