Toward efficient modeling of fuzzy expert systems: a survey

O zvýšení účinnosti modelování fuzzy expertních systémů

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Abstract: Efficient modeling of the artificial intelligence tools has become a necessity in order to cut down the development and maintenance cost associated with building application systems in the business, industrial and agriculture sectors that are frequently amendable to sudden unexpected environmental and economic conditions changes. This can be accomplished through developing an efficient modeling language which exploits the beneficial features of the emerging object-oriented technology. This research is aimed at reviewing the recent scientific aspects of the research concerning conceptual modeling of fuzzy knowledge-based system, which exhibits a large extent of applicability in last few decades due to its capability to deal with vagueness, uncertainty and subjectivity, those are inherent in real world problems. The most recent researches and applications of fuzzy expert system are surveyed. The existing knowledge modeling techniques are reviewed and the prominent ones are pinpointed. This paper is intended to identify the main and common bottlenecks of the existing knowledge modeling tools to overcome it in developing a reliable conceptual model of fuzzy expert system.

Key words: fuzzy expert systems, knowledge modeling, object-orientation

Abstrakt: Efektivní využití nástrojů umělé inteligence je nezbytností, pokud chceme snížit náklady na vytvoření a údržbu provozních systémů v obchodním, průmyslovém nebo zemědělském odvětví, které se používají v podmínkách nenadálých změn prostředí a ekonomických podmínek. Toho lze docílit vytvořením efektivního modelovacího jazyka, který využívá vlastností objektově-orientované technologie. Cílem této práce je vytvořit přehled vědeckých aspektů výzkumu konceptuálního modelování fuzzy znalostních systémů, které vykazují značnou použitelnost v posledních desetiletích díky své schopnosti vyrovnat se s neurčitostí, nepřesností a subjektivností, což jsou přirozené vlastnosti reálného světa. V práci je přehled nejnovějšího výzkumu a aplikací fuzzy expertních systémů. Je uveden přehled existujících technik pro modelování znalostí a jsou zdůrazněny ty nejpodstatnější. Cílem článku je rozpoznat hlavní a obvyklá omezení existujících nástrojů modelování znalostí, aby tato omezení mohla být zmírněna při tvorbě spolehlivého konceptuálního modelu fuzzy expertního systému.

Klíčová slova: fuzzy expertní systém, modelování znalostí

Artificial intelligence (AI), software engineering, and systems engineering are important tools for knowledge management. Expert systems is a branch of AI that makes extensive use of specialized human expertise to solve semi or ill-structured problems for which there is no exact guaranteed solving algorithm. The expert system has been defined as "an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions" (Feigenbaum 1982).

DISTINCT FEATURES OF FUZZY RULE-BASED EXPERT SYSTEMS

A fuzzy expert system is an expert system, which consists of fuzzification, inference, knowledge base,

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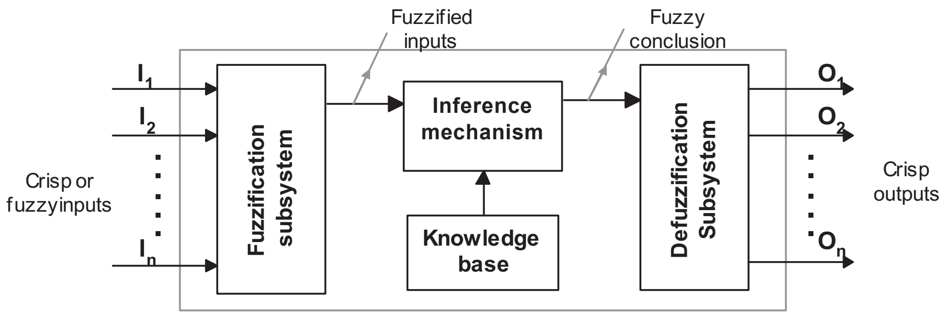

Figure 1. Structure of fuzzy expert system

and defuzzification subsystems, and uses fuzzy logic instead of the Boolean logic to reason about data in the inference mechanism. This approach is used to solve decision making problems, for which no exact algorithm exists, but instead the problem solution can be satisfactorily approximated heuristically relying on human expertise in form of If-Then rules. Fuzzy expert system is well suited to the problem, which exhibits uncertainty resulting from inexactness, vagueness or subjectivity. The structure of fuzzy expert system is illustrated in Figure 1.

METHOD AND AIM

The main purpose of the article is to pinpoint the main advantages and limitations of the currently existing approaches and philosophies for developing and modeling expert systems, and this is in order to avoid such limitations, and superimpose such advantages. In order to achieve such aim, a comprehensive review of the relevant techniques is surveyed.

DISCUSSION

Reviewing concepts, advantages, and limitations of the existing approaches for expert system development (Kaula, Lander 1995)

The rule-based approach

Traditionally, expert system development is based on the production systems approach (rule-based systems) which emphasizes building a single monolithic knowledge-base. Production rules are written in form of IF-Then rules:

If *premise(condition)* **Then** *consequent(action)*

The advantages of rule-based systems are many. Among them, there are: they are easy to formulate, they emulate human cognitive process and decision making ability, and finally, they represent knowledge in a structured homogeneous and modular way. However, there are several limitations associated with those systems: control structures are contained in the order of rules cause loss of flexibility, large number of rules in the knowledge base causes the system to become unwieldy and complicates its maintenance specially in the case of subtle updates, and the difficulty in assigning confidence rating to each rule.

The blackboard system approach (Chi et al. 2001)

This emphasizes the development of a set of independent domain-specific modules called knowledge sources, which interact via a shared global-data structure – the blackboard that organizes and stores the intermediate problem solving data. Knowledge sources produce changes to the blackboard that lead incrementally to a solution of the problem. Communication between knowledge sources is conducted solely through changing the blackboard. The advantage of the blackboard model is that it provides a very flexible control structure for solving the problem. Over and above, blackboard model provides for modularity. However, one of the limitations of the model is that such system does not specify how the specific piece of knowledge should be handled by other knowledge sources.

The frame-based approach

This approach provides a more structured representation in the form of frames. A frame describes an object, consisting of slots containing default values, pointers to other frames, sets of rules, or procedures. Frames are linked to provide for inheritance and communicate by passing messages. However, the modularity of knowledge represented in frames cannot be defined clearly, and the representation lacks flexibility. Also, frame-based systems do not provide a way of defining unalterable slots (Kaula, Lander 1995).

The open-based expert (OES) architecture
(Kaula, Lander 1995)

The OES architecture proposes an expert system consisting of a number of independently developed smaller autonomous expert subsystems (AESs) that communicate during problem solving. Every participating AES exists with its own self-knowledge, i.e., rules. No AES controls directly the knowledge of another AES, thereby making communication and negotiations essential for problem solving. An AES is made aware of the other AESs by accessing the concept dictionary. Communication between AESs is facilitated by a single communication dictionary, which contains the procedures for implementing communication protocols called message acts. The open system approach is suitable for the development of large expert systems. One advantage of such open system is that it emphasizes direct communication of knowledge between expert subsystems from within their background knowledge. Furthermore, the use of human communication mechanisms makes passing of messages more representative of the working environment. Moreover, it is possible to add or remove subsystems (AESs) with minimal impact on the environment. Also, there is no global schema or global consistency. However, one limitation of such system is the problem of inconsistency, which may exist.

The object-oriented approach

It is an extension of the frame-based approach, and it provides for the development of autonomous objects, which communicate by passing messages to one another during problem solving. The technical benefits of OO paradigm to the system development are summarized as follows:
– OO contributes to increased modeling and programming productivity.
– OO reduces development cost and time through greater reusability, modularity, inheritance and independence.
– OO simplifies and reduces problem complexity through a hierarchical and systematized modeling.
– OO greatly reduces system maintenance cost and facilitates modification through encapsulation.
– OO greatly enhances system flexibility through polymorphism.
– OO produces a more reliable system, through ease of communication and understandability.
– OO enhances object sharing, which promotes integration, and clarify interfacing.

Amongst the limitations of OO systems, there is that the system may be slower in execution. Also, the message-passing mechanism in the OO approach does not include the provisions of how a message has to be handled by the receiving object from a sender object's background and perspective. In addition, as human communication includes context and intention apart from content, merely sending a message content becomes a very restricted form of communication.

The most recent literature review on fuzzy expert systems

Table 1 gives the literature review on diversity of fuzzy ESs researches and applications from 1995 up to date (Liao 2005).

Table1. Fuzzy ESs researches and applications from 1995 till 2005

Fuzzy expert systems/application	Authors
Power load forecasting	Kim et al. (1995)
Chemical process fault diagnosis	Ozyurt, Kandel (1996)
Power system diagnosis	Cho, Park (1997)
Uncertainty reasoning	Pan et al. (1998)
Knowledge integration	Lee (1998)
Power system classification	Dash et al. (2000)
Hotel selection	Ngai, Wat (2003)
Computer security	Reznik, Dbake (2004)

The existing knowoledge modeling tools

In the past, most knowledge systems had to be developed from the scratch every time a new system was needed, and it could not interact with other system in the organization. Models are used to both describe the problem domain in software and to define system development process. Most models are constructed from knowledge objects such as concepts, instances, processes (tasks, activities), attributes and values, rules and relations (Abdullah et al. 2002). Amongst the many techniques used to model knowledge, the most common are CommonKADS (Schreiber et al. 1999), Protégé 2000 (Grosso et al.

1999), UML (Booch et al. 1999) and Multi perspective Modeling (Kingston, Macintosh 2000). They are reviewed below.

CommonKADS has become the *de facto* standard for knowledge modeling. It incorporates an object oriented development process and uses UML notations and diagrams, but it still has its own graphical notations for task decomposition, inference structures, and domain schema generation.

Protégé 2000 is an extensible, platform-independent environment for creating and editing ontologies and knowledge bases. It is a frame-based ontology-editing tool with knowledge acquisition tools that are widely used for domain modeling.

UML is the *de facto* standard of object-oriented modeling. It is a general purpose modeling language.

Multi-perspective modeling enables a number of techniques to be used together, each technique being the most appropriate for modeling that perspective of knowledge.

RESULTS

The current trend is to adopt the object-oriented paradigm in modeling knowledge attributed to all distinct advantages mentioned earlier. Also, the open-based expert is a promising approach for developing knowledge-diversified, large expert systems.

The economic impact of developing an efficient knowledge modeling language

The development and maintenance costs of software required to implement AI tools in organizations remains a great obstacle to implementing and making use of such intelligent and powerful knowledge engineering tools. This is due to the inherent computational complexity involved in such intelligent paradigm which required additional skills and knowledge of trained developers. Moreover, the adaptability and flexibility of such intelligent tools is necessary and vital issue in order to cope with the currently fast changes in economic conditions. An efficient OO knowledge modeling language can offer the following economic benefits:

- Reduced development time cost through: reusability, object sharing and integration, reduced complexity, improved communication and understandability, increased productivity, and modularity.
- Reduced maintenance costs through: clarity and understandability of modules and interfaces, flexibility, modularity.
- Improved system quality which adds value that has a direct impact on the system operational efficiency and effectiveness, and that leads in general to improved organizational performance and productivity and to reduced costs.

CONCLUSION

The well-known expert system approaches and the currently existing knowledge modeling techniques are reviewed, in an attempt to superimpose their relative merits, and to avoid and treat the associated bottlenecks of them in developing a proposed fuzzy expert system conceptual model. The survey has indicated that the trend for system developers and researchers is to adopt object orientation paradigm in developing conceptual models for knowledge based systems, attributed to the inherent beneficial characteristics of OO described earlier. One major problem is that there is no standardized technique available to model knowledge.

REFERENCES

Abdullah M.S., Evans A., Benest I., Kimble C. (2002): Developing a UML Profile for Modeling Knowledge-based Systems. Knowledge Based Systems.

Booch G., Rambaugh J., Jacobson I. (1999): The Unified Modeling Language User Guide. Addison Wesley, Reading, Massachusetts.

Chi X., Haojun M, Zhen Z., Yinghong P. (2001): Research on hybrid expert system application to blanking technology. Journal of Material Processing Technology, *116* (2): 95–100.

Cho H.J., Park J.K. (1997): An expert system for fault section diagnosis of power systems using fuzzy relations." IEEE Transactions on Power Systems, *12* (1): 342–348.

Dash P.K., Mishra S., Salama M.M., Liew A.C. (2000): Classification of power system disturbances using a fuzzy expert system and a Fourier Linear Combiner. IEEE on Power Delivery, *15* (2): 472–477.

Feigenbaum E. A. (1982): Knowledge Engineering in the 1980s. Deptartment of Computer Science, Stanford University, Stanford, CA.

Grosso W.E., Eriksson H., Fergerson R.W., Gennari S, Tu S., Musen M.A. (1999): Knowledge Modeling at the Millennium (the Design and Evolution of Protege 2000). Stanford Medical Institute.

Kaula R., Lander L.C. (1995): A module-based conceptual framework for large-scale expert systems.

Industrial Management & Data Systems, *95* (2): 15–23.
Kim K.H., Park J.K., Hwang K.J., Kim S.H. (1995): Implementation of hybrid short-term load forecasting system using artificial neural networks and fuzzy expert systems. IEEE Transactions on Power Systems, *10* (3): 1534–1539.
Kingston J., Macintosh A. (2000): Knowledge Management Through Multi-perspective Modeling: Representing and Distributing Organizational Memory. Knowledge-based Systems, *13* (2–3): 121–131.
Lee K.C., Han J.H., Song Y.U., Lee W.J. (1998): A fuzzy logic-driven multiple knowledge integration framework for improving the performance of expert systems. International Journal of Intelligent System in Accounting, Financing, and Management, *7* (10): 213–222.
Liao S. (2005): Expert system methodologies and application – a decade review from 1995 to 2004. Expert Systems with Applications, *28* (1): 93–103.
Ngai E.W.T., Wat F.K.T. (2003): Design and development of a fuzzy expert system for hotel selection. Omega, *31* (4): 275–2863.
Ozyurt B., Kandel A. (1996): A hybrid hierarchical neural network-fuzzy expert system approach to chemical process fault diagnosis. Fuzzy Sets and Systems, *83* (1): 11–25.
Pan J., DeSouza G.N., Kak A.C. (1998): Fuzzy Sell: A large-scale expert system shell using fuzzy logic for uncertainty reasoning. IEEE transactions on Fuzzy Systems, *6* (4): 563–581.
Reznik L., Dabka K.P. (2004): Measurement models: application of intelligent methods. Measurement, *35* (1): 47–58.
Schreiber G., Akkermans H., Anjewierden A., de Hoog R., Shadbolt N., de Velde W.V., Wielinga B. (1999): Knowledge Engineering and Management: The CommonKADS Methodology. MIT Press, Massachusetts.

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