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NEURAL NETWORKS AS A DECISION SUPPORT SYSTEM FOR THE DECISION TO BID PROCESS

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Neural networks are information processing systems that can automate semi-structured knowledge domains. Neural networks complement and enhance the capabilities of conventional systems in order to increase productivity in a given domain. Research into the application of neural networks in the construction industry indicates the maturity of the technology and the system development approach. In order to have practical application and contribute to the notion of wealth creation in society, research must be focused on transferring the know-how acquired through research to the industry. The paper recommends involving the end users throughout the system development process, and creating an environment within which direct and indirect learning can be achieved by practitioners. An example of this approach, which develops a decision support system for the decision to bid process, is described and evaluated.

Key words: bidding, decision support system, neural networks.

INTRODUCTION

There has been plethora of research activity into the application of neural networks in the construction industry. These studies have generally been focused on demonstrating the feasibility and usability of neural networks within the construction industry. However, transfer of this know-how to the businesses within the industry to increase productivity and effectiveness of the businesses is rare.

Neural network technology has reached the stage of maturity that its real life implementation should be encouraged and facilitated. To achieve this objective, a different set of communication skills to reach the target audience, the decision-makers and practitioners in the industry are required to create further awareness of the potential and capability of neural networks, which should increase the demand for these systems.

This research focused on achieving this objective by real life implementation of a neural networks system as a Decision Support System (DSS) for the decision to bid process. To be successful a neural networks DSS must satisfy a number of criteria:

Validity of response, that is the practitioners in the field must acknowledge the system's recommendations as valid;

Ease of use; and

Creating awareness of how it functions, its strengths and limitations.

The approach of involving the end user in the development process, from inception of the idea about utilising the potentials of neural networks through to its real life implementation and update provides the following benefits:

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Ensures that all notions the users perceive as important are taken into account.

Creates an environment within which direct and indirect learning can be achieved,

Develops the desired awareness among the end users of capability of the system.

To achieve full user participation, an additional step can be defined to complement any system development approach: professionals in the field (representative sample of the users) need to challenge the developed DSS and confirm the validity of the system's recommendations.

NEURAL NETWORKS APPROACH

Artificial neural networks (ANNs), commonly referred to as neural networks, are inspired by the functioning of the brain. They are composed of elements that perform in a manner that is analogous to biological neurons. ANNs have learning capability, utilize numeric processing, and perform parallel distributed processing. Additionally, they have the capability to automate semi-structured knowledge.

Knowledge can be defined to form a continuum, from structured knowledge to unstructured knowledge. Semi-structured knowledge is a domain of knowledge, where the inputs and the outputs are known but the relationships between them are unknown, and requires human (expert) judgment for processing it. The term intelligent systems is used to refer to automated systems that are capable of processing semi-structured knowledge.

Structured knowledge refers to the knowledge domain where the inputs, outputs, and the relationships between the inputs and outputs are known. The structured knowledge can easily be automated, because of the known relationships. An algorithm can be defined and implemented in a computer environment for speedy processing. The term conventional systems refers to the automated systems that are capable of processing the structured knowledge.

Conventional systems have been widely used in businesses, and have resulted in increased productivity, and in some specific cases, produced a strategic competitive advantage. The proposition that " the utilisation of the potentials of conventional systems is a strategic necessity " is widely being used in the literature concerning information systems and strategic management. The concept is very simple; using the potential of conventional systems can be seen as a business necessity for survival of any organisation in today's competitive and global market.

To increase productivity further in businesses, automation can be extended to the semi-structured knowledge domain where intelligent systems (Zahedi, 1993) are being exploited. Artificial neural networks and expert systems are two types of intelligent systems, which are capable of providing this enhanced productivity, which organisations are seeking.

Intelligent systems, specifically artificial neural networks, which are the focus of this research, are developed to enhance and complement the potentials of conventional systems, by extending the boundaries of automation further to semi-structured knowledge. This approach can provide increased productivity, add value to an organisation's processes and products, and its innovative exploitation might provide strategic competitive advantage.

A prominent feature of ANNs (Wasserman, 1993; Anderson, 1995) is their ability to learn from samples or historical data. There is no need for any explicit programming of ANN systems. Therefore, there is no need to devise any algorithm to map the relationships between inputs and outputs.

The obstacle to automating semi-structured knowledge by a conventional system is that the relationships between inputs and outputs are unknown. Although identification of these relationships are not always impossible, in most cases it is a difficult and expensive task (McGraw and Harbison-Briggs, 1989), because of the tacit and fuzzy (Sestito and Dillon, 1994; Buchanan and Wilkins, 1993) nature of semi-structured knowledge. In trying to identify these relationships, two factors must be considered. First, the cost and the validity of the elicited knowledge, in cases where experts are available in the field. Secondly, the fact that if the relationships in a specific domain of semi-structure knowledge are identified with acceptable validity, then the specific knowledge domain can no longer be classified as semi-structured knowledge, but must be classified as structured knowledge, which is suitable for automation by the conventional systems.

The approach adopted by the expert system concept and technology (Durkin, 1994; David, Krivine, and Simmons, 1993) in order to extend automation to the semi-structured knowledge domain is inspired by the notion of identifying (eliciting) relationships between inputs and outputs in a narrow knowledge domain. Therefore, the narrow knowledge domain becomes suitable for automation by conventional systems. Rule production in expert systems is simply the creation of an algorithm for implementing as an automated system. The complexity of this algorithm is determined by the number of rules produced to manage the automation of that narrow knowledge domain. In addition to the deficiencies of cost and validity of elicited knowledge, this approach suffers from inefficient symbolic processing, and the lack of extending the boundaries of automation to the knowledge areas where there is no expert.

The ANNs approach, due to its learning potential from existing data, makes it feasible to model (map) the relationships between inputs and outputs, and develop a generalisation of these relationships. The ANN approach to automation of semi-structured knowledge is highly superior to the expert system approaches. This superiority is not limited to its numeric and parallel processing, but also to its ability to model the knowledge domain where there is no expert and only historical data or sample data are available.

IMPORTANT FACTORS FOR DECISION TO BID

Literature related to the bidding decision process was investigated and analyzed to identify those factors that affect the decision-making process.

Initially, literature concerning the construction industry, based on primary data, was analyzed (Shash, 1993; Odusote and Fellows, 1992; Ahmad and Minkarah, 1988; Eastham, 1987), then the prescriptive and descriptive literature (The Charted Institute of Building, 1997; Thorpe and McCaffer, 1991; McCaffer and Baldwin, 1995; Smith, 1995; Skitmore, 1989; Skitmore, 1991; Kwakye, 1994; Park and Chapin, 1992; Fellow and Longford, 1980; Marsh, 1987) based on secondary data, and / or opinion of the authors, was considered. Further semi-structured and unstructured interviews with practitioners in the field, aided the development of a model. It was thought that by involving practitioners, the model would be more readily accepted by the practitioners.

Functional decomposition, to organize and classify the important factors for the decision to bid was performed. The aim of functional decomposition is to develop a conceptual view of the relationships between the factors. The decision to bid, as a function, can be decomposed to two further lower levels for analyses. The term functional decomposition or process hierarchy (Analytic Process Hierarchy) (Anderson, Sweeney, and Williams, 1997) is used to refer to this analytical approach. The lowest level is defined by the factors. The processes that assess these factors can be referred to as elementary processes. A set of these elementary processes (factors) defines a higher-level process or sub-function. The set of higher-level processes (sub-functions) define the decision to bid function.

The aim was to develop a conceptual view, which can be shared and related to by the end users of the system, to depict relationships between factors. The important factors set, which was inclusive of the factors identified as important by the literature review, was organized to depict a model of the relationships for the decision to bid. Later, the model was validated and developed in collaboration with Henry Boot Construction Limited. The validated conceptual model is as following:

Factors and their related higher level processes

Opportunities:

Economic contribution of the project (Hirschy and Pappas, 1996)

Strategic and marketing contribution of the project (Hamel and Prahalad, 1989; Prahalad and Hamel, 1990; Ansoff, 1957; Kotler, 1988)

Competitive analyses of the tender environment

Feasibility of alternative design/s to reduce cost

Resources:

Resources to tender

Managerial and technical resources

Financial resources

Physical resources

Project Relations:

The current relationship with the project client

The current relationships with the project client's professional team

Project Procedures:

Form of contract

Contract conditions

Tendering procedure

Project Characteristics:

Project type

Project size

Location

Experience

Risks:

The risks involved owing to the nature of the project

Financial capability of the client

The speed of payment of the client

COMPETITIVE ADVANTAGE:

Lowest cost (Porter, 1985)

A questionnaire to assess the relevant factors for the decision to bid was devised. The questions function as elementary processes to elicit numeric assessment for the factors. They additionally facilitate a systematic approach to decision making through ensuring that all relevant factors are being considered and assessed.

DATA COLLECTION AND EVALUATION

Data on the historical decision to bid were collected from a UK contractor company. Data collection was based on the developed questionnaire using a scale of 1 to 4. One hundred and fifteen historical projects were assessed by the decision-makers. There were no missing values. The data set consists of 16 projects, for which the opportunity to bid was rejected, and 99 projects for which the opportunity to bid was accepted by the company.

MODELLING THE DECISION TO BID PROCESS USING REGRESSION MODELS

Several regression models to depict the relationships between the decision to bid options and the important factors were developed. Table 1 summarizes the results of the one of the models, developed by entering all the important factors into the model. The model has the highest coefficient of determination in comparison with the other regression models generated. However, the linear regression model fails to provide sufficient accuracy for the decision model. The linear approximation of this non-linear relationships with coefficient of determination of .318 indicates that the regression model is not a valid approach and tool for modelling the decision to bid process.

Table 1: Regression Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Linear regression	.666	.444	.318	.2871

Failure of the linear model, would be an indication that non-linear relationships exist between the important factors and the decision to bid options.

To model the decision to bid process validly and effectively, a tool that can model non-linear relationships needs to be employed. Neural networks approach, which is capable of modelling non-linear relationships, was used, therefore, to model the process. The approach successfully modelled the process attaining sufficient accuracy of prediction.

THE DSS SYSTEM DEVELOPMENT APPROACH

Neural networks can be defined as a non-linear function-mapping tool, which maps the relationships between a set of input (input vector) to a set of output (output vector). The input vector consists of important factors that require due consideration and assessment for the decision making in the domain that is being modeled. The output vector represents the desired response set from the model.

A numeric assessment, on a continuous scale of 1 to 4, for 21 important factors for the decision to bid process are considered as the input vector for the DSS. Therefore, the input layer of the neural networks system, which supports the DSS, would consist of 21 nodes.

The historical decision to bid options, which were bid / no bid, were expanded to include the following four options:

Accept the opportunity to bid,

Add to a reserve list,

Replace with another project in the reserve list,

Reject the opportunity to bid.

The output layer of the neural network, therefore, consists of 4 nodes, with each node representing one of these options.

The collected data set, which consists of 115 historical projects from a contractor company in the UK, were used as training and test data sets for development of neural network systems.

The term prototyping is used to refer to the system development approach, which searches for the optimum network architecture through the development of a number of neural networks systems (prototypes), which differ in hidden layer architecture. These prototypes are then assessed for accuracy of response. A prototype that provides the desired accuracy in respect of Root Mean Square (RMS) of error and/or classification rate is then selected for further development.

The prototyping methodology was employed to search for the optimum network architecture for the neural network for the DSS for the decision to bid. The learning rule used to train the networks was the modified back-propagation learning rule (Rumelhart, McClelland, and the PDP Research Group, 1986; McClelland and Rumelhart, 1988) called Extended Delta Bar Delta (EDBD) (Minai and Williams, 1990), with the sigmoid transfer function. The optimum network architecture that was selected for further development and integration into the DSS consisted of a network with 21 nodes in the input layer, 3 hidden layers, with 15 neurons in the first hidden layer, 10 neurons in the second hidden layer, 10 neurons in the third hidden layer, and 4 nodes in the output layer. The network produced the desired accuracy in the training data and test data sets (RMS error of 0.001 and the classification rate of 100%).

DEVELOPMENT OF THE DSS USER INTERFACE

The C programming language was used to develop a user-friendly user interface with an online help facility that provides information related to the operation of the DSS.

Data entry into the system is performed through a set of dialog boxes. Each dialog elicits a numeric assessment related to a sub-set of the input variables. Online help on each dialog provides further information related to each dialog. The data entry is validated on each dialog to ensure that the numeric assessment for each factor is within range, before allowing the user to proceed to the next dialog.

The DSS recommendation is provided in a separate dialog box, which becomes active when the user requests an output. The neural network is recalled at this stage to process the input vector and the result is presented to the user. Facility for storage of information to file is also provided.

GETTING THE USERS INVOLVED

The users have been involved in the development process from the inception of the idea and throughout the development of the neural network. The input variables were generated in consultation with them, and the questionnaire and the data collection form were modified according to their feedback to ensure effective communication.

The developed neural network system, with the user-friendly interface, in addition to demonstrating the feasibility of neural networks as a DSS, enhances communication with the target users concerning the potential and capability of neural networks. The professionals challenged the developed system, and were pleased with the capability of the system, its accuracy and speed of response. It is our understanding that the users' involvement in the development process created such an environment that direct and indirect learning have been achieved by both parties involved.

The questionnaire and data collection form have been introduced as the standard procedure within the organisation for the purpose of evaluating new opportunities to bid and for collecting a new data set. These evaluations, and therefore, the new data set, should be free of any bias due to the passage of time. The new data set will be used for statistical analyses and to develop a further neural networks DSS. This DSS hopefully will be used as a standard procedure in the organisation.

CONCLUSION AND FURTHER RESEARCH

Analysis of the literature on the application of neural networks in the construction industry revealed the fact that neural network technology and its system development approach have reached a stage of maturity. The real challenge now is to transfer the know-how acquired from the research to the businesses and practitioners within the industry. The motive for this transfer of know-how is increased productivity and the effectiveness that can be provided by neural networks to automate semi-structured knowledge domains. This involves a different target group, which demands a different set of communication skills and terminology. Notions of prototyping system development and getting users involved in the development process are recommended to enhance communication, further awareness of the potentials of the neural networks and to increase the demand for neural network systems.

Important factors related to the decision to bid are identified. Consideration and assessment of these factors ensure a systematic approach to the decision making process, which improves quality of the decision making, increases productivity, and assists in achieving the strategic objectives of the organisation.

Automation in the form of Decision Support Systems (DSS) can enhance these benefits further. The DSS can be based on best practices and the most productive approach to the decision-making.

Adopting the recommended methodology, a neural networks DSS for the decision to bid was developed. The approach provided the benefits of improved usability and acceptability of the system, and assisted in developing a system with high accuracy of responses.

Data collection from historical projects, and the neural network system development approach adopted, in fact, acted as a feasibility study to validate the factors, the questionnaire, and the DSS development tool and methodology.

After the data collection, further consultation meetings were held with the organisation's decision makers for the decision to bid process to further refine the factors and the questionnaire. The factor related to availability of resources to tender (item 5) was replaced with two items. These are: availability of human resources to tender for the project, and availability of financial resources to tender for the projects. The questionnaire was modified accordingly.

The modified questionnaire is to form the internal procedure for the contractor company when assessing the suitability of present and future projects for the decision to bid. This set of data would be free of any bias due to time. A further DSS will be developed to model this set of data. To assess the usability of the DSS, its performance will be measured by qualitative assessment of the target users of the systems, and its contribution to productivity of the organisation by a comparative evaluation of the success rate for bidding for the successful projects.

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