Extended Fuzzy Methods in Risk Management

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Abstract: - In the paper after a short review of main characteristics of risk management applications, some novel fuzzy calculation based possibilities will be presented, like the hierarchical grouping of risk factors, type-2 fuzzy sets representation and decision making on distance-based operators' platform. The examples are given from the medical diagnostic and risk factor management.

Key-Words: - risk management, risk factors, fuzzy decision making

1 Introduction

Management of the complex, multi-parametrical and multi-criteria problems is one of the significant challenges of this century. The uncertainty and the vagueness of conditions render more difficult the modeling of the system behavior and the real-time and sound decision making. Nowadays the identification, assessment, and prioritization of tasks and risks followed by coordinated application of resources to minimize, monitor, and control the probability and impact of unfortunate events is called risk management [1]. These systems are managed not only by experts, but by all, including the micro-communities, families to the macro society structures and global phenomena of nature monitoring.

The problems to be solved by risk management are complex and full of uncertainties, and the emphatic, user-friend representation of the problem is as important as the fast decision making process. There is no better decision mechanism than the human brain, but in a lot of cases the subjective factors must be eliminated. Man is able naturally to choose the important risk group in real-time process, but this selection may not be complete and subjective again.

There exist different models for risk management and decision making in risk situations. The mathematical background is very often the optimization model, operation research or statistical based hypothesis test. The well known statistical based numerical reasoning methods need long-time experiments and they are time- and computing-demanding. The numerical methods and operation research models are ready to give acceptable results for some finite dimensional problems, but without management of the uncertainties. The complexity of the systems increases the runtime factor, and the system parameter representation is usually not user-friend. Considering all those conditions fuzzy set theory helps manage complexity and uncertainties and give visualization of the system parameters, moreover it represents the inputs and outputs in qualitative linguistic form.

There are different applications, where the statistical methods and fuzzy technologies are combined or compared to achieve better results. The features of these systems are usually complexity and a large number of various input/output parameters. In [2] the best evaluated investigation of the completeness of mineral exploration probabilities was introduced by a joint application of the fuzzy set theory and Bayesian method. In [3] the measures of statistical to fuzzy variable interaction were compared, and the conclusion was, that the measure of variable interaction in nature is captured robustly by fuzzy measures and not so by standard statistical measures. In both of the mentioned research field, geology and diagnostics, statistical calculation based decision making was widely applied, but in recent time soft computing based reasoning technologies have appeared.

In this paper after a short review of main characteristics of risk management applications some novel fuzzy calculation based possibilities will be presented, like the hierarchical grouping of risk factors, type-2 fuzzy sets representation, decision making on distance-based operators platform and preference modeling. The examples are given from the medical diagnostic and risk factor management.

2 Risk management models and steps

The techniques used in risk management have been taken from other areas of the system management. Information technology, availability of resources, and other facts helped to develop new risk management where the method to identify, measure and manage the risks thereby reducing the potential for unexpected loss or harm. [4]. A typical risk management process involves the following main stages.

The firs step is the identification of risks and potential risks to the system operation at all levels. Some of these risks will be immediately identifiable; others may be less recognizable. Evaluation and the measure of the identified risks is the next step. Measurement is defined by how serious the risks are in terms of consequence and likelihood of occurrence. It can be a qualitative or quantitative description of their effects on the environment. Plan and control are the next stages to prepare risks management system. This can include the development of response actions to these risks, and the applied decision or reasoning method. If possible, further actions can be evaluated such as eliminating a particular activity because it is too dangerous, the use of protective measures, special training, or new policies and procedures to improve the current arrangements. As the part of planning resource control should be carried out. An agreed risk management control plan is to ensure that adequate resources are or will be available to meet the impact of the actions (decisions) and measures that have been identified. Monitoring and review as the next stage is important if we have a system with a feedback, and the risk management system is open to improvement. The goal is to establish a system where all risks have a review process and defined reassessment timetable. This will ensure that the risk management process is dynamic and continuous, with correct verification and validity control. The review process includes the possibility of new additional risks and new forms of risk. The role of the complex risk control is in the future to try to increase the effects of risk factors.

A simple health-diagnostic system in the preliminary form contains the identification of the risk factors of the investigated illness, the representation of the measured risks, and the decision model. The system can be enlarged by the monitoring and review, like a self-learning system in order to improve the risk measure description and decision system.

2. 1 Fuzzy risk management

Fuzzy logic modeling techniques can be used as well in risk management systems to assess risks level in the cases where the experts have not enough reliable data to apply the statistical approaches. Nowadays the experts' experiences are suited for modeling operational risks not only in the engineering sciences, but for a broad range of applications. The long time used engineering fuzzy applications offer the promised alternative measuring of operational risks and risk management globally. The use of fuzzy sets and fuzzy-based techniques helps to incorporate inherent imprecision, uncertainties and subjectivity of available data, as well as propagate these attributes throughout the model, yielding more realistic results.

The descriptions of the uncertainties in the risk analysis confirm the pertinence of the fuzzy methodologies. The uncertainties in the risk analysis can be classified in the class of model structure vagueness and in the class of quantity-type uncertainties [5]. Empirical quantity and statistical variation arises from random error in direct measurements of a quantity, but the expert risk factor choice depends on the subjective judgment and on differences of opinion between informed experts. Language imprecision, variability and randomness of parameters in the system are usually handled by approximation.

Starting by simple definition of the risk as the adverse consequences of an event, such events and consequences are full of uncertainty, and inherent precautionary principles, such as sufficient certainty, prevention, and desired level of protection. All of those can be represented as fuzzy sets. The strategy of the risk management may be viewed as a simplified example of a precautionary decision process based on principles of fuzzy logic decision making [6]

The relationship between risk factors, risks and their consequences are represented in different forms, but in [7] a well-structured solution, suitable for the fuzzy approach is given

2.2 Fuzzy methods in diagnostic and health risk factor management

Support of medical decision making for the single patient means a correct diagnosis, selection of an optimal therapy, correct assessment of prognosis and optimal patients` management in medical institution. The models for solving are knowledge based models, where the linguistically communicated modeling of mental processes is needed, and the objective and subjective knowledge (definitional, causal, statistical, and heuristic knowledge) is included in the decision process. The measured and observed data representation and data-to-symbol conversion should be user-friend. Fuzziness in medical applications are represented by the vagueness of medical concepts and gradual transition from one concept to another, uncertainty of medical conclusions, uncertainty of co-occurrence of vague medical concepts, incompleteness of medical data, and medical theory and partially known explanations of medical phenomena [8]. Klauss Peter Adlassnigs' fuzzy diagnostic applications are well known for decades, and there are even more new approaches, like the fuzzy clustering of data [9], but new theoretical fuzzy results offer new application models.

3 Novel fuzzy methods for risk management models

3.1 Multilevel fuzzy model for risk management

Considering the fact that the real system is even more complex than its simplification, the model, it is necessary to find the priorities of the risk factors. Some of the risk factor groups, risk factors or management actions have a different weighted role in the system operation. The system parameters are represented with fuzzy sets, and the grouped risk factors values give intermitted result. Considering some system input parameters, which determine the risk factors' role in the decision making system, intermitted results can be weighted and forwarded to the next level of the reasoning process.[10]

Generally the indicators of the ranking are: the nature and extent of the risks, the degree and category of risk, the likelihood of the risks materializing, the potential impact on the further connected events, and the cost or benefit of controls in relation to the identified risks. . Based on the main ideas from [7] a risk management system can be built up as a hierarchical system of the risk factors (inputs), risk management actions (decision making system) and direction or directions for the next level of risk situation solving algorithm. Actually, those directions are risk factors for the action on the next level of the risk management process. To sum this up: risk factors in a complex system are grouped to the risk event where they figure. The risk event determinates the necessary actions to calculate and/or increase the negative effects. Actions are described by the 'if … then' type rules. With the output those components frame one unit in the whole risk management system, where the items are attached on the principle of the time-scheduling, significance or other criteria.

Input Risk Factors (RF) grouped and assigned to the current action are described by the Fuzzy Risk Measure Sets (FRMS) such as 'low', 'normal', 'high', and other.

Risk is the chance or likelihood of the hazard, under the circumstances of its use, producing an injury, disease, etc. The risk management system requires correct judgment of the risk factor entities. Reasonably risk factor choice is based on the following general issues:

- severity of the hazard,
- probability of the risk,
- current knowledge regarding the hazard and the risk,
- availability of suitable hazard control and elimination methods,
- cost of such control or elimination methods.

A hazard is sometimes a physical, measurable entity, but sometimes it is represented with qualitative linguistic terms, e.g., 'low', 'medium', 'dangerous'. Fuzzy-based techniques seem to be particularly suited to modeling data, which are scarce, and where the cause-effect knowledge is imprecise. The use of fuzzy sets and fuzzy-based techniques helps to incorporate inherent imprecision, uncertainties and subjectivity of available data, as well as to propagate these attributes throughout the model, yielding more realistic results [5].

Humans have their role in the risk management system, building it up based on their experiences. The human's tasks are risk identification and model construction. Globally, the human factors are a set of circumstances in which people interact with the complex risk management system. In this set of circumstances human error can occur at any point in a complex decision system.

In [10] a possible preliminary system construction of the risk management principle is given based on this structured risk factors classification and on the fact, that some risk factor groups, risk factors or management actions have a weighted role in the system operation. The system parameters are represented with the fuzzy sets, and the grouped risk factors' values give intermitted result. Considering some system input parameters, which determine the risk factors' role in the decision making system, intermitted results can be weighted and forwarded to the next level of the reasoning process.

The hierarchically structured, weighted risk factor groups are represented in a fuzzy logic (FL) based inference mechanism environment. The generally given method is applied in a diagnostics example:

for the calculation of the stroke risk taking into account risk factors selected by experts.

3.2 Risk Factor Management Based on Type-2 Fuzzy Sets and Distance-based operators

If the fuzziness of membership functions is important, the fuzziness is represented by type 2 fuzzy sets. In [11] a construction of the risk management principle is given based on the system parameters representation with the type 2 fuzzy sets, and decision making model based on modified Mamdani type decision making, representing the control surface, i.e. the output parameter in 3D form. Approximate reasoning methods' platform was the distance based operators group [12]. From a complex, hierarchically constructed system the detailed description is given for one item. The decision making system is based on distance based operators taking into the consideration the fuzziness of fuzzy sets.

Calculating the rule output the weightiness at the *i*th rule is considered proportionally with the fuzziness of rule premise and rule input in that rule. Special types of fuzzy distance based operators support the effectiveness investigations. Applying Matlab Fuzzy Toolbox, and using Gaussian distribution for the representation of the fuzziness of the rule premise and system input (in this case Input Risk Factors (RF) described by the Fuzzy Risk Measure Sets (FRMS)), and based on the basic operators of min and max, the presented control surfaces show that using gains a significant result was achieved. There are areas of the universe of inputs, where the output direction (signal) surface represents a stable, almost constant output, thanks to the rule outputs weighted by the level of fuzziness of the fuzzy outputs. The colorization of the output signal is corresponding to the generally accepted visualization of the risk level: the blue represents the low level of the risk, the orange the medium level, and the red color the high level of the risk. As it was mentioned, this output signal is the input risk factor for the next level of the risk management algorithm or for the next item in this hierarchical system.

4 Conclusion

Management of the complex, multi-parametrical and multi-criteria risk management problems is one of the significant challenges of this century. In this article main characteristics of generally defined and fuzzy logic and reasoning based risk management are presented based on different sources. Considering the new fuzzy theoretical results, some novel fuzzy calculation based possibilities where presented, like the hierarchical grouping of risk factors, type-2 fuzzy sets representation and decision making on distance-based operators platform. The examples are given from the medical diagnostic and risk factor management. The further investigations will be focused on the comparison of effectiveness and applicability of statistical hypothesis tests based diagnostic models and fuzzy based diagnostic models in medicine.

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