INTIGRATING AI TECHNIQUES IN STRUCTURAL DESIGN PROCESS

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Abstract— Artificial intelligence is a branch of computer science, involved in the engineering, research and application of intelligent computer. Researchers have made significant contributions by developing numerous tools and methods of structure design but at the same time, the field demands further work to come up with new ideal solutions for various ongoing issues. Research study reveals that Artificial Intelligence based method can provide efficient options for solving complex problems in structural design up to some extent. This paper identifies the issues in each of the stages of the structural design process and possibility of AI techniques to overcome these identified issues. Additionally the paper provides an overview of the advances of AI applied in structure design process.

Keywords— Artificial Intelligence, Structural Design Process, Artificial Intelligence Techniques.

I. INTRODUCTION

The structural design problems are not tedious, as the problem classification is always influenced by a various factors such as importance of structure, financial approach and site conditions etc. Therefore, the use of computer system in structural process started long years ago, the work has not been able to make use of computers entirely, especially, for structural design and planning. This is generally because of problem specific nature, need for logical reasoning, feasibility constraints and use of past experience required in actual design process and planning.

Based on the affirmation views it is clear that structural design require a major place to incorporate AI to improve the efficiency of design process. Artificial Intelligence is a very versatile and potential technology in the field of computer science technology. AI techniques include expert systems, pattern recognition, fuzzy system, reasoning, knowledge based engineering learning and classification. Expert systems have capabilities to incorporate some of these requirements for programming a machine for solving a design problem.

In civil engineering, structural design is considered as a phase having ample scope to incorporate AI techniques because of requirement of more logical reasoning. However, structure design phase have a tendency to be production delays, incomplete designs, rework, change orders, and have a big impact in all the development stages. Therefore, the usage of AI techniques in order to improve design phase favorably affects the quality of civil engineering.

This paper aims to study the techniques developed in AI from the standpoint of their applications in structural design process. In particular, it focuses on techniques developed or that are being developed of AI that can be arranged in solving problems associated with design process. The rest of the paper is organized as follows: various AI techniques and contributions of AI in each stage of structure design process are briefly reported. Finally, conclusion is reported in the last section of the paper.

II. STRUCTURAL DESIGN PROCESS AND ITS KEY ISSUES

The structural design process is the task of forming or generating design artifacts afterwards analyzing, evaluating, and optimizing these artifacts until the result satisfies the requirements of the problem definition. In other words, the design process is the task of mapping problem requirements into design solutions. The design process should be influenced by these key points: creativity, cost effectiveness, and organize- label methodology that will ensure a high quality product. Structural Design process can be grouped into four phases, which assist to have a positive effect on the quality as well as on the efficiency of the design process [7].

A. Synthesis

Design synthesis is an attempt to create structure to fulfill desired behavior, which include both qualitative and quantitative aspects. The synthesis process can be divided into two phases, namely, conceptual synthesis and parametric synthesis. Conceptual synthesis regards the process of generating conceptual solution as well as parametric synthesis seeks the specification of the properties of the elements. A detailed study reported various methods in synthesis process such as: axiomatic design, computational methods and agent based synthesis; however it has been observed that there are still certain issues as well as challenges in synthesis, which are given as follows[8]:

- The principal problem found in design phase is lack of information. The designers do not deliver proper information during construction phase causing many issues such as delay, incomplete design and rework [8].
- Parametric synthesis requires property of parameters. But what information content is required for the parametric model is still doubtable area [8].
- The major issue in synthesis process is to collect design experiences and how to represent it in conceptual model [9].
- Some parametric design problems such as: topologic relations, physical integrity constraints, and embodiment scenario and performance parameters. But which methodology can be suitable for these parametric design problems is a key issue [8][9].
- Another key issue occurs during the creative process of translating the requirements in to high level design. Bridging the gap between functional to technical is hurdle [8][9].

B. Analysis

Analysis phase is considered as a systematic approach to enhance perceptive of the process of an organization to support in the identification of significant benefits such as: process efficiency, cost reduction, and efficient human resource distribution. Additionally, Analysis techniques allow to quantify the achievement of the design object expected behaviors. This procedure provides help in modeling and solving of equations to predict the response of a selected structure [10]. Major issues reported by experts and practitioners in analysis are given as follows:

- In several cases, design drawings are usually incomplete, vague and inefficient, which require a great amount of specification. An efficient Design specification is also a great challenge in design process [10].
- Design documents have errors, omissions, inconsistencies or lack of transparency in the presentation [10].
- There is lack of standard for the existing technology, which is also a reason for software failure [10].
- The wrong predictions in design process can increase the risk in development process and decrease the quality of software [10].

C. Evaluation

Evaluation phase measures how ideal the original aim of the new system have been achieved. The main purpose of evaluation is to see whether or not the new system has solved the original problem and achieved the goals defined in the Analysis phase [11]. Major issues reported by experts and practitioners in evaluation phase are given as follows:

- In most cases, designers do not have proper domain knowledge, which is required in evaluation of structure [11].
- Usability evaluation techniques in the evaluation process are very costly and time consuming, due to this concern, these techniques is performed manually [11].
- The major issue in outcome evaluation, it requires lot of time to collect information, organize and describe the program [11] [12].
- In addition, other major issue is lack of database program to manage and analyze a lot of data and need extra resources for participant incentives [11][12].
- Cost production is a fundamental criterion of design process. However, several issues reported in this area such as a framework for cost-based productivity, modeling of whole life prediction, assessment and incorporating cost analysis tools within a design. Therefore, more attention is needed to understand the uncertainties of cost risks involved in cost estimation [11] [13].

D. Optimization

Optimization phase explore over the collection of possibilities to advance the design as much as possible. It is a significant portion of structural design and used to find the best solution so that a designer or a decision maker can develop a maximum benefit from the available resources [14][15]. However, Major issues reported by experts and practitioners in optimization are given as follows:

- The major practical optimization problem is constrained optimization problem. It has been formulates in terms of design variable and design constrains [16][17].

III. AI TECHNIQUES IN STRUCTURAL DESIGN PROCESS

The main aim of design phase is to formulate the collected requirements, analyze them and to develop it into structural representation. But, some issues in this phase such as inefficiency, misinterpretation, and wrong prediction of information decrease the quality of software. Therefore, some AI methods and techniques with respect to aforementioned issues that are identified in section II of this paper may be used to overcome the same.:

3.1 AI Techniques to Overcome the Issues of Synthesis

In accordance with the issues related to synthesis stage, highlighted above, the paper now proceeds to explain the AI techniques, which are given as follows:

- DSPL Language: DSPL language used to allow the expression of design information. It recognize the different portions of information, which represent the action for major sub problems such as design decisions, constrains, plans, suggestion and software failure during design construction. These expressions captured in DSPL language which forms a design expert system. Designer can deliver proper information using DSPL language and reduce the problem during construction of design up to some extent [18].
- Case-based reasoning: One of the major goal of synthesis process is to collect design experience and propose a model to represent the collected design experience. Simultaneously it faces some challenges and limitations too such as formulate a structural model for design experience. The use of case based reasoning seems promising for addressing these challenges. It is a method of design that directly uses design experience in the form of episodes rather than compiles and generalizes it. Case-based reasoning solves a problem by recalling similar past problems assumed to have similar solutions. This model is attractive because it is less time consuming and easy [18] [19].
- Expert System: Many system failures occur due to parametric problems. Expert systems are the computer program that solve parametric problem and give solution about some particular area using reasoning. It generally involves heuristic reasoning and structure of reasoning, based on experience of an expert. The group of expert system use set of rules, which describe some key aspect of a situation and suggest the appropriate action [19].
- Automate Transformation: An important portion of the design process during development process is translating business problem in to high level design. Automate transformation is a method of AI, which help to bridge gap between functional to technical. The transformation model follows a theoretical scheme, where preliminary set of design information is transformed into technical form [9].

3.2 AI Techniques to Overcome the Issues of Analysis

Major AI techniques, which may be used to overcome the issues relating to analysis, are given as follows:

- Fuzzy System: A proper design pattern is very necessary for quality of software. Natural language associate with vague and imprecise concepts, some statements are difficult to translate into more precise language without losing some of their meaningful value. Therefore, Fuzzy system is a technique of AI, which uses fuzzy sets to deal with incomplete and imprecise design data [19].
- Knowledge based system: The key issue in design analysis is mostly design specification is incomplete and incorrect due to lack of proper attention on design. Knowledge engineering is a subfield of AI that produces a type of computer system called knowledge-based systems also known as expert systems to ensure the quality of software. Knowledge-based systems are computer programs designed to perform tasks usually done by human experts, or to solve problems that are beyond the capability of conventional computer systems. Knowledge based system process includes rule based reasoning and frame based model [20].
- Neural Network: Many system development failure occur because incomplete, incorrect prediction of outcome in design process. Additionally the wrong prediction can increase the risk factor in the process of development. Neural network is related discipline for solving these kinds of issues. Artificial neural network is useful in solving data intensive problem where algorithm or rules solve the design problem which is difficult to express and provide help in outcome prediction of software. It also resolve problem such as function approximations, pattern classification and clustering [21][22].

3.3 AI Techniques to Overcome the Issues of Evaluation:

Major AI techniques, which may be used to overcome the issues relating to evaluation, are given as follows:

- Rule Based Reasoning: The rule based reasoning is suitable for handling domain knowledge. It offers more flexible and easy use of domain knowledge. In comparison with conventional techniques, rule based techniques split up complex calculation in to a basic function and connects them in sequence. It improves the evaluation process and deal with high quality [19].
- Automated usability evaluation: Automation usability evaluation has great potential over non-automated evaluation. Automated evaluation approaches and techniques improves the design process and provides several advantages such as improved error tracing, reduced costs and time, better feedback, and increased coverage of evaluated features [11].
- Genetic Programming: Some of traditional evaluation method does not give efficient result in given schedule, which is the reason of delay in software. Therefore genetic programming is automated technique, which enables computer to solve the problem. It works by using genetic algorithm to mechanically produce computer program. It collects and organizes information. Evaluate each of

solution of every given problem and keep best solution. It keep continues until the satisfactory result of problem [23].

3.3 AI Techniques to Overcome the Issues of Optimization

Major AI techniques, which may be used to overcome the issues relating to optimization, are given as follows:

- Particle-swarm Optimization: Constrained Optimization problems have been found in many applications. There are some specific fields such as engineering design, economics, allocation, location problem, structural optimization in which CO problems are frequently met. Particle swarm optimization is an artificial intelligence method that can be used to find estimated solutions to extremely complicated or impossible numeric maximization and minimization problems [17].
- Genetic Algorithm**:** Genetic algorithm has an ample potential to achieve approximate solution for constrained optimization problem. Genetic algorithm is one of the AI methods, which work on a coding of the design variables- binary string. This characteristic allows the genetic algorithm to be extend to a design space for design process. Genetic algorithm can be great solution for constrained problem, which is need to focused [17].

CONCLUSION AND FUTURE WORK

Research studies reveal that the design process has an ample scope to incorporate AI techniques to improve the efficiency of process. In the current scenario, the demand to formulate a framework, based on integration of AI techniques and methods, ontologies, expert system and others techniques/tools has increased dramatically, which is raising many new research questions. Accordingly, the paper presented various techniques/methods developed in AI to eliminate the issues such as parametric problems, wrong predictions, constrain optimization problems and inconsistency in documents of design phase. The paper also described significant use of AI techniques in each stage of design phase. In addition, proper mapping of the issues belonging to each of the design stages with the relevant AI techniques has also been accomplished with the help of Venn-Diagram. These diagrams present a clear vision of the current status of the research in the area along with the scope for future research. The future work may be to work on given unresolved issues and develop some suitable techniques to overcome the same. Additionally, apart from the existing AI techniques, some more advanced techniques may also be explored to improve the efficiency of design process.

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