6

Developing Construction CAD-Based Experience Management System

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1. Introduction

Experience is valuable, stored specific knowledge obtained by a problem-solving agent in a problem-solving situation (Bergmann, 2002). Construction experience is knowledge that is based on construction methods, field operations and results of prior projects. Construction experience transfer is the use of knowledge gained in previous projects to maximize achievement of current project objectives (Reuss &Tatum, 1993). Although knowledge management is already well established in the construction industry, experience management (EM) is a new concept in information systems. Knowledge management (KM) is the collection of processes governing the creation, storage, reuse, maintenance, dissemination and utilization of knowledge. Experience is the life blood of individuals and organizations, and EM, a sub-discipline of KM, refers to the collection of processes controlling the creation, storage, reuse, evaluation and usage of experience in a particular situation or problem solving context. To transfer experience between similar projects, construction professionals have traditionally used techniques ranging from formal annual meetings to face-to-face interviews (Reuss and Tatum, 1993). To realize potential benefits, construction experience should influence all phases of a project (Tatum, 1993). Furthermore, knowledge gained from experience often requires action and may add cost-effective scope to other functional actions to avoid repeating past problems (Tatum, 1993). EM focuses on the acquisition and management of important issues and experience from participating engineers. Useful experience can be recorded in different forms and media, such as in the minds of experts, in operating procedures or in documents, databases and intranets. EM in the construction field aims to effectively and systematically transfer and share experience among engineers.

This study views experience as the knowledge gained by executing construction projects. To enhance the quality of EM gained by engineers involved in construction projects, this study proposes a Computer-aided Design (CAD)-based Maps (CBM) approach to achieving EM solutions in the construction industry. Combined with web-based technology and CBM, this study proposes a Construction Web-based Dynamic CAD-based Maps Experience Management (CBMEM) system enabling engineers to reuse domain knowledge and experience by dynamically exchanging and managing experience during the construction phase of a project. In the proposed CBMEM system, the map-based experience exchange environment enables engineers to manage and dynamically share their experience with

other engineers in current projects. Engineers are, thus, invited to exchange and share their experience, and construct valued content through their own experience. In this study of a Taiwan construction building project, the survey (questionnaire) results indicated that the CBMEM system, integrated with a CBM approach is effective for construction experience exchange and management.

2. Problem satement

Unlike manufacturing, each construction project is designed and executed to serve specific needs of the owner. The nature of the work and the constitution of the work force in a construction project change with time (Manavazhi, 1995). Experience provides strength in a competitive business environment. Thus, effectively leveraging experience is essential to business success. The complicated nature of the construction industry makes it an important field for experience management (EM), particularly regarding experience gained from completed projects. Sharing experiences between engineers can improve construction management during the construction phases of projects, thus helping avoid mistakes that past projects have already encountered. Transferring construction experience between projects can significantly contribute to achieving project objectives such as cost, schedule, quality and safety (Reuss & Tatum, 1993). Learning from experience, also, avoids problem-solving from scratch, i.e., problems that have already been solved need not be solved repeatedly. However, no effective platforms are available to assist engineers or experts in exchanging and sharing their know-how and experiences when contractors execute construction projects. The inability to share the experience of engineers and experts represents a major loss for contractors in the construction industry. When completing projects, these engineers and experts typically accumulate domain knowledge and valued experience, but share little or no experience with others. In view of EM, these significant issues and experiences of construction engineers and experts are particularly valuable due to associated factors such as manpower, significant cost and time.

 The primary problems derived from the questionnaire survey of twenty junior and senior engineers from five participating construction building projects, in the sharing and exchanging of experience, specifically during the construction phase of projects, are as follows: (1) difficulty in determining which engineers and experts have helpful and relevant experience; (2) limited efficiency and quality when using only document-based media for experience management; (3) difficulty in finding engineers with relevant experience in similar projects; (4) inadequate documentation of unofficial discussion and communication regarding problem solving for future reuse; (5) tendency for engineers to communicate orally in person or by telephone; and (6) unease with illustrating experience in current commercial information management systems. Documenting and applying experience may avoid problem-solving from the outset, i.e., problems already solved need not be solved repeatedly. However, few suitable design platforms have been developed to assist engineers in illustrating and sharing their experiences when needed. Although enterprises in the A/E/C industry have begun to collect and store explicit information in enterprise databases, they have not always been successful at retrieving and sharing tacit knowledge (Woo et al., 2004). Sharing and using previous tacit experiences in construction projects is, therefore, the primary and significant challenge of this study.

3. Research objectives

This study proposes a novel and practical methodology for capturing and representing the experience and project knowledge of engineers by utilizing a Computer-aided Design (CAD)-based Maps (CBM) approach. Furthermore, this study develops a Construction Dynamic CAD-based Maps Experience Management (CBMEM) system for engineers. The CBMEM provides a dynamical experience exchange and management service in the construction phase of a project for the reuse of domain knowledge and experience (see Fig. 1). Contractors often execute similar projects; accordingly, the problems encountered in like projects can provide a reference for comparable projects in the future. The capture, transfer, reuse and maintenance of construction project experience are, thus, critical (Kamara et al., 2002). To be competitive, a contractor needs to make innovative use of knowledge, accumulate experience through previous projects and apply it in relevant projects. Senior engineers that participate in projects act as knowledge workers; they facilitate the collection and management of experience between current and past projects.
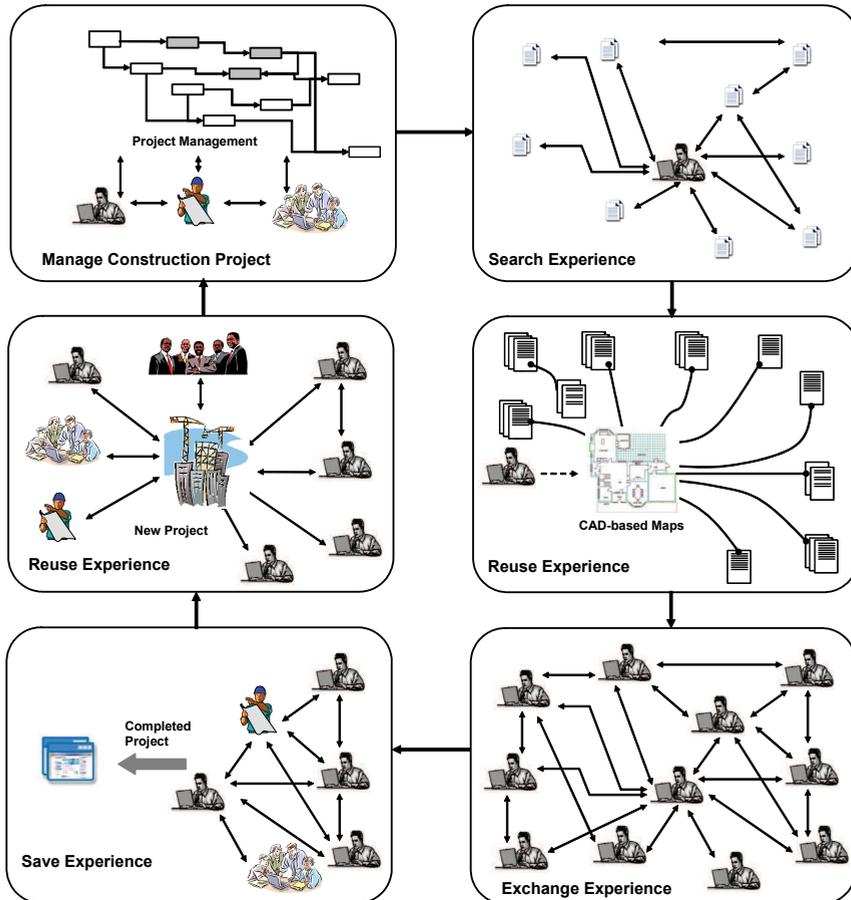

Fig. 1. The application of experience management in construction projects.

This study concentrates on new approaches for managing and reusing past specific experience for a construction project framework. With the newly proposed CBM approach and integration of web-based technology using EM techniques, service engineers and practitioners can exchange original ideas, experience, knowledge and commands. By integrating CBM and web-based technology, engineers can obtain problem solutions and experience directly from senior engineers, decreasing the time and reducing the cost of on-the-job training. By exchanging and sharing previous experiences among engineers, similar and related experiences used to execute similar projects can clarify domain knowledge and enable the exchange of knowledge through web-based EM. The CBMEM system provides a service to users who can request assistance from selected or all engineers in the enterprise who have relevant experience. The user can also submit a problem description through CBM. Moreover, senior and junior engineers can effectively and easily exchange concepts and experience regarding a specific aspect of their current construction project.

 To apply EM to new or other construction projects, the process and content of project experience must be collected, recorded and stored effectively in the CBMEM system. To assist the participating engineers in illustrating and managing their own project experience, CAD-based mapping is presented to help them explore their acquired experience. The main objectives of this study are as follows: (1) enhance the illustration capabilities using the CBM approach of captured experience of engineers and experts related to construction projects; (2) optimize the communication of tacit experience among participating engineers in the exchanging environment; and (3) design an efficient web-based platform and maps for users to effectively locate parallel experience from relative engineers. The CBMEM system is then applied in selected case studies of a Taiwan construction building project to verify the proposed approach and demonstrate the value of sharing experience in the construction phase.

4. Background research

4.1 Previous research in experience management In the construction industry

Experience management (EM) deals with collecting, modeling, storing, reusing, evaluating and maintaining experiences (Bergmann, 2002). In the construction industry, EM is a discipline that promotes an integrated approach to the creation, capture, sharing and reuse of the domain knowledge of a profession obtained from projects that have been previously undertaken. Most project-related problems, solutions, experience and know-how are in the minds of individual engineers and experts during the construction phase of a project. Implicit experience is generally undocumented or stored in a system database. To preserve implicit experience as corporate property, capturing the implicit experience and making it in the form of explicit experience is a vital aspect of EM. Two broad categories of experience are tacit experience and explicit experience. Tacit experience is personal, context-specific experience that is difficult to formalize, record or articulate; it is stored in the minds of people (Malhotra, 2000). Tacit experience is personal knowledge acquired through individual experience, which is shared and exchanged through direct, face-to-face contact (Malhotra, 2001). Explicit experience can be codified and transmitted in a systematic and formal language, and can be obtained from documents, including reports, articles, manuals, patents, pictures, images and video (Malhotra, 2000; Tiwana, 2000).

Numerous research efforts have focused on applications of knowledge management in construction. A Hong Kong study examined the main barriers to effective knowledge

sharing, as well as critical factors and benefits in the construction companies in Hong Kong and the United Kingdom (Fong & Chu, 2006). Intelligent representation structures store and access construction domain knowledge and couple it with advanced planning tools to facilitate rapid formulation and assessment of initial construction project plans (Udaipurwala & Russell, 2002). Fong et al. (2007) pointed out that the knowledge-creating capability of value management teams not only enhances the reputation of value management, but also, helps to dispel the perception of value management as an outdated problem-solving tool.

4.2 Previous research on knowledge maps in construction

A knowledge map includes the sources, flows, and points of knowledge within an organization (Liebowitz, 2005). All captured knowledge can be summarized and abstracted through the knowledge map. The knowledge map, also, provides a blueprint for implementing a knowledge management system. Well-developed knowledge maps help users identify intellectual capital, socialize new members and enhance organizational learning (Wexler, 2001). A knowledge map is a consciously designed medium for communication between makers and users of knowledge by a graphical presentation of text, model numbers or symbols (Wexler, 2001). Knowledge mapping helps users understand the relationship between stored knowledge and dynamics. Knowledge maps have been applied in various applications, including development of knowledge maps for knowledge management software tools (Noll et al., 2002).

Numerous research efforts have focused on the use of knowledge maps to support various knowledge management tasks (McAleese, 1998). Davenport & Prusak (1998) observed that developing a knowledge map involves locating significant knowledge in an organization and publishing a list or image that indicates a roadmap to locate it. Mind maps (Buzan & Buzan, 1993) illustrate the structure of ideas in an associative manner which attempts to represent how ideas are stored in the brain. A concept map provides a structure for conceptualization by groups developing a concept framework that can be evaluated by others (Trochim, 1989). Dynamic knowledge mapping can assist in the reuse of experts' tacit knowledge (Woo et al., 2004).

5. Methodology- CAD-based maps

Although maps of knowledge representation have been developed for knowledge-based applications, no knowledge map has been developed for experience management (EM) in construction. To assist engineers in extracting the knowledge gained from their own experience in projects with which they have been involved, this study proposes a novel dynamical Computer-aided Design (CAD)-based Maps (CBM) approach for the application of EM in construction. Dynamical CBM help to efficiently illustrate the experiences in the minds of engineers to generate and organize experience within a construction project framework. Dynamical CBM are based on associations flowing outward from a central image in a free-flowing, yet organized, and coherent way. The above content also functions as the experience acquisition tool in the Construction Dynamic CAD-based Maps Experience Management (CBMEM) system. Furthermore, engineers may access and edit many resources, as attachments, in the system. Hence, the CBMEM system can provide engineers with an experience exchanging environment, as well as a web-based platform for acquiring experience from more seasoned engineers.

5.1 Concept of CAD-based maps

The proposed CBM are specific approaches to EM in the construction field. Although knowledge and concept maps are easily recognized in knowledge management, the proposed dynamical CBM approach is a novel concept and is specific to construction EM. CBM can be defined as a diagrammatic and graphic representation of experience linking relationships between experience and attributes of CAD. The CBM mainly provide assistance for easily and effectively obtaining the necessary experience of users. The primary advantages of CBM are as follows: (1) CBM are simply, clearly and dynamically represented in the CBMEM (the EM system); (2) users can easily navigate the CBMEM in order to: a) understand and determine which engineers and experts own special experience related to a problem as it arises, and b) edit their experience based on what the situation may require; (3) CBM enable users' ability to expand flexible experience illustration and linkage; and (4) CBM enhance the available visual experience illustration in the CAD maps.

CBM are designed to be easily integrated with CAD and their construction experience. The key reason for using CBM is the ease with which the combined experience can be understood and reapplied. Figure 2 illustrates an overview and conceptual framework of CBM utilized in construction EM. Like construction project management, EM is based on the concept of undertaking project planning and control activities. Experience gained from activities in previous projects can be collected, managed and applied in future projects. Acquired experience from participating engineers can be accessed and saved as map units in categories for efficient collection, management and finally, retrieval for use in the current projects.
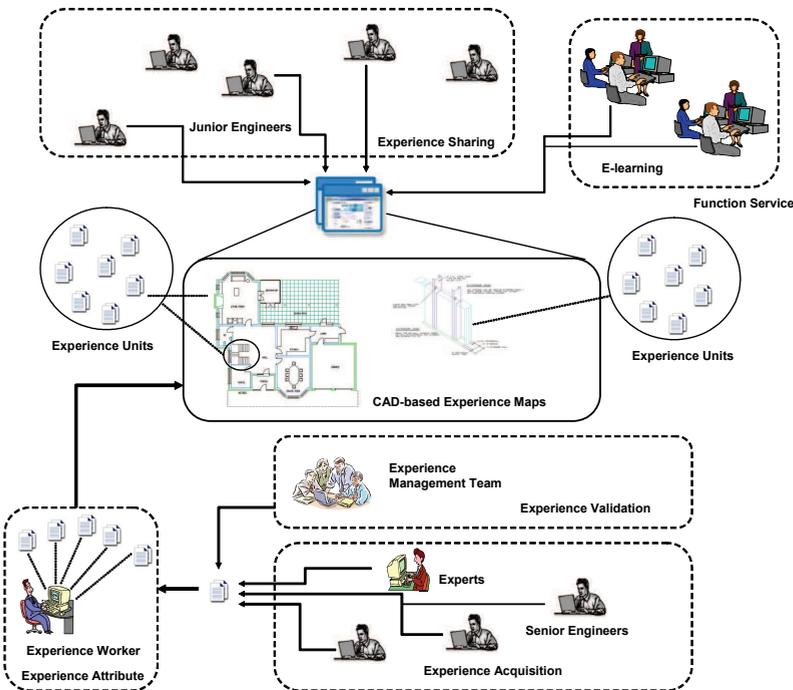

Fig. 2. The application of CAD-based Maps in experience management

5.2 Framework of CAD-based maps

CAD-based Maps (CBM) are defined in multiple levels, and constructed from variables which can be broken down by decomposing the experience units into smaller map units into which the acquired experience is stored. CBM may be comprised of several layers. The project unit is modelled in the first layer. The second-level layers model CAD units (drawing illustration). The lower-level layers model experience units. Similarly, any map unit in this lower layer can be broken down further to incorporate other components in lower layers. The map contents can be viewed as either a single point or as ranges. The structure of CBM enables users to access stored experience through layers based on the attributes and types of acquired experience. Experience stored in map units of a project map includes both tacit and explicit experience. Explicit experience may be comprised of an experience topic, experience description and experience attachments (documents, reports, drawing and other explicit sources). Tacit experience may include problems-faced descriptions, problems-solved explanations, solution suggestions, and know-how explanations. Additionally, CBM give users an overview of available and unavailable experience in core project areas, enabling effective management of tacit and explicit experience. The tacit and explicit experience of map-based experience management (EM) is likened to the duration and relationship of stages-based project management. Identifying the relationship between current and past map units is significant for users to link related experience together. The system is naturally designed to automatically or manually link activities which are highly similar. For example, the experience of a current project can be utilized, and the same or similar map units contributed by past projects can be accessed while the experience of current users is being recorded. There are some cases in which the overall project experience may be captured; however, it may not be clearly classified in project units.

CBM have components and procedures based on construction project management and, thus, differ from existing knowledge maps. The proposed CBM consist of eight components. These ten components are number of experiences, experience topics, experience relationships, experience owners, experience diagrams, experience packages, experience attributes, and similar experiences. Procedures are presented for constructing CBM based on an experience management framework. The procedure consists of the following six primary phases: experience determination; experience extraction; experience attribute; experience linking; experience validation; and, experience sharing.

6. System implementation

This section describes the details of the Construction Dynamic CAD-based Maps Experience Management (CBMEM) system. The CBMEM system is based on the Microsoft Windows 2003 operating system with Internet Information Server (IIS) as the web server. The prototype is developed using Java Server Pages (JSP), which are easily incorporated with HTML and JavaScript technologies to transform an Internet browser into a user-friendly interface.

Three search functions are supported in the system. The server of the CBMEM system supports four distinct layers: interface, access, application and database layers; each has its own responsibilities. The interface layer defines administrative and end-user interfaces. Users can access information through web browsers such as Microsoft Internet Explorer or FireFox. Administrators can control and manage information via the web browser or by

using a separate server interface. The access layer provides system security and restricted access, firewall services and system administration functions. The application layer defines various applications for collecting and managing information. These applications offer indexing, experience map edition, digital photo/video management functions, full text search, collaborative work and document management functions. The database layer consists of a primary SQL Server 2003 database and a backup database (also based on SQL Server 2003).

All experience information in the CBMEM system is centralized in a system database. Project participants may access some or all of these documents through the Internet according to their levels of access authorization. Any information/experience about the project can be obtained from and deposited into the system database only through a secure interface. The web and database servers are distributed on different computers, between which a firewall and virus scans can be built to protect the system database against intrusion.

The CBMEM system provides project category search, keyword search and expert category search. The project category and keyword search functions enable users to find the knowledge they need directly from the activities of selected projects. The system, also, provides another function in the expert category for users to find related knowledge according to domain experts. The information held by each domain expert is provided to the users seeking the domain knowledge-related experts. One of the main features of the CBMEM system is enabling users to request assistance in experience support and exchange from specific selected engineers or all engineers in the enterprise through the CAD-based Maps (CBM).

7. Case study

The following case study involves a contractor with seven years of specific experience in Taiwan construction building project. The contractor hoped to take full advantage of experience management (EM) to obtain the valued experience from participating engineers and effectively manage it for exchange and reuse in other comparable projects. The contractor, therefore, announced that all engineers would be encouraged to use the CBMEM system to apply EM to effectively manage acquired experience from participating engineers. The CBMEM system was utilized in the Taiwan construction building project to verify the proposed methodology and demonstrate the effectiveness of sharing previous experience in the construction phase. The case study was undertaken in a 8-month construction project with a schedule including approximately 2,108 activities. Moreover, all engineers were encouraged to explore and edit their own experience in the CBMEM system.

In the experience acquisition phase, senior engineers and knowledge workers undertook most work experience acquisition, since tacit experience must be acquired directly from the minds of engineers. Further, the tacit experience may be transferred into explicit experience by senior engineers and knowledge workers themselves. Most tacit experience extracted for reuse and storage may be available from the memories of experts and engineers. In a broader view, experience extraction may also include capturing knowledge from other sources such as from problem-solution descriptions, suggestions, innovation and collaboration.

In the case study, the senior engineer attempted to edit domain knowledge and experience in the "Interface management among subcontractors" learning lesson. The learning lesson experience in interface problem-facing description among subcontractors, detailed situation description and problem-solution explanations. The knowledge workers and senior

engineer initially sketched the main experience map based on the original project network-based schedule plan. After the main map was identified, the five experienced senior engineers were invited to edit their experience in the map regarding interface problem-facing. Related information/documentation was then collected and converted into a digital format. The attached files included digital documents, video and photo files. After the related attached files were digitized, the senior engineer packaged them as an experience set for submission. The knowledge workers, also, assisted the senior engineers in completing the above digitization work and conferred with them weekly to accelerate the problem solving process. The project activities continued for ten months. All engineers were required to provide their own experience regarding the tasks for which they were responsible. Each engineer created an experience map and summarized his experience and domain knowledge in the map to enable the reuse of the solution process for future projects. The experience map included: the experience topic, experience descriptions, experience diagram, experience attribute, experience packages and linkage, the solution to the problem, including related documents, photographs and videos of processes, and expert suggestions, including notes, discussions and meeting records. Experience was extracted based on every process defined as it related to the map units of a project. Domain knowledge and experience were organized according to the attributes of the map units concerned. When the submitted experience set was approved, the system illustrated the process automatically, and an assistant in the EM team attributed the knowledge and classified the experience by placing it in an appropriate position (map units in the experience map) in the system. Restated, users can locate and directly access related experience simply by clicking on these map units located on the multilevel experience maps. In the experience storage phase, all experience was centralized and stored in the central database to avoid duplicating data. All experience can be stored in the system by ensuring that data are all electronic and in a standard format for each file type such as a specific document or drawing format. All experience maps must be validated to perform well before the experience maps are published. All validation is performed in enterprise EM terms by domain experts, knowledge workers and experience map makers. Finally, the experience set is automatically backed up from the experience database to another database. The system automatically sends a message confirming the update to the appropriate users after approving and storing the experience.

A new project is started after completion of the construction project ten months earlier. A senior engineer encounters three different problems in a new project whose information is unavailable in the CBMEM System. The engineer requests suggestions and assistance from other senior engineers involved in the international project to handle the problems directly using communication services in the CBMEM system. After referring suggestions and assistance from senior engineers, the senior engineer solves the problem and shares the new solution with senior engineers. Finally, the senior engineer creates a new map unit and experience package, and submits the obtained suggestion and experience to the map unit of the experience map, linked with the related experience topics. Moreover, the experience is later updated when further feedback and another solution to the same problem are added. The updated experience set is republished in the map units of the experience map after completing the approval process, and a notice is transmitted to the authorized members.

8. Field tests and results

During the field trials, verification and validation tests were performed to evaluate the system. The verification process was proposed to determine whether the system operated

as intended while validation was performed to evaluate the system's usefulness. The verification test was conducted by checking whether the CBMEM system could perform tasks specified in the system analysis and design. The validation test involved asking selected case participants to use the system, who then provided feedback via questionnaire. The seventeen respondents included four project managers with 5 years of experience; three senior engineers with 20 years of experience; three engineers with 10 years of experience; four junior engineers with 1 year of test experience; two knowledge workers with 5 years of experience; and one Chief Knowledge Officer (CKO) with 3 years of experience. The CBMEM System was demonstrated to the respondents, who were then requested to express their opinions of the system via the questionnaire.

To evaluate system function and satisfaction with system capabilities, questionnaires were distributed, and the system users were asked to separately rate the conditions of system, system function and system capability, in comparison with the previous system using a five-point Likert scale. A 1, 3 and 5 on the Likert scale corresponded with "not useful", "moderately useful" and "very useful," respectively. Table 1 shows system evaluation result. Some comments for future improvements in the CBMEM system were also obtained from the project participants.

The functionality of system	Mean Score
Ease of acquiring experience	4.7
Reliability	4.3
Applicable to Construction Industry	4.8

The use of system	Mean Score
Ease of Use	4.8
User Interface	4.5
Over System Usefulness	4.4

The capability of system	Mean Score
Reduce Unnecessary time	4.6
Reduce Unnecessary Costs	4.4
Reduce Happening Mistake Percentage	4.6
Ease of finding related experience	4.7
Enhance Experience Updating Problems	4.3
Improve Experience Sharing Problems	4.4

Note: the mean score is calculated from respondents' feedback on fivescale questionnaire: 1(Strongly Disagree), 2, 3, 4 and 5 (Strongly Agree)

Table 1. System Evaluation Result

The use of web technology and CAD-based Maps (CBM) to share and illustrate available experience significantly enhanced the efficiency of experience management (EM) processes. Based on the user satisfaction survey, most users agreed that the CBMEM system enables engineers to exchange and share previous experience using CBM to express their ideas and

thoughts. Furthermore, the CBM provided clear and dynamic representations of experience and effectively identified CAD units with experience and knowledge related to the project. The survey revealed a user satisfaction rate of 91 %, indicating that the CBMEM system is useful for assisting engineers in editing their previous experience through the CBM approach to enhance experience acquisition and management. The experimental results showed that the CBMEM system significantly enhanced progress in the construction experience exchange progress and management. Overall, the use of CBMEM system minimized ineffective experience communication and exchange among engineers.

The significant findings of the case study are summarized as follows: (1) the total number of experience units in the system was 1,437 experience units with 129 experience packages during execution of the project; (2) most senior engineers and experts considered recording and editing their experience to be too time consuming; (3) assisting more senior engineers in transferring tacit experience can be problematic, because most senior engineers cannot type their experience by themselves, and (4) most engineers agreed that the CBM approach and CBMEM system are helpful to enabling experience sharing and management in construction projects.

9. Conclusions

This study proposed a novel and practical methodology for capturing and representing the experience and project knowledge of engineers by utilizing a CAD-based Maps (CBM) approach. Furthermore, this study developed a Construction Dynamic CAD-based Map Experience Management (CBMEM) system for engineers which provides a dynamical experience exchange and management service for the reuse of domain knowledge and experience. CBM divide experience into map units, thus forming an effective experience management tool in construction projects. Effective integration of web technology in CBMEM system has been demonstrated in the case study in the Taiwan construction building project. The CBMEM system enables engineers to exchange and share previous experience using CBM to express their ideas and experience. Furthermore, the CBMEM system enables users to request experience support and to exchange experience with selected engineers or all enterprise engineers by submitting problem descriptions through CBM. Novice engineers directly accessing the system can effectively share and exchange experience. The integration of experience management (EM) and the CBM approach appears to be a promising means of enhancing construction EM during the construction phase of a project. In summary, the CBMEM system can assist engineers in illustrating their ideas clearly and sharing their experience. Furthermore, CBMEM system and CBM approach enable users to survey and access effectively the tacit and explicit experience of previous engineers and experts in similar projects.

Although further effort is needed to update the explicit/tacit experience related to various projects, the proposed system benefits construction experience management by (1) providing an effective and efficient web-based environment for exchanging experience specifically regarding construction projects; and (2) providing users options by requesting assistance from selected engineers or all engineers in the enterprise who have relevant experience by submitting a problem description.

The use of the CBM approach in the system mainly provides assistance to help engineers illustrate their own knowledge easily and effectively. The questionnaire results indicate that the primary advantages of CBM in the system are as follows: (1) the CBM provide clear and dynamic representations, thus identifying the experience and knowledge of engineers relevant to the project, (2) the CBM clearly identify the available engineers or experience to request for experience exchange regarding the special experience and knowledge in the current project and (3) users can locate needed experience easily and effectively based on CBM illustration.

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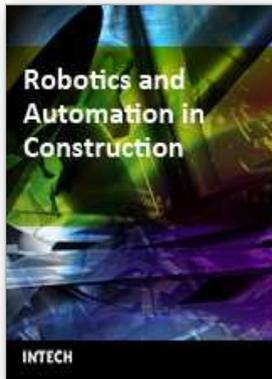
Robotics and Automation in Construction

Edited by Carlos Balaguer and Mohamed Abderrahim

This book addresses several issues related to the introduction of automaton and robotics in the construction industry in a collection of 23 chapters. The chapters are grouped in 3 main sections according to the theme or the type of technology they treat. Section I is dedicated to describe and analyse the main research challenges of Robotics and Automation in Construction (RAC). The second section consists of 12 chapters and is dedicated to the technologies and new developments employed to automate processes in the construction industry. Among these we have examples of ICT technologies used for purposes such as construction visualisation systems, added value management systems, construction materials and elements tracking using multiple IDs devices. This section also deals with Sensorial Systems and software used in the construction to improve the performances of machines such as cranes, and in improving Human-Machine Interfaces (MMI). Authors adopted Mixed and Augmented Reality in the MMI to ease the construction operations. Section III is dedicated to describe case studies of RAC and comprises 8 chapters. Among the eight chapters the section presents a robotic excavator and a semi-automated façade cleaning system. The section also presents work dedicated to enhancing the force of the workers in construction through the use of Robotic-powered exoskeletons and body joint-adapted assistive units, which allow the handling of greater loads.

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