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HARNESSING THE POTENTIAL OF NEURAL NETWORKS FOR EFFECTIVE DECISION MAKING IN THE DECISION TO BID PROCESS

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ABSTRACT

Important factors in the decision to bid process are identified. A rational and optimal model of decision making for the decision to bid process, which depicts the relationships between these factors and the decision to bid options, is developed. Regression models and neural networks approach are employed to automate the rational and optimal model. Prototyping system development methodology is used as the neural networks system development. The neural networks approach in addition to the ability to model non-linear relationships, demonstrates superior performance in respect of higher accuracy of prediction and classification. The developed neural networks system is harnessed to develop a Decision Support System to support effective and efficient decision making for the decision to bid process.

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

INTRODUCTION

Neural networks are information processing systems, which can learn and model linear and non-linear relationships in a domain from either a representative sample or historical data. The feasibility, and potentials of neural networks to model non-linear relationships in addition to linear relationships was clearly demonstrated through the development of a neural network system for decision to bid process from a collected data set from historical project of a contracting company (Parvar *et al.,* 2000a).

Neural networks architecture consists of a set of inputs or an input layer, and a set of outputs or an output layer. There could be different layers of Processing Elements (PE) or neurons between input layer and output layer; these layers of processing elements are referred to as hidden layers. The network is usually fully interconnected, that is the input layer is fully connected to the neurons in the first hidden layer, and first hidden layer is fully connected to the next hidden layer, and the last hidden layer is fully connected to the output layer.

The hidden layer/s enable the neural network to model non-linear relationships. Neural network architecture without hidden layer is only capable of modelling linear relationships.

Neural networks through learning process develop a mathematical model of relationships between a set of input and a set of output. The mathematical model of these relationships is stored in the network's connections weights or weight vectors.

The set of inputs in neural networks system should represent the set of factors, which are considered important or relevant for decision making in the domain that is being modelled. The set of outputs represents the desire outcome/s for prediction, or optimization.

The number of hidden layer and the number of neurons or Processing Elements (PE) in each hidden layer are problem dependant. The hidden layer network architecture is decided by developing neural networks systems with different hidden layer architecture. These networks are monitored during training and recall in respect of Root Mean Square of Error (RMS), and classification rate. The network architecture, which can provide acceptable and desired accuracy, deemed to be preferred network architecture. This approach can be labelled as prototyping system development.

Getting target users involved in development process of neural networks can increase the usability and acceptability of the developed system. It can also facilitate the transfer of knowledge about the potential and the capability of the neural networks, and know-how acquired from neural networks system development (Parvar *et al.,* 2000b).

The learning rule refers to algorithm used to minimize the global network error. Fortunately there are a number of effective learning rules available, which can be utilized for training neural networks systems.

THE DECISION MODEL

The rational and optimal model of decision-making for the decision bid process (Parvar *et al.,* 2001) is the decision model for automation by neural networks.

The decision model optimizes the utilization of resources through ensuring that resource are fully employed and focused to the most appropriate projects which rate favourable above average with respect to the important factors, and there is balance between risks and returns.

Each decision to bid option is recommended as set/s of patterns of relationships which are depicted in tabular format in APPENDIX A.

Regression models are applied to automate the decision model. Regression models fail to provide an acceptable accuracy of prediction (Parvar *et al.*, 2001).

NEURAL NETWORKS SYSTEMS TO AUTOMATE DECISION TO BID PROCESS

21 factors are identified as important for decision making in the decision to bid process (Parvar *et al.,* 2000c). Therefore, the input layer of the neural networks systems to automate the decision to bid process would consist of 21 input nodes. Each node represents one of the factors in the decision to bid process.

Four decision options are identified for the decision to bid process:

1. Unconditionally accept the opportunity to bid.
2. Reject opportunity to bid.

Provisionally accept and prioritize by:

3. Adding to a reserve list.
4. Replace another project with the current project in the reserve list.

The output layer of the neural networks systems must represents these four decision to bid options. Therefore, the output layer of the neural networks systems consists of four neurons which represent these four decision to bid options. Each neuron in the output layer provides a measure of fitness on a continuous scale from 0 to 1 for each one of the decision to bid options.

The input layer nodes, in fact, do not perform any processing and just fan out the input vector to the first hidden layer neurons, for processing.

The hidden layers' neurons perform the main processing of information. The results of these processings are passed to the output layer neurons for final processing and presentation of the processed information.

The hidden layer architecture, that is number of hidden layers, and number of neurons in each hidden layer of neural networks to provide acceptable accuracy for modelling, prediction or classification would be dependant on the complexity of the problem domain for automation. It is also dependent on the learning rule selected for development of neural networks system.

The knowledge domain to which neural networks are applied can be labelled as semi-structured knowledge domain. That is, the domain of knowledge, which there are awareness about the inputs and outputs, but there is no knowledge about their relationships, and linear approximations of the relationships are not capable of providing an acceptable accuracy for modelling, prediction or classification. Therefore, awareness of the complexity of the semi-structured problem domain would be very limited or non-existence.

Adopting prototyping system development approach for the development of neural networks systems, in fact, assists in assessing the complexity of the semi-structured problem domain of interest for automation. The more complex hidden layer architecture that is required to model and automate the problem domain with acceptable accuracy, it would be indicative of more complex and non-linear relationships between inputs and outputs in the problem domain.

Learning rules, most often require specific hidden layer architecture, and differ in their ability for compact representation of problem domains. The most compact representation can be provided by back-propagation learning rule, and its modified versions. Learning Vector Quantization (LVQ) also has potential to provide compact hidden layer architecture for classification purposes only. Radial Basis Function (RBF), and counter propagation learning rules provide less compact representation than back-propagation, but a more compact representation than General Regression Neural Network (GRNN).

Inexpensive processing power available today makes criteria such as speed of convergence, and compact representation of problem redundant criteria, for selection of a learning rule and its related network architecture.

The ability of a learning rule and its related network architecture to model a decision domain with an acceptable and a desired accuracy seems to be the prominent criterion for its selection.

Back-propagation learning rule has been widely used for neural networks system development, due to its versatility and robustness. Back-propagation seems to be the first choice for system development in neural networks. After developing a back-propagation neural network to automate a decision domain, we can experiment with other learning rules to assess their abilities to provide additional benefits for automation of the decision domain, and select the neural network system, which provides the best solution to the problem.

A representative data set was generated from the rational and optimal model of the decision making for the decision to bid process, which is used as training and test data sets for the development of neural networks systems to automate the decision to bid process.

Extended Delta Bar Delta (EDBD), which is a modified back-propagation learning rule to increase the rate of convergence of the network was used to develop prototype neural network systems to automate the rational and optimal model of the decision making for decision to bid. 19 neural network prototypes with different hidden layer architecture, which can manage the information processing with acceptable accuracy, were developed. The most favourable of these prototypes was a network with 3 hidden layer, and 20 neurons in each hidden layer. The network provides RMS error of 0.0002 and classification rate of 100% over entire training data set. This neural network system was selected to be integrated with a user interface to act as Decision Support System (DSS) for decision to bid process.

Further prototype systems were also developed using LVQ, RDF, and GRNN neural networks. These networks were able to manage the information processing required for modelling the rational and optimal model of the decision to bid successfully, but they did not provide any additional benefits in comparison with the neural network system developed by the EDBD.

DECISION SUPPORT SYSTEM FOR DECISION TO BID PROCESS

The research aims to develop a real life DSS for the decision to bid process which can assist the decision makers to systematize the decision making process and improve the effectiveness of their decision making to achieve organizational objectives. The DSS to have wide acceptability and usability by the professionals in the field, in addition to supporting effective decision making by a rational and optimal neural network model of decision making, must benefit from:

1. Stand alone functioning
2. Speedy response
3. User-friendly interface
4. Ease of use
5. Availability of online help system and context sensitive help
6. Facility for storage of information to text file.

The stand-alone functioning of the DSS that is to run and execute on a window based operating system environment, without aid of any other software was achieved by developing and writing the entire DSS programme which is inclusive of user-interface and neural networks system in a third generation environment such as C/C++ language. The developed programme was then compiled to produce the executable stand-alone programme.

The DSS was developed with a user-friendly interface, with intuitive menus and commands to ensure its ease of use. Help system and context sensitive help facility are also provided. The ease of use was confirmed by a representative sample of the target users.

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 box provides further information related to each dialog. The data entry is validated on each dialog box to ensure that the numeric assessment for each factor is within range, before allowing the user to proceed to the next dialog box.

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. The response time is almost instantaneous. The facility for storage of information to file is also provided.

VALIDATION OF THE DECISION MODEL AND THE DSS

The decision makers for decision to bid process, that is chief estimators and estimating directors of the UK's contractor companies were invited to a semi-structured interview to assess the developed rational and optimal model of the decision making, and the DSS. So far, four contracting companies' decision makers for the decision to bid process have been interviewed. These experts assessed the developed rational and optimal model of decision making for decision to bid process, and challenged the neural networks DSS for the decision to bid. They all shared the view that:

1. Systematizing the decision to bid process would improve the quality of decision-making.

2. Considering and assessing the important factors for the decision to bid process would facilitate a systematic approach to decision-making, which improves the quality of the decision.

3. The developed rational and optimal model of the decision making for the decision to bid process is a valid approach to decision making.

4. The responses of the neural networks DSS for decision to bid are valid.

5. They also confirmed the ease of use and usability of the DSS.

Additionally, the experts expressed their interests to use the DSS for their decision-making for decision to bid process. Copies of the neural networks DSS were provided to each organization. The DSS would be used to support decision making for the decision to bid process by these organizations.

RECOMMENDED SYSTEM DEVELOPMENT METHODOLOGY FOR NEURAL NETWORKS DSS

The approach adopted to systematize the decision making process for the decision to bid process, modelling the decision domain, and development of the DSS is recommended as methodology for neural networks system development to function as DSS for automation of semi-structured knowledge domain.

The uniqueness of this approach is the development of a conceptual view based on patterns of the relationships between a set of inputs and a set of outputs to model the decision domain. Additionally, the development of functional decomposition assisted in identifying the important decision factors, and the elementary processes to assess the factors.

Review of literature, analysing secondary data, and discussions with experts and practitioners in the field to identify important factors for decision domain and the decision options or the desired outcomes seem standard and reasonable approach to understanding the domain, and forming a conceptual view of the decision domain. Functional decomposition, in fact, formalizes and expresses these views in a way that can easily be communicated to practitioners and researchers in the field. The degree of acceptability of the functional decomposition by the practitioner and researchers in the field would be indicative of how successfully the researcher/s have been in capturing the perceived conceptual view of the decision domain.

Development of a questionnaire and collection of primary data based on the questionnaire provides a new source of data to extract information about the decision domain. Statistical tools are, also, very valuable approaches in aiding our understanding of the decision domain.

The regression models, which are inherently linear function mapping tools, can be used to model the collected data, and therefore the decision domain. If regression models succeed in providing an acceptable and desired accuracy for modelling, the regression model can be used for prediction and better understanding of the linear approximation of the relationships. Moreover, if regression models fail to provide an acceptable degree of accuracy, or there is desire for higher degree of accuracy, neural networks can be used for modelling, which can capture non-linear in addition to linear relationships. Neural networks develop a mathematical model of the relationships between the input vectors and output vectors, which is stored as network connection weights. It is hard to visualize and conceptualise the relationships.

Another suitable approach to modelling would be to develop a rational and optimal model of relationships patterns, which has wide acceptability by the experts and practitioners in the field, for the decision domain. This approach facilitates visualization of the relationships, enhance communication about the patterns of the relationships between professional in the field, and serves as an explanation facility if neural networks are used to automate the model.

The model can easily be automated through generating data from the rational and optimal model and training a neural networks system to learn and generalize the model.

CONCLUSIONS

A neural networks system with high accuracy of prediction is developed to automate the rational and optimal model of decision making for the decision to bid process. The developed neural networks system is further integrated with a user interface to function as a DSS.

The developed rational and optimal model of the decision-making and the DSS have been assessed and evaluated by the professionals in the field as valid and effective approach to decision making. The DSS is also being used to support decision making for the decision to bid in their organizations.

Experience acquired during system development is recommended as methodology for effective development of neural networks DSS.

Automation of semi-structured knowledge domains enhances the effectiveness of decision-making and increases productivity within organizations through systematizing the decision making process.

The research indicates that neural networks approach is highly productive tool for the automation of semi-structure knowledge domain. It is highly recommended that the potential benefits of neural networks be harnessed to increase productivity.

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APPENDIX A: PATTERNS OF RELATIONSHIPS FOR DECISION TO BID OPTIONS

The first set of patterns (vectors) for accepting the opportunity to bid option is presented in Table 1.

High risks are acceptable, if there are high returns for the accepted risks. The second set of vectors for accepting the opportunity to bid (Table 2) represents this notion.

The opportunity to bid is rejected for projects, which rate below average favourable with respect to all the important factors (Table 3).

When there are shortage of resources for bidding, management, and implementation of a project, but the project is assessed as favourable above the average. The project is added to a reserve list, that if the resources to become available to be utilized for the favourable projects in the reserve list (Table 4).

When a project possesses the most favourable characteristics according to the factor set, but there are not sufficient resources available for bidding, management, and implementation of the project. The project is replaced with another project in the reserve list (Table 5). This approach would ensure that the reserve list contains the most favourable projects for effective and efficient utilization of the scarce organizational resources.

Table 1 First set of vectors for accepting opportunity to bid

	1.00	**2.00**	**3.00**	**4.00**
Economic contribution				
Strategic and marketing contribution				
Competitive analyses of the tender				
Feasibility of alternative design				
Resources to tender				
Managerial and technical resources				
Financial resources				
External resources				
Relationships project client				
Relationships professionals				
Form of contract				
Contract conditions				
Tendering procedure				
Project type				
Project size				
Location				
Previous experience				
Risks owing to nature of the project				
Financial capability				
Speed of payment				
Competitive advantage for lowest cost				

Table 2 Second set of vectors for accepting opportunity to bid

	1.00	2.00	3.00	4.00
Economic contribution				
Strategic and marketing contribution				
Competitive analyses of the tender				
Feasibility of alternative design				
Resources to tender				
Managerial and technical resources				
Financial resources				
External resources				
Relationships project client				
Relationships professionals				
Form of contract				
Contract conditions				
Tendering procedure				
Project type				
Project size				
Location				
Previous experience				
Risks owing to nature of the project				
Financial capability				
Speed of payment				
Competitive advantage for lowest cost				

Table 3 Reject opportunity to bid vectors pattern

	1.00	2.00	3.00	4.00
Economic contribution				
Strategic and marketing contribution				
Competitive analyses of the tender				
Feasibility of alternative design				
Resources to tender				
Managerial and technical resources				
Financial resources				
External resources				
Relationships project client				
Relationships professionals				
Form of contract				
Contract conditions				
Tendering procedure				
Project type				
Project size				
Location				
Previous experience				
Risks owing to nature of the project				
Financial capability				
Speed of payment				
Competitive advantage for lowest cost				

Table 4 Add to a reserve list vectors pattern

	1.00	**2.00**	**3.00**	**4.00**
Economic contribution			■	
Strategic and marketing contribution			■	
Competitive analyses of the tender			■	■
Feasibility of alternative design	■	■	■	■
Resources to tender	■			
Managerial and technical resources	■			
Financial resources	■			
External resources	■			
Relationships project client			■	
Relationships professionals			■	
Form of contract			■	
Contract conditions			■	
Tendering procedure			■	
Project type			■	
Project size			■	
Location			■	
Previous experience			■	■
Risks owing to nature of the project	■	■		
Financial capability				■
Speed of payment				■
Competitive advantage for lowest cost			■	■

Table 5 Replace with another project in the reserve list vectors pattern

	1.00	**2.00**	**3.00**	**4.00**
Economic contribution				■
Strategic and marketing contribution				■
Competitive analyses of the tender			■	■
Feasibility of alternative design	■	■	■	■
Resources to tender	■			
Managerial and technical resources	■			
Financial resources	■			
External resources	■			
Relationships project client				■
Relationships professionals				■
Form of contract				■
Contract conditions				■
Tendering procedure				■
Project type				■
Project size				■
Location				■
Previous experience			■	■
Risks owing to nature of the project	■	■		
Financial capability				■
Speed of payment				■
Competitive advantage for lowest cost			■	■