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Knowledge Management (Intellectual Capital) Assessment using Fuzzy Expert System

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1. Introduction

The economy of the world is changing fast, and the knowledge assets and the process are become the primary source of the organization. This is clear when we browse the stock market websites and see the companies with unequal physical assets and stock market value. Also, this notion of knowledge management, as a corporate resource, has been looked to deliver sustainable core competencies in the future (Jans B. D. & Prasarnphanich P., 2003, Khoshsima G., 2003).

Companies today are facing important challenges such as the need to reduce the time-to-market, the development and manufacturing costs, or to manage products with more and more technology. Thus, this current situation is encouraging the implementation of new management techniques such as knowledge management to increase competitive advantages (Gholamreza Khoshsima et al., 2004). Knowledge is an intangible asset, and measuring the effectiveness of knowledge management solutions is challenging. This paper attempts to address the challenges. In order to achieve competitive sustainability, many firms are launching extensive knowledge management efforts. To compete effectively, firms must leverage their existing knowledge and create new knowledge that favorably positions them in their chosen markets (Gold A. H. et al., 2001).

The first step in developing knowledge management is to determine the current position of knowledge management systematically or, more activities and organizational conditions (Gholamreza Khoshsima et al., 2004).

Even if there are some modules and techniques for measuring intellectual capital (IC) (Sveiby, 2003); but, lack of such systems which improve our ability for measuring is observable. The designed expert system act based on three categories: knowledge Capital (KC), management capital (ManC), and market capital (MarC).

Fuzzy numbers, average, mathematics, and inference have been embedded in our system in order to enhance the efficiency and effectiveness of our expert system.

In this paper, we will propose a fuzzy expert system to measure the intellectual capital via fuzzy mathematics. So, in the next section we will discuss more about the literature of subject and determine the Intellectual Capital Measures. Next, the

basic concepts of fuzzy set theory for fuzzy expert system design have been presented. The expert system structure has been illustrated in the next section. A numerical example for four Intellectual Capitals of ITRC has been shown the accuracy of designed system; finally, Conclusion has been determined the results of the employing of designed fuzzy expert system in measuring the Intellectual Capitals.

2. Intellectual capital measures

The intangible property mainly comes from the demand of market and formed by the legal right (Reilly R.F. & Schweihs R.P., 1998). Since the intangible assets are valued as a type of property, it will be appropriate for us to discuss the meaning of a property, and then the meaning of intangible assets is elucidated. There are kinds of rights, while the traditional concept is related mostly to those of real estate. However the intangible assets in accountancy, citing from the general business accounting law, trademark, patents, copyright, permits. Some experts add computer software and organizational cost (Edvisson L. & Malone M., 1999).

Intellectual property rights consist with the industrial property right, copyright, trademark right, and patent right etc, which are created by the human knowledge. Copyright includes the right of copy, issue, public display, selling, artistic performance and translation etc. Edvisson and Malone suggested that the IPR consist with knowledge capital, non-financial capital, concealed property capital, non-visible property, or intangible assets (Edvisson L. & Malone M., 1999). Brooking, Board and Jones (1998) indicates that IPR include market assets, intellectual property assets, infrastructure assets, human-centered assets. Such intellectual property, being the difference between the company market value and the book value, is the counterpart of visible entity capital and finance capital (Brooking Annie et al., 1998).

Reilly and Schweihs, and Edvisson and Malone propose that intellectual capital includes three basic classes, such as human capital, structural capital, and relationship capital. Human capital represents the individual skills applied to satisfy customers (Edvisson L. & Malone M., 1999, Reilly R.F. & Schweihs R.P., 1998). Structural capital is the organizational capabilities of the enterprise, demanded by the market. Relationship capital is the strength of a franchise afforded by a business's ownership of rights. While Mar (2000) surmise the literature and suggest that the intellectual capital in the wide sense, including Knowledge Capital (KC), Management Capital (ManC), and Market Capital (MarC) (Mar S., 2000).

3. Fuzzy set Theory

Fuzzy set theory provides a framework for handling the uncertainties. Zadeh initiated the fuzzy set theory (Zadeh L. A., 1965). Bellman presented some applications of fuzzy theories to the various decision-making processes in a fuzzy environment (Bellman R. E. & Zadeh L. A., 1970). In non-fuzzy set every object is either a member of the set or it is not a member of the set but in fuzzy sets every

object is to some extent member of a set and to some extent it is member of another set. Thus, unlike the crisp sets membership is a continuous concept in fuzzy sets. Fuzzy is used in support of linguistic variables and there is uncertainness in the problem. Fuzzy theory is widely applicable in information gathering, modeling, analysis, optimization, control, decision making and supervision.

4. The Basic Concepts of Fuzzy Numbers

A fuzzy number is a fuzzy set $\tilde{A}$ on R which possesses as the following three properties:
$\tilde{A}$ is a normal fuzzy set;
Special cases of fuzzy numbers include crisp real number and intervals of real numbers. Although there are many shapes of fuzzy numbers, the triangular and trapezoidal shapes are used most often for representing fuzzy numbers. The following describes and definitions show that membership function of triangular and trapezoidal fuzzy number, and its operations (Mehdi Fasanghari & Farzad Habibipour Roudsari, 2008a, Mehdi Fasanghari et al., 2008).
A fuzzy number $\tilde{A}$ is convex, if

$$\mu_{\tilde{A}}[\lambda x_1 + (1-\lambda)x_2] \geq \min[\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)]. \qquad x_1, x_2 \in X, \ \lambda \in [0,1] \tag{1}$$

Alternatively, a fuzzy set is convex if all α-level sets are convex.
A fuzzy set $\tilde{A}$ in the universe of discourse X is normal if (A. Kaufmann & M.M. Gupta, 1988, S. Mabuchi, 1988)

$$\sup_x \mu_{\tilde{A}}(x) = 1 \tag{2}$$

A nonempty fuzzy set $\tilde{A}$ can always be normalized by $\mu_{\tilde{A}}(x) / \sup_x \mu_{\tilde{A}}(x)$.
A fuzzy number is a fuzzy subset in the universe of discourse X that is both convex and normal.
One of the most important concepts of fuzzy sets is the concept of an $\alpha - \text{cut}$ and its variant. It is a bridge from well-defined structure to fuzzy environment.
A triangular fuzzy number can be defined by a quadruplet $\tilde{A} = (a_1, a_2, a_3)$, where $a_1 \leq a_2 \leq a_3$, its member function represented as follows.

$$\mu_{\tilde{A}} = \begin{cases} 0 & x < a_1 \\ (x - a_1) \big/ (a_2 - a_1) & a_1 \leq x \leq a_2 \\ (x - a_3) \big/ (a_2 - a_3) & a_2 \leq x \leq a_3 \\ 0 & x > a_3 \end{cases} \tag{3}$$

Let $\tilde{A}$ and $\tilde{B}$ $\tilde{B}$ be two fuzzy numbers parameterized by the quadruplet (a_1, a_2, a_3) and (b_1, b_2, b_3), respectively. Then the operations of triangular fuzzy numbers are expressed as (S.J. Chen & C.L. Hwang, 1992):

$$\begin{aligned}
\tilde{A}(+)\tilde{B} &= (a_1,a_2,a_3)+(b_1,b_2,b_3)=(a_1+b_1,a_2+b_2,a_3+b_3)\\
\tilde{A}(-)\tilde{B} &= (a_1,a_2,a_3)-(b_1,b_2,b_3)=(a_1-b_1,a_2-b_2,a_3-b_3)\\
\tilde{A}(\times)\tilde{B} &= (a_1,a_2,a_3)\times(b_1,b_2,b_3)=(a_1\times b_1,a_2\times b_2,a_3\times b_3)\\
\tilde{A}(\div)\tilde{B} &= (a_1,a_2,a_3)\div(b_1,b_2,b_3)=(a_1\div b_3,a_2\div b_2,a_3\div b_1)
\end{aligned} \tag{4}$$

Triangular fuzzy numbers are appropriate for quantifying the vague information about most decision problems (C.H. Cheng & Y. Lin, 2002). And the primary reason for using triangular fuzzy numbers can be stated as their intuitive and computational-efficient representation.
In this paper, the triangular fuzzy number is used for measuring Intellectual Capitals. More details about arithmetic operations laws of trapezoidal fuzzy number can be seen in (Lee et al., 2004).
Considering experts E_i provide the possible realization rating of a certain Intellectual Capital. The evaluation value given by each expert E_i are presented in the form of a triangular fuzzy number

$$\tilde{A}^{(i)}=(a_1^{(i)},a_2^{(i)},a_3^{(i)}),where \quad i=1,2,...,n \tag{5}$$

The average $\widetilde{A}_m$ of all $\widetilde{A}^{(i)}$ is computed using average means

$$\tilde{A}_m=(a_{m1},a_{m2},a_{m3})=(\frac{1}{n}\sum_{i=1}^{n}a_1^{(i)},\frac{1}{n}\sum_{i=1}^{n}a_2^{(i)},\frac{1}{n}\sum_{i=1}^{n}a_3^{(i)}) \tag{6}$$

5. Fuzzy Expert DSS

Fuzzy expert decision support system is an expert system that uses fuzzy logic instead of Boolean logic. It can be seen as special rule-based systems that uses fuzzy logic in its knowledge base and derives conclusions from user inputs and fuzzy inference process (Kandel A., 1992) while fuzzy rules and the membership functions make up the knowledge-base of the system. In other words a "fuzzy if-then" rule is a "if-then" rule which some of the terms are given with continuous functions (Li-Xin Wang, 1994).
Most common fuzzy systems are: pure fuzzy systems, Takagi-Sugeno-Kang (TSK) and fuzzy system with fuzzifying and defuzzifying parts (Li-Xin Wang, 1994).Since in the system developed in this paper the input and output are real numbers, the last kind is used. This system has a fuzzifier module in the input that changes the real numbers to fuzzy sets and a defuzzifier module in the output that changes the fuzzy sets to real numbers. The architecture of system is described in more detail in the next section.

6. Architecture of Fuzzy Expert System

System architecture defines the system function, System blocks and the way they interact with each other (Mehdi Fasanghari & Farzad Habibipour Roudsari, 2008b). The architecture of the system is composed of three main blocks as shown in figure 1.

6.1 Fuzzy Inference Engine

A program which analyzes the rules and knowledge aggregated in the database and finds the logical result. There are different selection for the fuzzy inference engine depending on the aggregation, implication and operators used for s-norm and t-norms (Li-Xin Wang, 1994). Mamdani inference is used as equation 7 cause of its local rules and appropriate inferences among the collected rules.

$$\mu_{B'}(y) = \max_{l=1}^{M}[\sup_{x \in U} \min(\mu_{A'}, ..., \mu_{A'_n}(x_n), \mu_{B'_y}(y))] \tag{7}$$

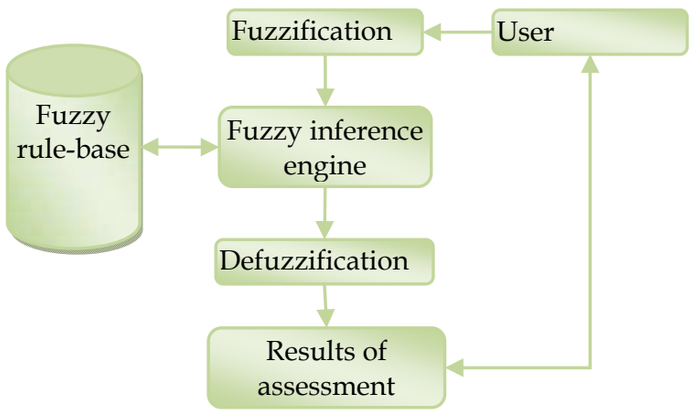


Fig. 1. Process of intellectual capital assessment

6.2 User Interface

Users of this system are organizational decision makers that enter the real number of all linguistic variables via user interface. Also, user interface shows the result scoring of all vendors; therefore, as providing this aim in the designed system, Matlab user interface is used.

6.3 Fuzzy Rule Base

Experts' experience is used to build up the fuzzy rules. These rules are conditional statements and in general can be represented as
IF x is X_i and y is Y_i and … THEN o is O_i.

Where x and y are linguistic input variables. X_i and Y_i are possible linguistic values for x and y; respectively. They are modeled as fuzzy sets based on reference sets containing x and y: Similarly the output or decision variable, o is a linguistic variable with a possible value, O_i modeled as a fuzzy set. The clause x is X_i and y is Y_i can be interpreted as fuzzy propositions delivering partial set membership or partial truth. Consequently the partial truth of the rule premise can be evaluated, modifying the fuzzy set parameters of the output fuzzy sets (Matthews C., 2003).
The language value for each one of the selected parameters in fuzzy expert system (KC, ManC,and MarC) are combined by: *Low*, *Medium*, and *High*. Therefore, there will be 3^3=27 rules out of our depth interviews as below:
Rule 1: IF "KC" is *High* AND "ManC" is *Medium* AND "MarC" is *Low* THEN "Intellectual Capital" is *Medium*.

6.4 Fuzzification

Fuzzification refers to the process of taking a crisp input value and transforming it into the degree required by the terms. We do this by simply recognizing that many of the quantities that we consider to be crisp and deterministic are actually not deterministic at all: They carry considerable uncertainty. If the form of uncertainty happens to arise because of imprecision, ambiguity, or vagueness, then the variable is probably fuzzy and can be represented by a membership function. If the inputs generally originate from a piece of hardware or drive from sensor measurement, these crisp numerical inputs can be fuzzified in order for them to be used in a fuzzy inference system (Timothy J. Ross, 2005). So, as our inputs data are manually, we use singleton Fuzzification method to benefit of its simplicity and speed of calculations in our fuzzy expert DSS.

6.5 Defuzzification

The inference process is complete the resulting data for each output of the fuzzy classification system are a collection of fuzzy sets or a single, aggregate fuzzy set. The process of computing a single number that best represents the outcome of the fuzzy set evaluation is called defuzzification. There are several existing methods that can be used for defuzzification. These include the methods of maximum or the average heights methods, and others. These methods tend to jump erratically on widely non-contiguous and non-monotonic input values (Diego C. E. S., 1999). We chose the centroid method, also referred to as the "center-of-gravity (COG)" method, as it is frequently used and appears to provide a consistent and well-balanced approach (Klir G. J. & Folger T. A., 1998).
For each output using this defuzzification method illustrated in equation 8, the resultant fuzzy sets are merged into a final aggregate shape and the maximum or the average heights of the aggregate shape computed to smooth the procedures and decrease the complexity of expert system calculations for its acceleration.

$$y^* = \frac{\int_{hgt(B')} y dy}{\int_{hgt(B')} dy} \tag{8}$$

whereas

$$hgt(B') = \{y \in V \mid \mu_{B'}(y) = \sup_{y \in V} \mu_{B'}(y)\} \tag{9}$$

7. Case Study

In order to evaluate the applicability of the proposed system, we implemented it in telecommunication research center in Iran (ITRC) in order to measure some Intellectual Capital of its projects.
All linguistic values KC, ManC, and MarC are fuzzy sets. We then conducted a group that included 4 experts in the field of Information and Communication Technology to determine the factors value for 4 projects, which has been done in ITRC in last year (2006), while the values have been signified in triangular fuzzy numbers that is illustrated in Table 1.
At first level one system is designed to assess Intellectual Capital, which has three components, at IF-part a triangular fuzzy number scale is used, therefore with respect to three linguistic variables and three linguistic terms and all of 3^3=27 rules should be fired to the expert system be able to measure the intellectual capitals. After the data of questionnaires was aggregated degree of each component was determined (Table 1). The aggregate data (Table 1) can enter Fuzzy system as either crisp or fuzzy. In the first procedure, fuzzy numbers were embedded into rules through singleton fuzzification and entered fuzzy system designed at MATLAB 7.04. The scores of Intellectual Capital has been computed and changed to crisp numbers by maximum of heights defuzzification method. The following results were acquired (Table 2).

	Expert's number	KC	Management Capital	Marketing Capital
Intellectual Capital of project 1	1	(2.2,4,5.5)	(3.4,4.5,5.6)	(6.1,7.2,8)
	2	(1.2,2.3,4.6)	(4,4.1,4.5)	(5,6.2,6.5)
	3	(3,3.5,4)	(3,3.5,4)	(3,3.5,4)
	4	(1.7,2.1,3.2)	(2.4,3.5,6.2)	(1.2,4.3,5.7)
Intellectual Capital of project 2	1	(6.2,7.6,8.8)	(5.4,7.2,7.9)	(4.4,6.2,7.4)
	2	(7.2,8.1,8.9)	(3.2,4.3,5.8)	(5.2,6.8,7.2)
	3	(2.2,3.5,4.2)	(1.2,3.4,6.6)	(5.7,6.8,9)
	4	(3,5.3,6.8)	(5.2,4.6,8.9)	(6.5,7.5,8.6)
Intellectual Capital of project 3	1	(4.2,5.1,5.4)	(2.3,4.6,7.2)	(4.2,6.2,6.8)
	2	(4,5,6)	(4,5,6)	(4,5,6)
	3	(3,3.5,4)	(3,3.5,4)	(3,3.5,4)
	4	(6.4,7.9,9.2)	(3.5,6.5,7.8)	(2.5,3.4,4)
Intellectual Capital of project 4	1	(1.4,2.5,3.2)	(1.9,2.5,3)	(3.2,3.5,4.8)
	2	(4,5,6)	(4,5,6)	(4,5,6)
	3	(0.4,0.5,1.2)	(3.4,4.1,4.8)	(0.3,0.8,0.9)
	4	(3.4,4.2,4.7)	(5.2,6.7,6.8)	(2.2,3.1,3.3)

Table 1. The experts score for selected Intellectual Capitals of ITRC

As shown in Table 2, Intellectual Capital of project 2 is better than project 3, and respectively Intellectual Capital of project 1 and 2 are in the next stages.

	Final Score
Intellectual Capital of project 1	4.43
Intellectual Capital of project 2	6.31
Intellectual Capital of project 3	5.02
Intellectual Capital of project 4	3.76

Table 2. The final output results of fuzzy expert system

8. Conclusion

In this study, the proposed fuzzy expert system is a flexible system that: (a) simultaneously considers all the different criteria in determining the most suitable Intellectual Capital, (b) takes advantage of the best characteristics of the existing methods, (c) involves the full participation of the users in deciding the number of experts, alternative Intellectual Capitals, and evaluation criteria and sub-criteria, and (d) provides that users can investigate the impact of changes in certain parameters on the solution and quickly receive feedback on the consequences of such changes. The implementation of the proposed fuzzy expert system for a Intellectual Capital Measuring undertaken by telecommunication research center in Iran confirmed the above considerations. The experts of the telecommunication research center in Iran were pleased and agreed with our recommendations since the fuzzy expert system can reduce the decision-making time, and are a practical tool for dealing with the uncertainty problem of linguistic terms.

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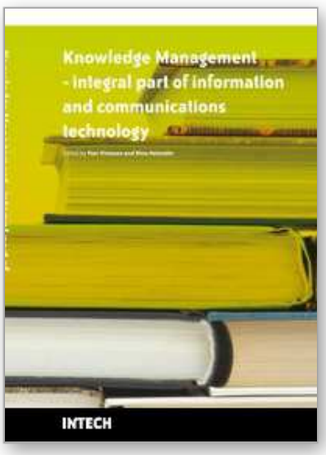
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This book is a compilation of writings handpicked in esteemed scientific conferences that present the variety of ways to approach this multifaceted phenomenon. In this book, knowledge management is seen as an integral part of information and communications technology (ICT). The topic is first approached from the more general perspective, starting with discussing knowledge management's role as a medium towards increasing productivity in organizations. In the starting chapters of the book, the duality between technology and humans is also taken into account. In the following chapters, one may see the essence and multifaceted nature of knowledge management through branch-specific observations and studies. Towards the end of the book the ontological side of knowledge management is illuminated. The book ends with two special applications of knowledge management.

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