Dynamic information support system for the process of prefabricated member installation using RFID technology and multi-agent system

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Abstract

Nowadays, high expectation of efficiency and effectiveness encourages the prefabrication usage in housing construction industry. However, the expected benefits cannot always be obtained. One of the reasons is the inadequate skill and experience of personnel for normal situation and changed situation. The skills and experiences are required for some tasks in the normal situation, although personnel can follow the static information which is created based on a planned scenario. In the changed situation, the static information may become inappropriate. The appropriate information must be updated and provided to personnel using the current information and conditions. Otherwise, the personnel cannot perceive the actual situation and select the countermeasures properly. Consequently, undesired productivity and mistakes tend to occur.

Thus, this research aims to develop a support system for improving productivity and for reducing the number of mistakes in the process of prefabricated member installation by identifying available resources, collecting actual conditions, managing knowledge, generating alternative methods, and providing appropriate information. The system is developed by the integration of Radio Frequency Identification (RFID) technology, a multi-agent system, and a database using Microsoft Visual Studio, Java Agent Development Framework (JADE), and Microsoft SQL Server. The RFID technology is employed for identifying resources. The multi-agent system consists of the following seven agents: (1) information providing agent, (2) general information agent, (3) specific information agent, (4) actual condition recording agent, (5) alternative generating agent, (6) quality assurance and control agent, and (7) evaluation agent. Additional five user interface agents are included in a user interface container. The database stores data such as inspection results, and other related information and knowledge.

To verify the proposed methodology, a prototype is being implemented in a personal digital assistant (PDA) with a RFID reader and a laptop PC. The system will be tested in a real prefabricated housing construction site.

*Keywords:* prefabricated construction, RFID, productivity improvement, multi-agent system

1 Introduction

In the competitive era, efficiency and effectiveness attract the construction industry to change its manner from conventional method to prefabricated construction. Thai residential projects also increasingly employ prefabrication with the high expectation in terms of construction period, cost, or quality. Unfortunately, this expectation cannot always be reached, and undesired low productivity and
many mistakes are often observed. One of the reasons for this is the inadequate skill and experience of the personnel involved.

Although the prefabrication method seems simple and easy for installation, it has some special features, i.e., the sequential work, the small margin for error, and the usage of special materials, tools, and equipment. Moreover, the implementation of modern management principle, such as supply chain management or just-in-time concept, reduces the room for any mistakes. All of them increase the importance of the personnel’s skill and experience in construction.

In order to improve the productivity and to reduce the number of mistakes in the process of prefabricated member installation, the inadequate skill and experience of the personnel has to be solved and the requirements of the personnel’s skill and experience have to be relaxed by providing information and knowledge. However, actual conditions often change because of unavailable resources, different component locations from the planned, inaccessible areas, defective components, etc. Thus, the static information, which is created by designers, planners, or experienced personnel based on a planned scenario before execution, may become inappropriate for operation. Appropriate information must be updated and provided to the personnel using the current information and conditions. Otherwise, the personnel cannot perceive the actual situation and select the countermeasures properly, especially for the low skilled and experienced personnel. Therefore, this research aims to develop a dynamic information support system for improving productivity and for reducing the number of mistakes in the process of prefabricated member installation.

2 Current practice

The process of prefabricated member installation is one of the most important processes in prefabricated construction because the process is on the critical path and directly affects the efficiency and effectiveness. In this process, the skill and experience of personnel are necessary not only for the workers, who install prefabricated members, but also for foremen, mobile crane operators, inspectors, and supervisors. The requirements of personnel’s skill and experience are different among the personnel’s position based on the roles and responsibilities.

Two situations exist in practice, i.e., normal situation and changed situation. In the normal situation, the condition is the same as planned. Thus, the personnel can follow the static information directly. However, the skills and experiences are still required. As for the low skilled or experienced personnel or the personnel of the conventional method, their skills and experiences are inadequate for prefabricated construction because it requires additional skills such as prefabricated member recognition, member handling and installation, and jointing. Construction situations can be changed by any causes in the three related phases shown in Figure 1. When the situation changes, the static information may not be adequate because the situation is different from the planned scenario. Thus, the appropriate information, which the current information and conditions are considered, is needed.

<table>
<thead>
<tr>
<th>Manufacturing phase</th>
<th>Transportation phase</th>
<th>Installation phase</th>
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<tbody>
<tr>
<td>• Production problems</td>
<td>• Transportation constraints</td>
<td>• Inaccessible areas</td>
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<tr>
<td>• Defective products</td>
<td>• Incorrect loaded or unloaded members</td>
<td>• Unavailable resources</td>
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<td>• Damages from transportation</td>
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Figure 1. Causes of changed situations in each phase.

In the current practice, the foreman is assigned to supervise the process of prefabricated member installation. This process requires the skills and experiences of foreman, especially for change detection and problem solving. The inadequate skill and experience personnel do not have the ability to detect the change in timely manner, which affects the current and further processes. Moreover, the
proper method may not be selected for problem solving that causes the wide range of damage from the resource overrun to the structural damage. Thus, the prefabricated construction organization needs the information system to store and provide working information and troubleshooting. The advanced production and stock of prefabricated members increase the importance of information system. The system is employed to provide the working information and troubleshooting for the changes or problems that cannot be solved instantly in the manufacturing phase because the members are already produced or stored.

As mentioned above, the process of prefabricated member installation is human-driven and dynamic. The efficiency and effectiveness of this process depends on the personnel’s skills and experiences. In addition, the skills and experiences are necessary for the speed and accuracy of data collection process. The data collections such as available prefabricated members, resource and time consumption, and inspection results, are utilized for paperwork, evaluation, and improvement. However, some of these skill and experience requirements can be relaxed by the appropriate information providing and the data collection system. Therefore, both of static and dynamic information are collected, stored, managed, and provided by the identification technology and information support system. The identification technology is utilized for resource identification and data collection while the information support system is utilized for storing, managing, and providing the data and information.

3 Technology consideration

From the analysis of the current practice, technologies were investigated for the following three purposes: (1) resource identification, (2) data collection, and (3) information support. For (1) and (2), RFID technology is suitable, while multi-agent system is suitable for (2) and (3). Therefore, the authors integrated RFID technology and multi-agent system in this research.

3.1 RFID technology

RFID technology has been employed in construction industry for various purposes such as tool tracking (Goodrum et al., 2006), material tracking (Song et al., 2006; Ergen et al., 2007; Yabuki and Oyama, 2007), and inspection (Yabuki et al., 2002). In this research, RFID technology was selected because tag reader can detect multiple tags fast and accurately without contacting. Furthermore, tags can be detected in harsh environment, dirty surface, and blocked line of sight (Jaselskis et al., 1995). Therefore, RFID technology is utilized for resource identification and data collection. The identification leads to the reduction of skill and experience requirements for prefabricated member recognition. Further, it operates as an information access initiator and improves the speed and accuracy of data collection process.

3.2 Multi-agent system

Construction industry has employed the multi-agent system to resolve the conflicts, support the decision making, and find out the better solution (Ren and Anumba, 2004). The multi-agent system has been applied to solve large, complex, and dynamic problems in construction industry because single agent has limitations in knowledge, computing resources, and perspectives. In this research, the authors use the following three agent characteristics: (1) autonomy, (2) cooperation, and (3) learning (Nwana, 1996) to develop a dynamic information support system for improving efficiency of the system. The agents are assigned to detect the current conditions and to activate the appropriate actions.
4 System architecture

The proposed system is comprised of a user interface container, seven agents, and a database as shown in Figure 2. Each user interface agent is implemented in the different computer hardware based on the personnel working characteristics. Foreman user interface agent and inspector user interface agent in personal digital assistant (PDA) are connected to other agents in a laptop PC through wireless connection. The other agents and a database are implemented in a laptop PC and linked together through wired connection.

Figure 2. System architecture

The user interface container consists of five user interface agents, each of which is for information providers, foremen, mobile crane operators, inspectors, and supervisors. Each user interface agent is assigned to cooperate with other agents, input data, and display information. The additional seven agents are: (1) information providing agent, which is employed by information providers to access database and input information such as RFID tag assignments, resource information, troubleshooting, (2) general information agent, which provides static information such as project details, personnel details, resource requirements, (3) specific information agent, which provides the dynamic information specific to current conditions and installation sequence, (4) actual condition recording agent, which is utilized to check the available components, check the inaccessible areas, and record the actual executions, (5) alternative generating agent, which generates the installation sequence, checks the completeness of resource, and generates the alternative work methods with expected results, (6) quality assurance and control agent, which provides the inspection checklists and records the inspection results, and (7) evaluation agent, which is employed for serving the supervisors to evaluate the operations. The database stores data such as inspection results, and other related information and knowledge. The agent access is authorized by the user’s roles and responsibilities, for example, evaluation agent can be accessed only by supervisors.

5 The application

The proposed system is employed for several tasks in prefabricated member installation, i.e., locating and checking of available prefabricated members, available resource checking, comparing of available resources and required resources, generating of alternative work methods, information providing for prefabricated member installation, operation recording, quality inspection, and evaluation. In this
section, the workings of information providing for prefabricated member installation and operation recording are briefly explained.

The specific information agent and actual condition recording agent, which response for information providing and operation recording respectively, are automatically requested to perform the actions by alternative generating agent after the foreman selects an installation sequence. These two agents are running on the user interface agents of mobile crane operator and foreman. While the prefabricated members are being installed, specific information agent provides the following information through both user interfaces: (1) selected installation sequence, (2) current installing member, (3) location of each prefabricated member in a rack, (4) plan of a current installing member, and (5) location where the current installing member has to be installed. The provided information on the user interface of mobile crane operator is shown in Figure 3. However, the arrangement of provided information on the screen of foreman user interface is different because of the display size. In addition, mobile crane operator and foreman can access the general information agent and the troubleshooting in specific information agent whenever they need further information to support the operation. This provided information can relax the skill and experience requirements of mobile crane operator and foreman in the recognitions of prefabricated member and installation location. It also supports the personnel to detect any defects and solve them using the troubleshooting.

![Figure 3. Provided information on the user interface of mobile crane operator](image)

In the system, mobile crane operator and foreman have to press a specific button after each step of installation is finished for the next step information. This button press is also assigned for the operation recording. In each cycle of a prefabricated member installation, mobile crane operator is assigned to press the button for two steps: (1) after a lifting hook arrives a rack or stock position, and (2) after a member arrives at the installing location. Foreman is also assigned to press the button for other two steps: (1) after a member is hooked, and (2) after a member is installed. When all members in a selected sequence are installed, actual condition recording agent will integrate two logs from both user interface agents. Then, the duration of each step in a member installation cycle can be calculated as shown in Figure 4. These durations will be used for evaluation and improvement processes.
6 Results and discussion

In order to improve the productivity and to reduce the number of mistakes in the prefabricated construction, RFID technology and multi-agent system are integrated and employed in this research. The proposed system consists of a user interface container, seven agents, and a database. The system can be used for resource identification, actual condition recording, information and knowledge management, work method generation with expected results, and proper information providing. Therefore, the proposed system can handle dynamic changes in the prefabricated member installation.

The requirements of personnel’s skill and experience in the process of prefabricated member installation can be relaxed using this system. The installation process, problem solving, data collection, and other related tasks are improved in terms of speed, accuracy, standardization, or manpower consumption. The system also supports the collection and transfer of knowledge to reduce the impacts of personnel turnover and to leverage the learning curve of personnel. This system will be tested in a real prefabricated housing construction project for evaluation, improvement, and validation.

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References


