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A Review of Development and Applications of Expert System

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Abstract: ***This paper surveys expert systems (ES) methodologies and applications and using a literature review and classification of articles from 1995 to 2004 with a keyword index and article abstract in order to explore how ES methodologies and applications have developed during this period. From their first applications until now, expert systems have provided solutions to multiple problems in companies of all types. Based on the scope of 66 articles from 28 academic journals (retrieved from five online database) of ES applications, this paper surveys and classifies ES methodologies using the following four categories: rule-based systems, knowledge-based systems, neural networks, fuzzy expert system. Present analysis from related academic journals, conference proceedings and literature reviews. Our results show an increase in the number of recent publications which is an indication of gaining popularity on the part of Fuzzy Expert Systems and Neural Expert System Discussion is presented, indicating the followings future development directions for ES methodologies and applications: (1) ES methodologies are tending to develop towards expertise orientation and ES applications development is a problem-oriented domain. (2) It is suggested that different social science methodologies, such as psychology, cognitive science, and human behavior could implement ES as another kind of methodology. (3) The ability to continually change and obtain new understanding is the driving power of ES methodologies, and should be the ES application of future works.***

Keywords— Expert systems;Fuzzy Expert system; Nural Expert System; Expert system methodologies; Expert system applications;

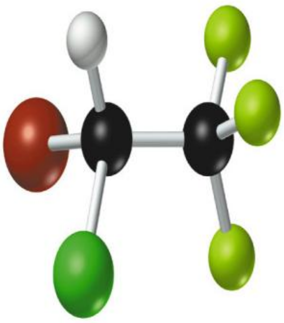
1. INTRODUCTION

Expert system (ES) [1] are a branch of applied artificial intelligence (AI) [2], and were developed by the AI community in the mid-1960s.An expert system is a computer program that is designed to hold the accumulated knowledge of one or more domain experts. The basic idea behind ES is simply that expertise, which is the vast body of task-specific knowledge, is transferred from a human to a computer. This knowledge is then stored in the computer and users call upon the computer for specific advice as needed. The computer can make inferences and arrive at a specific conclusion. Then like a human consultant, it gives advices and explains, if necessary, the logic behind the advice.

Applications of Expert Systems

- MYCIN: Medical system for diagnosing blood disorders. First used in 1979.
- DENDRAL: Used to identify the structure of chemical compounds. First used in 1965.
- PUFF: Medical system for diagnosis of respiratory conditions.
- PROSPECTOR: Used by geologists to identify sites for drilling or mining.

MYCIN



DENDRAL

Components of an Expert System

- The knowledge base is the collection of facts and rules which describe all the knowledge about the problem domain.

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- The inference engine is the part of the system that chooses which facts and rules to apply when trying to solve the user's query.
- The user interface is the part of the system which takes in the user's query in a readable form and passes it to the inference engine. It then displays the results to the user.

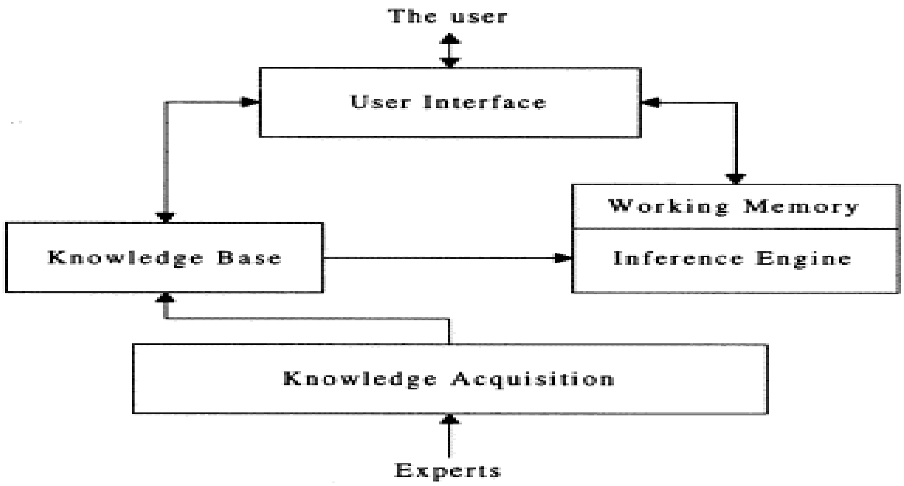

Figure 1: Components of Expert System

The remainder of this paper is organized as follows. The related work section provides an overview of web-based expert systems and the available frameworks. Section 2 and 3 summarizes the rule base and knowledge-based the proposed framework. Section 4 describes the framework architecture of neural network and Section 5 describes the framework of fuzzy expert system. The related work in section 6 provides an overview of expert systems and the available frameworks. Finally, the conclusions and future work section conclude the paper and outlines the future work.

2. Rule-based systems and their applications

A rule-based ES [3] is defined as one, which contains information obtained from a human expert, and represents that information in the form of rules, such as IF–THEN. The rule can then be used to perform operations on data to inference in order to reach appropriate conclusion. These inferences are essentially a computer program that provides a methodology for reasoning about information in the rule base or knowledge base, and for formulating conclusions. Applications of rule-based systems on ESs are including: state transition analysis, psychiatric treatment, production planning, advisory system, teaching, electronic power planning, automobile process planning, hyper graph representation, system development, knowledge verification/ validation, alcohol production, DNA histogram interpretation, knowledge base maintenance, scheduling strategy, management fraud assessment, knowledge acquisition, knowledge representation, communication system fault diagnosis, bioseparation, material processing design, resource utilization, biochemical nanotechnology, probabilistic fault diagnosis, agriculture planning, load scheduling, apiculture, tutoring system, geosciences, and sensor control.

3. Knowledge-based systems and their applications

The most common definition of KBS [4] is human-centered. This highlights the fact that KBS have their roots in the field of artificial intelligence (AI) and that they are attempts to understand and initiate human knowledge in computer systems (Wiig, 1994). The four main components of KBS are usually distinguished as: a knowledge base, an inference engine, a knowledge engineering tool, and a specific user interface. Some of these applications which are implemented by knowledge-based systems include the following: medical treatment, personal finance planning, engineering failure analysis, waste management, production management, thermal engineering, decision support, knowledge management, knowledge representation, power electronics design, framed buildings evaluation, financial analysis, chemical incident management, automatic tumor segmentation, business game, climate forecasting, agricultural management, steel composition design, strategic management, environmental protection, wastewater treatment, decision making and learning, is kinetics interpretation, chemical process controlling, therapy planning, plant process control, outage locating planning, concurrent system design, case validation, chip design, agriculture planning, power transmission protection, crop production planning, troposphere chemistry modeling, planar robots, and urban design.

4. Neural networks and their applications

An artificial neural network (ANN) [5-6] is a model that emulates a biological neural network. This concept is used to implement software simulations for the massively parallel processes that involve processing elements interconnected in network architecture. The artificial neuron receives inputs that are analogous to the electrochemical impulses that the

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dendrites of biological neurons receive from other neurons. The output of the artificial neuron corresponds to signals sent out from biological neuro nover its axon. These artificial signals can be changed similarly to the physical changes occurring at neural

Synapses (Turban & Aronson, 2001). Artificial neural networks (ANN) [7] have been developed as generalizations of mathematical models of biological nervous systems. A first wave of interest in neural networks (also known as connectionist models or parallel distributed processing) emerged after the introduction of simplified neurons by McCulloch and Pitts (1943). The basic processing elements of neural networks are called artificial neurons, or simply neurons or nodes. In a simplified mathematical model of the neuron, the effects of the synapses are represented by connection weights that modulate the effect of the associated input signals, and the nonlinear characteristic exhibited by neurons is represented by a transfer function. The neuron impulse is then computed as the weighted sum of the input signals, transformed by the transfer function.

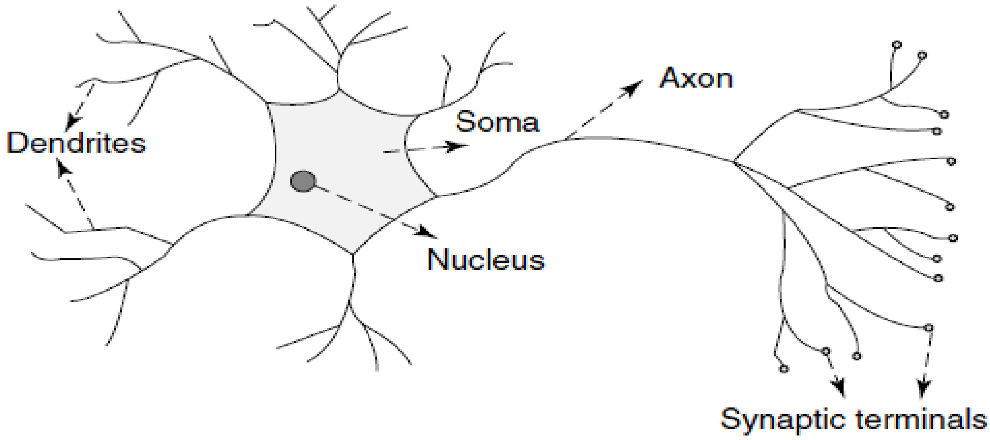

Figure 2: Mammalian Neuron

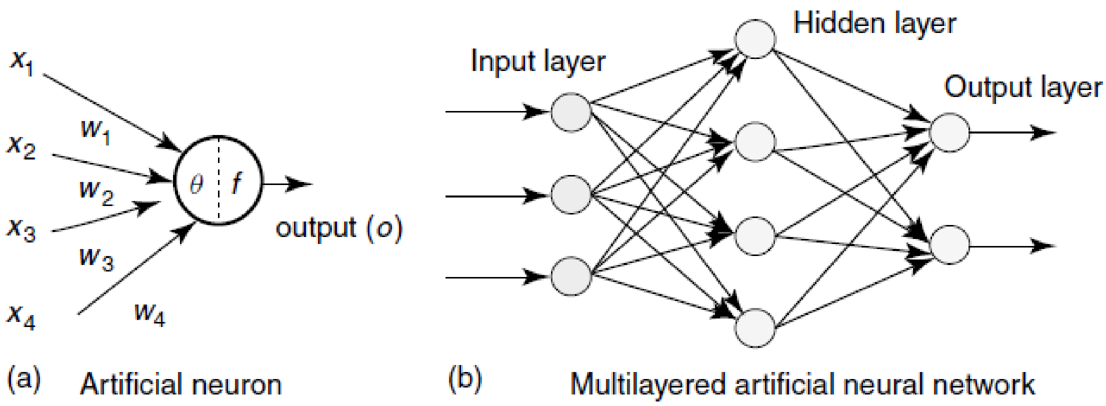

Figure 3: Architecture of an Artificial Neuron and a Multilayered Neural Network

A typical artificial neuron and the modeling of a multilayered neural network are illustrated in Figure 2. Referring to Figure 2, the signal flow from inputs x1. . . xn is considered to be unidirectional, which are indicated by arrows, as is a neuron's output signal flow (O). The neuron output signal O is given by the following relationship:

$$O = f(net) = f(\sum_{j=1}^{n} w_j x_j \qquad (1)$$

where w_j is the weight vector, and the function f(net) is referred to as an activation (transfer) function. The variable net is defined as a scalar product of the weight and input vectors,

$$net = w^T x = w_1 x_1 + \cdots + w_n x_n \qquad (2)$$

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where T is the transpose of a matrix, and, in the simplest case, the output value O is computed as

$$O = f(net) = \begin{cases} 1 \; if \; w^T x \geq \theta \\ 0 \; otherwise \end{cases} \quad (3)$$

where θ is called the threshold level; and this type of node is called a linear threshold unit.

Some of the applications that are implemented by neural networks are the following: fault diagnosis, optimal power flow, decision making, alarm processing system, inference mechanisms, diagnostic system, machine learning, power load forecasting, facility layout design, process control, knowledge learning, gold mining process design, robotic systems, parameter setting, waste treatment, engineering ceramics, mitigation processes control, acoustic signal diagnosing, crude oil distillation, and biomedical application.

5. Fuzzy expert systems and their applications

The theory of Fuzzy Logic [8] was first raised by the mathematician Lotfi A. Zadeh in 1965. This theory is a result of the insufficiency of Boolean Algebra to many problems of the real world. As most of the information in the real world is imprecise, and one of humans' greatest abilities is to effectively process imprecise and "'fuzzy" information.
According to the Oxford English Dictionary, the word Fuzzy is defined as blurred, indistinct, imprecisely defined, confused or vague. Fuzzy systems are knowledge based or rule based systems. The heart of a fuzzy system is a knowledge base consisting of the so called fuzzy IF-THEN rules. A fuzzy IF-THEN rule is an IF-THEN statement [9] in which some words are characterized by continuous membership functions.

5.1 Fuzzy Sets

In the classical set theory a set can be represented by enumerating all its elements using

$$A = \{a_{1,} a_{2,} a_{3 ......} a_{n\}} \quad (2.2)$$

If these elements *ai* (i = 1,.....,n) of A are together a subset of the universal base set X, the set A can be represented for all elements $x \in X$ by its characteristic function

$$\mu_A(x) = \begin{cases} 1 & if \; x \epsilon A \\ 0 & otherwise \end{cases} \quad (2.3)$$

In classical set theory $\mu_A(x)$ has only the values 0 (``false'') and 1 (``true''), so two values of truth. Such sets are also called crisp sets. Non-crisp sets are called fuzzy sets, for which also a characteristic function can be defined. This function is a generalization of that in equation 2.3 and called a membership function. The membership of a fuzzy set is described by this membership function $\mu_A(x)$ of A which associates to each element $xo = X$ a grade of membership $\mu_A(xo)$. In contrast to classical set theory a membership function $\mu_A(x)$ of a fuzzy set can have in the normalized closed interval [0 1]. Therefore, each membership function maps elements of a given universal base set X which is itself a crisp set, into real numbers in [0,1]. The notation for the membership function, $\mu_A(x)$ of a fuzzy set A is as equation 2.4 below.

$$A: X \rightarrow [0,1] \quad (2.4)$$

Each fuzzy set is completely and uniquely defined by one particular membership function. Consequently symbols of membership functions are also used as labels of the associated fuzzy sets, such as big, small and others. Figure 2.4 shows the differences in the crisp and fuzzy sets.

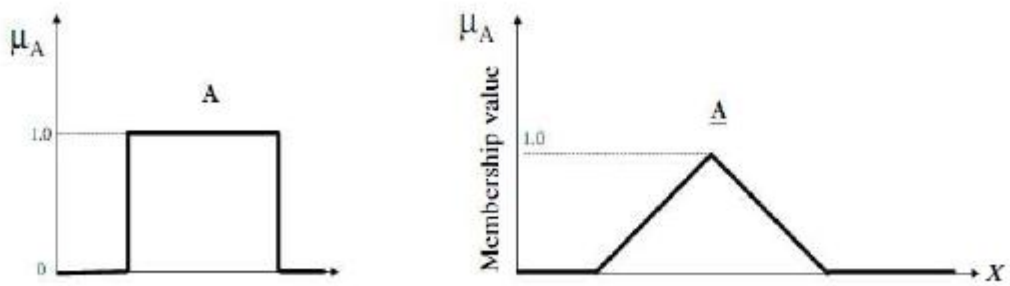

Figure 4: Membership Functions of a Crisp Set and a Fuzzy Set

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5.2 Components of a Fuzzy System

There are basically four components in the fuzzy logic [10] system which is fuzzification, inference engine, rule base and defuzzification. In some cases, a fuzzy system is drawn as a black box with some inputs and an output. Figure 2.6 shows the components of a fuzzy system.

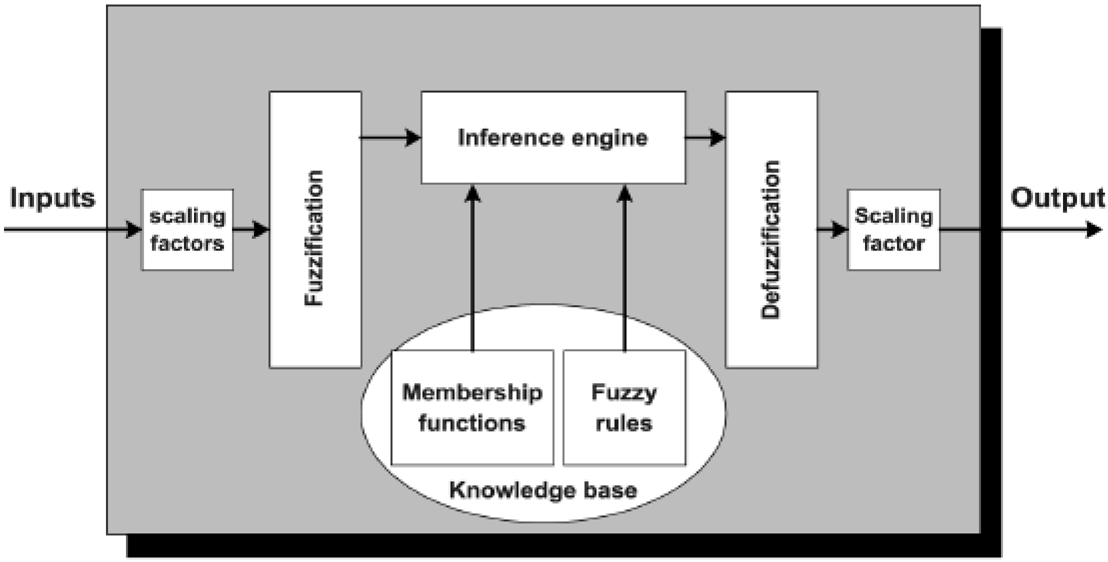

Figure 5: Components of a Fuzzy Logic System

The first block inside the controller is fuzzification. Fuzzification is used to convert each piece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block thus matches the input data with the conditions of the rules to determine how well the condition of each rule matches that particular input instance. There is a degree of membership for each linguistic term that applies to that input variable.

A fuzzy rule base consists of a set of fuzzy IF-THEN rules. It is the heart of the fuzzy system in the sense that all other components are used to implement these rules in a reasonable and efficient manner. Inference engine simply implies the combination of certain rules into a mapping from a fuzzy rule base to get some output corresponding to the inferred rules. There are two ways to infer with a set of rules which are composition based inference and individual rule based inference. In composition based inference, all rules in the fuzzy rule base is combined into a single fuzzy relation which is then viewed as a single fuzzy IF-THEN rule. Most common type of inference used is shown below:-

• The *fuzzy intersection* operator $\cap$ (fuzzy AND connective) applied to two fuzzy sets *A* and *B* with the membership functions $\mu_A(x)$ and $\mu_B(x)$ is

$$\mu_{A\cap B}(x) = \min\{\mu_A(x), \mu_B(x)\}, \qquad x \epsilon X \qquad (2.5)$$

• The *fuzzy union* operator $\cup$ (fuzzy OR connective) applied to two fuzzy sets A and B with the membership functions $\mu_A(x)$ and $\mu_B(x)$ is

$$\mu_{A\cup B}(x) = \max\{\mu_A(x), \mu_B(x)\}, \qquad x \epsilon X \qquad (2.6)$$

• The *fuzzy complement* operator (fuzzy NOT operation) applied to the fuzzy sets *A* with the membership functions $\mu_A(x)$ is

$$\overline{\mu_A}(x) = 1 - \mu_A(x), \qquad x \epsilon X \qquad (2.7)$$

In individual rule base inference, each rule in the fuzzy rule base determines an output fuzzy set and the output of the whole fuzzy inference engine is the combination of many individual fuzzy sets. The combination can be taken either by union or by intersection. In general, there are three criteria of choosing the inference methods which are intuitive appeal, computational efficiency and special properties. For intuitive appeal, the choice should make sense from an intuitive point of view. Simple computation of fuzzy inference system is also one of the issues that need to be considered besides the intuitive issue and some inference need special properties.

Fuzzy ESs are developed using the method of fuzzy logic, which deals with uncertainty. This technique, which uses the mathematical theory of fuzzy sets, simulates the process of normal human reasoning by allowing the computer to behave less precisely and logically than conventional computers. This approach is used because decision-making is not always a

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matter of black and white, true or false; it often involves gray areas and the term may be. Accordingly, creative decision-making processes can be characterized unstructured, playful, contentious, and rambling (Jamshidi, Titli, Zadeh, & Boverie 1997).
Some applications implemented by fuzzy ESs are such as: power load forecasting, online scheduling, chemicalprocess fault diagnosis, ecological planning, control systems, uncertainly reasoning, knowledge integration, faultdiagnosis, power system classification, fault detection, demand evaluation, wastewater treatment, machinability data selection, water supply forecast, radiography classification, on-line analytic processing, hotel selection, dryer tool integration, pooled flood frequency analysis, medical consultation system, job matching, performance indexing, computer security, gesture recognition, and medical diagnosis. The methodology of fuzzy ESs together with their applications is categorized in Table 2

6. Related work

In recent years, the Internet has developed into a business. Along with the evolution of computer science and communications, Knowledge Engineering has advanced in knowledge based and expert systems, creating more effective management systems. The objective of these systems is to help the creation, transfer and application of knowledge in companies (Alavi & Leidner, 2001). Knowledge is increasingly viewed as an important company asset. Knowledge holds important competitive advantages for anyone who possesses it, and it is necessary to manage it properly. During this evolution, expert systems have had numerous applications, noteworthy among them medical and industrial uses. In the field of web-based expert systems, there have in recent years also been important advances which have created a variety of applications in the wake of the Internet's expansion. The Internet can be a source of data for offering solutions as well as a means to accessing the help of the system from anywhere (Lin, Hamalainen, & Winston, 2002). An example of a web-based expert system is the one developed by Slater (1999) on the basis of the tool Rule- Works, which was used to consult about the most appropriate components in the manufacture of computers by the firm Digital (which later became Compaq). Other examples of web-based expert systems are applications to strategic planning of marketing (Li, 2005) and decision-making support, which involves calculating the complexity of different aspects of the company's productive process on the basis of its specific characteristics (Efstathiou, Calinescu, & Blackburn, 2002). In another field, Thomson and Willoughby (2004) proposes creating an expert system that helps in deciding which specific herbicide to use. To achieve interoperability among different intelligent systems, Jovanovic and Gasevic (2005) proposes using XSLT-type sheets to change between different XML-based languages of knowledge representation. This approach requires at least an intermediate language based on XML and knowledge of this language to be able to create expert systems. Dunstan (2008) presents a method for creating web-based expert systems on the basis of descriptions of a specific domain in XML format. The procedure consists of converting the XML format definition into Prolog rules, HTML pages and CGI programs. However, this method requires low-level technical knowledge to define the domain in XML format. Han and Park (2009) propose a system of knowledge management relative to business processes. However, this system is oriented to knowledge management to facilitate the gathering of information and then using this information to support decisionmaking. With regard to technical aspects, Kim, song, and Hong (2005) classifies web-based systems as function of the location of the inference engine. They can be located in the server, accessible through CGI programs, scripts like JSP, ASP or PHP, or as an integrated model in the server like API, or they can be located in the client, through an external viewer or a Java applet. The disadvantage of those located in the client is that the system has to be downloaded to be executed. Taking as his starting point the problems of performance that web-based systems can have, be they in the client or the server, Kim et al. (2005) points out that, in this type of system, an HTML-based approach is more efficient. The authors propose an inference mechanism based on the hyperlinks of HTML documents and contribute a tool for the generation of this type of system. However, the disadvantage of this approach lies in that the change of rules or the incorporation of new elements entails the complete generation of the entire system. When guiding the creation of a web-based expert system, the use of questionnaires adapts perfectly to the application of web technologies associated with expert systems. Interaction between the user and the expert system entails a web dialogue that must be controlled (Yu, 2004). In response to applications that link the questions in a static manner, Yu (2004) proposes a module for generating a dialogue which is manifest in an intelligent choice of the next question to make and groups of possible answers that reflect the knowledge the system possesses. This is a clear case of using the Internet to reach clients and offer them personalized solutions, thanks to a knowledge based system. The integration of AI and knowledge based technologies with Internet technology applied to manufacturing leads to a new technology which makes it possible to achieve very short development cycles and take advantage of sudden opportunities that arise in the market (Xie, 2006). With the aim of integrating knowledge management and business process management, Jung, Choi, and Song (2007) proposes an architecture whose goal is to combine the advantages of both paradigms. However, it is necessary to have tools which make it easy for people who are not computer experts to create these systems, and especially for small and medium-sized companies which cannot afford the cost of a development that is on scale with their potential.

7. Conclusions

This paper is based on a literature review of ES methodologies and applications from 1995 to 2004 using a keyword index and article title search. We conclude that ES methodologies are tending to develop towards expertise orientation and that ES applications development is a problem-oriented domain. It is suggested that different social science methodologies, such as psychology, cognitive science, and human behavior could implement ES as another kind of methodology. Integration of qualitative, quantitative and scientific methods and integration of ES methodologies studies

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may broaden our horizon on this subject. Finally, the ability to continually change and obtain new understanding is the power of ES methodologies, and will be the ES application of future works.

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