Modeling, Planning, Decision-Making and Control in Fuzzy Environment

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Abstract. The use of proposed technology is oriented for *persons*, who want *to interact* with systems *to make relevant decisions* in real-time, *fuzzy conditions*, heterogeneous *subject areas* and *multi-lingual communication*, where the *situations are unknown in advance*, *fuzzy structured* and *not clearly regulated.* The *essence* of the technology consists in the *situational control* of fuzzy *data*, *information* and *knowledge*, extracted from texts in different *natural languages*, dissimilar *subject areas* for *situational fuzzy control* of the object in *Intelligent* real-time system. The technology is formalized using *Fuzzy Logic*, *Situational Control* theories and is defined by methods of *knowledge representation*, *situational data control*, *fuzzy logic inference*, *knowledge modeling*, *generalization* and *explanation knowledge*, *dialogue control*, *machine translation* and others.

1 Introduction

In order to control an object it is required to know its structure, the purpose of its existence and its control criteria [5]. The task becomes more complicated when there is a need to control objects in real time, in situations unexpected in advance, using data, information and knowledge, presented in a variety of natural languages and subject areas. In these circumstances, arises a problem of decision making in fuzzy environment [3] based on the data, information and knowledge.

The solution to this problem in this article is focused on the approach of *modeling*, *planning* and *controlling* of linguistic and subject area data, information, knowledge, fuzzy inference and others, by mapping the objectives and constraints in fuzzy environment.

The *novelty* of the technology consists in using of:

- fuzzy modeling and situational fuzzy control of fuzzy data, information and knowledge for implementing an automatic fuzzy inference and finding on that basis a correct, accurate, timely and adequate solution, taking into account the current situation and impact of fuzzy environment;
- the conclusion for planning of control actions on the controlled object and realizing in such way of fuzzy control of the object in the fuzzy environment;
- the processors for *creating* and *synthesis* of images, concepts and meaning, extracted from texts in various natural languages and subject areas, and *serialization* them in bases of data, information and knowledge;

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- the bases for organizing of *multi-lingual* human communication through fuzzy dialogue, generalization and explanation of knowledge in the Intelligent fuzzy control system.

There are a lot of interested ideas, methods and algorithms for decision-making in a fuzzy environment, as example in:

- [12] are described two models and methods of Decision-making in one particular subject area of Power Engineering;
- [13] are considered adjustable autonomous agents, that possess partial knowledge about the environment. In a complex environment and unpredictable situations these agents are asked the help of human on base of the model, called HHP-MDP (Human Help Provider MDP) and requests, which are set in advance;
- [14] are reviewed the basic concepts, related to decision-making in fuzzy environments, ontological control for system of systems (SoS) engineering applications, and use ModelSim to simulate such process.

The comparative analysis of these and other works, associated with our work, showed, that there is no integrated linguistic approach to the problem of *situational fuzzy control* in a *fuzzy environment*, including the techniques of *situational control of fuzzy* data, information and knowledge, modeling, planning, decision-making and *situational fuzzy control* of the *object*, based on the achievements of Fuzzy Logic, Situational Control, Artificial Intelligence, Linguistics and others.

2 Main Results

Modeling decisions is defined as construction of a new conceptual situation and a state of controlled objects (fuzzy data, information, knowledge, inference and others), which meets the criteria in the internal and external levels of fuzzy environment. *Planning decisions* is defined as a use of modeling results to create a sequence of alternative decisions that are suitable to the situation and a state of these environments. *Decision-making* is defined as a process of modeling fuzzy logic inference [7] for selecting the relevant decision from a limited number of alternative fuzzy decisions. *Control* is the process of using the modeling results of planning and decision-making in fuzzy environment, in order to implement a control action on the objects (data, information, knowledge, solutions and others) to shift them and their control system to a new state that matches a specified criterion.

To realize targets of Manager (and/or system) to control of organizational object K^R on base of chosen relevant and pertinent decision A^N from a large number of alternatives A, the control task, which is defined by formula [4]

$$\langle A, E, S, T \rangle, \tag{1}$$

can be represented by model (2), [5], [6], (Figure 1, Figure 2),

$$T = \langle A^N, K^R, (S_i : Q_j \overset{u,x,z}{\Longrightarrow} Q_i; I) \rangle, \tag{2}$$

where:

E: Environment of task of decision-making and control (a set of alternatives);
S: System of preferences of the decision maker (DM) (objectives and criteria);
T: The actions of the DM over A of the selection and ordering of alternatives A^N (identification of objective and criterion).

This action of DM is considered as modeling and control data process , which realizes the modeling and generalization of knowledge [8], [9] fuzzy logic inference [7], control dialog [10] and other means and methods of situational control of fuzzy data using natural language (NL) and other languages.

In this case, the approach of *knowledge modeling* is the process of forming, processing and actualization of a semantic network of frames – concepts, which are units of knowledge and data organized in a databases (DB) and knowledge bases (KB), and formally are presented by the module $A^N(G^D, G^Z, G^Y)$ and the model $K^R(R^D, R^Z, R^Y, A^N)$.

The components in these rations are indexed by i, j, k, and are, respectively, the ordinal numbers of: modulated *generalized linguistic variables* ($i = 1, \ldots, l$), serialized in DBs and KBs on the *extensional* level H of modeling knowledge; *terms* of *subject, linguistic* and other knowledge about indicators ($j = 1, \ldots, s$) on the *intentional* level I of modeling knowledge; DBs and KBs ($k = I, \ldots, r$) on the *reformative* level P of knowledge modeling. D, Z, and Y, respectively, identifiers of modulated data information and knowledge frames.

G^D, G^Z, and G^Y, respectively, identifiers of accumulation segments of *subject, linguistic, behavioral* and others data, information and knowledge.

R^D, R^Z, and R^Y, respectively, identifiers of the *rules* of *modeling subject, linguistic, behavioral* and other frame-based representations of data, information and knowledge about indicators and mentioned *linguistic variables* (situations).

A^N are modulated indicators and mentioned *linguistic variables* (generalized situations).

K^R is a formal system of data, information and knowledge modeling, a model of generalized knowledge module, working on base of *rules* R^D, R^Z, R^Y and *relations* R^H, R^I, R^P in the considered segments G^D, G^Z, G^Y of DBs (KBs).

The set of modules are implemented on H, I, and P levels of modeling data, information and knowledge in subject areas by considered methods.

H is the level of purposeful modeling, organized by the use of *fuzzy relations* R^H on the set of components (terms) GLV (corteges in DBs and KBs).

I is the level of purposeful modeling, organized by use of *fuzzy relations* R^I, allowing to determine the membership of the GLV to the certain concept of a particular subject area.

P is the level of purposeful modeling, organized by use of *fuzzy relations* R^P on the set of *fuzzy relations* R^H, R^I, allowing them to determine compliance of set of components GLV (selection of certain concepts) to a particular subject area. The *modeling of fuzzy logic inference* [7] is realized on basis of fuzzy fragments (parcels) of natural and other languages. For this are developed heuristic algorithms, realized by modules K^R of modeling knowledge using rules R^D, R^Z, R^Y, facts (situations) and their subsets (segments) $G^D, G^Z, G^Y, R^D, R^Z, R^Y$, extracted from the considered BDs and KBs.

According [6], the ratio

$$T = \langle A^N, K^R, \mu_L^R, (S_i : Q_j \stackrel{u,x,z}{\Longrightarrow} Q_i; I)\rangle \tag{3}$$

represents a formalized model of *modeling of fuzzy logic inference* in the decision making system, where μ_L^R is the *characteristic (logical) function* of Fuzzy Logic.

The result of the reference is a multi-dimensional generalized *rule - relation* R (computational generalized frame) with the area of values $\mu^R : x \to L_x$. The R is defined on H, I and P levels as chain of parcels μ^R each of which forms the group of coded (computing) values. These values are used by the algorithms of the systems for resolution inductive and deductive *fuzzy inference* in each of the observed levels.

Thus, the multi-dimensional relations (generalized rules) R^D, R^Z, R^Y and the values b^H, b^I, b^P of functions μ^H, μ^I, μ^P, mapped by the DM and his support group, respectively, on the considered levels are the result of *modeling fuzzy logic inference* in the *Situational Data Control* system [6].

This system, interactively interacts with DM or/and *Decision Making System* (DMS) (2), to generate the *fuzzy relevant decision* from the number of the selected alternatives (Figure 2).

The process of *generalization and explanation of knowledge* [9] is considered as a search process for a target logical function (situation) by DMS, which uses for that the mentioned *logic inference* and semantic knowledge network. Consequently, the ration of (3) can be represented as

$$T = \langle A^N, K^R, \mu_L^R(\mu_G^R), (S_i : Q_j \stackrel{u,x,z}{\Longrightarrow} Q_i; I)\rangle \tag{4}$$

The extents of compliance of the numerical and verbal estimates for concepts x from X are determined by fuzzy sets $A^\alpha = \{x, \mu_A(x) \geq \alpha_A\}$ and relations $R_\alpha = \{x, \mu_A(x) \geq \alpha_R\}$ on the level of knowledge modeling and fuzzy logic inference.

In this case, $\mu^P(x) = \bigvee(\mu^H(x) \bigwedge \mu^I(x)) \bigwedge Poss(a/a_\alpha)$ is a composite rule of *generalization* and knowledge *explanation* in the considered *Situational Data, Information and Knowledge Control* (SDIKC) system, where the rule $\mu^P(x)$ is interpreted as a desired logic function, which identifies the *disjunction* of *conjunctions* of modulated logical functions $\mu^H(x), \mu^I(x)$ and $Poss(a/a_\alpha)$.

Establishing the values of α - level for A_α (in certain, and various distributive lattices L), "nearest" to the top of the curves μ_A at each of the considered levels of the modeling of knowledge, - leads (using μ^P) to unite all of "tops" α-slices and to the formation of the resulting fuzzy set of unique (generalized) and relevant data, information and knowledge.

Similarly, the *Dialog control* is based on the ended operations of fuzzy *logic inference, generalization* of knowledge and *control* actions of SDIKC. His model is presented in [10] by (5) as

$$T = \langle A^N, K^R, \mu_L^R(\mu_G^R(\mu_D^R)), (S_i : Q_j \overset{u,x,z}{\Longrightarrow} Q_i; I)\rangle, \tag{5}$$

where $\mu_D^R = f(((\mu_L^R(\mu_G^R)), u, x, w)$.

The μ_G^R depends on other fuzzy logic functions μ_D^R, μ_L^R and managed of environmental influences *u,x,w* on the object with the target to make relevant decisions on control, respectively, at the P, I, and H levels of their modeling [6], [7].

$S_i : Q_j \overset{u,x,z}{\Longrightarrow} Q_i; I$ - determines the *elementary act* of control in the process of modeling and selecting the relevant decision, that *transforms* the control system in the new situation S_i, which characterizes its new state Q_l, after the state Q_j was shifted to Q_l (Figure 1, Figure 2).

Figure 1: Principle of situational control

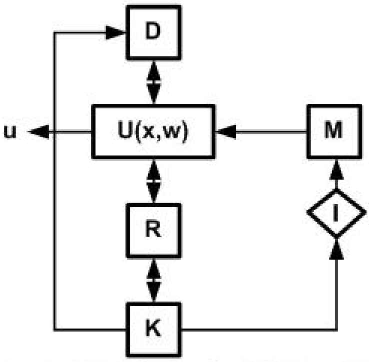
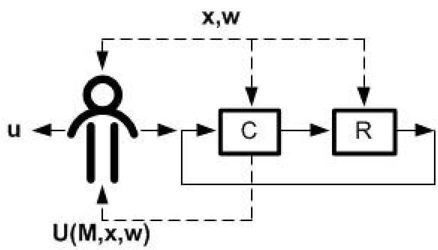


Figure 2: Decisions modeling, planning and control in human interaction



The systems R and C (Figure 2) are using the *Principle of situational control* and are, respectively, control systems for *modeling* and *planning* decisions.

Together with the Manager they represent the *Decision Making System.* The R (analyst, reviewer) and C (expert, approver) together with Manager (decision maker) define a *Organizational Object Management System* (OOMS).

The Manager interacts with C using Natural Language (NL), sends control actions and receives in response to the situation a few number of relevant alternatives. The result of the interaction between C and R - is obtaining by C (in response to the situation) a few number of improved alternatives.

The C and R are implementing the process of modeling and chosen relevant decisions [7] using SDIKC system.

The *x,w* were fuzzy influences, where the first of them is accessible for estimation, but the second is not.

The formula (5) represents the OOMS in heterogeneous subject fields by using the multi-lingual communication.

The mentioned above K^R is a model of generalized knowledge module K (Figure 1), which is functioning on base of R^D, R^Z, R^Y rules and knowledge segments A^N, represented in DBs and KBs.

I - is a SDIKC system. The main its function in the model M - is interpretation by using K the feed-back reactions from the environment influences x, w and control object $U(x, u)$.

M - is *Intellectual Interface* of data, information, knowledge, decisions and *control dialog*. It contains procedures for recognition of reasons, regularities, fixing the facts and their interpretation.

D and R - components of *Linguistic Processor* (LP). The first is the *Interpreter* and the second is the *Synthesizer*. The LP realizes transformation target's actions, which are expressed in NL and other languages. The method of the LP realization is represented in [11].

Each Manager's action me be interpreted as Data, Information and Knowledge Modeling processes [8], fuzzy logic inference [7], dialogue control [10], generalization knowledge [9] and other methods, which are support the processes of modeling, planning and control decisions in fuzzy environment.

3 Conclusions

The proposed methods and technology are oriented for using in the autonomous (Smart) Information Management Systems, which are operating in a fuzzy environment, interacting with people and other systems in different languages and dissimilar subject areas, where the situations and factors of influence on the control object cannot be determined and structured in advance.

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