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APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN STRUCTURAL ENGINEERING

1. INTRODUCTION

The civil engineering problems are not repetitive, as the problem definition is always influenced by a number of factors like financial modes, importance of structure and site conditions and so on. Therefore, although the use of computers in structural analysis started almost four decades ago, the profession has not been able to make use of computers fully, especially, for structural design and planning. This is mainly because of problem specific nature, need for logical reasoning, feasibility constraints and use of past experience required in actual design process and planning. Expert systems have capabilities to incorporate some of these requirements for programming a machine for solving a design problem. Artificial Intelligence (AI) is a very versatile and potential technology in the field of computer technology, which enables computer users in various fields to solve problems for which algorithmic approach cannot be formulated and which normally requires human intelligence and expertise. Expert Systems (ESs) and Artificial Neural Networks (ANNs), the best known manifestations of AI, have today gained immense credibility and acceptance in many professional fields. Artificial neural networks are biologically inspired in the sense that neural network configurations and algorithms are usually constructed with the natural counterpart in mind. The tremendous processing power of human brain is basically the result of the massively parallel processing units called neurons. A human brain functions with hundreds of thousands of such biological neurons, which are interconnected by a highly complex network. Every neuron consists of a cell body, axon and dendrites. Dendrites extend from the cell body to the other neurons where they receive signals at a connection point called the synapse. These inputs are communicated to cell body where all such inputs are essentially summed up. If the resulting sum exceeds a specified threshold value, the cell fires and a signal is sent down the axon. Using this model, an artificial neuron is developed which performs the basic characteristics of the biological neuron. ANNs consist of small processing units called nodes, which operate in parallel, and these nodes are densely interconnected by elements called weights. The information to be stored is fed at the input and small values are assigned to the weights. The weights are modified until the output of the network is satisfactory. The artificial neurons can be arranged in a network in a variety of ways by changing the type of connectivity, the number of neurons and the number of layers. In a multi layer arrangement, the input and the output layers are separated by a number of hidden layers.

1.1 Expert Systems for Analysis and Design

After selecting the preliminary section, an analysis was carried out using some simple formulas and then the results were checked for design constraints. After the analysis-design cycles (if required), the developed expert system has facility to provide member wise details of the design in graphical form along with a detailed report on the flow of information. A new architecture for the development of expert system was suggested in 1993 by introducing first time the concept of pre-, main- and post-expert system stages for structural design. Both symbolic and numeric processing were integrated to provide complete solution to design problems in an integrated environment of Turbo Prolog. Developing an inference mechanism demands very high programming skills particularly for

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developing a general expert system shell, which can be used for diverse types of applications. This is not an easy task particularly for those who are not familiar with much programming. For them it is better to develop an ES for the selected domain using an available shell. Many such shells are commercially available out of which Rule Master was selected for developing an expert system package for concrete mix design based on the procedure outlined in IS: 10262 - 1982 known as Indian Standard (IS) code method. This facility was found very useful particularly for developing expert systems for concrete mix design as most of the knowledge available for mix design can be easily put in tabular form. Because of all these features it was further used for development of expert systems for the design of concrete mix for flexural strength and also for selecting concrete constituents based on A. C. I. Method. The developed expert systems eliminate the tedious procedure of referring to charts, graphs and tables of IS codes and help the user to arrive at final quantities of cement, water, sand and coarse aggregates per cubic meter of concrete. Expert systems were developed to determine safe bearing capacity of soil, to select suitable foundation and to design isolated footing subjected to axial load only or to an axial load and moment or a combined slab footing as the case may be. Also, in 1994, many author developed a knowledge based expert system to determine the nature of loading on the rectangular column and to calculate slenderness ratio for the type of column, i.e. axial, uniaxial or biaxial and thus to fire rules related to design of that particular type of column. Further in 1996, expert system was developed to arrive at optimal design of T-beam floors using the commercially available VP-Expert shell. For developing knowledge base, in the rule form, available design charts for the cost of materials and magnitudes of imposed loads for different spans of slab were used and to obtain optimal design section, the goal driven backward chaining of VP-Expert shell was used. A problem of design of singly reinforced section was chosen in 1997 for the optimal design. For simplicity, an optimal design polynomial was considered for the development of an expert system with the design constraints as equilibrium constraints, bending moment constraint and beam width/depth ratio constraint. The objective function considered was the cost of beam, which included cost of steel, concrete and shuttering. Some of the salient features of VP-Expert which offered a suitable base for development of rule based expert system are menu driven navigation, simple English-like rule stytax, the ability to execute external DOS programs and good interface capabilities to external programs such as spread sheets, databases and batch files. Particularly, the facility of ``induce" command that automatically creates a knowledge base from a table contained in a data base was found very much suitable in transforming directly the tabular information available in design codes.

1.2 ANN in Non-destructive Testing

Two popular methods, namely, Schmidt test hammer method and Ultrasonic pulse velocity method were considered to study, for the first time, the feasibility of using Artificial Neural Network (ANN) for correlation of Non Destructive Testing (NDT) parameters to the strength of the structure. As there is no direct relation between rebound number and concrete strength or pulse velocity, the development of an ANN simulator seems to be the natural choice for such problems because predefined mathematical relationship among the variables is not required in an artificial neural network. A neural network simulator was prepared in Fortran 90 language and processed on Pentium machine with a clock speed of 133 MHz. The feed forward back propagation training algorithm was selected for the preparation of program for its simplicity and good generalization capabilities. As the neural networks in this study

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were trained on actual data, they were automatically trained to deal with any noise or imprecise data. A study of training and recall results for both the concrete hammer and ultrasonic tests indicated that the neural networks are able to learn examples of NDT and give reasonable predictions of concrete strength for any new value of rebound number or pulse velocity. To facilitate rapid assessment of flexural behaviour, multi-layer feed forward ANNs were trained to learn the relationship between input and output data generated from the available experimental data. The error correcting back propagation algorithm was used to map the relationship. The flexural behaviour of two different types of steel fibre reinforced concrete beam problems was modelled using neural networks. The results obtained for both the problems were found to be in excellent agreement with the actual experimental values. The engineering importance of the whole exercise was thus demonstrated by predicting the behaviour for new test values without performing any expensive and time consuming experiments. A generalized delta rule was used to train the networks based on the existing experimental results for two different types of deep beam problems, i.e., FRC deep beams with and without reinforcement. In the case of FRC deep beam without reinforcement, four inputs (length of beam, shear span, span/depth ratio and percentage fibre content by weight) were related to five outputs (first cracking load, failure load, maximum average shear stress, maximum experimental moment at failure and theoretical maximum moment) using one hidden layer with 7 nodes.

1.3 ANN in Predicting Large Deflection Response

Recently, feasibility of using neural networks to evaluate large deflection response of fixed immovable rectangular plates subjected to patch loading has been investigated. The error back propagation algorithm with sigmoidal function in the range 0 to 1 was used to map the relationship between the inputs-plate aspect ratio, the patch size and pressure coefficient and the 8 outputs, namely, the central deflection, bending and membrane stresses in the x and y directions at key locations of the rectangular plate.

CONCLUSIONS

Developed expert systems for analysis-design, concrete technology, design of R.C.C. and structural steel components and use of artificial neural networks in non-destructive testing, behaviour modelling of fibre reinforced concrete beams, and predicting large deflection response of rectangular plates were discussed clearly the advantages of using AI in these areas. To facilitate development of knowledge-based expert systems for a variety of problems, a number of commercially available expert system shells such as Rule Master, Insight 2+ and VP Expert have been used. Developed expert systems in the field of concrete technology are not only used by engineers during their laboratory work of concrete technology, but are also used in commercial testing of material for arriving at proper concrete mix for compressive and flexural strengths. Developed artificial neural networks for the non-destructive testing are also used in the field for commercial testing work for finding strength based on rebound number and pulse velocity while using concrete hammer and ultrasonic concrete tester respectively.

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