ANN Applications in Aluminum Formwork Construction (Postprint)

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Abstract

Aluminum formwork, fully termed as the building aluminum alloy formwork system, represents a new generation of formwork support system. The application of aluminum formwork systems in the construction industry has enhanced overall construction efficiency, yielding substantial savings in both construction materials and labor allocation. The design, research and development, and construction application of aluminum formwork systems constitute a significant advancement in the construction industry. However, aluminum formwork systems present challenges regarding on-site modifications, necessitating precise and seamless assembly. This paper investigates the employment of artificial intelligence algorithms to identify optimal construction sequences for time savings, and proposes construction simulation methods within virtual environments to mitigate error probability.

Full Text

Application of ANN in Aluminum Formwork Construction

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Abstract

Aluminum formwork, formally known as the building aluminum alloy formwork system, represents a new generation of formwork support systems. Its application in the construction industry has significantly improved overall construction efficiency, yielding substantial savings in both building materials and labor allocation. The research, development, and construction application of aluminum formwork mark a major advancement for the building industry.

However, aluminum formwork presents challenges in on-site modifications and demands precise, seamless assembly. This paper explores the use of artificial intelligence algorithms to identify optimal construction sequences for time savings, and employs virtual environment construction simulation methods to reduce error probability.

Keywords: ANN; Aluminum Formwork; Project Management

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Since its inception in the United States in 1962, aluminum formwork has accumulated 55 years of application history. It has been widely adopted in construction projects across developed nations such as the United States and Canada, as well as in emerging industrial countries including Mexico, Brazil, Malaysia, South Korea, and India. Although aluminum formwork has only been developed in China for a few years, it has already gained favor among numerous construction companies, with enterprises like Vanke and China State Construction Engineering Corporation utilizing aluminum formwork systems.

Artificial Neural Network (ANN) has emerged as a research hotspot in the field of artificial intelligence since the 1980s. It abstracts the human brain' s neural network from an information processing perspective, establishing simplified models that form different networks through various connection patterns. In engineering and academic circles, it is often directly referred to as neural networks or neuro-inspired networks. The integration of neural network technology with specialized knowledge across various domains of the construction industry has enabled extensive applications of this technology in building projects. Numerous ANN systems applied in the construction industry have achieved excellent economic and social benefits. This paper utilizes ANN to optimize the selection of aluminum formwork usage sequences to achieve optimal results.

2. Research Status

Currently, Gantt charts are commonly used to manage on-site construction workflows during building projects, which proves useful for providing an overall view of the entire process. However, this method lacks spatial master planning capabilities. When assigning numerous similar tasks across different spaces to the same specialized work team, the approach fails to demonstrate effective allocation strategies. Such planning methods suffer from insufficient automation and unified resource coordination, with operational conflicts among different personnel leading to time wastage.

The planning methodology involves decomposing complex work into simpler subproblems, known as Work Breakdown Structure (WBS). The subsequent workflow employs Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) [6].

In the field of construction management, practitioners have access to tools that assist in determining work processes. Recently, researchers have begun applying artificial intelligence (AI) technologies to manage and establish workflows. Reference [8] utilizes BIM models and database operations to automatically identify near-optimal schedules; furthermore, [9] employs agent-based models to simulate construction activities; while [5] applies ANN learning techniques to achieve similar objectives.

This trend represents a shift from reactive to predictive behavior models, enabling early identification of project risks. Through construction process simulation, when unexpected situations occur, contingency plans can be proposed to mitigate impacts on the final product—ranging from formwork layout effectiveness to structural components and even the overall building outcome.

3.1 Agent-Based Model (ABM)

Construction activities at aluminum formwork sites represent complex endeavors. However, this complexity comprises the sum of many simpler problems, typically resolved by small worker teams or, in many cases, individual workers. For this reason, agent-based models (ABM) closely approximate real-world phenomena and can accurately express interactions both among workers and between workers and project content—where project content refers to our data models (such as BIM models).

Furthermore, in ABM, the correspondence between computer agents and real-world formwork installers [2] enables clear and straightforward representation of installers, their environment, and their relationships. This holds true for both stimulus-response patterns and advanced proactive response modes.

Construction project management represents a field particularly well-suited to ABM modeling capabilities, as it is inherently interdisciplinary, encompassing social and human factors alongside spatial and temporal interactions among different participating teams. On the other hand, current BIM and construction management tools offer embedded agent reasoning engines: only when designers establish data based on knowledge embedded within the model can these tools represent work phase durations (BIM4D) or costs (BIM5D). In reality, the methods described here address only part of the problem. The automated reasoning algorithms for agents in our ABM model can provide managers with information regarding how much space workers require to achieve their objectives.

In our system, each agent represents a task. Our partitioning method defines a task as the result of fully installing formwork in a single room, with agents assigning relevant formwork installers to complete the corresponding work. The completion of formwork layout for an entire floor constitutes our desired outcome, and we establish a neural network through ABM. The optimal solution derived from this network—including how many workers should participate and what the formwork installation sequence should be—will be discussed next.

3.2 Gradual Artificial Neural Network (GANN)

Continual learning represents a long-term objective in machine learning, wherein agents in ABM not only learn (memorize) a series of tasks but also possess the ability to transfer knowledge from previous tasks to improve convergence speed. Gradual Artificial Neural Networks (GANN) directly integrate these requirements into the network structure: by instantiating a new neural network (column neurons) for each task, catastrophic forgetting is prevented [7].

Agent-based systems and their associated information can be conceptualized as a type of artificial neural network, where each agent represents a neuron and information exchanged between agents can be considered as synapses between neurons [1].

The statistical factors of information frequency and selection embedded within the "neuro-actor" can be described as "experience" acquired through the neural network. During application, if designers deem the selected parameters valid, the network' s results are classified into the correct results repository.

When designers or the BIM environment require improvements to the network' s results, these results are classified into the error results repository. When decision-makers adopt construction plans that approximate past results stored in the error repository, the network will issue warnings. The training method for the decision network—namely, adjusting synaptic factor values and termination criteria—is determined using distributed constraint optimization and its variant algorithms.

3.3 Distributed Constraint Optimization DCOP

In multi-agent systems, coordination plays a fundamental role, as coordination rate metrics indicate how closely agents function as a unified whole. Consequently, managing internal dependencies among agent activities becomes essential.

Numerous methods exist for agent coordination strategies, typically transforming the problem into a Constraint Satisfaction Problem (CSP) and employing depth-first algorithms to search for optimal paths among agents [4]. The technique adopted in our system is the asynchronous DCOP algorithm (Adopt), inspired by Distributed Constraint Optimization DCOP algorithms [17] [3].

To optimize the model' s objective function, participants (formwork installers) must coordinate their selections. Each agent understands the constraints affecting it and operates asynchronously. This problem requires that the global objective function—namely, the output of the gradual neural network—represents a set of constrained values. The algorithm returns a set of values within a range, rather than binary 0 or 1 results.

3.4 Simulation Method

For the algorithm’ s basic requirements to be realized, the two systems (ABM and BIM) must communicate correctly. Computational results obtained from simultaneous agent actions must be updated within the building model.

Since our system accesses the Building Information Modeling system (BIM) asynchronously, access conflicts may occur during modifications. To prevent such conflicts, communication between ABM and BIM employs a BIM Event Manager (BEM). When objects in BIM require creation, modification, or deletion, BEM generates an event.

Idling in the BIM system plays a primary role in event processing. BIM generates idle events during intervals between user interactions, occurring after external systems successfully access the model.

BEM first creates a special agent system called the Master Actor (MA). The MA broadcasts or sends relevant messages to specific participants.

Every modification activity in the agent system is activated and recorded by the MA, processed through a First-In-First-Out (FIFO) queue. For query information, we bypass the MA and directly utilize the BEM system.

In our simulation process, BEM first generates an MA, then creates existing tasks (Agents). The MA broadcasts messages, which participants receive and process until completion. Participants then proceed to the next task until all tasks for the entire floor are finished. At this point, the simulation of the floor’ s formwork layout task is complete. We employ asynchronous distributed constraint optimization to identify the optimal completion sequence and required number of participants. This information is stored in our system in the form of a gradual artificial neural network. During simulation, if designers deem the process (network parameters) effective, results are stored in respective repositories to guide future formwork installation.

Once the final formwork installation plan is selected and the installation sequence determined, we can generate a virtual 3D animation of the formwork installation process, providing designers with a more intuitive understanding of the entire operation.

4. Conclusion

Our designed system represents a proactive, continuously learning ANN system that enables designers to dynamically select optimal construction plans during the initial design phase. This approach reduces time wastage and promotes construction sustainability.

To enable designers to complete aluminum formwork assembly tasks according to well-defined, reliable schedules, this paper proposes defining WBS as the outcome of multi-agent system interactions, which can dynamically determine the most appropriate construction sequence.

During the design process, our system collaborates with designers to evaluate the outcomes of participant type and quantity selections under optimal construction time conditions, while ensuring team work continuity and appropriate resource allocation.

Future work may consider integrating our system with formwork procurement and subsequent operation and maintenance activities to achieve better

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Note: Figure translations are in progress. See original paper for figures.