AR(Augmented Reality) based 3D Workspace Modeling for Quality Assessment Using As-Built On-Site Condition in Remodeling Construction Project

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Abstract –

In case of re-modeling construction project, it has various difficult situations to carrying out the projects comparing with general construction project. The re-modeling project needs to do several make decision makings which is to define the scope of utilization, extra works and O&M(operation & maintenance). Especially, the construction delays and cost-increase are caused by absence of reviews on existing building, especially structure and facilities conditions. Therefore, the objective of this study is establishment of 3D environment for augmented reality based decision-making for re-modeling project management. The scan-data based 3D as-built model is generated by using LiDAR to provide AR based 3D information. The matching process between as-built model and model of additional structure is used to review for constructability. However, the method using AR technology based on marker has a limitation on reading range. This study proposes a marker-less AR rendering based method to set 3D environment using android based NFC tag technology. As a result, this study develops analysis method of constructability by matching between existing structure and remodelled structure. Through the process to establish 3D environment, there are following results expected. First, this method provides high-quality visual information to project participants. Second, the result of this study makes project managers easily to set rapid-decision by using mobile device.

Keywords –

Augmented Reality, As-built Model, Remodeling, Human Assisted Matching

1 Introduction

1.1 Research background and purpose

According to the survey by the Korea Ministry of Land, Infrastructure and Transport, approximately 2,543,217 building are included in Deteriorated building, accounting for 36% of total in Korea[1]. Besides, the number of deteriorated building will be even larger when New Town Development project and Two Million Housing Unit Construction Plan project led by the government at the end of 1980s are reflected.

Demands on remodeling is growing, following the deterioration of physical and social function of buildings due to aging. Remodeling project is a kind of conditional construction project targeting buildings or infrastructures that are older than 20 years. Remodeling projects, which include deregulation on extension building, are aimed at preventing aging and improving functions. For the activation of remodeling, Korean public and local government implemented a number of supporting policies such as improvement of legal system, expansion of construction cost support, and publication of remodeling guidelines.

The main difference between general construction project and re-modelling project is that remodeling projects have a constraint on the construction period to ensure profitability of remodeling project owner. By a shorter construction period compare to any other projects, more rapid and accurate evaluation to construction quality based on as-built condition while carry out additional construction and facility change is very important. In design phase, 3D model has been utilized to check the feasibility of construction. In construction phase, however, even though still there are many errors occurred by worker's the review of

construction quality has regarded as trivial work.

Therefore, this study aim to purpose 3D based decision-making model for review of construction quality in construction phase on remodeling project.

1.2 Research coverage and procedure

This study has focus on construction phase on remodeling project. And we confined the target on review of construction quality on construction phase which reflect a characteristic of remodeling project. Compare to general building that construct sequentially, remodeling project site has unique as-built condition due to remained some structures. It is suitable target for 3D based improvement of construction quality check.

The process of this research is:

First, Carrying out examination the building construction supervision guideline by Ministry of Land, Infrastructure and Transport of Korean government, project management guideline of CM companies, and construction quality certification check-list by Korea remodeling association.

Second, Carrying out construction items extraction related to review of construction quality on construction phase among guidelines and check-list.

Third, Extraction of the check-items which have to evaluated relate to as-built preparation.

Forth, Analysis on how to generate an as-built environment suitable to remodeling construction.

Fifth, Suggestion of 3D based construction quality evaluation process considering characteristics of remodeling construction process.

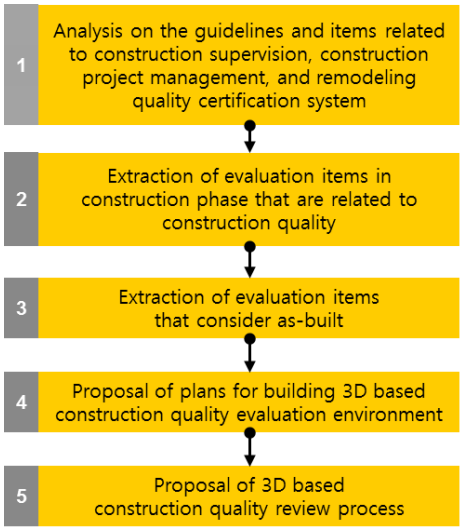

Figure 1. Flow chart of this study

2 Research Trend & Literature Review

2.1 Construction management for remodeling construction

The remodeling construction differs from general construction in that surveying and diagnosis process is accompanied. Such difference affects the entire area of construction management. Meeting construction period and cost is particularly difficult in case of remodeling project compared to other construction projects, due to the characteristics of remodeling construction management. Table 1 summarizes the characteristics of remodeling construction management.

Table 1. The characteristics of remodeling construction management

Characteristics	Considerations by characteristic
Variety of Construction plan	-Reflecting operation of existing facility to construction process -Minimize the changes by communication between contractor and owner -Minimize damages to building users
Survey and diagnosis for target building	-The extent of missing drawings Reliable result of diagnosis
Delay in decision making	-Application for approval of subcontractor has been checked by contractor, CM and project supervisor
Low productivity for construction	-Remodeling construction is carried out on as-built building environment -Many joint-section between additional parts and existing parts
Difficulty in the estimation of construction cost	-Even though remodeling project has low productivity, costs are estimated by quantity of material -Inappropriate standard unit cost

Remodeling target buildings are mostly 15 to 20 years old after the completion of construction. As such, as-built drawing is not stored in most cases. Even if it is stored, it has been usually changed for user's convenience. As a result, 2D drawing and as-built environment does not coincide in many cases. Because of this, remodeling construction causes a lot of difficulties for workers to understand works in the construction progress.

Moreover, productivity of field workers decreases in case of remodeling construction compared to general construction due to the restriction of structural frame of the existing building. For example, wall is completed after plumbing in general construction. However, in case of remodeling project field, plumbing should be implemented in a condition where there are existing walls. Hence, there are many joint rooms of pipes and material procurement also requires a lot of workforce and time. This is one of the major reasons that cause construction error by workers.

2.2 Literature Review

Yeo at el. (2004) proposed construction management method through an integration of decision making system and coloring-based planning that uses perspective drawing written in design phase. Han at el. (2009) proposed a process that can analyze feasibility of construction. Specifically, the study converted 2D drawing in 3D CAD and combined it with WBS (Work Breakdown Structure) and CBS (Cost Breakdown Structure) that reflect remodeling characteristics to build 5D CAD. Lee at el. (2010) wrote BIM model that reflects remodeling characteristics and proposed a scheme for detecting clash in design phase. However, most of these studies are focused on the evaluation in design phase, rather than post-construction evaluation. The researches have limitation in that it cannot accurately propose as-built environment of remodeling.

Table 2. Previous literature on remodeling evaluation method

Researcher	Contents
Yeo at el. (2004)	Proposed ways to improve construction management (integration of decision making system and establishment of coloring-based planning that uses perspective drawing written in design phase)
Han at el. (2009)	Analyzed feasibility of construction through conversion of 2D drawing to 3D CAD
Lee at el. (2010)	Proposed clash detection scheme that reflects the characteristics of remodeling by distinguishing between as-is, demolition, retention, and extension rooms when writing BIM model

Samir El-Omari & Osama Moselhi (2008) proposed a 3D modeling plan by integrating images that were collected from LADAR and digital camera. Pingbo Tanga at el. (2010) argued that as-built generation method through laser scanner shows highest accuracy and reviewed techniques that are related to automatic establishment of BIM model through laser scanner. Ankit Bhatla at el. (2012) proposed a way of building 3D model by using handheld digital camera that has high portability. However, there is scarce study that involves data acquisition or modelling scheme that reflects the characteristics of remodeling.

Table 3. Previous literature on as-built model generation method

Researcher	Contents
Samir El-Omari & Osama Moselhi (2008)	3D modeling by combining 3D image collected from 3D laser scanning (LADAR) and images collected from digital camera
Pingbo Tanga at el. (2010)	Review on technologies related to automatic generation of BIM by using point cloud data obtained from laser scanner
Ankit Bhatla at el. (2012)	3D modeling based on pictures taken with handheld digital camera

The most important thing in remodeling construction is managing construction phase based on as-built that was accurately understood. The previous researches mentioned in Table 3 focused on how to generate 3D environment similar to the real-world. However, research on the acquisition plan for as-built model that reflects the characteristics of remodeling or usage plans based on as-built environment is insufficient as of now.

3 Review of construction quality

3.1 Constructability

Although review on constructability covers entire phase of a project, the term is mainly used to indicate

understanding of the possibility of construction in phase prior to the construction. CII (Construction Industry Institute) defines constructability as "use knowledge and experience on construction regarding planning, design, procurement, and on-site work as much as possible for the purpose of achieving overall business goal" [8]. Among the factors that affect constructability, detection of clash with existing building through on-site inspection is carefully implemented based on the existing drawing that was performed in the design phase. Meanwhile, response to the construction error that occur during construction or inference control are managed by workers.

Performance of selective construction evaluation through sample selection and complexity of detection reporting process despite the restriction on the construction duration causes insufficiency of construction quality review. Hence, there is a rise in technical demands in construction phase for simpler provision of information including on-site arrangement plan, appropriate construction method, construction sequence, and on-site interference check.

3.2 Review items of construction quality through on-site check

In this research, we checked into the building construction supervision guideline by Ministry of Land, Infrastructure and Transport of Korean government, project management guideline of CM companies, and construction quality certification check-list by Korea remodeling association.

According to the building construction supervision guideline by Ministry of Land, Infrastructure and Transport of Korean government, construction supervisor has an obligation of preventing unnecessary argument on site by proposing objective and accurate inspection result to contractor. Project management guideline of CM companies d that construction project manager has an obligation of establishing guideline for inspection that reflects the characteristics of the site (inspection process, period of each work, frequency, and check-list) before implementing the inspection.

Among the evaluation items including common work, steel-frame work, and concrete placement in the construction quality certification check-list by the Korea remodeling association, items that evaluate the quality through field check are summarized in Table 4 [9]. Field check items have common feature of making evaluation based on the situation on site, instead of using regulation, guideline, or relevant documents. More accurate understanding about the on-site situation can increase the reliability of the quality evaluation. Hence, it is very important to accurately understand the as-built environment. Providing as-built environment and construction management guideline to users in 3D can be useful for managing the construction quality based on on-site check as it enhances users' intuitiveness.

Table 4. Construction management items requiring on-site check

Work type	Check-items
Common work	Whether the structural frames are drawn or not Defect status and Method of repair on structural frames Records of design, construction and maintenance
Steel-frame work	Evaluation of shop-drawing and construction plan Whether existing construction errors are reflected to steel work or not Degree of error Appropriateness of the steel-frame design Anchor bolt spacing
Concrete placement	Preparations before concrete placement Measure to reinforcement of adhesive power to existing concrete Making the sample concrete cylinder & examination Status of joint surface condition of existing frame(ex. column, slab and wall) Checking the difference of canter line between foundation and columns

4 Review of construction quality that reflects as-built environment

4.1 Generation of as-built model through laser scanning

This study attempts to generate as-built model using laser scanner. Lee (2014) applied laser scanning to indoor environment and proposed optimal point accuracy for generating as-built model and computational reverse engineering (CRE) process that is optimized for remodeling.

Below describes the process of establishing as-built model through laser scanner.

1. Selection of location and number of scanning
2. Installation of scanner (trembling prevention and levelness check)
3. Scanning
4. Merge of the acquired point cloud data
5. Correction of errors that occurred during merging
6. Completion of the modelling

Using this process, Lee scanned ten rooms that have diverse sizes from 540 mm x 249.5 mm x 266 mm (W x B x H) to 760 mm x 1186.6 mm x 264 mm. Remodeling has a feature of having existing structures such as crossbeam, column, and equipment. Hence, it is important to make sure not to create blind spot by appropriately selecting location, angle, and number of scanning when building plans for laser scanning. In Lee's experiment, average error was ±1 mm in case of indoor scanning using laser scanner. Hence, we believed that establishment of as-built model that has high accuracy can be achieved by using laser scanning.

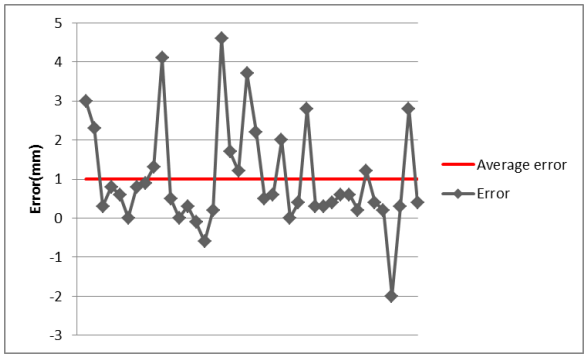

Figure 2 Error graph in case of 20cm per 100m accuracy [10]

Moreover, scanning with accuracy of 20cm per 100m, 10cm per 100m, and 5cm per 100m produced average scanning time of 135.775sec, 358.750sec, and 2145.425sec, respectively. Hence, we decided that scanning with 20cm point per 100m accuracy is most efficient considering the data acquisition time and its relationship with error. Finally, condition for tearing down and additional construction differ by rooms in case of remodeling. Review on the construction quality should match the characteristics of each room. Hence, it is efficient to model by room unit in case of as-built model as well.

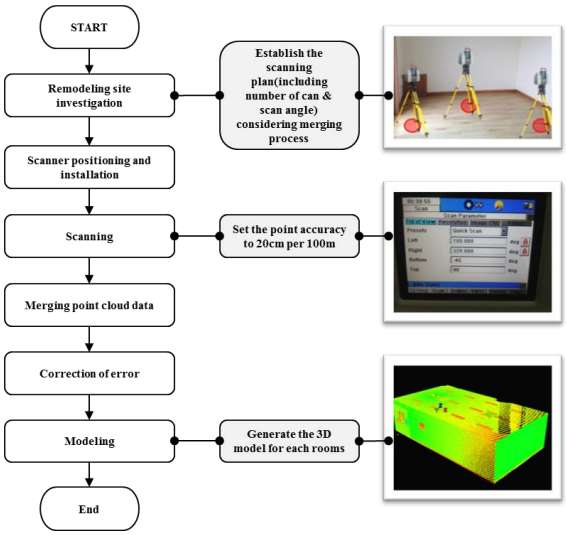

Figure 3. Laser Scanning process that reflects the remodeling characteristics [10]

4.2 Review of construction quality based on as-built

This study attempts to establish as-built model by using point cloud data that were collected from 3D image acquisition device (laser scanner) and propose process for construction quality evaluation that considers as-built.

Remodeling construction process considering as-built that this study proposes is largely composed of three phases. First is to establish as-built model through laser scanner that can accurately express the field and model on the additionally building structures and MEP. Second is to write detection guideline based on as-built. Third is to evaluate the construction quality based on the detection guideline that was written by considering as-built.

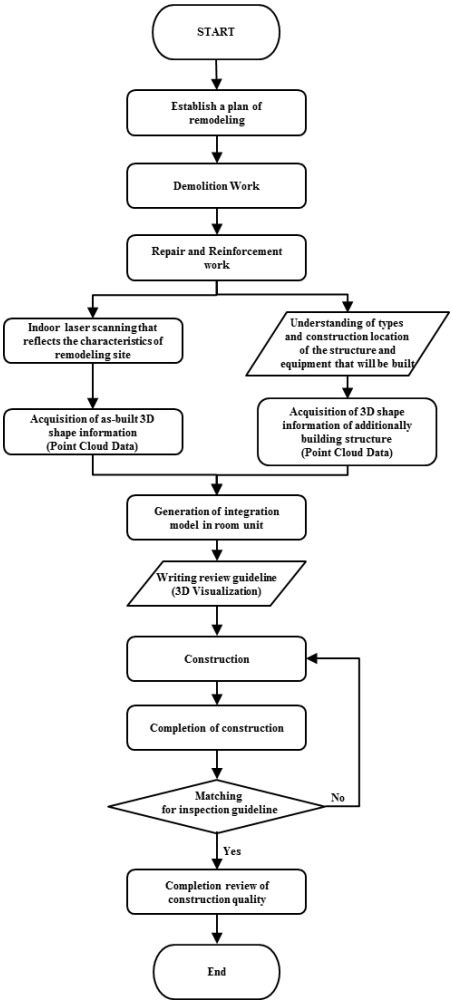

Figure 4. Remodeling construction process considering as-built

5 3D environment for review of construction quality

augmented reality technology.

Augmented reality is largely divided into marker based AR and marker-less AR according to the scheme of implementing model. Marker-less AR is often called as natural feature tracking-based AR.

In general, black and white or colour pattern image is inserted to marker form to be used as a marker in mobile augmented reality industry. However, construction project including remodeling has extensive size and complicated process than other areas. Hence, AR display system that uses image marker form is not appropriate. Moreover, image pattern scheme has a shortcoming in that it can simply read previously input information only.

Hence, this study attempts to use NFC tag technology for mobile-based AR implementation. NFC technology, which is one of the short-range wireless technologies, does not require separate reader as chip is built in mobile devices (Smartphone and tablet PC). As NFC is free to read and write, correction of information inside chip is easy. Smooth mutual communication can be made through this. Moreover, NFC tag has advantage of excellent portability due to its small size and light weight.

Different from new construction, each room has different condition in case of remodeling construction. Hence, information including as-built model, MEP model, construction plan in each phase, construction specification, and detection guideline is stored by room unit. Through this, workers or supervisor can easily sort out the information on the room that they have to work only out of the huge amount of information

Hence, users tag NFC tag with mobile device they are carrying and render necessary information among the registered information on display. User can compare model or information expressed in augmented reality and reality at a glance by matching images in reality world and visual coordinate through 3D rotation of the rendered model.

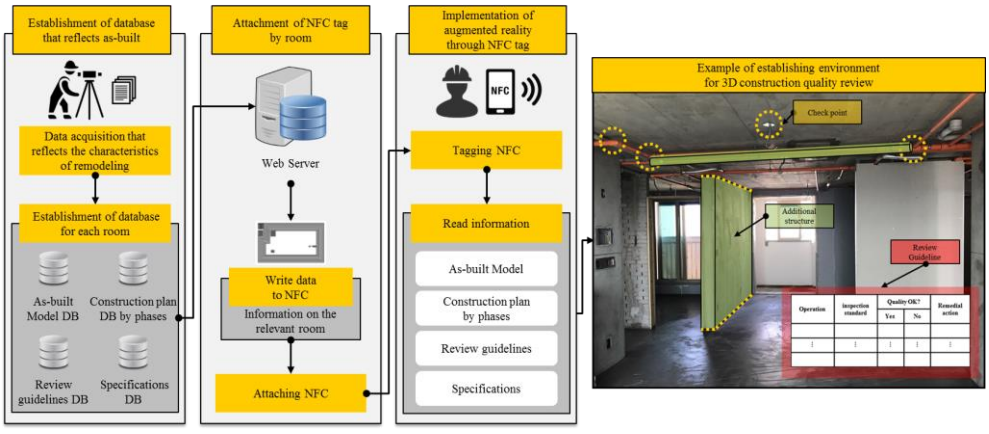

Figure 5. Establishment of 3D environment for construction quality review

5.1 Process of augmented reality-based construction quality review

This study proposes establishment of as-built model in remodeling project and visualization of construction plan, specification, and detection guideline phase by phase using augmented reality. Based on the suggested contents, we derived plans for improving remodeling process.

In remodeling construction phase, field workers and quality manager are provided with necessary information that are visualized in 3D. Information can be obtained through augmented reality, including types and quantity of materials required for the preparation of construction, construction plan by each phase, construction specification, model at the time of construction completion, and guideline for construction quality review that was obtained from as-built model-based construction simulation. In particular, use of augmented reality enables comparison of reality and information at a glance. Hence, user can simultaneously proceed on working and reviewing/testing of the work outcomes.

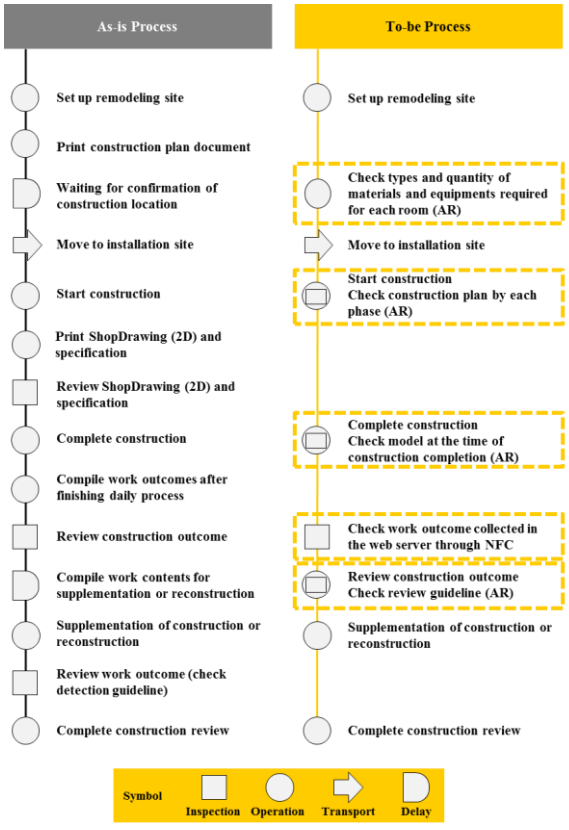

Figure 6. Augmented reality based review of construction quality process chart

6 Conclusion

The purpose of this study is to provide 3D-based decision making environment for construction quality evaluation in the construction phase of remodeling project. To propose better evaluation method, we investigate evaluation items and method of the quality certification of the Korea Remodeling Association. We decide that accurate understanding of as-built model is important for the evaluation of remodeling construction quality.

As construction plan differs by each room in case of remodeling, we proposed a plan that provides 3D visualized information through augmented reality by storing information in NFC tag by room unit. We suggest potential process improvement plan that is expected when contents proposed in this study are reflected and compared it with the existing process.

In this study, we can accurately understand as-built environment by reflecting the characteristics of remodeling and write detection guideline that fits the properties of the project. As on-site construction condition can be compared at a glance through the visualized detection guideline, we could achieve more accurate and prompt construction quality test.

This study has significance in that it helps accurate understanding of as-built model and that it proposes construction quality evaluation process in construction phase based on as-built. We expect that our study can be used as fundamental research for future studies that are related to management of remodeling construction site, quality improvement, and quality evaluation.

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