FLINS-related activities in Russia

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Abstract: For FLINS'94, the first international workshop on fuzzy logic and intelligent technologies in nuclear science, held in September 1994 in Mol, Belgium, a total of 35 percent of all accepted papers were submitted by Russian scientists. They were presented by only five participants from Russia. This was due to the limited funding available for the workshop. As a result, some important results from our Russian colleagues with possible applications in the framework of FLINS were not reported on. In this paper, we fill this gap, by summarizing all the contributions (20 extended abstracts in the FLINS'94 proceedings) from Russia to FLINS'94, as a survey of the current FLINS-related activities in Russia.

Keywords: FLINS, Russia, international cooperation.

1 Introduction

It was around the time of the IFSA'93 conference in Seoul, Korea, that the first idea of establishing FLINS activities came out of the Belgian Nuclear Research Centre (SCK•CEN). A short time after the call for papers for the FLINS'94 workshop, many Russian researchers submitted their proposals, current work, and finished results within the scope of FLINS. Due to the scarcity and poor quality of the communication channels between Belgium and Russia, and probably also due to our lack of experience—at that time—in optimally exploiting what little means existed, the three of us had to put up with a fair amount of difficulties and hard work in gathering, proofreading and typesetting all the interesting material, and in making the accepted papers for FLINS'94 reach Belgium at all.

As we already indicated, the idea of using fuzzy systems and other intelligent technologies in the nuclear domain stirred up a large interest in Russia. Scientists there prepared in all twenty reports that were accepted by the organizing committee for presentation during the FLINS'94 workshop. This is more than thirty-five percent of all the accepted papers, which serves as an illustration of the Russian interest in FLINS. However, as a result of the well-known economic difficulties in Russia, the larger part of the Russian scientists who submitted a paper, were not able to attend the workshop and report on their work. It is the aim of this paper to somehow fill the gap thus created, by providing a brief survey of the accepted papers, and bringing the Russian interest in and contributions to FLINS before the attention of a larger public.

It could be argued that Russian scientists more than others have been confronted with the necessity of managing nuclear objects in extreme situations, and controlling the non-proliferation of military nuclear technology. This is a consequence of the Chernobyl accident and the political and economic difficulties accompanying the disintegration of the USSR. As these management, monitoring and control problems are characterized by large uncertainty and are based on evaluations by experts providing diverse and inconsistent information, fuzzy and other intelligent technologies seem, in our opinion, to provide adequate

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methods for their solution. These problems, certainly, are of worldwide importance. Solving them successfully can save many lives and at the same time contribute to the improvement of the world's ecological situation.

The papers submitted by Russian scientists and engineers cover a wide spectrum of problems and their possible solutions. Some of them are directly related to the nuclear domain, while others are more general in nature, but relevant to nuclear science and technology. First of all, there are the papers about the theoretical and practical aspects of creating intelligent systems on the basis of fuzzy set theory and chaos theory with possible applications in nuclear technology (see [2, 4, 8, 9, 11, 14, 17, 18, 19]).

A second group of contributions deals with the development of software environments for the diagnosis and control of complex technical systems (see [3, 10, 12, 13]).

In a third group, we may gather work on the applications of fuzzy and other intelligent technologies to maintenance, preventing nuclear accidents and evaluating, minimizing and eliminating their impact and consequences (see [1, 6, 7, 20]).

Finally, and in our opinion also very interesting, is the work on the interpretation of results of physical experiments (see [5, 15, 16]).

It should also be noted that contributions have been submitted by various organizations, and not only by government institutions. This is a new phenomenon for Russia, and lets us hope that science may still flourish despite of the recent economic problems in that country.

2 A brief survey of the Russian contributions to FLINS'94

The acquisition of new types of fuzzy logic, based on t-norms and t-conorms, for use in inference engines of expert systems is described by A. N. Averkin in "Fuzzy logic acquisition and simulation modules for expert systems to assist operator's decision for nuclear power stations" [2]. The author introduces a new type of fuzzy expert system for assisting operators in making decisions in a nuclear power plant in accident situations. Such a fuzzy expert system makes extensive use of the acquisition and testing of different types of fuzzy logics. Averkin proposes a new module FLAMEX to handle both of these tasks. Its main functions are: generation of families of fuzzy logics using a t-norm axiomatic system; visualization and on-screen editing of these logics using multi-coloured truth tables; and testing of fuzzy logics on performance and quality of reasoning by performing appropriate simulations of the corresponding inference process in the expert system.

After the design phase using FLAMEX, the designed logic can be injected in the inference module of the expert system used. In this way, the author argues, the inference process can be made more compatible with human thinking and decision making.

In "Fuzzy logic in monitoring the non-spread of nuclear weapons" [4] A. Belenki and A. Ryjov describe a new information management technology, created for the development of information support systems that must be able to monitor complicated multidimensional problems. An example of such a problem is the task of monitoring the spread of nuclear weapons. It consists in the evaluation of the possibility of the production of a particular nuclear weapons by a particular country on the basis of its intellectual, scientific and technical potential, its raw material resources, its export-import potential and other parameters. The information upon which such an evaluation can be based, is typically stored on different kinds of media and obtained from different sources: newspaper articles, videos, audio tapes, photographs, expert reports, etc. It tends to be diverse and multifaceted, it can furthermore be fragmentary and is not necessarily reliable or trustworthy. Finally, it can be distributed over a large number of locations. Of course, a monitoring system should be able to allow for these peculiarities of the relevant information.

The authors have built a working prototype of such a system, using the expert system GURU. In order to deal with the diversity and fragmentation of the available information, they use the concept of an evaluation tree, the branches of which deal with typical aspects of the evaluation: political, economical, intellectual, cultural, etc. The reliability of the information stored in the different nodes of this tree is represented using a linguistic description of its accuracy. Once the necessary information has been retrieved, the system performs its evaluation using a bottom-top approach, and also assesses the reliability of the reached result. It is interesting to note that this system allows, besides evaluation, also a kind of simulation by changing information at different points in the tree, or by modifying its reliability, and then studying the effect this has on the overall evaluation.

In "APL-Graphics application for maps of science construction in expert system "Forecaster-E" using for scientific forecasting in atomic science and technology" [9] B. A. Makeev and A. V. Zoueva describe the expert system 'FORECASTER'. This system is designed for the diagnosis, analysis and prediction of progress in research and development, and in science in general. It gets its information from large bibliographic databases. Scientific publications and documents in diverse scientific fields are scanned in order to find the frequency of occurrence of typical scientific terms. On the basis of this information, interpenetration rates of different scientific branches are calculated. These rates indicate to what extent scientific branches are influenced by each other, and make it possible to quantify the intensity of interaction between scientific 'trends'. This information can be represented in so-called 'maps of science'. These maps allow the identification of key scientific branches and the study of their influence on other domains of science. They provide at least some quantitative background against which possible actions towards the improvement of the management of science can be discussed and even measured.

Among the more mathematical contributions is the category-theoretic paper "Construction of fuzzy automata by fuzzy experiments" [11] by A. Mironov, in which the author extends the optimal construction problem for finite deterministic automata by experiments. Mironov starts with the description of an *automaton*, in, or defined on, a *category*. He only considers a special subclass of these, namely those automata for which the associated process is an *input-output process*. He then turns his attention to *partial reaction morphisms*, which can be considered as abstractions of the observed behaviour of a system in an experiment. The problem he then faces is, roughly speaking, to find a class of automata that display the observed behaviour, or that, in his words, are *realizations* of the partial reaction morphism under consideration. Among a subclass of these realizations, he furthermore wants to find the *canonical realization* in that subclass, or roughly speaking, the optimal realization with minimal state set. It turns out that canonical realizations are not unique, but depend on the choice of the class of realizations chosen.

Mironov succeeds in solving the canonical realization problem in the class of automata in any topos, and presents sufficient conditions for the existence of canonical realizations for partial reaction morphisms in topoi. As a consequence of this result, the existence of canonical realizations for partial reaction morphisms in the category of (his type of) fuzzy sets over an arbitrary complete chain is proven.

In "Sophisticated object estimation using complex criterion" [14] A. I. Piskunov and G. A. Kleymionov describe a method for evaluating an object S on the basis of a complex, multifaceted criterion Cr. Very often, in order to make decisions and take appropriate actions, a decision maker needs an analysis or evaluation of how well an object S satisfies a certain complex criterion Cr. To give an example, this could be the evaluation of a complex industrial *system*, such as a nuclear power plant, using the criterion of its *safety*. Sometimes it is quite difficult to perform such an evaluation, because the complexity of the criterion does not allow a direct estimation. In order to help a *decision maker* perform such a task, the authors suggest to represent the initial complex criterion Cr, set up by the decision maker, as a binary tree of criteria. At each level of this tree, the criteria are independent, complementary subcriteria of the criterion directly above them. The bottom level consists of a collection of diverse subcriteria, the so-called *aspects* of the criterion, on the basis of which the experts engaged in the evaluation task can evaluate the object S directly. The evaluations are considered as fuzzy sets on a universe of possible evaluations. The decision maker then assigns to every criterion in the tree, except for the aspects, a rule (e.g. a fuzzy mapping) for combining the evaluations of its lower-level subcriteria into one evaluation of the criterion itself. In this way, using the expert evaluations of the aspects, an overall estimation X of the complex criterion Cr is computed using a bottom-top approach. This gives the decision maker a basis for making decisions.

Indeed, if for some reason the decision maker does not find the state of the object S as reflected in its estimation X satisfactory, the model described above can be used by the decision maker to find out where the problems lie. This gives rise to a task of searching for a more suitable state of the object. The decision maker will analyse the current state (i.e., the current estimation X) of the object S, set up a goal (a target overall estimation G) and try to find a new state (reflected in new expert estimations) of the object that corresponds most closely to the goal G. This process gives the decision maker a basis for improving the state of the object if the current one is not satisfactory. Because of the exponential complexity of this task, the authors suggest to use methods in the field of *genetic algorithms* for this purpose.

An important problem in the construction of databases is addressed by A. Ryjov and D. Loginov in "On the choice of an optimal value-set of qualitative attributes for information retrieval in data bases" [18] and by A. Ryjov in "The practical use of the technique of choosing an optimal value-set of qualitative attributes: the problem of stability" [17]. Consider the situation in which a database is constructed using information derived by interviewing human beings in natural language. As an example, assume that we want to store information about a person's stature using linguistic variables. With the property, or *attribute*, 'stature' we can associate what the authors call a *set of significances*: a set of linguistic terms such as 'small', 'large', etc. With each of these linguistic terms, we can associate a linguistic variable, i.e., a fuzzy subset of the universe of the possible numeric lengths, reflecting the meaning of the term. Then the following problem arises. If the set of significances, used to interview our source of information and to store this information in a database, is very small, our description will be very unspecific and will lack in relevant detail. In this case, the authors say that the *loss of information* is high. If, on the other hand, the set of significances is very large, there will be significant overlap between the linguistic variables used to describe them, or, in other words, the distinction between the significances tends to become irrelevant. The authors describe this situation by saying that the *information noise* is very high. Clearly, what must be done here, is to try to find an optimal set of significances, which compromises between information loss and information noise.

In [18], Ryjov and Loginov attack this problem by quantifying the notions of information loss and information noise, using the concept of a degree of fuzziness. Using this quantification, they solve the corresponding optimization problem. Furthermore, they describe the software prototype that allows the user to apply these theoretical results in any particular problem he is faced with. It enables him to calculate, on the basis of the statistical parameters of the given database, the losses of information and the information noise for arbitrary sets of significances of qualitative attributes. It also permits him to compare various sets of significances of qualitative attributes and to choose the optimal set of significances.

In [17] Ryjov considers the stability of this technique, and presents the top and bottom valuations of the degree of fuzziness, of information loss and of information noise. He succeeds in proving that his technique is stable with respect to small changes of the initial data. This permits him to assert that its use in practical tasks is possible. Thus, he argues, his results can be used for the development of information retrieval systems or expert systems in the framework of FLINS.

In "A fuzzy linguistic interface for data bases in nuclear safety problems" [8] B. Lyapin and A. Ryjov address another problem related with databases. They describe the idea of a fuzzy linguistic interface for large-scale databases, making it possible to effectively handle and retrieve a large amount of information. More often than not, an important property of the information that a human database user handles, which distinguishes it from the information in any non-fuzzy database, is the vagueness inherent in the concepts that he uses. In other words, the user, like any human being, thinks in vague and qualitative terms, whereas the information stored in databases is basically non-fuzzy and quantitative. In order to improve the quality and efficiency of man-machine interaction in this domain, a tool is needed that translates the specific information needs of the database user into a proper database query.

The authors describe a prototype system which makes it possible to search the database for information on the basis of generalized concepts, or in other words, linguistic descriptions. The user is allowed to give a linguistic description, in natural language, of the objects he wants to find in the database. The concepts he uses in his query are suitably modelled by fuzzy sets, defined on the universes of the various values that the database objects can assume. These fuzzy sets can be stored and edited, in such a way that the system can be personalized, and provides for every user a suitable 'window' on the database. On the basis of these fuzzy sets, the linguistic query is translated towards a proper database query, and results in an ordering of the records in the database on the basis of their satisfying the request.

In "Autological model of a decision making problem" [19] Yu. P. Shankin uses the elements of fuzzy set theory to describe automatical control structures with elements of reflection. The author draws his inspiration from the work of V. A. Lefebvre on autological modelling, which is based on the representation of an implicative tie between the notions b of an observer, his objective position a and the observer's estimation c of his notions: $(c \rightarrow b) \rightarrow a$. He extends this work by allowing the use of fuzzy sets instead of only characteristic mappings in his model. He then applies this extended autological model to the representation of the typical situation of the planning of an experiment, either in the social or in the exact sciences, where an experimenter has notions about himself and the object under investigation. In a social sciences experiment, the object under investigation may also have notions about itself and about the experimenter. On the basis of the expressions obtained in these cases, the author argues that the proposed approach helps to classify possible types of emerging reflexive structures and to conduct a quantitative analysis of the planning stages of the experimental work thus modelled. He also points out that his approach is notable for the comparative simplicity of its algorithmic and software implementation.

In "Expert system based on algebra of uncertainties with memory in process optimization" [3] I. Batyrshin, R. Zakuanov and G. Bikushev describe the hybrid system 'SMOPLEX'. This system assists a user in the optimization of an industrial process, *in casu* a polypropylene polymerization reaction in a chemical reactor. It contains on the one hand a traditional simulator of the chemical reactor based on functional equations. On the other hand, the qualitative advice on the optimization of the polymerization process is provided by an expert system, bases on Batyrshin's algebra of uncertainties with memory. It is precisely this expert system part of SMOPLEX which lends itself to applications in other industrial domains, and specifically in the nuclear domain.

The authors describe how a rule base is used to model the influence of eighteen possible input parameters (influences on the reaction) on four output parameters (the resulting quality of the polymer). These rules are of the form 'IF (result wanted) THEN (recommend action)', each having a certain *plausibility value*. On the one hand, the authors explain how a rule can be used to infer actual changes in input variables, or rather, actual recommendations to the user, from wanted results. On the other hand, they describe how the algebra of uncertainties is used to combine the results for the different rules, taking into account their respective plausibility values.

The problem of building a special environment 'DIADEMA' for the automation of the development of intelligent on-line diagnostic systems (OLDS) is tackled by V. Mikishev, S. Sokolov and V. Tarassov in their paper "Building integrated environment for the development of intelligent on-line diagnostics systems" [10]. First, some general observations on the use of shells and environments to build diagnostic systems in the nuclear industry are made. According to the authors, OLDS in the nuclear field must be able to perform the following functions: monitor processes; diagnose anomalies at a very early stage of their occurrence; predict and prevent the consequences of failures; provide automated assistance to human operators; and allow the retrieval and inspection of data obtained from various sources. This already implies that OLDS software must contain the following basic modules: a diagnostics manager allowing the choice between several diagnostic methods, amongst which qualitative models such as fuzzy set theoretical and possibilistic ones; inference engines realizing these diagnostic methods; a user-friendly interface with display facilities; and service routines for information retrieval.

The authors describe in detail the integrated environment 'DIADEMA' which is currently being built by them in the framework of a four-year project. They dwell upon the architecture of the environment and the technology used for developing the applications based on it. They discuss the most important possibilities that this environment offers to developers of diagnostic systems: assistance in choosing the optimal diagnostic model, assembly of software from various basic modules, representation, debugging and verification of diagnostic knowledge, and description of the man-machine interface.

S. A. Orlovski describes in his report “Integrated fuzzy cluster, choice, and knowledge acquisition technology in problem of nuclear safety” [12] a computerized integrated information technology ‘FICCKAS’ based on fuzzy set theoretical methods. It is designed for the structural analysis of fuzzy and linguistic data in the form of object-attribute relations. It allows the use and combination of multiple evaluation scales, both fuzzy (numerical) and linguistic. Also, it allows an analysis of the logical redundancy of any attributes used. On the basis of selected collections of attributes, the system can be used to group objects into classes of similar objects. Alternatively, attributes can be grouped to reveal representative classes. Interestingly, the system can also generate collections of logical rules that explain the observed differences between classes of objects.

The author argues that this system is efficient in the processing of fuzzy and linguistic expert data typical of decision problems regarding nuclear safety, where many parties are involved with different objectives and criteria, and information must be used that can be precise or fuzzy, and can even be expressed in the form of linguistic judgments.

In “Two models for energy distribution control in the nuclear power plants” [13] I. G. Perfilyeva and V. V. Postnikov discuss two alternative methods for the control of the energy distribution in the core of a nuclear reactor. In order to perform such a control, the possible control actions are only the lowering and raising of appropriate control rods. According to the authors, the existing control methods are based upon crisp models of the nuclear reactor, and optimizing the energy distribution using these models is extremely complicated and time consuming. Therefore, methods that are potentially simpler are worth looking into.

The first alternative method is an advisory system already realized in the Ignalinsk nuclear power plant, and used for assisting skilled operators. In this approach, a goal function is constructed that is a weighted sum of ten different criteria, all of them characterizing the deviation between the observed distribution and the ideal one. This goal function is calculated for each control rod. A maximum of four control rods with the highest positive value of the goal function are then candidates for lowering. The unknown coefficients appearing in the goal functions are defined using the expertise of skilled operators. It turns out that this method shows good results.

The second alternative consists in building an automatic fuzzy controller on the basis of a fuzzy input-output relation R and a fuzzy modus ponens inference system. The comparative novelty of this approach lies in the way in which R is obtained. Starting with a number of N fuzzy implication rules ‘$A_i \rightarrow B_i$’ $i = 1, \ldots, N$, with $\{A_i \mid i = 1, \ldots, N\}$ and $\{B_i \mid i = 1, \ldots, N\}$ fuzzy partitions of the input respectively output universe, R is chosen in such a way that the fuzzy modus ponens based upon it, maps every A_i into the corresponding B_i. Thus, to put it differently, R is the solution of a system of N fuzzy relational equations.

In the report “Principles of design for nuclear reactor safety system on the basis of neural network” [1] V. K. Abrosimov and E. S. Verbin discuss how to design safety systems for nuclear reactors using neural networks. The principles they propose are intended to serve as the theoretical basis for the practical development of the appropriate software and equipment.

In order to defend their neural network approach, they remark that it is of crucial importance for a nuclear reactor safety system that it should be able to recognize (transitions to) potentially dangerous situations. Due to their associative properties, neural networks tend to be very good at this, and may even point to appropriate actions and decisions in dangerous situations for which the network has not been trained. Also, decisions can be taken instantly on the basis of a certain number of parameters influencing the reactor safety, even if the rest of the parameters are inexact, or absent due to possible equipment faults.

The authors propose to use a three-layer network, every layer performing its part of the task of pattern recognition. In the third layer, there is supposed to be a subfield in which a catalogue of ensembles, describing diverse emergency situations with various degrees of detail, is stored. Training the network (or the separate layers) can be done using Hebb's rule, or a backpropagation method combined with methods from the field of genetic algorithms.

In "Principles of expert fuzzy controller design: AI mobile wall climbing robots for decontamination of nuclear power-station" [6] V. G. Gradetsky, G. Rizzotto, A. Pagni, Yu. V. Slesarev, D. A. Pospelov, S. V. Ul'yanov and K. Yamafuji describe the general principles for designing complex 'AI control systems'. Their methodology is based upon the notion of *hierarchically distributed intelligence*: for local, specific tasks requiring little intelligence and not very complicated control actions, systems with low intelligence are used; for complex, organizational tasks, including the control of the low-intelligence systems, use is made of systems with a high degree of intelligence.

As an ideal application of this special methodology for AI control system design they describe a robot with different intelligence levels, designed for the decontamination of surfaces in nuclear power stations. First, the authors discuss the differences between their wall climbing robot (WCR) and traditional mobile robots. These differences find their origin in the higher requirements imposed on robots used for decontamination: safety, manoeuvrability, being able to function under extreme conditions, high radiation levels and in complex geometries, etc.

For the 'simple' tasks of the WCR, such as cleaning, painting, inspection, welding and cutting, controllers of low intelligence are used, that have a limited amout of electronic components, and therefore have the advantage of not being very sensitive to radiation. For these tasks, for instance, the use of automatic fuzzy controllers with WARP's (Weight Associative Rule Processor) is examined. For the more complex organizational and navigational tasks, an expert system residing on an intelligent workstation is used, that need not be exposed to damaging radiation.

The paper "An expert system for the evaluation of the negative effects of environment on person during the liquidation of nuclear, industrial and ecological accidents" [7] by V. Kudrjavcev, A. Ryjov, V. Kozlov and A. Strogalov describes a general method for the assessment of radiative and toxic effects on participants in (clearance) missions to the heavily polluted and/or contaminated sites of large-scale accidents. The paper is based on experiences with the liquidation of the effects of the Chernobyl accident. It was the author's task to increase the reliability of the evaluation of the radiation doses received by the participants in this liquidation. The problem that presented itself was the following. On the one hand, they had at their disposal detailed information about the radiation types and levels at the different points on the accident site, besides fairly reliable information about the effects of this radiation on the human body. On the other hand, there existed rough and approximate information about the routes taken by the personnel and the time spent at various locations. This information was based on routing sheets, filled out afterwards by the personnel, and containing vague statements of the type "some minutes", "fairly close to", etc. Of course, on the basis of this inaccurate information, it is extremely difficult to give a reliable evaluation of the radiation doses received, and the effects this has on the human body.

The authors formulate the mathematical problems and the approaches to their solution. They describe how an expert system can be used to evaluate the radiation doses received by the clearance personnel, taking into account the available information. They argue that the scientific work that has already been done, and the methods that have been developed and tested so far can be further extended and used in the construction of a more general system, oriented towards the liquidation of the consequences of large-scale accidents.

In his contribution "Catastrophes control problem" [20] V. V. Velichenko discusses a mathematical framework for the construction and study of catastrophe control systems. The purpose of these control systems is to automatically control a complex system, e.g. a nuclear power station, in such a way that, when an important accident (catastrophe) occurs, the undamaged resources of the system and special emergency resources (automatic 'fire brigades') can lead the system out of the catastrophe with minimal further damage. Given the complexity of the physical phenomena occurring during the accident, and the short time-scale during which optimal decisions must be made, it is clear that catastrophe control systems must be highly 'intelligent'.

Velichenko deals with the mathematical aspects of such complex systems in accident conditions. He considers them as dynamical systems. He argues that a catastrophic process or scenario is a finite sequence of interrupted scenes, each governed by definite laws for its dynamical evolution and concrete conditions for its shifting to another scene. Also, every scene has its own appropriate and possible control actions. The author furthermore introduces a damage functional, which is a function of the final scene in a scenario, and measures the damage to the complex system for the given scenario (i.e., the given trajectory through phase space of the dynamical system). The object is then of course to devise control strategies that minimize this damage functional. However, unlike usual dynamical systems the vectors of conjugate variables during the catastrophic process change not only their values while passing through the consecutive scenes of the catastrophe scenario but, also, in accordance with the dynamical characteristics of the scenes, their dimensions.

Two solutions for the problem of choosing optimal control strategies are suggested. The first is the construction of an expert system that uses the described mathematical model for the simulation of possible catastrophes and the elimination of non-realizable control strategies. As the problem clearly consists in minimizing a damage functional, the second solution consists in the application of modern methods from optimal control and variational calculus. This leads to a purely mathematical approach with special equations for the systems of conjugate variables of the variational problem, corresponding to the internal dynamical processes of the scenes, to the motions of the scenes towards their boundaries and to the transitions between the scenes, with the boundary conditions specified in the terminal point of the catastrophe. A global as well as a local variational analysis is discussed, in order to demonstrate the mathematical complexity of the problem.

In the domain of Computer-Aided Measuring Systems (CAMS) we mention the contribution "Dialogue interpretation of stochastic measurement with fuzzy a priori information" [5] by A. I. Chulichkov, N. M. Chulichkova, Yu. P. Pyt'ev and L. I. Smolnik. These authors consider a physical system, made up of an object together with its environment. Measurements done on this system disturb it, and really give us information about the physical system 'object-environment-measuring apparatus'. However, the mathematical theory of CAMS, developed by Put'ev, makes it possible to still infer reasonable information about the system 'object-environment' from the measurements, i.e., to obtain information about the values of the parameters of the object under investigation from the results of the measurement.

The quality of this analysis depends to a large extent on a priori information about the object under investigation, i.e., on what we already know about this object without actually performing the measurements. This a priori information can for instance be a set of possible values that the parameters of the object can assume. Or, alternatively, a probability distribution of these parameters. In this paper, however, the authors consider a third possibility: what if the a priori information takes the form of a fuzzy set on the possible values of the object parameters?

In an attempt to answer this question, they consider the special case where the influence of the measurement on the system 'object-environment' can be modelled by the combination of a linear measurement operator and random additive noise. The result of their minimax measurement interpretation for a measured value ξ turns out to be a fuzzy element $(u, h, \alpha, \mu_\xi(u, h, \alpha))$, where u is the object's parameter estimation, based on the measurement ξ, h is the accuracy of the estimation and α its reliability; $\mu_\xi(u, h, \alpha)$ is a characterization of the agreement between the fuzzy a priori information and the measured data.

In the computer-aided measurement system described, an experimenter using the system enters the information about the parameter values of the object under investigation into the computer in a dialogue with that computer.

In the paper "Fuzzy experiment interpretation" [16], Yu. P. Pyt'ev, V. P. Manolov and B. I. Volkov consider a related problem. They propose a fuzzy generalization of methods of data analysis and measurement models which were previously worked out by them and have already been used in nuclear-physics investigations and remote diagnostics of the environment state. Indeed, they discuss a Computer-Aided Measuring System that uses two fuzzy models for the interpretation of the measurement results. On the one hand, there is a fuzzy relation M between the measurement results, which are the outputs of the measurement system, and the input signals entered into the measurement system, i.e., the values of the system variable that we want to measure. This relation could be called the *measurement relation*, and roughly speaking models the influence of the measurement. On the other hand, the authors consider a fuzzy relation I between the values of the system variable that we want to measure and the parameter values of the object under investigation. They call this relation the *interpretation relation.* Roughly speaking, it provides a link between the values of the system variable and the description of the object under investigation.

Using the measurement relation M, Pyt'ev, Manolov and Volkov introduce the notion of the reliability α of the measuring model, a fuzzy set which is the fuzzy projection of M on the set of the measurements.

The fuzzy composition of the measurement and the interpretation relation yields a fuzzy relation R between measurement results and parameter values. Roughly speaking, it indicates how measurement results provide us with information about the system that is being observed. Using the example of a seismometric experiment, the authors explain how the relations M, I and R can be obtained and used in computer modelling.

The presented method has the peculiarity that not only parameters of the object under investigation are determined (measurement interpretation), but that at the same time the reliability of the results is estimated (analysis).

In "On fuzzy uncertain sets" [15] Yu. P. Pyt'ev presents the concept of a *fuzzy uncertain (FU) set* $A = (\mathcal{X}, \mu_A(\cdot), \tau_A(\cdot))$ on a set $\mathcal{X}$, specified by two *characteristic functions* $\mu_A(\cdot)$ and $\tau_A(\cdot)$. The value $\mu_A(x)$ of the first characteristic function in the object $x \in \mathcal{X}$ gives the extent to which the element x is contained in the FU set A. Thus $\mu_A(\cdot)$ can be interpreted as the membership function of an ordinary fuzzy set. The value $\tau_A(x)$ of the second characteristic function in x gives the likelihood or reliability of the fact that x belongs to A to the extent $\mu_A(x)$. Therefore, $\tau_A(\cdot)$ characterizes the indeterminacy of the FU set A. In summary, a FU set permits an investigator to formulate his fuzzy ideas about certain notions and, at the same time, to represent their reliability.

The discussion covers μ- and τ-algebras of FU sets, in which the characteristic functions μ and τ respectively play the principal role. The author introduces and studies notions such as inclusion and equality of FU sets, and operations such as the complement, inverse and negation of a FU set, and the intersection and union of two FU sets. He also defines *fuzzy uncertain (FU) relations* between two sets $\mathcal{X}$ and $\mathcal{Y}$ as fuzzy uncertain sets on the Cartesian product set $\mathcal{X} \times \mathcal{Y}$. Furthermore, he defines the composition of fuzzy uncertain relations. Using these notions, the concept of a *fuzzy uncertain (FU) mapping* is introduced.

Pyt'ev then proceeds to make the link with his mathematical theory of Computer-Aided Measuring Systems, already referred to in the discussion of [5, 16] above. Extending the line of reasoning in [16], he introduces two fuzzy uncertain relations, the measurement relation and the interpretation relation. Drawing on the results described above, Pyt'ev studies the concept of a Fuzzy Uncertain Computer-Aided Measuring System (FU CAMS) as a measuring facility for research and industry. He also proposes methods for interpreting the result produced by the FU CAMS.

3 Conclusion

It is not without a certain feeling of satisfaction that we have briefly discussed in this paper the wide range of FLINS-related activities in Russia: our report should make it clear that international cooperation between Russian scientists and others is both feasible and necessary. We hope that this review paper will have indicated some areas of interest to the reader, and that it provides useful information for researchers both in the fuzzy logic domain and in the nuclear field, in order that they may assess the role and purpose of FLINS. We remark that none of the papers mentioned here are published in this special issue of Fuzzy Sets and Systems. Most of the extended versions of these papers will however be available in a separately published FLINS progress report.

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