The Use of a Knowledge-based System in the Investigation of Decision Making based on the Use of the Classical and Fuzzy Sets Theories

Ágnes Szeghegyi

szeghegyi.agnes@kgk.bmf.hu
Budapest Tech Polytechnical Institution
Keleti Károly Faculty of Economics

Abstract: Each problem always originates from constraints. The decision is a response to the challenges by the environment. In order to chose appropriate decision support techniques the structural complexity of the problem has to be determined. The aim of the application of knowledge based systems is to obtain decision support. In this paper the application of the system 'Doctus' is illustrated and exemplified in connection with processing an actual problem. The question is whether rather the 'yes-no' decisions representing the classical binary logic or the fuzzy logical way of thinking will be realized. The analysis was carried out by the application of inductive and deductive inference procedures taking into account the considerations which are influencing principally the decisions. The assessment of the results obtained may generate further dilemmas for the solution of which appropriate knowledge bases can be brought about or the already existing ones have to be refined.

Keywords: decision making, knowledge based systems, deductive reasoning, deductive graph, inductive reasoning, model graph fuzzy logic, fuzzy set theory, fuzzy entropy classical set theory

1 Introduction

To what extent can human thinking be substituted by computers?

By seriously establishing the idea of automating abstract mathematical proofs rather than merely arithmetic, Turing greatly stimulated the development of general purpose information processing only in 1936. Previously, Hilbert had emphasized between the 1890s and 1930s the importance of asking fundamental questions about the nature of mathematics. Instead of asking 'is this mathematical proposition true?' Hilbert wanted to ask 'is it the case that every mathematical proposition can in principle be proved or disproved?' This was unknown, but Hilbert's feeling, and that of most mathematicians, was that mathematics was indeed complete. Gödel destroyed this hope by establishing the existence of mathematical propositions which were undecidable, meaning that they could be neither proved nor disproved.

The next interesting question was whether it would be easy to identify such propositions. After Gödel, Hilbert's problem was re-phrased into that of establishing decidability rather than truth, and this is what Turing sought to address. In the search for an automatic process by which mathematical questions could be decided, Turing envisaged a thoroughly mechanical device, the Turing machine (1936), in fact a kind of 'glorified typewriter'. Its significance arises from the fact that it is sufficiently complicated to address highly sophisticated mathematical questions, but sufficiently simple to be subject to detailed analysis [1]. Turing's universal computer can simulate the action of any other, in certain sense. This is the fundamental result of computer science. Indeed, the power of the Turing machine and its cousins is so great that Church [2] and Turing [3] framed the 'Church-Turing thesis,' to the effect that '*Every function 'which would naturally be regarded as computable' can be computed by the universal Turing machine.*' This thesis is unproven, but has survived many attempts to find a counterexample, making it a very powerful result.

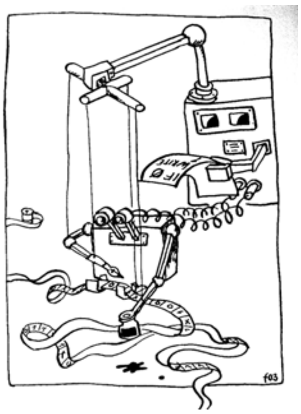

Figure 1
Turing's 'glorified typewriter', the Turing Machine

In the possession of the idea of Turing Machine the computational complexity of a problem can be determined by the number of steps a Turing machine must make in order to complete any algorithmic method to solve the problem. If an algorithm exists with the number of steps given by any polynomial function of the amount of information given to the computer in order to specify the problem then the problem is deemed tractable and is placed in the complexity class 'P'. If the number of the necessary steps in solving a task rises exponentially with this information, then the problem is hard and is in another complexity class. There is an even stronger way in which a task may be impossible for a computer. Such problems are termed incomputable. The most important example is the 'halting problem'. A feature of computers familiar to programmers is that they may sometimes be thrown into a never-ending loop.

According to the above outlined situation it can be stated that recent development of Information Technology made it possible the partial or in certain very special cases even the full automation of the process of human thinking, more formally speaking, at least in the realm of '*P class problems*'. In our days the decision supporting systems embodied in expert systems as software running on common computers are indispensable requisites for managers. Normally these decision supporting systems are used for managing decision dilemmas at the strategic level of decision making [4]. Their application can be extended for the rather 'soft' fields of application as social sciences as well as for the rather 'hard' subject areas of natural and technical sciences [5].

Management decision making level	**Information required for**	**Type of CIS support**
Top Strategic	Planning long-term policy decision and planning	Decision Support System (DSS) (Knowledge-based System)
Middle Tactical	Controlling comparing results of operations with plans and adjusting plans or operations accordingly	Management Information System (MIS)
Lower Operational	Operating maintaining business records and facilitating the flow of work in a project	Data Processing System

Figure 2
The role of computers in decision making [4]

In this paper, as an application example of the knowledge based technologies, analysis of the decision making through the classical and the fuzzy set theoretical approach is presented. As an example the binary respectively fuzzy way of thinking being realized during the decision making was examined adopting the knowledge based technology. The human way of thinking can better modeled with concepts having no sharp limits rather having a transition between the existence '1' and non-existence '0' of an attribute.

2 Fuzzy Logic in the Decision Making

Under real circumstances cannot be expected to get a catherogical answer to all arising questions, problems. Often it cannot be known exactly whether a fact is true or false. During the decision making we are working often with unsufficient, uncertain, practical information. The different sources of the uncertainties mean indecisiveness in the judgement of outcome of the events. If we have no precise starting information our conclusion will be also uncertain [6].

This uncertainty must be represented in some form and this representation must be considered in the conclusions. This will be possible by means of fuzzy logic which realizes the categories adequate to the human way of thinking and to the human language through the accordance with a continuous function. According to the type of the function each point is suitable to express the state of the given answer.

The fuzzy logic is principally understandable in the set theoretical approach mode. The set as a mathematical concept can be given as a fundamental concept of all mathematical knowledges and can be considered as complex entirety of certain homogenous things, objects. The fundamental concept of the set theory is the pertaining to the set. The elements pertaining to the set are determining unambiguously the given set. Accordingly a set is given unambiguously if it is possible to decide unambiguously of all elements of the World whether they are part of it or not. However an interpretation such type carries straight logical contradictions for itself which are called the antiomies of the set theory.

The limits of the traditional two-value logic and of the classical set theory led to the development of the fuzzy logic and fuzzy sets theory.

As first generalization of the two-value logic Lukasiewicz polish mathematician introduced the three- respectively more-value logic at the beginning of the third decade of the last century. In the same decade Max Blanck a german philosopher used some fuzzy logical rudiments and used for the first time the membership function. Lotfi Zadeh introduced the fuzzy sets in 1965 [7]. The theory and application of fuzzy sets achieved great development since the sities. A special advantage of the application of fuzzy solutions is that they offer a quite wide and flexible framework for modeling in which various mathematical details, as e.g. the precise definition of the particular fuzzy operations applied can flexibly determined within wider classes of operators [8]. The appropriate choices also concern the details of fuzzy inference processes [9]. In general fuzzy sets can represent various nonlinear mappings. As alternative method of representing nonlinear mappings Neural Networks can be mentioned. A particular case of such applications is when the model itself consists of certain nonlinear mapping, for instance in the linearization / correction of the nonlinear characteristics of various sensors [10]. In certain particular cases even simple fitting of special spline functions can also work well [11].

To understand them let us start from an cassical set.

$$X = \{x_1, x_2, x_3, x_4, x_5\}. \quad (1)$$

Be 'Y' the partical set of a classical set.

$$Y \subset X = \{x_1, x_2, x_3\} \quad (2)$$

Introducing the following characteristical function:

$$\chi(x) \begin{cases} 1, & if \quad x \in Y \\ 0, & if \quad x \notin Y \end{cases} \quad (3)$$

The 'Y' can then unambiguously characterized with a set of arranged pairs.

$$Y = \{(x_1,1),(x_2,1),(x_3,0),(x_4,0),(x_5,1)\} \quad (4)$$

Zadeh suggested for the first time that the value of 'μ', the membership grade appearing as the second element of the pairs can be not only '0' or '1' but any number within the [0,1] closed interval, the membership set, that $0 \le \mu \le 1$.

The values of the membership grade give the degree of pertaining to the set. Within the [0,1] closed interval the greater is the value of the membership grade the closer pertains the element to the set [7], [12].

If μ = 0, the element is not member of the set.

If μ = 1, the element is member of the set with all right.

The fuzzy entropy serves to answer the question of the uncertainty and to describe the grade of the uncertainty. To the determintion of the grade of uncertainty the most appropriate entropy is the modified version of the Hamming-type entropy where $\mu_A(x)$ is the membership function interpreted on the 'A' fuzzy set and $\varphi_A(x)$ is the entropy function interpreted on the 'A' fuzzy set [12].

$$\varphi_A(x) \begin{cases} \mu_A(x) & if \quad \mu_A(x) \le 1/2 \\ 1 - \mu_A(x) & if \quad \mu_A(x) > 1/2 \end{cases} \quad (5)$$

This definition is based on the natural consideration that the uncertainty of an element increases until its membership grade reaches ½ and exceeding this value starts to decrease.

The relation of the fuzzy entropy and the membership grade can be geometrically in the following manner delinated.

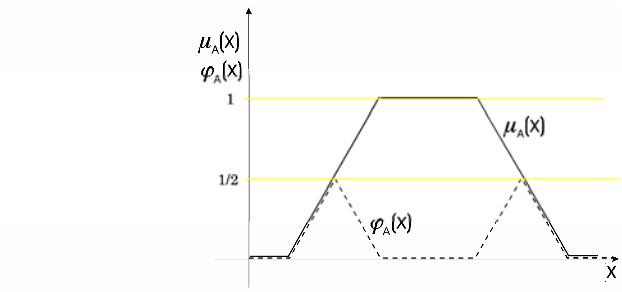

Figure 3
Fuzzy membership and entropy function

In terms of decisions the fuzzy way of thinking presents itself in following manner:

If μ = 0, the decision is unambiguously 'no'.

If μ = 1, the decision is unambiguously 'yes'.

This means the binary decisions. A fuzzy decision means ambivalency, uncertainty, since the value of the membership grade is $0< \mu <1$. The uncertainty of the decision is the greater the nearer approximates the membership grade the $\mu = ½$ value. The decision is at most fuzzy at $\mu = ½$. In such case in all probability the case of incapability to make decision exists.

3 Simulation Examination and Simulation Results

Problems arise always from a difficult situation, decision is an answer on the challenge of the environment. A decision maker can be able to make decisions only when he has recognized the difficult situation, has looked for the solution and has power and authorization to make decisions. The situation for a decision is for the decision maker difficult not at that conditions when the object of the decision is great stake, rather the difficulty is greater in situations when the decision attributes, their values and the relations between the decision attributes are uncertain [13].

In this particular case the decision dilemma is following:

To what degree prevails during the decision making the way of thinking according to the fuzzy logic representing our uncertain knowledge of the world. This problem was examined adopting the 'Doctus' knowledge-based frame system with inductive and deductive inference method.

3.1 Reasoning on Basis of Rules (Deductive Reasoning)

3.1.1 Knowledge Base

The knowledge base building denotes the decision preparing and the decision support denotes the decision proposal [13].

The decision attributes are shown in the first column on the table. The values pertaining to the decision attributes are given on nominal or ordinal scale. They are discrete terms. Their formulation and quantity is a delicate task, as at determining the rules of the depending attribute the not suitable formulation and the excessive refining of the values can cause problems. In such case it is necessary a subsequent refinement, correction [13].

The situation could be made easier by presenting on interval scale, while the application of fuzzy sets should eliminate all difficulties as the fuzzy logics deals with the mathematical handling of the uncertainty of the linguistic terms. Fuzzy systems can successfully be used for various purposes e.g. in motion control of wheeled systems [14], identification of various physical systems [15], and control of test devices [16]. The handling of the uncertainty will be realized most effectively in the fuzzy expert systems [7].

Decision	**binary**	**fuzzy**	
Result of decision	irreverzible	reverzible	
Consequence of decision	loss unavoidable	nothing	gain
Significance of decision	little stake	great stake	
Alternatives of decision	One	few	much
Standpoints of decision	uncleared	cleared	
Str. degree of the problem	unstructured	semi-structured	strurtured
Inclination to take risk	timid	taking risks	
Self cofidence	not existing	moderate	great
Control	inner	outer	
Feedback	not existing	perhaps	exist
Intuition	not existing	weak	strong
Values	unstable	stable	
Knowledge	uninformed	well-informed	
Constraint, outer effect	insignificant	strong	
Surround	strict	understanding	
Experience	not existing	exist	
Advisers	not existing	exist	
Time need	little	much	
Involvement	not existing	moderate	strong

Influenceability	not existing	partial	great

Figure 4
Decision criteria and typical 'values'

3.1.2 Deductive Graph

It is an empirical fact that the expert is not able draw together more than 3-4 decision attributes with '*if..then*' rules. Therefore it is practical to classify the attributes in graph form, arranging them in a hierarchy. The deductive graph presents the dependence conditions of the attributes [13].

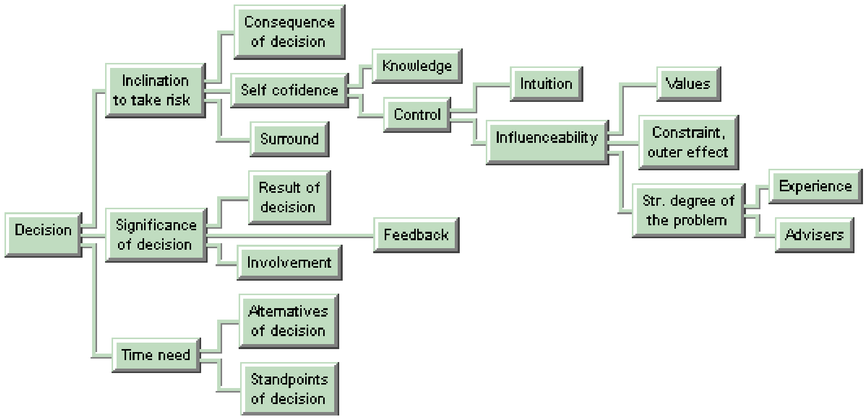

Figure 5
Deductive graph

3.1.3 Rules

The conclusion runs along the graph upwards from below, from the input attributes through the depending medians to the top of the decision tree, to the final decision [4].

3.1.4 Cases

Next step is presenting the cases.

	Feedback	**Intuition**	**Values**	**Knowledge**	**Constraint**	➔
1	not existing	not existing	unstable	uninformed	insignificant	➔
2	not existing	not existing	unstable	uninformed	insignificant	➔
3	not existing	not existing	unstable	uninformed	insignificant	➔
4	perhaps	not existing	stable	uninformed	insignificant	➔

5	perhaps	Weak	stable	well-informed	insignificant	➔
6	perhaps	Weak	stable	well-informed	strong	➔
7	exist	Weak	unstable	well-informed	strong	➔
8	exist	Weak	unstable	well-informed	strong	➔
9	exist	Strong	unstable	uninformed	strong	➔
10	not existing	Strong	stable	uninformed	strong	➔
11	not existing	Strong	stable	uninformed	insignificant	➔
12	not existing	Strong	stable	well-informed	insignificant	➔
13	perhaps	not existing	unstable	well-informed	strong	➔
14	perhaps	Strong	unstable	uninformed	strong	➔

Figure 6
Cases and their values (excerpt)

The parameters of each case were given on basis of the values of knowledge base in accidental relations or on basis of assumed decision situations.

The reasoning is the activation of rules. The shell is reasoning on basis of the input rules through the depending attributes on the output attributes [13], in the present case on the ‘decision’.

	1	**2**	**3**	**4**	**5**	**6**	**7**
Decision	binary	binary	fuzzy	fuzzy	fuzzy	binary	Fuzzy
	8	**9**	**10**	**11**	**12**	**13**	**14**
Decision	binary	fuzzy	fuzzy	fuzzy	fuzzy	fuzzy	Fuzzy

Figure 7
Results of the deductive reasoning

3.2 Reasoning on the Basis of Cases (Inductive Reasoning)

On the basis of known cases it is possible to come to general conclusion regarding the decision rules.

The knowledge base includes the decision attributes and their values. (Fig. 4)

3.2.1 Model Graph

The system generates the model graph, using the inputs of the cases.

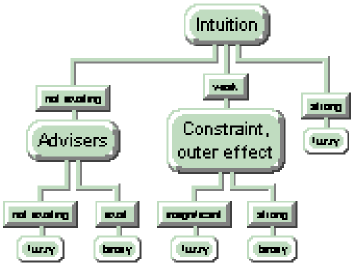

Figure 8
Model graph

From the model graph there are readable the 'if..then' rules constituting the base of decision making. There are visible the qualifying attribute and plotted against their values the attributes influencing the decision.

Through the application of the inductive method it is visible that in reality the weight of decision attributes is different. With regarded to this the informativy degree gives a numerical value that reflects the gain originating from the given information. The informativy degree can have a value from '0' to '1' [13].

4 Conclusions

Regarding to the examination of decisions the conclusion will be naturally the more reliable the more experts are taking part in the building of the knowledge base and in creating of the rules.

4.1 Deductive Reasoning

According to the accomplished analysis the binary approach is mostly unsuitable to describe the incidents of the real world. During the decision making is rather the fuzzy logical approach characteristic. This can be appreciated so that in the decisions appear various uncertainties, that is in the real life the fuzzy way of thinking stands nearer to the human way of thinking than the double-value logical approach.

Though the decisions must be made, the 'yes-no' decisions of the binary logic will be accompained by a feeling of uncertainty, that is the conviction is missing regarding the correctness of the decision. This can develop knowing the consequences of the decision.

Knowing the results more knowledge bases can be built or the refining of te existing one is possible within the limits given by the system.

- At the 'Decision' the number of the values can be increased. For instance in case of a 'fuzzy decision' more values give information also on the grade of uncertainty.
- The value set of each decision standpoints can be also increased that serves similary the refining of the result.
- The subjective, individual interpretation of the single values can also raise further problems.
- Etc.

4.2 Inductive Reasoning

Treating the parameters of particular cases the system generated the following general rule. On the base of model graph the 'intuition' is the determining attribute that is the instinctive recognition, sight into the deep of matters. Capability to recognize the truth directly without previous logical argumentation based on the accumulated experiences, on the previously obtained knowledges. The reality will be directly recognized by intuition independently of the sensory experience and of the rational thinking.

The informativity degree of the intuition is 0,4 that is within the [0,1] closed interval the gain of the information originating from this decision standpoint can be characterized, made numerical with this value.

Referring to a given decision situation, if the intuition is

- strong, a fuzzy decision will take place, that is decision will be characterized by uncertainty. Later on will be turned out whether the decision was right or not.
- weak, as further standpoint the decision will be influenced by 'constraint, outer effect'. Exact unambiguous decision will take place only under effect of a strong constraint.
- not existing, 'advisers' help the decision making. In this case is also true that a binary, unambiguous decision will take place by outer effect thanks to the advisers.

References

[1] Andrew Steane: Quantum computing, Department of Atomic and Laser Physics, University of Oxford, Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, England, July 1997

[2] A. Church: An Unsolvable Problem of Elementary Number Theory, Amer. J. Math, 58 345-363, 1936

[3] A. M Turing: On Computable Numbers, with an Application to the Entschneidungsproblem, Proc. Lond. Math. Soc. Ser. 2 42, 230); see also Proc. Lond. Math. Soc. Ser. 2 43, 544), 1936

[4] W. E. Leigh, M. E. Doherty: Decision Support SystemsSouth-Western Publishing Co., Cincinnati, Ohio, 1996

[5] Starkné Werner Ágnes: Mesterséges intelligencia-szakértői rendszerek, Veszprémi Egyetemi Könyvkiadó, Veszprém, 1997 (in Hungarian)

[6] Sántáné-Tóth Edit: Tudásalapú technológia, szakértő rendszerek, Miskolci Egyetem Dunaújvárosi Főiskolai Kar, Dunaújváros, 1997 (in Hungarian)

[7] Kóczy-Tikk: Fuzzy rendszerek , Typotex, Budapest, 2000 (in Hungarian)

[8] J. Tick, J. Fodor: Some Classes of Binary Operations in Approximate Reasoning, Studies in Informatics and Control, ISSN 1220-1766, Vol. 15, 2006, No. 3, pp. 259-270

[9] J. Tick, J. Fodor: Fuzzy Implications and Inference Processes, Computing and Informatics, ISSN 1335-9150, Vol. 24, 2005, No. 6, pp. 591-602

[10] Gy. Hermann: Application of Neural Network-based Sensor Fusion in Drill Monitoring. Proc. of Symposium on Applied Machine Intelligence (SAMI 2003), Herlany, Slovakia, February 12-14, 2003, pp. 11-24, ISBN 963 7154 14 0

[11] Gy. Hermann: Volumetric Error Correction in Coordinate Measurement. 4th Serbian-Hungarian Joint Symposium on Intelligent Systems (SISY 2006), September 29-30, Subotica, Serbia, pp. 409-416, ISBN 963 7154 50 7

[12] Á. Szeghegyi: Bizonytalanságok kezelésére is alkalmas tudásbázisú döntéstámogató rendszerek (manuscript in Hungarian)

[13] Szeghegyi-Velencei: Üzleti döntéshozásra alkalmas tudásalapú döntéstámogató rendszerek BMF-KGK-4007, Budapest, 2003 (in Hungarian)

[14] Gy. Schuster: Fuzzy Approach of Backward Identification of Quasi-linear and Quasi-time-invariant Systems, Proc. of the 11th International Workshop on Robotics in Alpe-Adria-Danube Region (RAAD 2002), June 30-July 2 2002, Balatonfüred, Hungary, pp. 43-50,ISBN 963 7154 09 04

[15] Gy. Schuster: Simulation of Fuzzy Motion Controlled Four-wheel Steered Mobile robot, IEEE Intenational Conference on Intelligent Engineering Systems (INES 97), September 15-17, 1997. pp. 89-94, ISBN 0-7803-3627-5

[16] Gy. Schuster: Adaptive Fuzzy Control of Thread Testing Furnace, Proc. of the ICCC 2003 IEEE International Conference on Computational Cybernetics, August 29-31, Gold Coast, Lake Balaton, Club Siófok, Siófok, Hungary, pp. 299-304, ISBN 963 7154 17 5