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RISK ASSESSMENT BASED UPON FUZZY SET THEORY

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Abstract:
Safety and reliability are essential issues in modern sciences. Modern technical systems should meet technical, safety and environmental protection requirements. The risk can appear as personal injury or death, mission degradation, property technical damage or destruction. The risk is a measure of harm or loss associated with the human activity. It is the combination of the probability and the consequence of a specified hazard being realized. For decision making we need the opinions of other sciences, sometimes we have to consider moral questions. To make reliable decision, the risk of the given system or process should be known correctly. Fuzzy set theory is a new mathematical tool to model inaccuracy and uncertainty of the real world and human thinking. The paper shows the possibility of use of the fuzzy set theory to assess the risk.

1. Introduction

In our age safety, reliability and security are essential issues in the engineering. Modern technical systems should meet technical, safety, security and environmental protection requirements.

The subject of Smalko’s paper deals with the relationship between safety and security of the man-machine system. A man can act in the man-machine system both as a decision-maker and operator. The critical events are the critical fault of the machine and/or erroneous decisions made by the operator, which can cause failure and accidents with undesirable effects in the form of fatalities, environment degradation, property loss and financial losses and also causes the different civil-legal consequences for the decision makers and operators (Smalko, 2007).

The risk assessment is an important step of the risk management. The goal of risk assessment or risk characterization is to determine risk context and acceptability, often by comparison to similar risk (Pokorádi, 2002). There are many qualitative and quantitative methods to assess risk. In the last case the risk is determined by multiplication of severity and probability measures.

Fuzzy Logic is a form of logic used in some expert systems and other artificial-intelligence applications in which variables can have degrees of truthfulness or falsehood represented by a range of values between 1 (true) and 0 (false). With fuzzy logic, the outcome of an operation can be expressed as a probability rather than as a certainty. For example, in addition to being either true or false, an outcome might have such meanings as probably true, possibly true, possibly false, and probably false (Zadeh, 2009).

There are countless fields in the modern engineering and management sciences in which fuzzy used the fuzzy logic. Bowles and Peláez demonstrate two methods of the fuzzy logic-based assessments of criticality (Bowles & Peláez, 1995).

During the last few years researchers have developed measurement techniques and mathematical models to predict the process risk safety of a plant or a processing unit (Mannan & Mannan & Bigoszewska, 2009). Paper mentioned above gives some results on the application of the fuzzy logic in the classical Process Safety Analyses, such as fault and event tree which can be further used in the so called bow-tie approach for accident scenario risk assessment. They proved that the success of this method depends on quality of failure data collection of process components as well as on the cooperation with plant operation staff. In publication of Markowski and Mannan the semi quantitative approach is taken into account and risk matrix is used for the risk evaluation and assessment (Markowski & Mannan 2008). Risk matrix is a mechanism to characterize and rank process risks that are typically identified through one or more multifunctional reviews, for example process hazard analysis. Risk matrix is a very useful tool for semi-quantitative risk assessment as well as a selection of risk control measures.

Hadjimichael has presented a methodology by which the safety knowledge inherent in an organization such as an airline can be elicited, represented, and used for operational risk analysis (Hadjimichael, 2009).

In their paper, Karimi and Hüllermeier presented a modular framework for fuzzy risk assessment and its components (Karimi I. & Hüllermeier, 2007). The fuzzy probability is characterized in terms of possibility–probability distributions, for which a new approach has been developed. This approach has been compared with an alternative approach. Moreover, uncertainties about the correlation of the parameters of hazard intensity, damage and loss, i.e. vulnerability relations, have been considered by means of fuzzy relations. The composition of fuzzy probability of hazard and fuzzy vulnerability relation yields the fuzzy probability of damage (or loss).

The fuzzy risk graph model proposed by Nait-Said et al. is a fuzzy rule-based-risk graph (Nait-Said et al. 2008). Its main advantages include:

- it preserves the four parameters used in the standard risk graph and can be adapted easily to improved risk graphs;
- fuzzy scales with fuzzy linguistic values are used to assess risk parameters and calibration of the model may be made by varying risk parameters values.

The paper gives a short overview of risk management and assessment and illustrates the possibility of use of the fuzzy set theory to assess the risk. The paper will be organized as follows: Section 1 shows the applied literatures. Section 2 words the risk and risk assessment. Section 3 presents fuzzy set theory based risk assessment method theoretically. Section 4 shows the possibility of use of proposed method bay a case study.

2. The Risk and the Risk Assessment

All human activity involves any risk. In our age, experts have to decide on moral base, during decision-making. It is very important to use risk management methods to investigate and to minimize risks which concomitance of human activity. The risk is the combination of the likelihood and the consequence of a specified hazard being realized.

The risk management is the systematic application of policies, practices, and resources to the assessment and control of risk affecting human health and safety or the environment (Pokorádi, 2002). A critical role of the safety regulator is to identify activities involving significant risk and to establish an acceptable level of the risk. In most cases, the near zero risk should be not achievable can be very costly.

The goal of risk assessment is to determine risk context and acceptability, often by comparison to similar risks.

The first step of risk assessment is to assess hazard severity. It is determination of the severity of the hazard in terms of its potential impact on the people, equipment. Severity assessment should be based upon the worst possible outcome that can reasonably be expected.

Using quantitative risk assessment method, the risk is product of probabilities and calculated "crisp" severity of investigated hazard. This method can be used when the factors mentioned above can be determined unequivocally. For example insurance companies use it.

Oftentimes the probability and severity cannot be identified unequivocally. These factors can be determined only by knowledge of experts. In this case we have to use severity and probability categories. In this case the risk is logical combination of them, and we should use fuzzy logic to model inaccuracy and uncertainty human thinking.

But in this case the determination of membership functions raises a problem. Interrogation of users and maintainers of investigated system or executors of given task can solve this problem. It is important to mention that a man of small experience has notable knowledge, but its transformation to numerical data is a very difficult task. The aim mentioned above can be accomplished by so called expert reports and statistical inference of their data. These data have notable subjectivity because they accrue from interpretation of individual experiences. Therefore these data should be used as fuzzy membership functions.

3. Fuzzy Risk Assessment Method

A fuzzy set theory-based risk assessment process realizes the following process (Pokorádi, 2001). This process uses several rules simultaneously. The attribute of set of rules is that their solution by classical logic can be different or antinomic at the same time. Practically, this inconsistency can be (should be) resolved by the fuzzy logic. This process is a combination of four subprocesses: fuzzification, inference, composition, and defuzzification. The defuzzification subprocess is optional.

In the FUZZIFICATION subprocess, the membership functions defined on the severities and probabilities of investigated hazards are applied to their actual values, to determine the degree of truth for each rule premise.

In the INFERENCE subprocess, the truth-value for the premise of each rule is computed, and applied to the conclusion part of each rule. This results in one fuzzy subset to be assigned to each output variable for each rule.

In the COMPOSITION subprocess, all of the fuzzy subsets assigned to each output variable are combined together to form a single fuzzy subset for each output variable.

Sometimes it is useful to just examine the fuzzy subsets that are the result of the composition process, but more often, this fuzzy value needs to be converted to a single number — a crisp value. This is what the DEFUZZIFICATION subprocess does.

There are more defuzzification methods than you can shake a stick at. Two of the more common techniques are the centroid and maximum methods. In the centroid method, the crisp value of the output variable is computed by finding the variable value of the center of gravity of the membership function for the fuzzy value. In the maximum method, one of the variable values at which the fuzzy subset has its maximum truth value is chosen as the crisp value for the output variable. There are several variations of the maximum method that differ only in what they do when there is more than one variable value at which this maximum truth value occurs. One of these, the average of maxima method, returns the average of the variable values at which the maximum truth value occurs (Pokorádi, 2008).

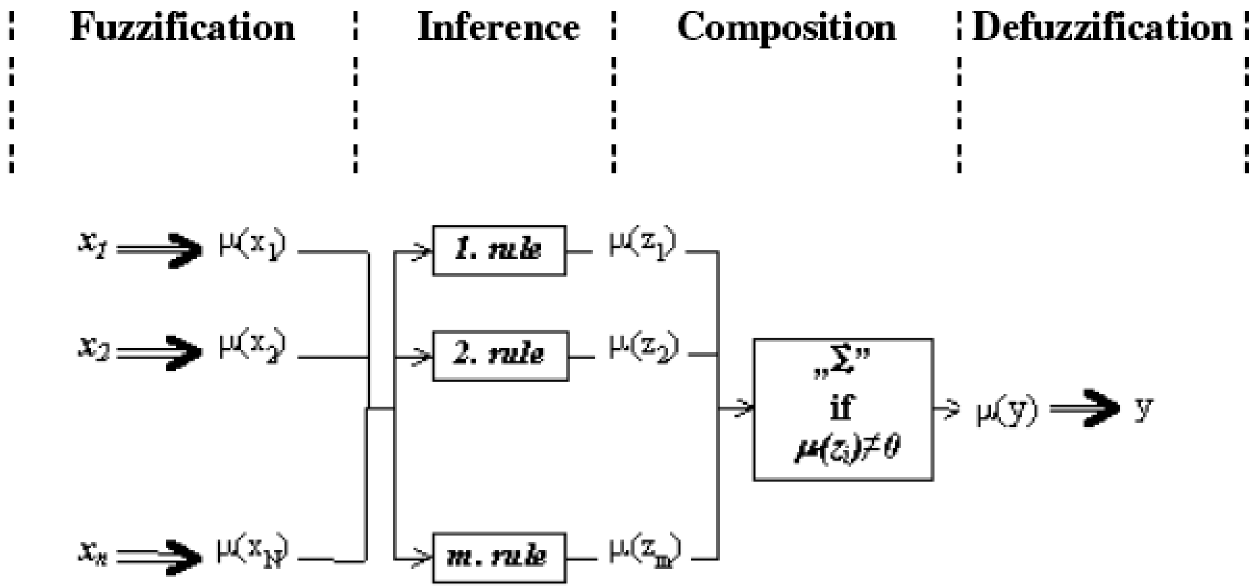

Figure 1: Fuzzy Risk Assessment Flow Chart (Pokorádi, 2001)

Sometimes the composition and defuzzification processes are combined, taking advantage of mathematical relationships that simplify the process of computing the final output variable values.

The flow chart of fuzzy logic application is illustrated by Figure 1.

4. Case Study

To demonstrate possibility of use of method submitted above in this chapter a case study will be shown shortly.

During risk management analysis of hydraulic system risks of its hazards was assessed by fuzzy set theory based method. Pending preparation of risk assessment, the experts defined categories of severity, probability (frequency) and risk. Then definitions, membership functions those categories were determined, which era shown by figures 2 – 4. Lastly they depicted the Risk Assessment Matrix (see Table I.)

Table I. *Risk Assessment Matrix*

	Frequent	**Likely**	**Occasional**	**Seldom**	**Unlikely**
Catastrophic	**EH**		**H**		**M**
Critical				**M**	
Moderate	**H**		**M**	**L**	
Negligible	**M**				

EH — Extra High; **H** — High; **M** — Medium; **L** — Low.

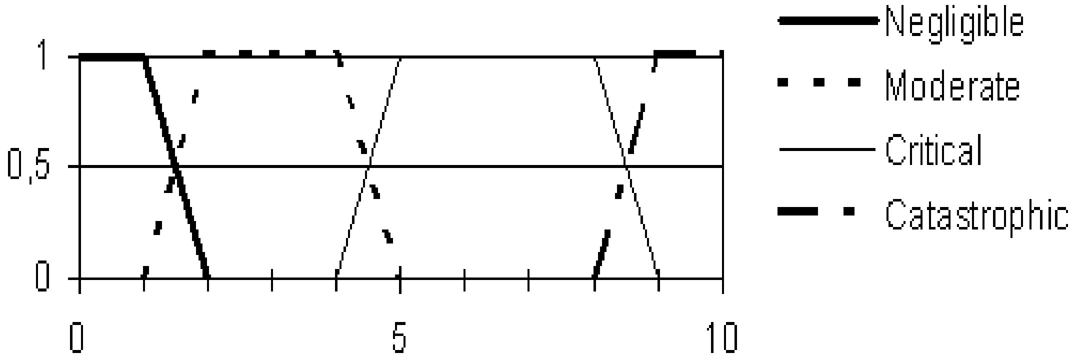

Figure 2: Severity Sets Definition

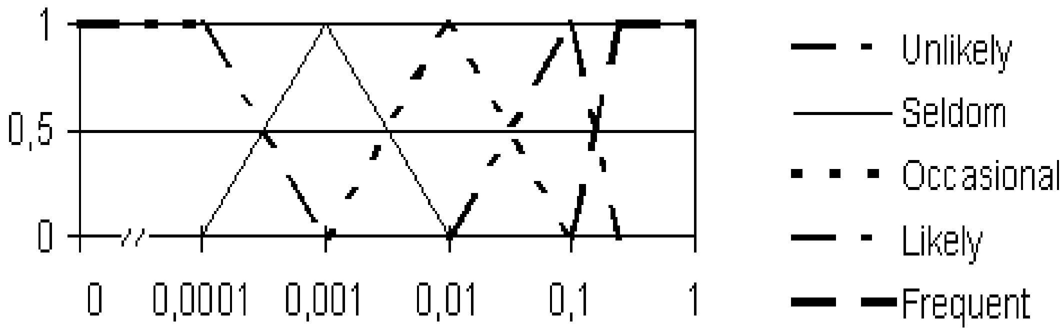

Figure 3: Probability Sets Definition

In the assessment period experts identified all potential hazards of system operation. Next step was to determine probability of identified system operation hazards statistically. Then hazards' severities were determined collectively. For risk assessment calculation the PLutorisK V.1.1D software was used which has been developed by author.

Table II. shows only three hazards and intermediate results of their risk assessments.

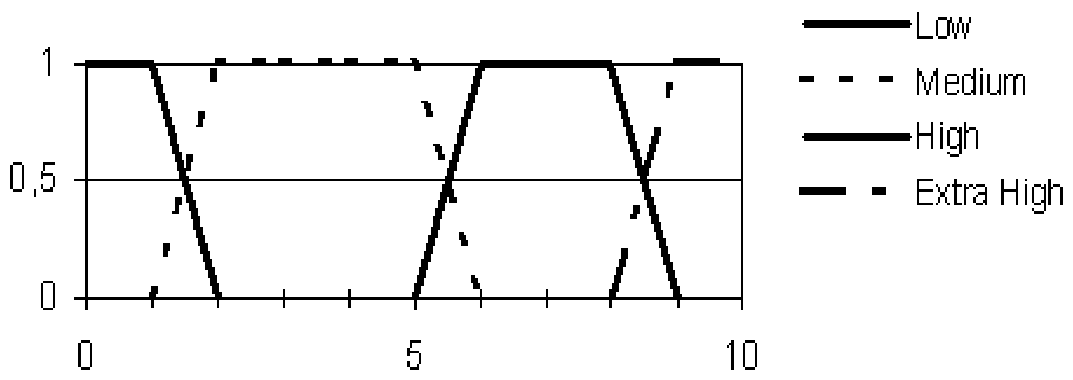

Figure 4: The Risk Sets Definition

After risk assessment, the experts' team used these results to rank risks of all hazards during the next step of risk management process. Balancing assessed risk and probable benefit, the decision-makers or admitted or ameliorated reliability of investigated hydraulic system by investigation of any risk control tools.

5. Summary, Future Work

This paper shown a fuzzy logic-based risk-assessment method. During prospective scientific research related to this field of mathematics, the author will complete following tasks:

- to investigate fuzzy logic's possibilities of use in the modern aircraft and other technical systems operation and its management;
- to popularize usage of fuzzy logic in the modern technical management decision-making;
- to investigate theory and methodology of working-up of diagnostic and trouble-shooting methods based upon fuzzy logic;
- to work up fuzzy logic-based method to investigate parametrical mathematical model uncertainties
- to study methodology and possibilities of use fuzzy tools, during reliability investigation

in the modern technical management.

Table II. *Results of Fuzzy Risk Assessment*

Input data	Name of Hazard	*burst in outgoing pipe*	*burst in return pipe*	*pump failure*
	Severity	9,5	4,2	8,5
	Probability	0,0003	0,0002	0,005
Severity fuzification	Catastrophic	1,00	0,00	0,50
	Critical	0,00	0,20	0,50
	Moderate	0,00	0,80	0,00
	Negligible	0,00	0,00	0,00
Probability fuzification	Frequent	0,00	0,00	0,00
	Likely	0,00	0,00	0,00
	Occasional	0,00	0,00	0,70
	Seldom	0,50	0,30	0,30
	Unlikely	0,50	0,70	0,00
Inference & Composition	Extra High	0,00	0,00	0,00
	High	0,50	0,00	0,50
	Medium	0,50	0,20	0,30
	Low	0,00	0,70	0,00
Defuzification		***5,170***	***1,284***	***5,685***

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