ELSEVIER

Expert Systems with Applications 27 (2004) 533–547

Expert Systems with Applications

www.elsevier.com/locate/eswa

Using a fuzzy approach to support financial analysis in the corporate acquisition process

R.T. McIvor[a,*], A.G. McCloskey[a], P.K. Humphreys[a], L.P. Maguire[b]

[a]Faculty of Business and Management, University of Ulster, Northern Ireland, UK
[b]Faculty of Engineering, University of Ulster, Northern Ireland, UK

Abstract

In the global market place, many companies have had to adapt their strategies to meet significant challenges. A strategy adopted by some companies has been international expansion via acquisitions. The need for expert knowledge to determine an appropriate company to acquire has been complicated by the sheer size of the global market place. The costs associated with this in relation to time and personnel have created the need for a computerised expert system to be developed. This paper endeavours to show how a proposed fuzzy based system can assist in the identification of a company for acquisition. The authors discuss the manipulation of the magnitude of fuzzy membership functions to communicate priorities within the system. The fuzzy system is designed to assist financial experts in identifying a suitable company for acquisition in the corporate acquisition process. This includes the deliberate weighting of certain inputs and results above others in the decision-making process. The system attempts to learn and simulate the human precedence given to particular financial statistics in company analysis. The system uses the magnitude of the fuzzy membership functions to reflect the human precedence given to each financial ratio. This enables a particular company's strengths and weakness to be considered while concurrently considering their significance and relevance to the acquiring organisation. The system will enable a larger number of companies to be analysed in a more time and cost-effective manner. The development of this system is intended to illustrate that a fuzzy system can aid the financial experts of an acquiring organisation in the global acquisition process.

Keywords: Fuzzy logic; Acquisition process; Decision making

1. Introduction

The development of the global market has created many changes that impact upon how individual companies must compete to survive (Harrison, 1994). In order for many companies to compete in the current market place, they have been forced to expand, either within their national market or in the international market. This required growth can be achieved in a number of ways; one strategy that firms have adopted is expansion via acquisitions (Newton, 1981; Schniederjans & Hoffman, 1992). In an international market place, the number of companies that an acquiring organisation must consider for acquisition can be immense. The access to financial data through on-line databases such as value line, FAME and compustat has provided more readily accessible sources of corporate information. However, the number of possibilities increases both the research effort from the company's financial experts and the cost to the acquiring organisation. This therefore represents a considerable investment by any acquiring organisation (Schoenberg & Reeves, 1999).

The availability of increasing amounts of data in all disciplines has encouraged the development of technologies that can perform data analysis on vast amounts of data. These technologies include machine learning (Murata, Ma, & Isahara, 2002) such as induction, data mining and statistical and conceptual clustering; neural networks (Dreiseitl & Ohno-Machado, 2002); genetic algorithms (Chi, Yan, & Pahm, 1996).

This paper sets out to identify how a fuzzy system (Bellman & Zadeh, 1970) can be effectively utilised to evaluate a large source of financial data while applying preferences to particular inputs within the analysis. The diversity of potential companies to acquire and the diversity of the acquiring organisations itself, dictate that varying data inputs and preferences will be required for different organisations. This promotes the necessity of a user centred

* Corresponding author. Tel.: +287-137-5275; fax: +287-137-5323.
E-mail address: r.mcivor@ulster.ac.uk (R.T. McIvor).

0957-4174/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2004.05.020

approach enabling the system to adapt to the user and their requirements (Marsala & Bouchon-Meunier, 1999).

The proposed fuzzy system employs a hierarchical system (Wei & Wang, 2000) with scalable fuzzy membership functions (Sharma & Tokhi, 2000; Warne, Prasad, Siddique, & Maguire, 2003) both of which are dictated by the requirements of the acquiring organisation. The basis on which the system architecture is designed is based on a detailed profile of the acquiring organisation. The system derives an architecture for the acquiring organisation with corresponding priorities for inputs within the system. A simplified version of the system containing the system architecture and priorities is presented to the user. The user can then approve the current settings or adjustment through the use of a graphical user interface (GUI).

This paper illustrates the potential benefits of the system by providing results obtained for a particular acquiring organisation over a number of corporate acquisitions. Section 5 illustrates how the system adapts to provide results in line with the requirements of the acquiring organisations. Particular attention is given to how the system can identify potential acquisition targets through the extraction and analysis of financial information from on-line databases. The authors have provided results that illustrate the potential benefits of the system by providing results obtained for different acquiring organisations from the same on-line database of companies. The system discussed serves as a basis for discussion and future research.

2. The acquisition process

National and international expansion can provide a firm with an external environment where: new markets exist; labour costs are cheaper; transportation costs are less expensive; and/or the taxes are less. Many European and US firms have expanded operations by moving to developing countries to take advantage of cheaper labour costs (Davis, 1992). In the 1990s, international acquisitions have been prevalent in a number of industries including newspapers and media, food and drink, and telecommunications. Cross-border acquisitions include all acquisitions of organisations across two national boundaries. In 1998, there were 3000 cross-border acquisitions in Europe, valued at $220 billion (Schoenberg & Reeves, 1999). The advantages and popularity of acquisitions as a policy for corporate development are well established (Johnson & Scholes, 2002; Rappaport, 1979). There are many reasons why such an organisation may wish to acquire another (Czogala & Pedrycz, 1981), have identified the following as potential motives for acquisitions:

- Low cost route into a new market or new product area
- Achieve operational synergies
- Increases in power
- Increased market share
- Cost reductions
- Financial credibility
- Managing an under-performing firm
- Reducing competition or over-capacity in an industry
- Reducing the threat of a take-over
- Personal ambition.

There are a number of key stages in the acquisition process a previous review (Grundy, Johnson, & Scholes, 1998) has identified the key stages as:

1. *Strategy and objectives*—the acquiring organisation must be clear about its current strategic position and intent.
2. *Search*—it is important that very clear criteria are established in order to screen potential acquisition targets.
3. *The deal*—essentially this stage is concerned with ensuring that the strategic objectives established in the previous two stages are being met.
4. *Integration*—during this phase any changes to management, operations and strategy are implemented and new opportunities for further development may be identified.
5. *Investment and learning*—during this phase, managers review whether the acquisition has delivered what was expected—strategically, financially and organisationally.

Once the objectives and criteria of the acquisition are established, the acquiring organisation must identify companies which meet these objectives; this is the focus of this paper. Clearly, in an international context, there may be thousands of firms representing dozens of industries that may be suitable. The corporate acquisitions model described in this paper attempts to overcome some of the problems associated with the acquisition process, and act as a decision aid in the analysis of large databases of potential acquisitions. However, it must be emphasised that the model is not a panacea for all of the problems associated with corporate acquisition analysis. The model illustrates how the process of evaluating potential acquisitions can be assisted with the aid of a fuzzy system to take advantage of advances in the electronic distribution of on-line corporate databases. The stages involved in this corporate acquisitions model are illustrated on a decision tree in Fig. 1. A full description of the stages involved in the model will be presented in Section 3.3.

3. The development of the acquisition system

3.1. Problem definition

The proposed system is concerned with providing an acquiring organisation with a structure to follow in the corporate acquisition decision-making process. The system proposes to obtain a precise set of aims

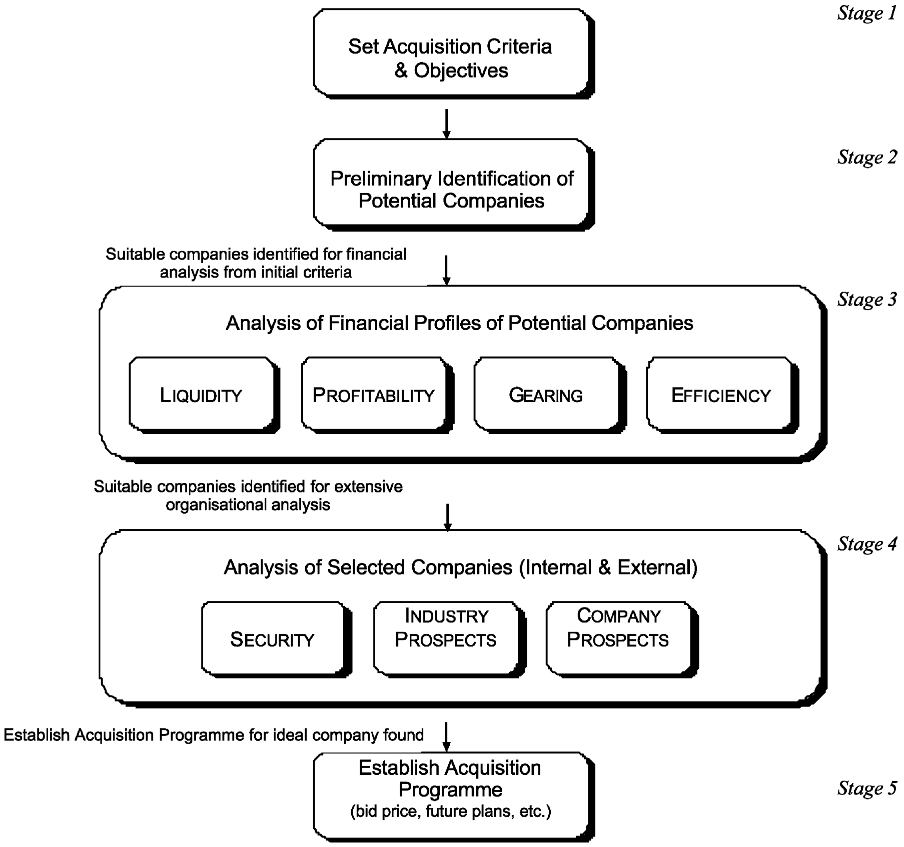

Fig. 1. The acquisition model.

and objectives from the acquiring organisation and the motivation they have in considering the acquisition of another company. Then utilising this information the system creates a hierarchical structure on which the system is based. The structure then contains the financial ratios that are deemed relevant to the particular acquiring organisation. A quality input may be added by the acquiring organisation that is not reflected in financial statistics such as the quality of a product, quality of management, quality of in-house machinery or even the perceived quality of a brand by the public.

3.2. The selection of development tools

The development tools selected for use in this application are visual basic (VB) developed by Microsoft Corporation and Matlab (Matrix laboratory) developed by The MathWorks, Inc. VB is used to acquire data directly from the user, through a series of GUI, while Matlab is used to implement the mathematical calculations used in the system. VB provides a development tool for the main development environment, as it enables sharing of data across applications, lower development costs and user familiarity, as most users will be familiar with other Microsoft Office applications. Matlab provides an interactive software system for numerical computations and graphics. It offers matrix based programming, advanced mathematical functions, and a simplified flexible language, all used to implement the fuzzy systems.

3.3. The five stages of acquisition

The system is structured around the acquisitions model as shown in Fig. 1. The model represents the basic hierarchical nature of the decision-making process for corporate acquisition. The fundamental basis of the system is that the user has a clearly defined objective for the corporate acquisition. Therefore, it is essential that a team from various functions of the business should be formed to effectively lay out the acquiring organisation objectives. An outline of the different stages in the model identifies what is required both of the user and the system at each stage of the acquisition process. An overview of the system as it has been implemented is shown in Fig. 2.

3.3.1. Stage 1—set acquisition criteria and objectives

This stage is carried out by the corporate acquisitions team. The initial impetus or motivation for an acquisition may come from the corporate level of the acquiring organisation. It is then the responsibility of the lower levels of management to define in detail the exact objectives of the acquisition and the criteria a possible target company must meet.

The initial stage of the process is divided into two sections the first section deals with the organisation

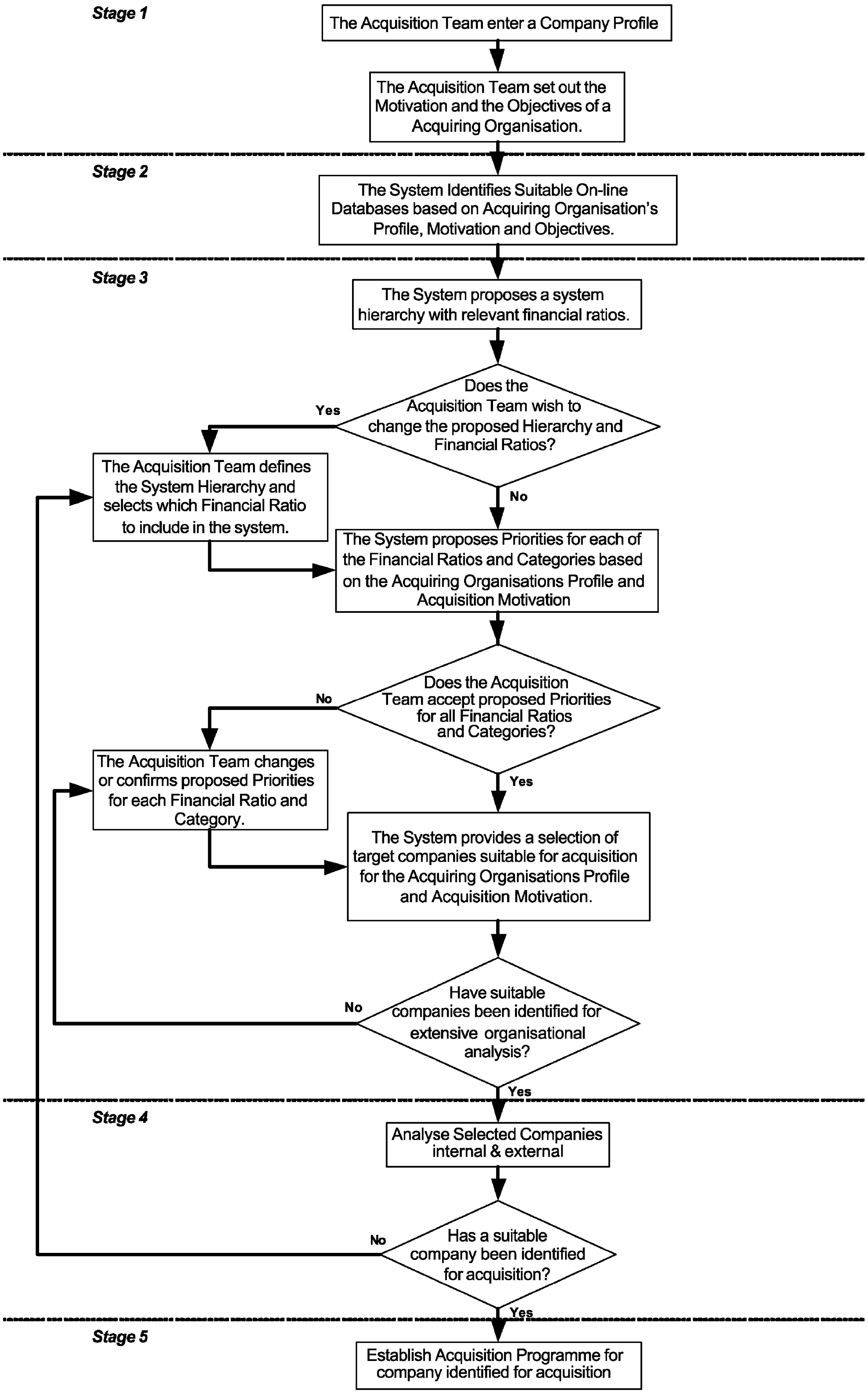

Fig. 2. Overview of acquisition system.

and setting up a profile for the acquiring organisation. This profile allows the system to know from what perspective the acquiring organisation is viewing the acquisition process. The perspective of the acquiring organisation can be of the utmost importance in identifying the correct company for acquisition. For example, if the acquiring organisation wishes to acquire a company to improve its market share then the profile will identify what market the acquiring

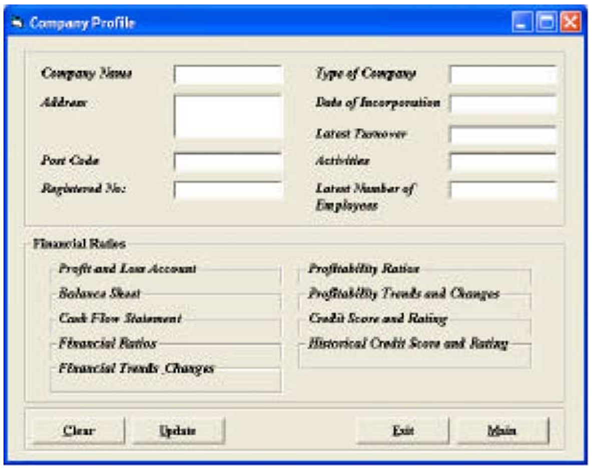

Fig. 3. Company profile GUI.

organisation is in and what share of the market it currently holds. This will help identify companies that are of smaller or similar market share to the acquiring organisation as it is unlikely that it wishes to buy out a much larger company that holds a much greater market share. This information along with other information in the acquiring organisation profile helps to personalise the acquisition process and identify more relevant companies for acquisition. The profile of the acquiring organisation need only be entered once but may be updated as required. The acquiring organisation profile is entered on the system through a VB GUI and stored for use in all future processes on the system. An example of the GUI design for this process is illustrated in Fig. 3. It contains all details required to establish a comprehensive understanding of the present position of the acquiring organisations.

The financial data for the acquiring organisation are entered under each tab as illustrated in Fig. 4 for the balance sheet.

The financial data is utilised by the system to define what strengths or weakness the acquiring organisation possess. The output is applied to a set of expert rules, which define the possible strengths or weakness the system should concentrate on in the acquisition process. This forms part

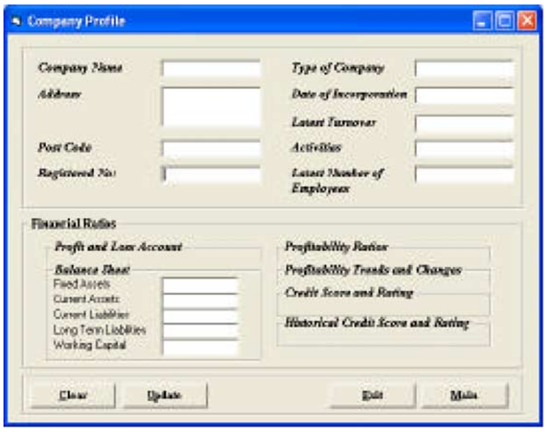

Fig. 4. Balance sheet of financial data.

Fig. 5. Motivations for acquisition GUI.

of the process which establishes what financial data should be analysed and the priority level it should be given within the acquisition system.

The second section of the process is identifying the motivations and objectives of the acquiring organisation. This is again achieved by using a VB GUI. The GUI allows the user to select their motivation from a listing of motivations. The GUI used to obtain the acquiring organisation's motivation is illustrated in Fig. 5.

When all available information has been obtained from the user this completes Stage 1 of the acquisition process.

3.3.2. Stage 2—preliminary identification of potential companies

An extensive list of possible companies for acquisition can be generated through the use of on-line financial databases. Utilising the information obtained through the acquiring organisation profile, motivation and objectives, the system can identify on-line databases to search and provide the preliminary companies for consideration. The companies identified can be from an individual on-line database or a combination of a number of on-line databases. The system will recommend suitable databases based on rules designed by a financial expert and the organisation profile entered by the user. The user can make use of the recommended databases, identify alternative databases or compose a combination of both.

When suitable databases have been identified all financial information for potential companies for acquisition is downloaded and stored on the system and can be accessed or updated for future acquisition processes. The GUI used to identify on-line databases for financial information is illustrated in Fig. 6.

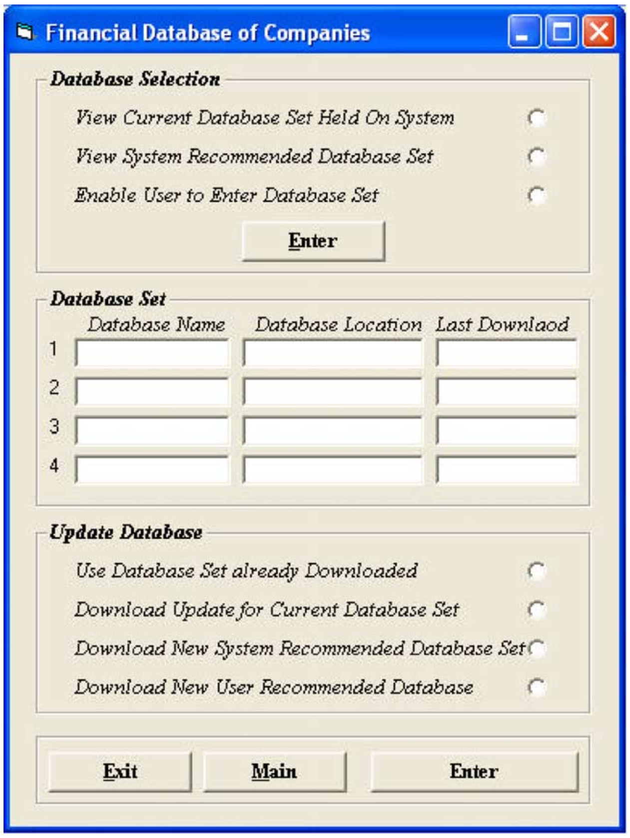

Fig. 6. Database identification GUI.

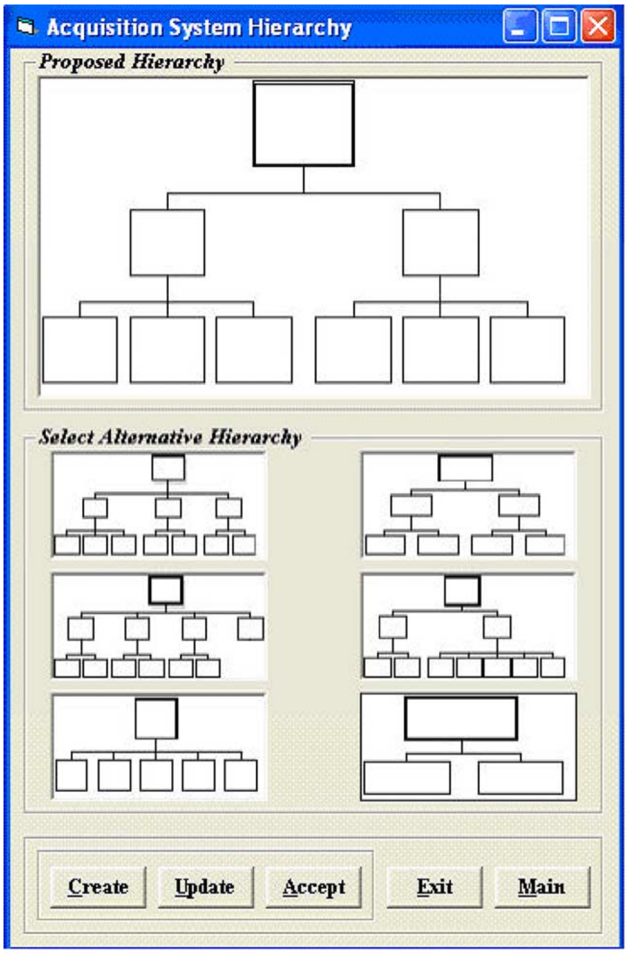

Fig. 7. System hierarchy GUI.

For the purposes of a demonstration of the system a single database was used. The FAME database provided financial profiles of a sample of companies. The FAME database is one of many online databases containing financial figures on companies from a range of industry sectors. For purposes of this analysis, the region was set to the UK and the industrial sector set to computing. This identified a set of 50 companies as potential acquisition companies. A file was then created containing all the financial results and other details concerning the performance of each company.

3.3.3. Stage 3—financial analysis of potential companies

Stage 3 of the system is the combination of the system structure identified in Stage 1 and the data identified in Stage 2. Stage 2 identifies a general listing of potential companies for acquisition. Further analysis is required to identify a limited set of companies to target for acquisition. The system uses the financial categories and ratios identified in Stage 1 of the process as the building blocks of the fuzzy hierarchical system. The system presents a hierarchy that is believed to be the most suitable for the data being analysed. The user is presented with the proposed hierarchy populated with the categories and ratios for analysis. Alternative hierarchies, financial categories and ratios are also presented, or the user may design their own hierarchy and populate it with their own financial categories and ratios. The GUI the user is presented with is displayed in Fig. 7. The hierarchical structure selected determines the rule base for the system. The rule base is generated from a linear average of the contribution from each input to form the output. The user can adapt the consequence if required at a later stage.

A fuzzy system is created for each of the categories with the relevant financial ratios as the inputs; this forms the bottom layer of the fuzzy hierarchical system. Subsequently, the output from each category fuzzy system forms an input to another fuzzy system which accumulates the categories, which is on the second layer of the fuzzy hierarchical system.

A separate screen is present to the user if they select ‘Create’. Then, they may proceed to build there individual hierarchy and populate it with their identified financial categories and ratios.

The first box of the Create GUI allows the user to specify the basic building boxes that make up the system hierarchy. The system uses this information to populate the screen with the stated number of hierarchical levels. Inside the Hierarchical level, the user states the number of categories that are at this level and the system will create a corresponding number of categories. Once inside a category the user states the number of financial ratios that are contained within this category and the system will again create the appropriate number of financial ratios. The user is requested to name the categories and ratios at each stage as they are created. A simple one level hierarchy with two financial categorises contain five financial ratios is presented in Fig. 8. The 'Show' button on the Create GUI simply allows the user to see in a graphical format the hierarchy they are creating.

Once the hierarchy of the system has been established and the financial categories and financial ratios to populate the structure have been identified the actual analysis of financial data begins. The output from Stage 3 is

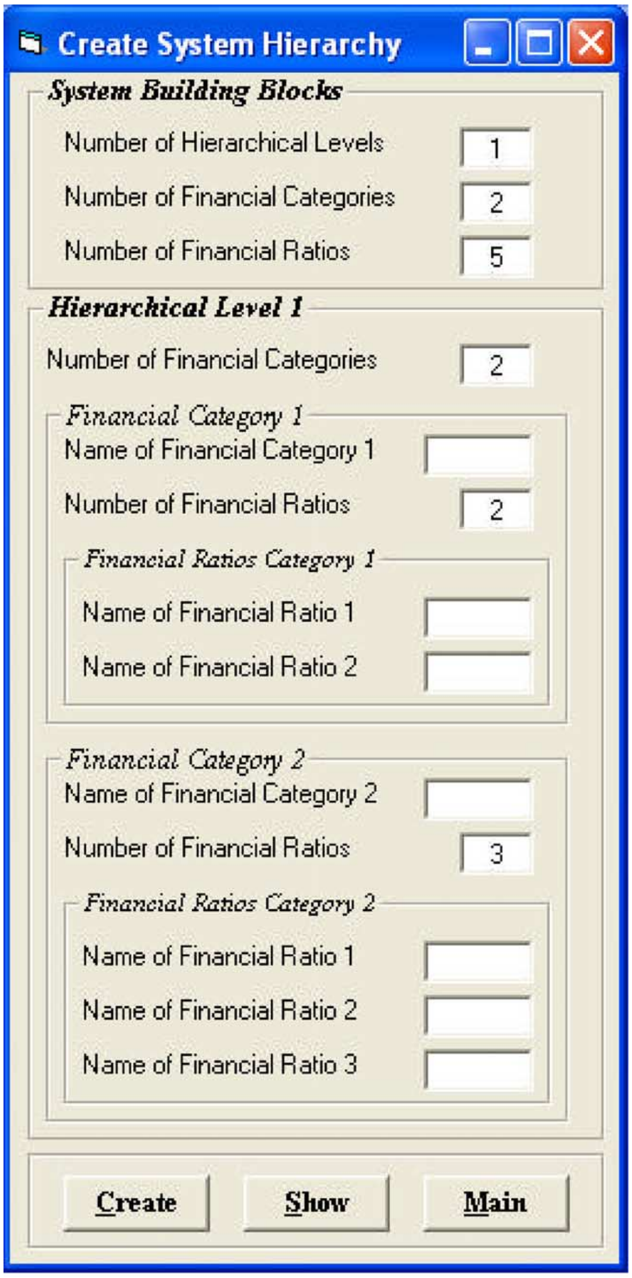

Fig. 8. Create system hierarchy GUI.

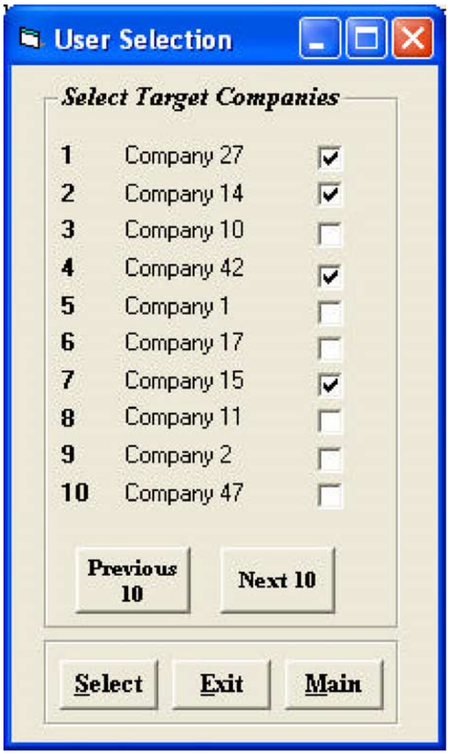

Fig. 9. User company selection GUI.

a descending list of companies with the most suitable company for corporate acquisition listed first. The user is then free to select from the listing a number of companies to proceed to Stage 4 of the acquisition process. The GUI that the user is presented with is illustrated in Fig. 9. The user may select companies by ticking the box adjacent to the company's name.

The fuzzy system behind the processing of Stage 3 is explained in detail in a later section. The results obtained in Stage 3 for two separate acquiring organisations looking at the same financial data are compared in Section 5.

3.3.4. Stage 4—analysis of selected companies (internal and external)

Stage 4 is not within the scope of this paper. However, a brief description will be given to identify how the entire system will work. The objective at this stage is to determine the compatibility of the potential take-over companies, to the motivation and objectives of the acquiring organisation set out in Stage 1. Multi-attribute analysis (MAA) is applied to the analysis of these categories. MAA is capable of selecting or identifying optimum choice in respect of the same objectives where the decision alternatives are predetermined (Holt, Olomolaiye, & Harris, 1994). Dean and Schniederjans (1991) found that employing simple ranking methods does not allow for the interactive effects of multiple criteria. The relative importance of differing criteria may not be adequately weighted in the final analysis because ranking are assessed on single criteria, rather than the ranking of importance of multiple conflicting criteria. The advantages of MAA are primarily that it facilitates decision making despite the presence of multiple conflicting criteria. Hence, it is suitable for the multi-criteria/multi-alternative nature of this stage, i.e. the evaluation and selection of a suitable company for acquisition. It is not within the scope of this article to describe the application of MAA. Once the analysis is carried out for each category within the organisation analysis, a total organisation profile score is computed for each company. The system will filter out any companies that are unsuitable on the basis of the total score each company attains under the organisation analysis.

3.3.5. Stage 5—establish acquisition programme

Having identified a target company and carried out a rigorous analysis of the company, the next stage is to establish an acquisition programme and complete the acquisition. Key issues to be addressed are: organising for acquisition, making the approach, handling negotiations, valuation, managing currency risk if appropriate, management issues, handling industrial relations and necessary commitment (Hill Samuel Bank Limited, 1992). This is not an exhaustive list of the factors involved in the analysis. However, it highlights and demonstrates the complexity and ramifications of making an effective acquisition. Each case will be different; but in every case considerable commitment is required by the acquiring organisation and a thorough analysis is necessary for each factor.

4. The fuzzy system

4.1. Membership functions

This section provides a more detailed look at Stage 3 of the acquisition process. Stage 3 is a hierarchical fuzzy system that uses the magnitude of the fuzzy membership functions to prioritise the inputs to the fuzzy system. Fuzzy systems were developed due to the understanding that measurements, process modelling and control can never be exact for real and complex processes. Also there are uncertainties such as incompleteness, randomness and ignorance of data in the process model. The seminal work by Zadeh introduced the concept of fuzzy logic to model human reasoning from imprecise and incomplete information by providing a computational framework for vague information (Zadeh, 1965, 1968, 1973). Fuzzy logic can incorporate human experiential knowledge and give it an engineering meaning.

In the proposed system, the hierarchical structure of the system is defined or confirmed by the user along with the financial categories and ratios to populate it. Each financial category or ratio is given a certain degree of influence over the decision-making process. This influence is defined by the priority each category or ratio is assigned by the system or user. The system can reflect this degree of influence in the fuzzy system.

In this paper, a two level hierarchical system is illustrated, however, this can be easily expanded to three levels to accommodate more complex priority settings. The additional levels allow the merging of financial categories at different levels within the hierarchical system therefore accommodating more complex priority settings. A model of the structure of a two level hierarchical system is illustrated in Fig. 10.

The number of financial categories, their priorities and where they fit in the hierarchy determine the structure of the system. For the purposes of this paper, four categories have been identified: profitability, liquidity, efficiency, and finally financial strength and gearing and a two level system with one accumulator fuzzy system. Within each category, important financial ratios are selected that are considered to offer the best information about that particular category. The financial categories and ratios selected for this

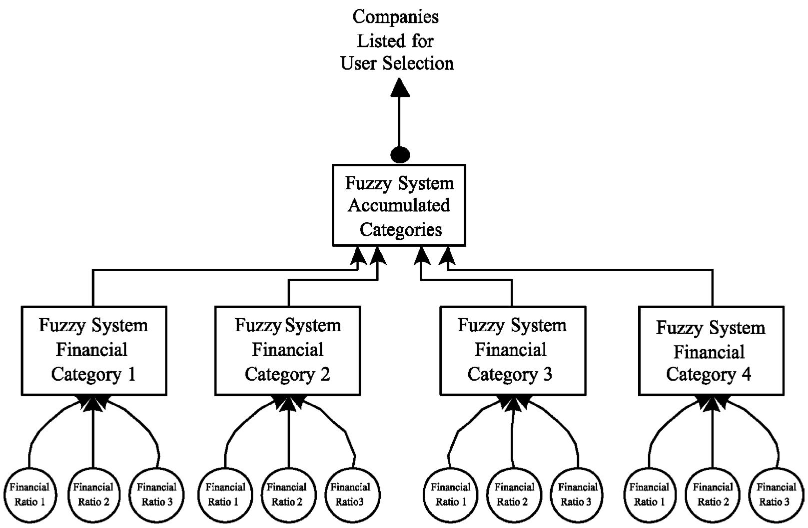

Fig. 10. Hierarchical fuzzy systems.

demonstration are:

- Category 1: Profitability
  Financial ratio 1: Gross profit percentage
  Financial ratio 2: Net profit percentage
  Financial ratio 3: Profit per employee
- Category 2: Efficiency
  Financial ratio 1: Return on capital employed
  Financial ratio 2: Net asset turnover
  Financial ratio 3: Fixed asset turnover
- Category 3: Liquidity
  Financial ratio 1: Liquidity ratio
  Financial ratio 2: Current asset ratio
- Category 4: Financial strength and gearing
  Financial ratio 1: Return on shareholders funds
  Financial ratio 2: Gearing
  Financial ratio 3: Solvency ratio.

Different companies may chose alternative categories or add more categories with alternative combinations of current or additional financial ratios that better reflect what they consider relevant in their acquisition process.

4.2. Fuzzy inference method

The fuzzy inference method used in this system is the Takagi–Sugeno–Kang (TSK) which was introduced in 1985 (Sugeno, 1985; Sugeno & Kang, 1988; Sugeno & Yasukawa, 1993). The TSK method was selected rather than the Mamdani's fuzzy inference method (Mamdani & Assilian, 1975), as it is more computationally efficient and it works well with optimisation and adaptive techniques. A zero order TSK fuzzy model is used in this paper but it is proposed to use a first order TSK fuzzy model in future work as the system evolves.

4.3. Input membership function

Heuristic selection of parameters of membership functions are widely used and practiced in fuzzy modelling and applications. Other techniques have also been proposed that reflect the actual data distribution by using learning algorithms where some input/output data are available. There are different approaches to construct membership functions such as:

- Heuristic selection,
- Clustering approach,
- C-means clustering approach,
- Adaptive vector quantisation, and
- Self-organising map.

Detail description of these approaches can be found in Chi et al. (1996). In this paper, three major factors are considered when determining the membership functions for each input.

- The first is the total range of all the membership functions, the universe of discourse. As the system must determine how each company in the database performs in relation to the strongest and weakest benchmarks for each financial ratio, therefore the strongest and weakest companies are used to determine the total membership range of all the membership functions.
- The second factor is how the data is dispersed between the strongest and weakest benchmarks. If data is evenly dispersed then membership functions with equal width would be suitable, however, if data is concentrated in a particular range then membership functions with unequal widths would be more appropriate. Therefore, the widths of membership functions will be determined by the dispersion of the data within the membership range.
- The last is the priority level given to the input in the system; this will determine the maximum degree of membership possible for each membership function.

4.4. Membership range

In this system, the range of the membership functions in any financial ratio is determined by the strongest and weakest value retrieved in the input data. All the input data is normalised with the strongest input value set as 1 (x-axis) and the weakest value set as 0 (x-axis). This sets the extremes that the fuzzy membership functions must cover. The authors have arbitrarily selected five membership functions across each universe of discourse for illustration purposes. Increasing the number of membership functions may improve the model accuracy but will increase computational demands. The five membership functions have been termed 'very poor', 'poor', 'average', 'good' and 'very good'. Assuming that the input is equally dispersed, the membership functions were evenly divided across the range. For example, in the profitability category one of the three input ratings is net profit margin, the strongest value in the industry was 46% and weakest value was 3% if the data was evenly dispersed across the range the membership functions shown in Fig. 11 would be employed.

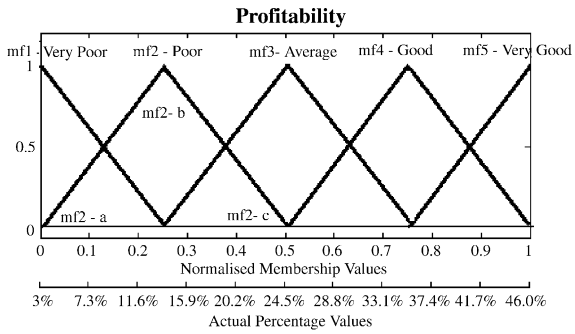

Fig. 11. Example of fuzzification scheme.

Using these membership functions (mf), each company in the sector under analysis is assigned a membership function based upon its position in the range. In the example shown in Fig. 11, a company with a net profit margin of 25% would be normalised to 0.58 and so would be a part of the mf3—'average' and mf4—'good'. The degree of membership of each function would relate to the shape of the membership function used, in this case a triangular shaped membership function.

The triangular curve is a function of a vector x, and depends on three scalar parameters a, b, and c as given by Eq. (1).

$$f(x;a,b,c) = \left\{ \begin{array}{ll} 0, & x \le a \\ \dfrac{x-a}{b-a}, & a \le x \le b \\ \dfrac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{array} \right\} \tag{1}$$

4.5. Width of individual membership functions to cover data dispersion

If data is dispersed evenly across the membership range then the fuzzy membership functions are divided evenly over the range with partition of unity as illustrated in Fig. 11. The even division of the membership function over the range enables the membership functions to have partition of unity. However, from analysis of the data, it was apparent that a small number of companies where present at the extremes of the membership range and that the data was not evenly dispersed across the membership range. In these circumstances, the fuzzy membership functions had to be altered to achieve a more evenly distributed set of fuzzy membership functions. In order for the membership functions to be more evenly distributed three points are found in the range. The three points correspond to the b parameter or the peaks of mf2, mf3 and mf4. The b parameter of mf1 and mf5 are set to 0 and 1, respectively. The other three b parameters are calculated using Eqs. (2), (3) and (4).

$$\mathrm{mf2}(b) = \frac{\sum_{i=1}^{n} x_i}{2(n)} \tag{2}$$

$$\mathrm{mf3}(b) = \frac{\sum_{i=1}^{n} x_i}{n} \tag{3}$$

$$\mathrm{mf4}(b) = \left(\frac{1 - \dfrac{\sum_{i=1}^{n} x_i}{n}}{2} \right) + \frac{\sum_{i=1}^{n} x_i}{n} \tag{4}$$

where n is the number of inputs for x.

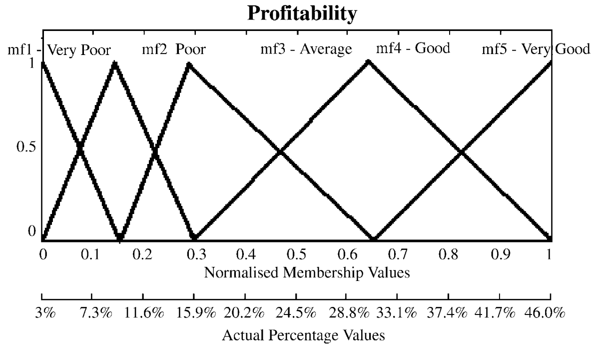

Fig. 12. Unevenly dispersed data in membership range.

The important factor in this calculation is that partition of unity must be maintained therefore once the peaks of the five membership functions have been calculated, points a and c the feet of the membership functions are routinely defined. An example of how the membership functions would change to account for the unevenly dispersed data across the membership functions is illustrated in Fig. 12. The data represented is more concentrated in the lower end of the membership range therefore the membership widths of the lower membership functions is smaller to more evenly divide the data between membership functions.

4.6. Priority levels and scaling

Each financial category and ratio on the system is set to a specified priority level the five priority levels are:

- Very high priority
- High priority
- Medium priority
- Low priority
- Very low priority.

To incorporate the priority levels into the system the fuzzy membership functions are adjusted to reflect the priority level given to the individual category or financial ratio. The standard membership function allows a degree of membership from 0 to 1 this is illustrated previously in Figs. 11 and 12 as each membership function rises to 1 on the y-axis. The proposed scaling of the membership functions replaces this membership function for each input with a scaled membership function. This scaling changes the membership functions in accordance to the priority level given to the input.

Very high priority	0 to 1.0
High priority	0 to 0.8
Medium priority	0 to 0.6
Low priority	0 to 0.4
Very low priority	0 to 0.2

The triangular function define in Eq. (1) is altered to enable the degree of membership of a function to be changed. The triangular curve is still a function of the vector x but now depends on four scalar parameters a, b, c and d. The d parameter determines the maximum degree of membership for the membership function. The triangular function is given by:

$$f(x;a,b,c) = \left\{ \begin{array}{ll} 0, & x \le a \\ \dfrac{(x-a)d}{b-a}, & a \le x \le b \\ \dfrac{(c-x)d}{c-b}, & b \le x \le c \\ 0, & c \le x \end{array} \right\} \tag{5}$$

The five membership functions for the five priority levels very high priority, high priority, medium priority, low priority and very low priority are illustrated in Fig. 13.

This scaling determines the magnitude of each mf and how influential a particular input can be in determining the final companies identified as being suitable for further analysis.

4.7. Rules for the fuzzy systems

Each fuzzy system produces an output from their respective inputs. This output is determined by the rules employed by the fuzzy system. The combination of rules that are fired and the firing strength of the rule determine the output from the fuzzy system. The number of rules defined in this system is a product of the number of membership functions in each input. For example, the profitability category has three inputs (*net profit, gross profit and profit per employee*), each with five membership functions (*very poor, poor, average, good, very good*). Therefore,

$$\text{The number of rules for the profitability category} = p^n \tag{6}$$

where

$p =$ number of sets
$n =$ number of inputs.

The set of if–then statements used to formulate the conditional statements that comprise fuzzy logic in this system, use the 'OR' operator. This gives an output to each rule each time any input in the rule is firing. The OR operator uses the maximum function which maintains the creditability of the scaling of the degree of membership for each input. Using an 'AND' operator or the minimum function negates the creditability of the scaling of the degree of membership for each input. The rules set on the system are systematically defined and will grow or reduce depending on the number of inputs to the system and the number of membership functions. The user can adapt the consequence of a rule if required. The rules account for every possible combination of inputs. They are set but what rules are fired and the strength of the firing is determined by the inputs to the system, which is determined by the input data of the each company. The maximum aggregation method is used in the aggregation of the rules in this system and an aggregate output fuzzy set is formed. The defuzzification method used in each fuzzy system is weighted average. The fuzzy output produces a crisp output. That is used as an input to the next level of the hierarchy,

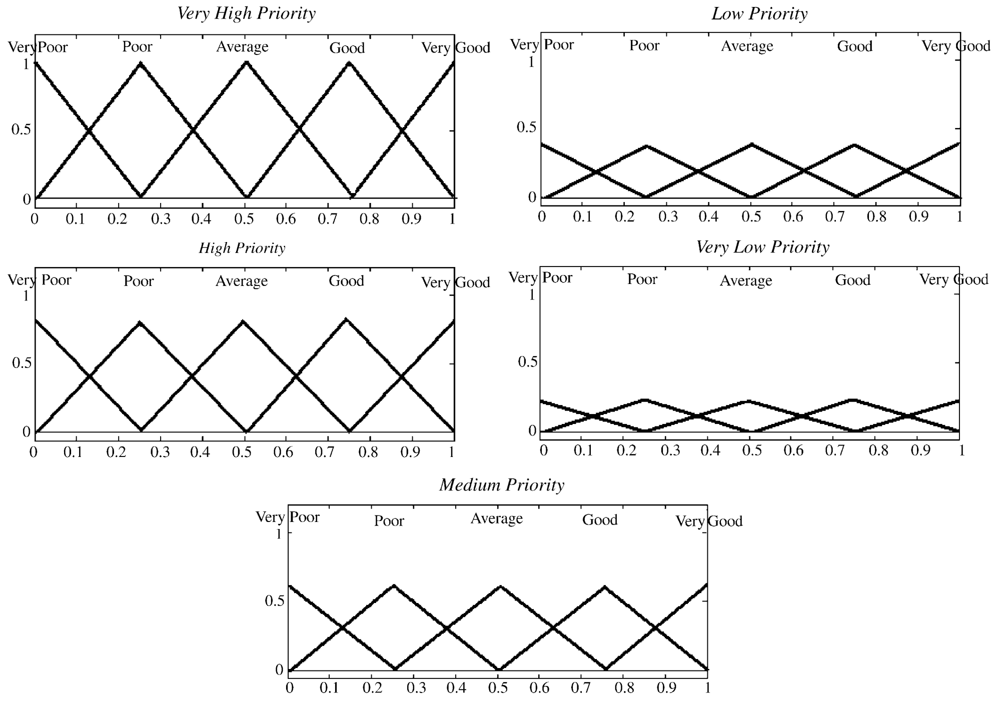

Fig. 13. Fuzzy membership functions—priority scaling.

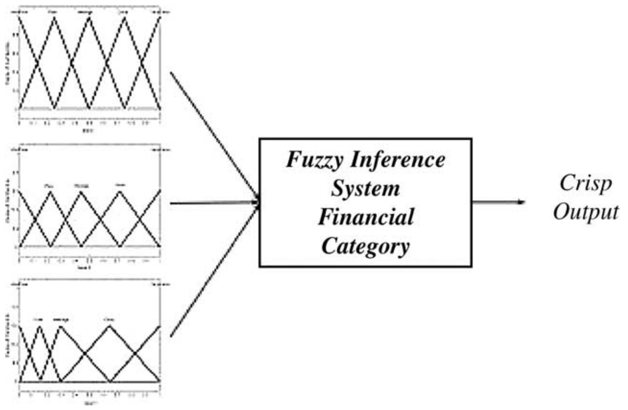

Fig. 14. Fuzzy inference system—financial category.

which combines the outputs of the four financial categories to form the final output. The output of this fuzzy system will determine what companies are to be considered for further analysis.

5. Results

This section reviews the results achieved in Stage 3 of the acquisition system. The merits of the acquisition system are illustrated in the processing of two acquiring organisations seeking companies for corporate acquisition. The financial categories and financial ratios used in both companies are the same, and the same, two level hierarchical structures are used. The acquiring organisation's profile and aims and objectives are different which results in different priority settings being identified for the two acquiring organisations. The difference in the priority settings will cause the system to identify different companies for acquisition for the two acquiring organisations.

Acquiring organisation A has been set with no financial priorities (i.e. setting all priorities to an equal very high level priority of priority). Acquiring organisation B has a range of priorities within each financial category and for the overall system.

5.1. Acquisition system results per fuzzy system

The fuzzy systems used to process the financial categories is represented in Fig. 14, the scaled financial ratios are used as inputs to the fuzzy system and the output is a single crisp number that represents the aggregation and defuzzification of the inputs. The fuzzy system calculates a single crisp output for each of the companies in the database.

The results show the output from the four fuzzy systems that account for the four financial categories chosen for this demonstration profitability, efficiency, liquidity and gearing. The results are shown in graphical form so comparison of results can be easily achieved. Due to the nature of the membership functions, the important fact is not in what position a company achieves although this is a good indicator; it is the magnitude of difference that is achieved in comparison to the other companies and the position in relation to the average of all the companies. The average is used to determine the position of the all the membership functions therefore a companies position in relation to the average ratio will determine which membership functions it will fall under. The results from the profitability fuzzy system will be analysed in detail in this paper. The output results from the profitability fuzzy system are shown in Fig. 15.

Table 1 identifies the order of the companies from the profitability fuzzy system for both acquiring organisation A and B. As can be seen in the table the general suitability of companies for the two acquiring companies is different. This is due to the changed priorities within the system. The system enables ratios of higher importance to have greater influence over the output but not to the extent that a high priority ratio can fully determine the output.

The strongest prospect for acquisition for both acquiring organisations is Company 42, but it is a more emphatic

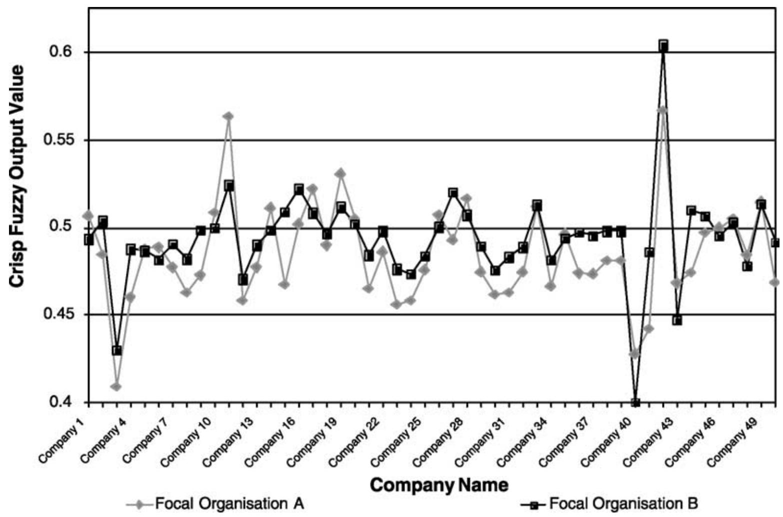

Fig. 15. Profitability output for acquiring organisation A and B.

Table 1
Top half of companies in the profitability category

Position	Profitability			
	Focal organisation A		Focal organisation B	
1st	Company 42	0.567	Company 42	0.6051
2nd	Company 11	0.5636	Company 11	0.5249
3rd	Company 19	0.531	Company 16	0.5227
4th	Company 17	0.5221	Company 27	0.5207
5th	Company 28	0.5169	Company 49	0.5139
6th	Company 49	0.5148	Company 33	0.5136
7th	Company 33	0.5121	Company 19	0.5124
8th	Company 14	0.5116	Company 44	0.5105
9th	Company 10	0.5089	Company 15	0.5095
10th	Company 26	0.5075	Company 17	0.5085
11th	Company 1	0.507	Company 28	0.5073
12th	Company 20	0.505	Company 45	0.5072
13th	Company 47	0.5049	Company 2	0.504
14th	Company 16	0.5025	Company 47	0.5035
15th	Company 46	0.5	Company 20	0.5025
16th	Company 45	0.4972	Company 26	0.5005
17th	Company 35	0.4967	Company 10	0.5001
18th	Company 27	0.4934	Company 9	0.4992
19th	Company 18	0.4903	Company 14	0.4988
20th	Company 6	0.4889	Company 38	0.4985
21st	Company 5	0.4879	Company 22	0.4984
22nd	Company 22	0.4863	Company 39	0.4982
23rd	Company 2	0.4849	Company 36	0.4976
24th	Company 48	0.4843	Company 18	0.4965
25th	Company 38	0.4814	Company 37	0.4958

prospect for acquiring organisation B. This is due to the fact that net profit is given a very high priority in acquiring organisation B and Company 42 is the best company in this financial ratio by a strong margin.

Company 11 which is returned in second position for both acquiring organisations is in 39th position in the net profit ratio but still holds second position when net profit is given a very high priority. This is due to the fact that although net profit is very high priority it is not the only determiner and because Company 11 has done well in the other financial ratios, second in gross profit ratio and first in the profit per employee ratio it hold its second position.

Company 16 which obtained third position for acquiring organisation B, is in 14th position for acquiring organisation A. It achieves this rise in position due to the fact that the net profit ratio for Company 16 is in fifth position and has a value of 0.6734 well above the average of 0.493. Company 16 does not do as well in the other two categories as can be seen in Table 2 but as they are of a lower priority they have less influence. The fact that Company 16 has done better than other companies that are above it in the net profit ratio such as Company 44, 27 and 15 is how it secures third position for acquiring organisation B. This illustrated how doing well in a high priority financial ratio will heavily influence a company's case for acquisition but will not be the only determining factor. As in the case with Company 11 the combination of doing well in a number of the lower priority financial ratios also heavily influenced

Table 2
Top 10 companies system output

Position	System output			
	Focal organisation A		Focal organisation B	
1st	Company 27	0.544	Company 42	0.5425
2nd	Company 42	0.5394	Company 14	0.5401
3rd	Company 14	0.5389	Company 10	0.5378
4th	Company 11	0.5374	Company 28	0.5377
5th	Company 28	0.5374	Company 17	0.5376
6th	Company 19	0.5365	Company 35	0.5375
7th	Company 44	0.5365	Company 18	0.5372
8th	Company 17	0.5363	Company 37	0.5372
9th	Company 47	0.5362	Company 33	0.5371
10th	Company 46	0.5361	Company 32	0.537

the company's case for acquisition. This system achieves a balance that enables a financial ratio to be more influential but without complete control. This enables a simulated human reasoning were one aspect may influence a decision more but not to the extent that it negates the influence of other aspects.

5.2. Acquisition system output fuzzy system

The final stage of the fuzzy hierarchy is the output fuzzy system, which summates the outputs from all the financial category fuzzy systems. The inputs to the output fuzzy system are also scaled membership function, the scaling depending on the priority level given to each individual financial category in the context of the entire system. An overview of the output fuzzy system has been illustrated in Fig. 16. The results obtained from the output fuzzy system provide a rating for each company, which indicated how suitable it would be for corporate acquisition for a particular acquiring organisation. The system or user can then select a number of the top companies identified for further analysis.

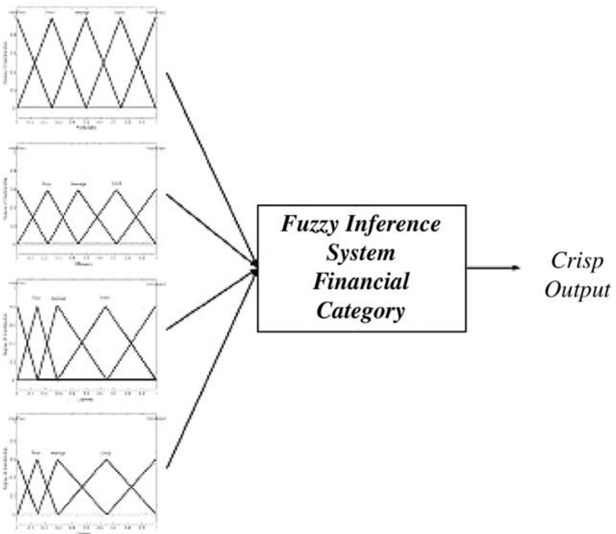

Fig. 16. Fuzzy inference system—accumulated categories.

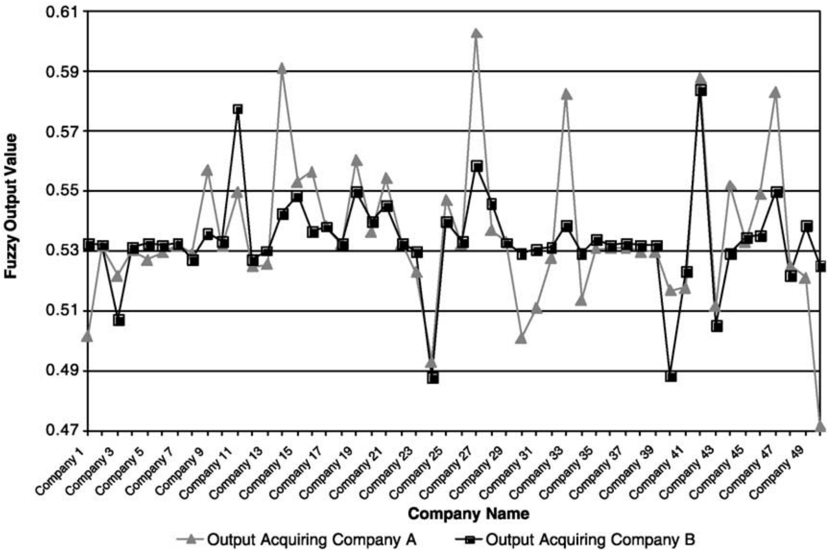

Fig. 17. Comparing company output ratings for acquiring company A and B.

For acquiring organisations A and B, the companies identified for corporate acquisition are presented in Fig. 17 and Table 2. The company with the highest output value is considered to be the most suitable company for acquisition for the particular acquiring organisation. As illustrated in the graph for acquiring organisation A the most suitable company for acquisition is Company 27 followed by Company 42 and then Company 14. The top three companies for acquiring organisation B are Company 42 followed by Company 14 and then Company 10. The change in order identified for each acquiring organisation can be attributed to two issues; the first is the change in companies identified as the strongest in each financial category due to the change in the priorities of the financial ratios and the second is the change due to the priorities given to the financial categories. This can be seen with Company 42 which has risen to top position for acquiring organisation B as it holds the top position in the profitability category for acquiring organisation B by a significant margin but also because it is around average in the efficiency category, high in the liquidity category and above average in the gearing category. Company 27 which is identified as the best company for acquiring organisation A has its real strength in liquidity in which it is top by a good margin but for acquiring organisation B liquidity is of a very low priority therefore Company 27's real strength is not of any benefit to acquiring organisation B and so it drops out of the top ten. The graphical representation of the results illustrates how close each company is in its suitability for acquisition, a large drop on the *y*-axis equates to a large drop in the suitability of the company for acquisition.

The results presented illustrate the levels of influence that can be obtained through the use of a fuzzy hierarchical system with scalable fuzzy membership functions. The results show how natural priorities are implemented to influence the results to varying degrees without completely controlling the final result.

6. Conclusions and future research

The acquisition system described in this article attempts to provide a system that assists financial experts in the evaluation of corporate acquisitions. The system considers the individuality of the acquisition process; therefore, a user centred approach has been designed. Using the magnitudes of the fuzzy membership functions, the proposed approach can adequately reflect the position of any acquiring organisation and the objectives of their acquisition. The system attempts to emulate the financial influences and priorities adhered to by a companies own financial experts, but on a larger scale and in a more timely and cost-effective manner.

The use of fuzzy logic as an alternative to other intelligent techniques such as neural networks or generic algorithms provides a computational inexpensive alternative. The development of this system has shown that it is possible in a computational inexpensive manner to imply varying degrees of influence on an intelligent system.

The results presented in this paper illustrate the varying degrees of influence that have been exerted on the system and how the system has successfully emulated the acquisition process adhered to by financial experts. The results demonstrate an accurate reflection of suitable companies for acquisition for individual acquiring organisations. Judging by the results obtained, it can be concluded that the approach is promising, for implementing the acquisition process.

Future investigation will concentrate on obtaining feedback from the user and the system to improve the system performance. The possible use of a reinforcement learning system will be investigated to enable continual learning from both positive and negative feedback. This will realise an evolvable system that develops with the user.

References

Bellman, R. E., & Zadeh, L. A. (1970). Decision-making in a fuzzy environment. *Management Science*, *17*(4), 141–164.

Chi, Z., Yan, H., & Pahm, T. (1996). Fuzzy algorithms: With applications to image processing and pattern recognition. *Advances in Fuzzy Systems Applications and Theory*, *10*.

Czogala, E., & Pedrycz, W. (1981). On identification in fuzzy systems and its application in control problem. *Fuzzy Sets and Systems*, *6*, 73–83.

Davis, E. W. (1992). Global outsourcing: Have US managers thrown the baby out with the bath water? *Business Horizons*, *July–August*, 58–65.

Dean, B. V., & Schniederjans, M. J. (1991). A multiple objective selection methodology for strategic industry selection analysis. *IEEE Transactions on Engineering Management*, *38*(1), 53–62. February.

Dreiseitl, S., & Ohno-Machado, L. (2002). Logistic regression and artificial neural network classification models: A methodology review. *Journal of Biomedical Informatics*, *35*(5/6) October.

Grundy, T., Johnson, G., & Scholes, K. (1998). *Exploring strategic financial management*. *Financial times*, Englewood Cliffs, NJ: Prentice-Hall, pp. 141–170.

Harrison, B. (1994). *Lean and mean: The changing landscape of corporate power in the age of flexibility*. New York: Basic Books.

Hill Samuel Bank Limited, (1992). *Mergers, acquisitions and alternative corporate strategies*. Mercury Books.

Holt, G. D., Olomolaiye, P. O., & Harris, F. C. (1994). Applying multi-attribute analysis to contractor selection decisions. *European Journal of Purchasing and Supply Management*, *1*(3), 139–148.

Johnson, G., & Scholes, K. (2002). *Exploring corporate strategy* (6th ed). *Financial times*, Englewood Cliffs, NJ: Prentice-Hall.

Mamdani, E. H., & Assilian, S. (1975). An experiment in linguistic synthesis with a fuzzy logic controller. *International Journal of Man-Machine Studies*, *7*(1), 1–13.

Marsala, C., & Bouchon-Meunier, B. (1999). *An adaptable system to construct fuzzy decision trees*. *Proceedings of NAFIPS'99, New York, USA, June*, pp. 223–227.

Murata, M., Ma, O., & Isahara, H. (2002). Comparison of three machine-learning methods for Thai part-of-speech tagging. *ACM Transactions on Asian Language Information Processing (TALIP)*, *1*(2) (June 2002).

Newton, J. K. (1981). Acquisitions: A directional policy matrix approach. *Long Range Planning*, *14*(6), 51–57.

Rappaport, A. (1979). Strategic analysis for more profitable acquisitions. *Harvard Business Review*, *57*(4) July–August.

Schniederjans, M. J., & Hoffman, J. (1992). Multinational acquisition analysis: A zero-one goal programming model. *European Journal of Operational Research*, *62*(2), 175–185.

Schoenberg, R., & Reeves, R. (1999). What determines activity within an industry. *European Management Journal*, *17*(1), 93–98.

Sharma, S. K., & Tokhi, M. O. (2000). Genetic evolution: A dynamic fuzzy approach. *Proceedings of FUZZ IEEE 2000: IEEE International Conference on Fuzzy Systems, Texas, USA, May*, *2*, 748–752.

Sugeno, M. (1985). *Industrial applications of fuzzy control*. Amsterdam: Elsevier Science Publishing Company.

Sugeno, M., & Kang, G. T. (1988). Structure identification of fuzzy model. *Fuzzy Sets and Systems*, *28*, 15–33.

Sugeno, M., & Yasukawa, T. (1993). A fuzzy-logic-based approach to qualitative modelling. *IEEE Transactions on Fuzzy Systems*, *1*, 7–31.

Warne, K., Prasad, G., Siddique, N. H., & Maguire, L. (2003). *A novel intelligent approach to anchorage measurement using electron microscopy*. *IEEE International Conference on Systems, Man and Cybernetics, Washington DC, October*, pp. 3810–3815.

Wei, C., & Wang, L. (2000). A note on universal approximation by hierarchical fuzzy systems. *Information Sciences*, *123*, 241–248.

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*, *8*, 338–353.

Zadeh, L. A. (1968). Fuzzy algorithms. *Information and Control*, *12*, 94–102.

Zadeh, L. A. (1973). Outline of a new approach to the analysis of complex systems and decision process. *IEEE Transaction on System, Man and Cybernetics*, *3*, 28–44.