Expert Systems with Applications 38 (2011) 3049–3057

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

The design of a fuzzy system shell using a database approach

Kun-Yung Lu *

Department of Electronics Engineering, National United University, 1 Lienda, Kungching Li, Miaoli 36003, Taiwan, ROC

ARTICLE INFO

Keywords:
Fuzzy system shell
Fuzzy inference
Fuzzy agent
Decision-making
Database support
SQL

ABSTRACT

This study presented a prototype of fuzzy system shell called FuzzyAccess. Using Microsoft Access database as a developing tools, the proposed system provided a friendly interface for user self-building a fuzzy system. A novice who has no programming-knowledge can also self-define a new fuzzy project. The main contributions of the proposed system were that using SQL method to search the candidate rules in rule evaluation stage and providing an integrated tuning interface for system adjustment. The SQL method can significantly reduce the search time in rule evaluation. The integrated tuning interface can assist user quickly inspecting the influence among different system parameters adjustment and reducing the system development time.

1. Introduction

Many control fields rely on making a real-time decision to solve the control problem or find a solution in resource allocation such as process quality control, job assignment in rush-order, repair policy on machine breakdown, and consultation on a diagnostic event. Normally, the mathematical approaches can be applied in finding an optimum solution. However, quantification methods cannot easily be applied to evaluate the many decision variables in control problems that are linguistically unclear and hard to quantify (Scarf, 1997; Sriram & Haghani, 2003). The sources of uncertainty usually include weak implications, imprecise language, unknown data and confusion among different experts (Negnevitsky, 2005). Consequently, the decision criteria are hard to estimate precisely.

Probability, fuzzy variables, and probability intervals are often applied to represent information uncertainty used in decision-making. The Bayes theorem and the Dempster–Shafer theory of evidence are among the most widely applied methods for managing uncertainty in human decision-making (McCauley-Bell, 1999). Zadeh has published an influential paper applying fuzzy set theory to analyzing complex systems, proposing the application of fuzzy rules to capture human knowledge (Zadeh, 1973). Fuzzy set theory has recently provided another valuable method for measuring uncertainty in control fields.

To assist the system controller self-developing a fuzzy project and quickly making a feasible decision in solving a control problem, this study presented a prototype of fuzzy system shell called FuzzyAccess. It was a database support system. Using Microsoft Access database as a developing tools, the proposed system provided a friendly interface for user self-building a fuzzy system. The main contributions of the proposed system were that using SQL method to search the candidate rules in rule evaluation stage and providing an integrated tuning interface for system adjustment. The SQL method can significantly reduce the search time in rule evaluation. The integrated tuning interface can assist user quickly inspecting the influence among different system parameters adjustment and reducing the system development time. Additionally, all system parameters about the system definitions such as variables, membership functions, and rule bases are stored in a database. The user can easily maintain or modify these parameters by SQL statements. The proposed system can be installed as three working modes: stand-alone, web-base and dynamic link library (DLL).

The rest of this study is organized as follows. Section 2 describes the problems in control and discusses the relative literatures. Section 3 then presents the system framework and describes the system working principles. The system verification and adjustment procedures of a user-defined project are then described in Section 4. Following, Section 5 demonstrates the implementation of the proposed system and introduces the application method of a user-defined system. Finally, conclusions are drawn in Section 6.

2. Review of the literature

Since Zadeh published an influential paper applying fuzzy set theory to analyzing complex systems, proposing the application of fuzzy rules to capture human knowledge (Zadeh, 1973). In control applications, using fuzzy logic enables the mathematical modeling approaches based on differential equations and relational equations to be avoided. The domain experts can quickly makes

* Tel.: +886 3 7381516; fax: +886 3 7362809.
E-mail address: carlu@nuu.edu.tw

0957-4174/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2010.08.095

a decision based on their experiences which are represented in intuitive natural language (Yamakawa, 1993).

Recently, many researches focused on the application of fuzzy logic in quickly making a management decision. Lu built an agent-base fuzzy system for making the decision about machine maintenance (Lu & Sy, 2009). Juang et al. proposed a fuzzy inference system for efficiently and effectively meeting to the requirements of customers (Juang, Lin, & Kao, 2007). Sokołowski applied fuzzy rule bases to monitor and detect the cutting tool wear (Sokołowski, 2004). Zhang and Tam established a fuzzy simulation model to analyze the uncertain demand on resources (Zhang and Tam, 2004). For setting an optimal production line, Beskese et al. applied fuzzy set theory to quantify the flexibility of advanced manufacturing systems (Beskese, Kahraman, & Irani, 2004).

Fuzzy set theory has recently provided another valuable method for measuring uncertainty in production control fields. To solve the uncertainty of inventory carrying cost and ordering cost per order, Hojati applied a fuzzy model to bridge the gap between probabilistic and fuzzy parameter on EOQ problems (Hotati, 2004). Fuzzy set theory usually handles decision-making uncertainty by representing the uncertainty of a proposition using a membership function, such as triangular, trapezoidal, Gaussian or generalized bell (Klir & Yuan, 1995). The membership function can also be extended to various levels of decision making, using fuzzy aggregation techniques to compute the certainty as it moves between different levels of the decision making process.

Jang addressed the key points of designing a fuzzy expert system including the following problems (Jang, 1993):

- There is no standard method available to transform human knowledge into a rule base and database of the fuzzy expert system.
- Effective methods are needed for tuning the membership functions so as to maximize the performance index in fuzzy expert system and minimize the output error measure in a fuzzy controller.

Normally, designing a fuzzy system is a team work in case of using a conventional fuzzy expert system shell or a program-base development tool. The main players include project manager, domain expert, knowledge engineer, programmer, and end-user (Negnevitsky, 2005).

To assist a user self-developing a fuzzy system, many researches devoted their efforts in providing a fuzzy system shell. Guangyu et al. presented a fuzzy system shell called SADEP (Guangyu et al., 1998). The SADEP was aimed at assisting an operator of fossil power plants to recognize the significance of events and state variables with respect to current plant conditions and predict the future propagation of disturbances. However, the SADEP is not an actually shell. FuzzyShell from Purdue Robot Vision Lab was a fuzzy expert system shell for large-scale general-purpose applications (DeSouza & Kak, 2000). The goal of FuzzyShell was focusing on improving all the currently available (either through commercial channels or as free-ware over the internet) fuzzy expert system shells work correctly for only one-shot inference. Omar provided a Java-base fuzzy tool kits (Omar, 2008). The tool kits wee an object-oriented class which can be called by other application program. However, the designer should have Java programming ability.

Other famous fuzzy system shells such as FuzzyTech (fuzzyTECH, 2001) and MATLAB Fuzzy Logic Toolbox (Mathworks, 2009) are very popular in practical fields and academic circles. Applying above fuzzy system shells usually requires somewhat program-base experience. Although the above tools provided many graphic editors for user establishing the prototype, these tools still deeply rely on human involving in tuning the project. However, the user must pay more attention in inspecting among the different editor to modify the project.

3. The system framework

The system framework of this study is depicted in Fig. 1. The system framework can be classified to two parts: system definition and system verification. System definition includes system variables definition, fuzzy sets definition, rule base definition, and fuzzy rules generation. System verification includes testing data collection, data fuzzification, fuzzy inference, rule evaluation, fuzziness aggregation, defuzzification, and output. The functions of each element mentioned above are described as follows.

3.1. System definition

In system design stage, user can configure the fuzzy system based on his/her domain knowledge. Normally, this is a team work in case of using a conventional fuzzy expert shell system. The main players include project manager, domain expert, knowledge engineer, programmer, and end-user. However, this study provided a friendly development tool to the domain users in assisting them to self-configure a fuzzy system.

3.1.1. System variables definition

This element is used to define the system input and output variables. Generally speaking, identifying the key input from the system and specifying the main output are important procedures of the system development. Normally, an experienced domain person should be in charge of the system variables identification. A data table is adopted to record the definition data. Fig. 2 demonstrates the partial of variables definition.

3.1.2. Fuzzy sets definition

Finishing the system variables definition, each variable should be given a piece of suitable fuzzy sets to map the control limits. Additionally, each fuzzy set should also be set a suitable membership function (MBF, hereafter) used to transform the input data to a corresponding fuzziness value. To simply the computation of the input data fuzzification, this study applied the following types of membership function depicted in Fig. 3.

Z type: the Z type of membership function is usually used at the left of the control limits.

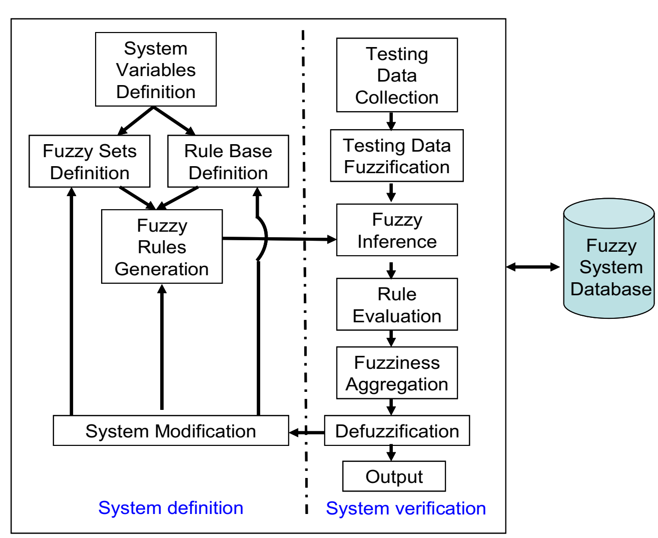

Fig. 1. The system architecture.