EMERGING INFORMATION AND COMPUTING TECHNOLOGIES FOR CONSTRUCTION AUTOMATION

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Abstract: Several new information and computing technologies in construction engineering and management are discussed. They include neural networks, object-oriented programming, concurrent engineering, Internet computing, and collaborative computing. Examples of research performed by the author and his associates in recent years are described briefly.

Keywords: automation, collaborative computing, concurrent engineering, CONSCOM, construction, design, Internet, Java, neural networks, object-orient programming.

1. NEURAL NETWORKS

1.1 Design Automation

Automation of design of large one-of-a-kind civil engineering systems is a challenging problem due partly to the open-ended nature of the problem and partly to the highly nonlinear constraints that can baffle optimization algorithms (Adeli, 1994). Optimization of large and complex engineering systems is particularly challenging in terms of convergence, stability, and efficiency. Recently, Adeli and Park (1998) developed a neural dynamics model for automating the complex process of engineering design through adroit integration of a novel neurocomputing model (Adeli and Hung, 1995), mathematical optimization (Adeli, 1994), and massively parallel computer architecture (Adeli, 1992a&b, Adeli and Soegiarso, 1999). The computational models have been applied to fully automated minimum weight design of high-rise and superhighrise building structures of arbitrary size and configuration, including a very large 144-story superhighrise building structure with 20,096 members. The structure is subjected to dead, live, and multiple wind loading conditions applied in three different directions according to the Uniform Building Code (UBC, 1997). Optimization of such a large structure subjected to the highly nonlinear and implicit constraints of actual design codes such as the AISC LRFD code (AISC, 1998) where nonlinear second order effects have to be taken into account has never been reported before. The patented neural dynamics model of Adeli and Park finds the minimum weight design for this very large structure subjected to multiple dead, live, and wind loadings in different directions automatically.

1.2 Construction Scheduling and Management

Adeli and Karim (1997) present a general mathematical formulation for scheduling of construction projects. An optimization formulation is presented for the construction project scheduling problem with the goal of minimizing the direct construction cost. The nonlinear optimization problems is then solved by the patented neural dynamics model of Adeli and Park (1998). For any given construction duration, the model yields the optimum construction schedule for minimum construction cost automatically. By varying the construction duration, one can solve the cost-duration trade-off problem and obtain the global optimum schedule and the corresponding minimum construction cost. The new construction scheduling model is particularly suitable for studying the effects of change order on the construction cost.

1.3 Construction Cost Estimation

Estimating the cost of a construction project is an important task in the management of construction projects. Quality of the construction management depends on the accurate estimation of the construction cost. Automating the process of construction cost estimation based on objective data is highly desirable not only for improving the efficiency but also for removing the subjective questionable human factors as much as possible. The problem is not amenable to traditional problem solving approaches. The costs of construction materials, equipments, and labor depend on numerous factors with no explicit mathematical model or rule for price prediction. Highway construction costs are very noisy and the noise is the result of many unpredictable factors. Adeli and Wu (1998) present a regularization neural network model and architecture for estimating the cost of construction projects. The model is applied to estimate the cost of reinforced concrete pavements as an example. The new computational model is based on a solid mathematical foundation making the cost estimation consistently more reliable and predictable. Moreover, the problem of noise in the data is taken into account in a rational manner.

1. 4 Other Applications

A number of other authors have presented applications of neural networks in construction automation in recent years. Moselhi et al. (1993) used the backpropagation neural networks (Hegazy et al., 1994) and the genetic algorithm (Adeli and Hung, 1995) to develop a decision-support system to aid the contractors in preparing bids. Backpropagation algorithm has also been used for estimating construction productivity (Chao and Skibniewski, 1994), evaluation of new construction technology acceptability (Chao and Skibniewski, 1995), and for condition rating of roadway pavement sections (Eldin and Senouci, 1995). Kartam (1996) uses neural networks to determine optimal equipment combinations for earthmoving operations. Pompe and Feelders (1997) use neural networks to predict corporate bankruptcy.

2. OBJECT-ORIENTED PROGRAMMING

In the 1990's the object technology gained increasing popularity for development of flexible, maintainable, and reusable CAD/CAE software systems (Yu and Adeli, 1991, 1993, Adeli and Kao, 1996, Adeli and Kumar, 1999). In addition to its desirable characteristics of abstraction, encapsulation, and inheritance and its reusability advantage, the object-oriented programming (OOP) paradigm facilitates the message passing constructs needed for collaborative computing on the Internet (to be discussed later).

Recently, Karim and Adeli (1999a) presented an object-oriented (OO) information model for construction scheduling, cost optimization, and change order management based on the new construction scheduling model discussed in the previous section, with the objective of laying the foundation for a new generation of flexible, powerful, maintainable, and reusable software systems for the construction scheduling problem. The model is presented as a domain-specific development *framework* using the Microsoft Foundation Class (MFC) library and utilizing the software reuse feature of the *framework*. The OO information model for construction scheduling and cost management can be integrated into a concurrent engineering model for the construction industry. The information and computational models have been implemented into a new generation prototype software system called CONSCOM (for CONstruction Scheduling, Cost Optimization, and Management) (Karim and Adeli, 1999b).

3. CONCURRENT ENGINERING

Integration of design, engineering, and manufacturing (CAD/CAE/CAM) is the critical issue in concurrent engineering. Concurrent engineering technology has been developed substantially in automotive and other manufacturing applications. It is now finding applications in the construction industry in both U.S. (El-Bibany and Paulson, 1999; Pena-Mora and Hussein, 1999) and Japan (Kaneta et al., 1999). The current prevailing practice is to complete the design before the construction is started. But, changes in the design might be necessary to improve the product or project even after the construction has already begun. For concurrent engineering in the construction industry it is necessary to integrate the construction management and scheduling with the design process.

Successful application of concurrent engineering in the construction industry should be based on effective integration of design and construction. Two essential prerequisites for such an integration are a tool to automate the complex process of engineering design (discussed in section 1.1) and a tool for construction scheduling, cost optimization and change order management (discussed in section 1.2).

Concurrent engineering processes will be refined further and advanced in several directions in the coming years. The current concurrent engineering technology relies primarily on management of large data bases (Adeli, 1999). One refinement will be integration of artificial intelligence techniques with virtual visual models. Knowledge management and knowledge engineering techniques have the potential to enhance concurrent engineering processes significantly. This can take several forms from natural language processing and speech recognition, to machine vision technology, to machine learning techniques (Adeli, 1990a,b, 1997) to strategic use of smart sensors and robots (Adeli and Saleh, 1999).

4. INTERNET AND COLLABORATIVE COMPUTING

In the second half of the 90's decade the Java programming language was developed to provide the high-level of user-machine interactivity needed on the Internet. Java is an OOP language with all its aforementioned desirable features. Java also provides multi-threading, that is a Java program can execute different processes simultaneously, for example loading an image while performing numerical processing (Adeli and Kim, 2000).

An attractive feature of Java is that it can be used in a heterogeneous environment using various operating systems such as Unix (common on workstations), Windows (common on PCs), and Linux without any need to change the source code. Java applets can be implemented on Java-enabled browsers such as Netscape and Internet Explorer. Further, Java's multithread function provides multiple and secure access to servers by many clients simultaneously without any need to write specific multitasking programs.

A Web-collaborative remote computing *framework* architecture is being developed for CAD/CAE applications (Qi and Adeli, 2001) using an advanced Java function, the Remote Method Invocation (RMI) (Sun Microsystems, Inc.,1997). The framework is a skeleton software that can be used to develop Web-collaborative CAD/CAE applications. RMI provides a remote procedure call mechanism through which objects at separate locations can communicate with each other. The proposed framework consists of two main components: clients and server. The server creates the remote objects (for transferring data to the client side, for example) and combines them with the *registry*. The client invokes the remote objects' methods through the registry located on the server side. RMI supplies a message passing mechanism between the client and the server including the registry to facilitate their communication.

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