DESIGN COLLABORATION FOR INTELLIGENT CONSTRUCTION MANAGEMENT IN MOBILIE AUGMENTED REALITY

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ABSTRACT: Building Information Modeling (BIM) is not a novel concept, but there is a growing interest in design collaboration using BIM for construction management in the AEC industry. Recently, mobile computing and augmented reality (AR) become new variations on desktop computers since the combination can create ubiquitous workspaces for practices by providing seamless interactions between the digital and physical worlds in the context of the real world. This paper introduces the a potential of MAR for design collaboration in the AEC industry by associating the concept of BIM with mobile computing and AR. Firstly, this paper reviews MAR and the concept of embodied interaction for understanding interactive experiences in collaborative environment and then illustrates the construction management process in MAR with BIM in the context of interdisciplinary collaboration. Two aspects of MAR technology are critical to the management process supports. Mobility enables seamless access to a shared workspace and team members without time and location constraints and the context-awareness in AR allows fluid interaction with shared representation immersed in context. Based on the understandings of MAR and BIM, we develop scenarios of MAR for the intelligent construction management in order to address the implications of the MAR on the future development of collaborative systems.

***Keywords**: Design Collaboration, Mobile Computing, Augmented Reality, Building Information Modeling, Construction Management Process, Context-awareness*

1. INTRODUCTION

Building Information Modeling (BIM) is not a novel concept, but there is a growing interest in design collaboration using BIM for construction management in the AEC industry. Recently, mobile computing and augmented reality (AR) are critical to collaborative supports as new variations on technologies in design collaboration. MAR is an emerging issue which emphasizes the ubiquitous paradigm and augmented visualization of the digital information. Mobile devices such as PDAs and mobile phones have realized the mobility as a personal media hub and AR augments the physical environment with the digital information. Compared to virtual reality (VR), AR can preserve existing elements of the real background with the virtual representations [1], which makes AR more valuable in the construction domain. Accordingly MAR can create ubiquitous workspaces that enable borderless interactions between the digital and physical worlds in the context of real places. Context awareness is much emphasized in MAR since it is connected to the settings in which the interaction occurs [2-4]. This research introduces the potential of MAR for intelligent construction management in the AEC industry by associating the concept of BIM with mobile computing and AR. Participants and activities in construction projects need continuous on-demand access to information where awareness of participants' context is one of the important factors to be considered in design collaboration [1]. Through MAR, mobile workers in construction sites can obtain context-aware information and perform communication in a collaborative setting where multiple parties contribute to a single shared model.

We expect that MAR would be the basis for the direction of how computing technologies could facilitate constructive participation in collaborative environments. Mobile computing enables designers to construct an embodied space without location constraints and the context-awareness in AR allows fluid interaction with a shared representation immersed in context. In the following chapter, MAR and the concept of embodied interaction will be reviewed for understanding interactive experiences in collaborative environments.

2. MOBILE AUGMENTED REALITY AND EMBODIED INTERACTION

In the line of virtuality continuum [5] , AR is characterized with the combination of the real and virtual, real time interaction, and registration in 3D [6] . Azuma et al. [7] described nine factors for the common usage of AR to be developed: Ubiquitous tracking and system portability, Ease of setup and use, Broader sensing capabilities, Interface and visualization paradigms, Proven applications, User studies and perception issues, Photorealistic and advanced rendering, AR in all senses, and Social acceptance. The above factors indicate that AR can be associated with ubiquitous computing, particularly in mobile and pervasive computing. Ishii and Ullmer's version of "ubiquitous computing" [8] includes interactive surfaces, coupling of bits and atoms, and ambient media in which computational power is seamlessly integrated into the objects and environment. Computation became embedded everywhere, thus disappeared from the view [9] . As a changing environment depending on location, user, time, and object, the focus of ubiquitous computing is contextual information; who the user is, when and where they are acting, and so on [10].

Considering the context, MAR extends the interaction beyond desktop making an embodied space on the move. Recently, mobile phones have become very smart MAR devices with a camera as a sensor [11] as well as a GPS receiver, accelerometers, a compass, and a brighten display [12]. The increasing sensitivity to settings caused by Location Based Service (LBS) leads to a concern with how interactions are embodied within those settings [10]. Grudin [13] argued that interaction moves currently to incorporating more and more of the user's world and the social setting in which the users is embedded. Various MAR applications have been developed, where the contents are changed continuously according to the context in the environment [14-17]. The related works have showed that the smart phone is a powerful platform of MAR enabling the embodied interaction throughout the physical environment [4, 18, 19] .

3. BUILDING INFORMATION MODELING IN CONSTRUCTION MANAGEMENT

This research focuses on intelligent construction management with MAR during design collaboration. Therefore, the adoption of BIM in the construction management is a crucial consideration for the collaboration. In a form of a data repository, BIM enables us to apply and maintain an integral digital representation of all construction information of the project lifecycle as well as design information in the building lifecycle [23]. BIM in the AEC industry provides the powerful visual documentation and facilitates more productively communication across different disciplines.

BIM is a process generating and managing building information [24]. While many research on BIM are associated with specific problems such as parameters and data standard, this research is concerned with supporting design collaboration for construction management by combining the concept of BIM with MAR. The capabilities of BIM may improve the effectiveness of the coordination and collaboration in MAR, thus the construction performance eventually. A building is constructed through the cooperation of several professions such as architects, structural and electrical engineers, and contractors [25]. The construction management process is varying with every change of the management goals of the AEC industry. This research presents the design management process derived from the scoping activities, purposes, and phase matrix in Gu's work [23] with a focus on collaborative activities as shown in Figure 1.

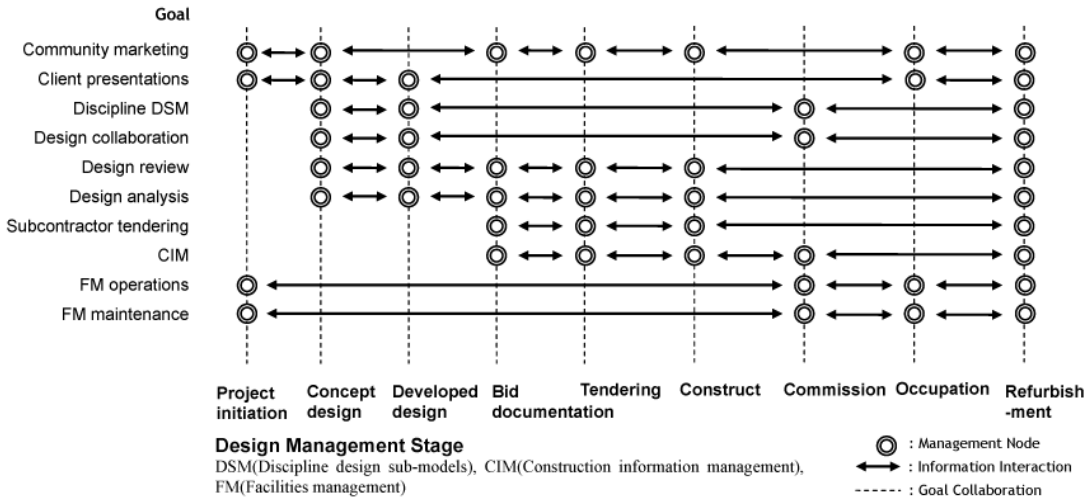

Fig. 1. Intelligent design management process in CM

Figure 1 shows the captured management goals according to each design management stage, which has a sequential process but the information interaction can be across several stages. The management goals for the design collaboration consist of Community marketing, Client presentations, Discipline design sub-models, Design collaboration, Design review, Design analysis, Subcontractor tendering, Construction Information Management (CIM), Facilities Management (FM) operations, and FM maintenance. During the construction process, management goals should consider the goal collaboration at the stage because they are all connected to each other. For example, in case of the management node of the design review goal at the construct stage, the information interaction with Tendering and Refurbishment stages will happen. In addition, the connected goals such as Community marketing and Design analysis should be considered. As seen in the above example, the proposed intelligent management process could be applied to BIM solutions and research as a guideline. For the integral support of as-built data for the construction management, the adoption of BIM is promising in the AEC industry.

4. SCENARIOS OF INTELLIGENT CONSTRUCTION MANAGEMENT IN MAR

Through the previous chapters, we have argued that MAR can facilitate the intelligent CM in easier and more intuitive ways because it provides architecture and construction practices with context-aware information as well as mobility in a ubiquitous environment. Also, the potential of BIM in the design management process was illustrated in terms of the scoping activities, purposes, and phase matrix. The information-intensive and dynamic nature of construction works requires intelligent ways to support on-site construction staff and personnel [1]. Considering the implications of MAR for the future, we present intelligent construction management scenarios to cope with the goals across different disciplines. The scenarios were developed in sequential formats corresponding to the intelligent CM process based on the context-aware scenario [26]. The context-aware scenario can grasp context-aware factors for the intelligent CM and reflect a management point of view. The context-aware factors are based on 5W1H [27-29] and situation information such as user, location, time, and activity.

The starting point of our context-aware scenarios is the management node with the goal collaboration and information interaction at the stage as shown in Figure 1. In order to develop scenarios, the context-aware factors should be configured initially. Here, we briefly present two scenarios that could facilitate the adoption of the MAR in the intelligent CM. Table 1 shows the components of the context-aware scenarios, which comprise several factors such as process, collaboration goal, participant as user, place in which events happen, time, and activity.

While the management node is connected with other goals and stages as mentioned in chapter 3, we present limited scenarios happening independently in each management node for understanding the context awareness in MAR. The scenario 1 describes an event with a goal of the design review at the design development stage and the scenario 2 represents an event with a goal of the construction information management at the construction stage.

Scenario 1: Design review at the design development stage.

Architects in a design office perform a design review with pipe engineers in a remote place. Using MAR with BIM, they can investigate augmented drawings or 3D models intuitively together. The event of the design review can happens in real-time on the move without time and location limitations. If a pipe engineer needs to show samples of materials to others, s/he can exhibit or post it through a shared mobile workspace using MAR in this stage. The design review can be coordinated in BIM at distance using MAR virtually.

Scenario 2: Construction information management at the construction stage.

A project manager in an office performs a construction information management with workers in a construction site. MAR with BIM enables workers to examine the working process effectively and to input the changing construction information in a shared database instantly. Therefore, the project manager can check and confirm the real-time working process in the office through MAR. Similarly, as soon as the project manager updates the construction information that needs to be taken by the workers, the changes in the shared database will be delivered to the construction site.

Both scenarios show the fundamental approach of the design collaboration in construction management with MAR. According to the information lifecycle of the context-aware scenarios [26], more circumstantial segmentations about the information interaction would be conducted and then more detailed scenario could be developed. For applying the scenario 1 in construction management, an intuitive mixed environment such as MRCVE [30], a review system for mechanical contracting, needs to be developed to support the design spatial comprehension. For the scenario 2, location tracking systems including GPS and WPS (WiFi Positioning System) as well as identification systems including Barcode and RFID would be initially utilized.

The contextual information based on locations, users, time, and objects could be presented through mobile devices at each stage [1]. Smart phones can transfer various contextual data like the location information using a GPS receiver, compass and accelerometer. Also, they have a sensitive camera and a bright display through which we can record and review the management information intuitively. Smart phones are recently the most potential platform for ubiquitous computing facilitating the intelligent construction management.

Table 1. The components of the context-aware scenario

Process	**Collaboration Goal**	**Participant**	**Place**	**Time**	**Activity**
Design development	Design review	**Architect,** **Engineer,** Contractor	**Office**, Any place (mobile)	**Real-time**, Asynchronous	**Reviewing**, Communicating, Modifying
Construction	Construction information management	**PM(project manager),** **Worker,** Architect, Engineer, Contractor	**Job site (Mobile)**, Office, Any place (mobile)	**Real-time**, Asynchronous	**Confirming,** Inspecting, Noticing, Reviewing, Communicating, Modifying

5. CONCLUSION

The intelligent construct management systems have been discussed eagerly during the last decade since the emergence of the notion of 4D or 5D in a computer aided design. Construction management is an information-intensive process where personnel need to access to a shared workspace and team members continuously. This research argues a potential of MAR associated with the concept of BIM for the intelligent construction management in the AEC industry. Time and cost are the most important factors in construct management. The adoption of BIM in construction management can save construction time and costs, thus support better building performance and control and MAR allows seamless interaction between the real and virtual worlds. The context-aware scenarios developed in this research play an important role in not just showing the possibility of design collaboration in MAR, but facilitating the adoption of BIM for collaborative communication across multi-disciplinary teams in construction management. This research could facilitate the adoption of MAR and BIM in the AEC industry, especially for the intelligent construction management in mobility and ubiquity with AR. The combination of MAR and BIM enables integrated visualization and distributed access to building data, thus eventually performing the intelligent construction management in multidisciplinary construction projects.

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