Expert System for the Concept Design of Bridge Structural System

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Abstract: *Bridge engineering is one of the vast and extremely fascinating subjects in civil engineering calls for expertise from several areas. It is not an easy option for any single person to make a proper judgment without the involvement of experts concerned to the field. This necessitates the importance of streamlining the expert's knowledge into a computer package which replaces the involvement of experts from the field. The current research paper presents the development of an expert system for the selection of bridge site, its substructure and superstructure types using artificial intelligence languages in Matlab environment. An attempt is made to make the system work even with incomplete inputs. Two well-structured techniques called Fuzzy Delphi method and fuzzy AHP have been used in the research.*

Keywords: *Expert, Fuzzy AHP, Fuzzy Delphi, Knowledge.*

1. Introduction

The various problems in bridge engineering are to be answered under expert's supervision. Reconnaissance survey and expert's consultation is the most commonly followed existing practices which seems to be time consuming and difficult to measure uncertainty. In the present research an attempt is made to build an expert system for the selection of bridge site, bridge substructure and bridge superstructure. The entire behavior of an expert system depends on the amount of knowledge stored in the system. Hence in the research the system knowledge is built using the knowledge obtained from the expert's who has tremendous practical and theoretical backgrounds, textbooks and codes. Fuzzy Delphi method is used due to the fuzziness in the common understanding of an expert. FAHP has been used in the system development to know the amount of influence made by each factor in the final decision.

2. System Design

The expert system is designed with user interface, inference engine, working memory and knowledge base as the main components along with explanation facility and comment base in Matlab environment using artificial neural network (ANN), production rules and fuzzy rules for knowledge representation.

2.1. User Interface

Graphical user interface is designed in the present work to get the efficient and designed results using minimal input. The program is planned to collect all the necessary input to the system during interaction with the user. Based on the type of information collected there are 4 types of question scenarios designed for the convenience of the user.

Under type 1, type 2, type 3 and type 4 question scenarios system accepts the user response "'yes', 'partial' or 'no'", "'high', 'average', or 'low'", "'good', 'satisfactory' or 'bad'" and "'straight', 'skew' or 'skip'" respectively.

2.2. Knowledge Base

"Knowledge base is the collection of rules and facts which describe all the knowledge about the particular domain". A set of general variables for the selection of bridge site, bridge substructure and bridge superstructure is obtained from experts in the area of bridge engineering using fuzzy Delphi method (FDM) where a questionnaire survey carried out with 11 experts from the industry, profession, academia and government organizations. The working of an expert system depends on the knowledge stored in the knowledge base.

2.3. Inference Engine

Inference engine is one of the major components of an expert system deduces new knowledge. The logic used is represented using if- then rules. Forward chaining and backward chaining reasoning methods are used for proper reasoning in the system. The present research work is aimed at designing a user friendly and flexible system comprising complete domain knowledge. In the research artificial neural network is used to develop knowledge base for the selection of bridge site, production rules and fuzzy rules are used for the selection of bridge site and bridge superstructure types. Flowcharts showing neural network inference system, rule-based inference system[7] and fuzzy inference system are shown in figure 1, 2 and 3 respectively.

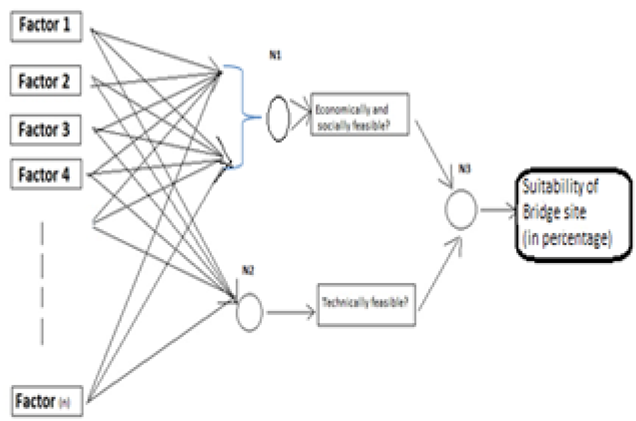

Fig. 1: Flow chart showing neural network inference system

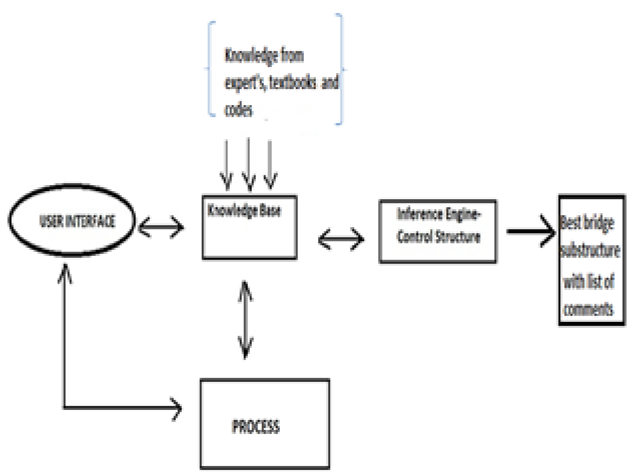

Fig. 2: Flow chart showing rule-based inference system

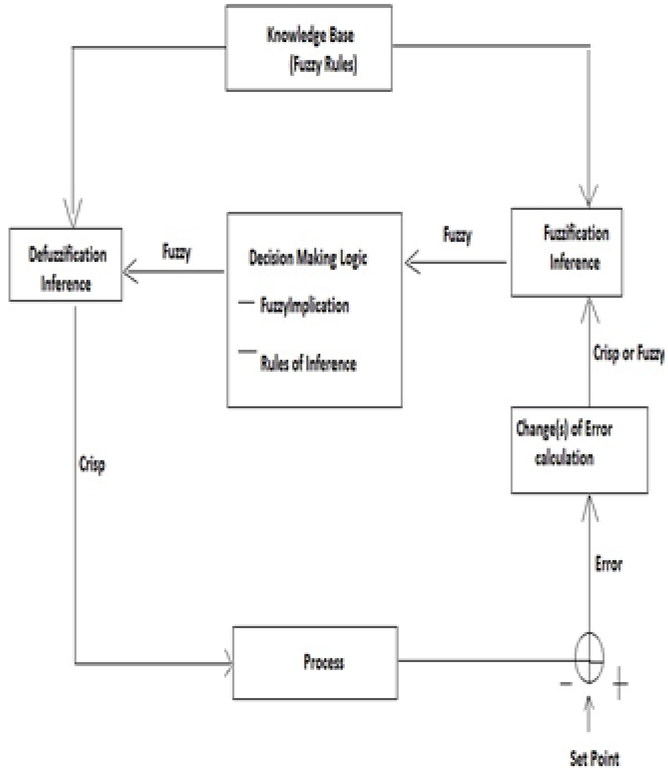

Fig. 3: Flow chart showing fuzzy inference system

2.4. Working Memory

"Working memory called as context which creates workspace for a problem generated by the inference engine from the information provided by the user". The facts and hypothesis generated during reasoning are stored in the working memory. Working memory automatically created in Matlab, as and when the program is loaded. Flowcharts showing the selection of bridge site, bridge substructure and bridge superstructure are shown in figure 4, 5 and 6 respectively. To build a practical system knowledge is acquired through experts, textbooks, codes and practical site data of 9 existing bridge sites.

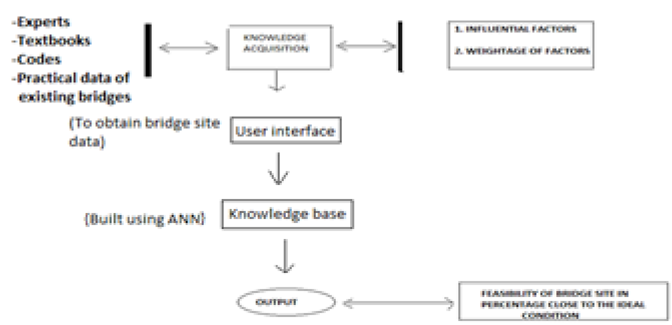

Fig. 4: Flowchart – Bridge site selection system

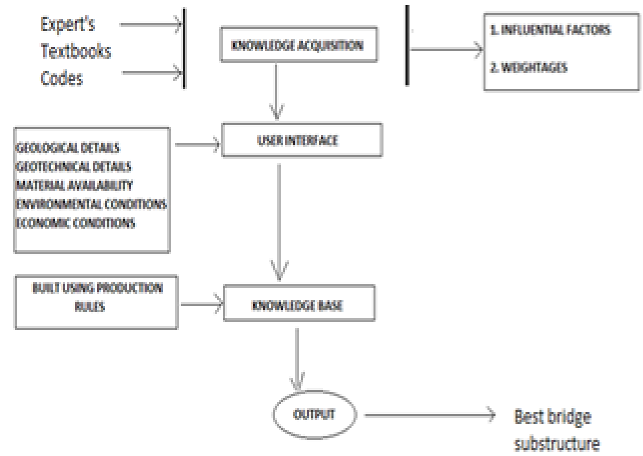

Fig. 5: Flowchart: Bridge substructure selection system

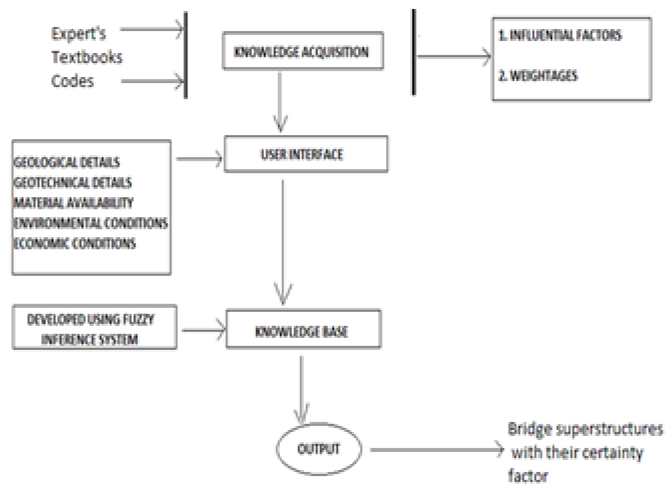

Fig. 6: Flowchart: Bridge superstructure selection system

Figure 4, 5 and 6 shows the work flow for the system design of "expert system for the selection of bridge site, bridge substructure and bridge superstructure". User interface components collects all the inputs needed from the user for taking decision and output components consists of the suitability of bridge site in percentage close to the ideal condition, best bridge substructure and bridge superstructure suitable for the site conditions. Inference engine uses the knowledge stored in the knowledge base and draws the output.

3. Results and Discussion

Expert system for the bridge site selection is designed using artificial neural network. ANN is trained from the data of 9 existing bridge sites situated in Palakkad (D), Kerala (S) of South India (SI). Network input is of size [27X9] and output matrix is of size [1X9]. Network architecture used in the system design is as shown in figure 7.

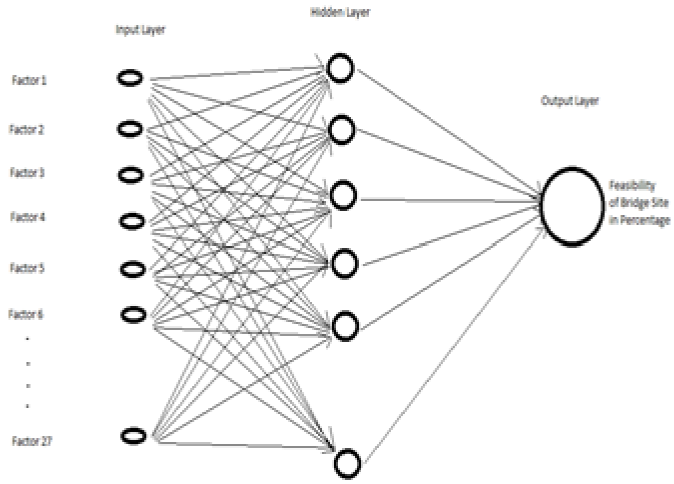

Fig. 7: Multilayer Network Architecture

A feed forward network is created initially with 10 hidden neurons and trained on the collected data of bridge sites then simulated. Since the network performance was not satisfactory, hidden neurons is increased to 20 to achieve maximum performance. The graph of network performance is shown in figure 8.

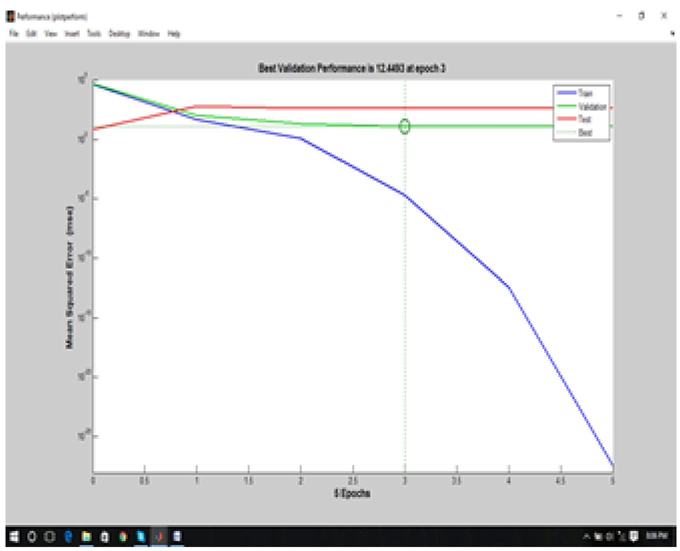

Fig. 8: Performance Graph

The training record structure is given below.

Network training is set to stop once the gradient reaches minimum. Best validation performance is achieved at epoch 3.

```
tr =
    trainFcn: 'trainlm'
    trainParam: [1x1 struct]
    performFcn: 'mse'
    performParam: [1x1 struct]
    derivFcn: 'defaultderiv'
    divideFcn: 'dividerand'
    divideMode: 'sample'
     divideParam: [1x1 struct]
```

trainInd: [2 3 5 6 7 8 9]
valInd: 1
testInd: 4
stop: 'Minimum gradient reached.'
num_epochs: 5
trainMask: {[NaN 1 1 NaN 1 1 1 1 1]}
valMask: {[1 1 1 1 1 NaN 1 NaN 1]}
testMask: {[1 NaN 1 1 1 1 NaN 1 NaN]}
best_epoch: 3
goal: 0
states: {'epoch' 'time' 'perf' 'vperf' 'tperf' 'mu' 'gradient' 'val_fail'}
epoch: [0 1 2 3 4 5]
time: [0.1320 0.2990 0.3660 0.4340 0.5040 0.5630]
perf: [4.4052e+04 53.4344 1.2755 2.1228e-05 3.9020e-13 3.8226e-28]
vperf: [5.3607e+04 117.9988 21.3055 12.4493 12.4641 12.4641]
tperf: [7.2088 684.6697 443.1215 440.1269 439.8990 439.8989]
mu: [1.0000e-03 1.0000e-04 1.0000e-05 1.0000e-06 1.0000e-07 1.0000e-08]
Gradient: [9.4145e+04 2.2086e+03 465.2611 1.4860 2.6995e-04 4.0718e-12]
val_fail: [0 0 0 0 1 2]
best_perf: 2.1228e-05
best_vperf: 12.4493
best_tperf: 440.1269

Expert system for the bridge substructure is designed using if- else conditional statements[5]. The output of the system displays list of substructures suitable for the bridge site. The system also provides provision to add or delete the substructure types from the system.

Bridge superstructure is designed using fuzzy rules.

Triangular membership function shown below is used in the design.

$$F(P; x, y, z) = \begin{cases} 0 & \text{if } P<=x \\ (P-x)/(y-x) & \text{if } x<=P<=y \\ (z-P)/(z-y) & \text{if } y<=P<=z \\ 1 & \text{if } P>=z \end{cases}$$

More compactly,

$$F (P; x, y, z) = \max (\min (P-x)/ (y-x), (z-P)/(z-y), x)$$

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Where, P is a membership value

x, y and z are the elements ranges between 0 and 1

There are 4 types of fuzzy editors developed in the system. Fuzzy editor 1 comprises of input attributes, output attributes and fuzzy rules designed for the selection of RC/STEEL/PSC types of bridges. Fuzzy editor 2 is designed for the selection of RC type of bridges. Fuzzy editor 3 comprises of fuzzy rules for the selection of steel type of bridges and fuzzy editor 4 is designed for the selection of PSC type of bridges. The graphical representation of the composition of fuzzy rules is as given below in figure 9.

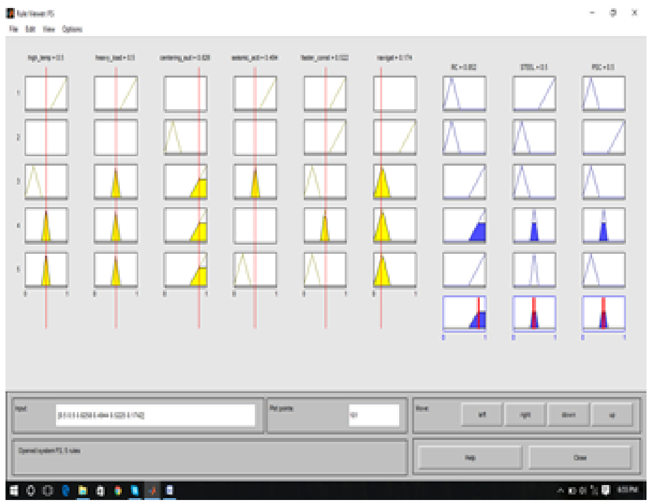

Fig. 9: Rule viewers for the selection of bridge types

Sample output of an expert system is as shown below in figure 10, 11 and 12.

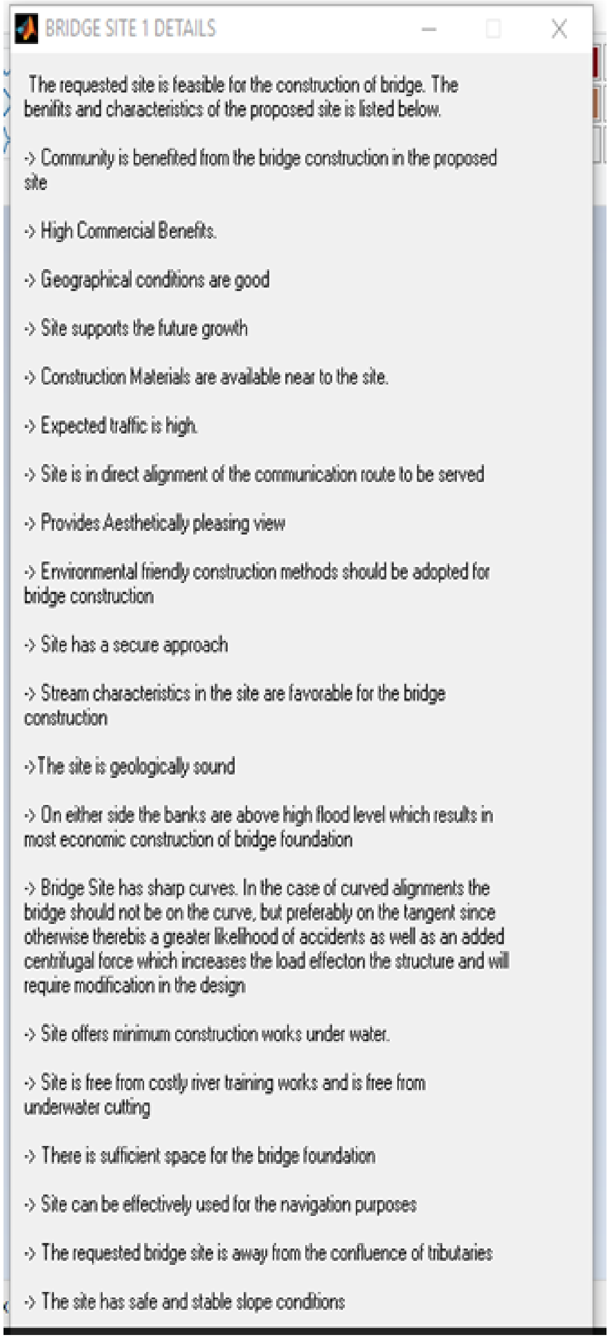

Fig. 10: Sample output of an expert system for the selection of bridge site

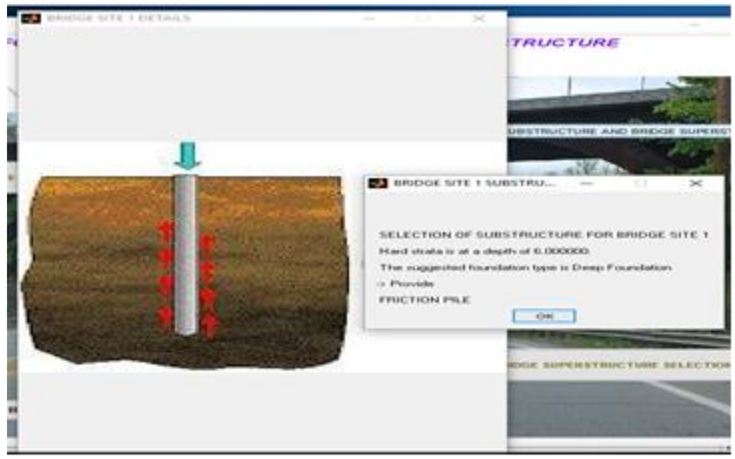

Fig. 11: Sample output of an expert system showing the best bridge substructure for the given bridge site conditions

Fig. 12: Sample output of an expert system showing the suitable bridge superstructures with their certainty factors.

4. Conclusion

Based on this research work, the following conclusions are made. System is capable of handling even insufficient input data of the river bridge site with some limitations. The knowledge base component of an expert system is quite extensive consisting of the knowledge collected from experts using Fuzzy Delphi Method, textbooks and codes; in addition, practical bridge site data of nine existing bridges situated in Palakkad district of Kerala, South India. Expert system allows the user to add or delete any number of substructures from the system knowledge base. The entire structural systems work as a comprehensive package.

5. References

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