A Framework for Camera Planning in Construction Site using 4D BIM and VPL

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Abstract –

With the recent rapid advancement of vision technologies, recognized research widely applies to resolve the construction industry's remaining problem as known quality, cost, time, and safety. However, there are few studies on how to place visual devices for effectively collecting images/videos on construction activities. This study proposes a framework for camera planning using 4D BIM and visual programming language (VPL) that considers construction's nature. A case study was also implemented, whose results reveal the proposed method's enormous potential in camera positioning, simulation, and schedule installation.

Keywords –

4D BIM; Camera planning; Visual data; Visual Programming Language

1 Introduction

Currently, construction managers still face the provision of quality, safety, time, and cost reduction projects. For these purposes, researchers have studied many different approaches aimed at achieving a higher level of automation throughout the project cycle. Computer vision technology (CST) has been one of the past decade's main directions, which has proven to be cost-effective, accurate, and easy to implement. The utilization of CST reveals in four main categories including (1) construction progress monitoring [1–3] , (2) quality control [4–6], (3) logistic (material, equipment,.etc.) [3,7,8], (4) safety management [9–12].

How to get visual data has become one of the critical and challenging questions for CST's success in the construction industry. Accordingly, it should be considered from the planning stage. First, it is the choice of data collection equipment that fits the job's needs. Recent innovations include making portable cameras such as smartphones, 360-degree camera devices, and UAVs accessible. These camera systems have led to an unparalleled rise in the number of images and videos routinely taken at construction sites [13]. Besides, fixed cameras still account for a large part of their usage through cost and real-time monitoring. The planner needs to choose which camera systems adapts to the condition of the project. For instance, the identification and tracking of construction-related workers' progress require a fixed camera for real-time monitoring. Therein, a high-resolution camera as a 360-degree camera is necessary to detect the wall's crack in the inspection process. Second, schedule planning is needed regarding the placement of installing the camera. Choosing locations with progress in mind will avoid unnecessary reinstallation for cameras and other monitoring equipment.

In the field of construction, Albahri [14] attempted to find an optimal positioning of cameras in indoor buildings using Building Information Modeling (BIM). Camera placement optimization also studies by Kim in the construction project. However, these studies have omission the changeable of constraints due to scheduling during construction progress. It leads that even project planner has camera placement plan, but they do not know when they can install during construction progress.

Building information modeling (BIM) has become an essential step to the digital management of construction projects, helping facility and construction managers with decision making [15]. 3D BIM can automatically provide the geometrical and nongeometrical attributes of these elements to be considered in the optimization camera placement process. Moreover, when integrating with scheduling into 3D model, as known, 4D BIM can provide visual the change of constraints.

This paper aims to propose a framework for camera installation planning that applying 4D BIM and Visual Programming Language (VPL). The proposed framework consists of four steps as "predefine camera parameter," "Camera Placement Optimization," "Installation Plan," "Visualization." The remaining of this work includes the following. Section 2 reviews the related study; section 3 defines the objective of research; then, the proposed framework is explained in section 4. A case study is implemented for evaluation following section 5. Finally, the author summarizes the method and discussion.

2 Literature Review

2.1 Camera Placement Problem in Construction management

Visual data acquisition is an essential first step in applying computer vision in the construction site. Depending on the quality of the data collection, the results of image processing-based may be the difference. Therefore, useful guidance for camera installation is crucial to the success of the subsequent adopt computer vision algorithm in the construction industry [1].

In practice, camera positioning is generally performed manually, relying on experts' expertise or observations [15]. Manual processes make camera placement time-consuming and cost-effective. Several researchers have made efforts to solve the Art Gallery Problem (AGP) [16]. In the field of construction, various researches put effort into solving this issue with a different objective. Kim [17] proposed the hybrid simulation-optimization of camera placement on construction job sites. Contributes in (1) interviewing expert to the identification of critical concern when installing fixed cameras, (2) developing a systematic framework for camera placement, and (3) visualization and quantification of the camera system network. While Yang [18] applied dynamic programming and developed general algorithms to the camera coverage and cost problems.

While the previous works showed promising results in seeking optimal camera configurations, there are still elements remaining concern. Camera type selection relies on the purpose of the visual data needed. Furthermore, the camera installation plans need to determine related to the progress of the project.

2.2 BIM and Visual Languages

Eastman [19] described BIM as a digital representation of the building process that simplifies interacting and exchanging information within a digital structure. The BIM model application was applied to a wide range of construction aspects, including improved safety, efficiency in the management of quality, and the optimization of project times and costs. In the indoor buildings, Albahri [15], for example, attempted to find an optimal camera positioning via BIM. Visual Programming Languages support utilization BIM easily. It adopted in different studies recently, such as KBIM code [20] or Khan [21], uses BIM to optimize fire extinguishing installations.

After conducting a review of current studies, this paper aims to develop a camera installation planning framework using 4D BIM and VPL that takes into account the characteristics of the construction industry.

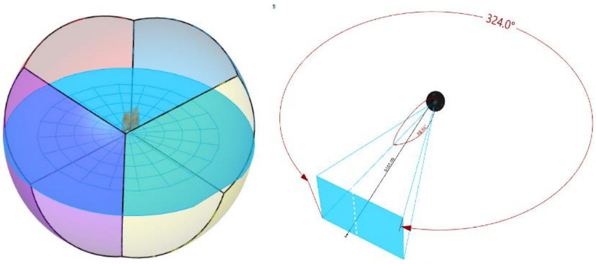
3 Propose Framework

The goal of this study is to (1) select the type of camera which is fixed or portable system according to task intended in the schedule, (2) deliver the amount and position of the camera for the specific working space (following scheduling), (3) integrate the camera installation plan into BIM 4D, and (4) simulate the view of the camera in BIM.

Following the objective, the author proposes the framework for camera planning in construction, as illustrated in Figure **2**. It comprises four steps that are "predefine camera parameter," "Camera Placement Optimization," "Installation Plan," "Visualization."

3.1 Step 1- Predefine Camera Parameter

4D BIM extracts the working space for each activity and schedules information. The planner should pick the camera style proper to the activity information, based on the visual data's intent. In this article, the author selects two common camera forms as a (1) fixed camera, which hangs on the wall for surveillance to detect and monitor much of the manual construction operation. And (2) portable camera, for easy inspection of quality. In our research, we choose the 360-degree camera representing for portable system.



(a) View of 360 camera

(b) view of fixed camera

Figure 1. The view of the camera

After choosing the type of camera, the need to consider is to determine the camera's coverage, from which can calculate the number of cameras needed for an activity working area. Figure 1 shows the working area of 360-degree cameras and fixed cameras.

3.2 Step 2- Camera Placement Optimization Module (CPOM)

In step 2, the CPOM converts mathematical information to computer-readable data using visual programming tools. First, this module includes determining the number of cameras and these placements. The following formulas are utilized for calculation.

(1) The number of the camera (N) using for specific

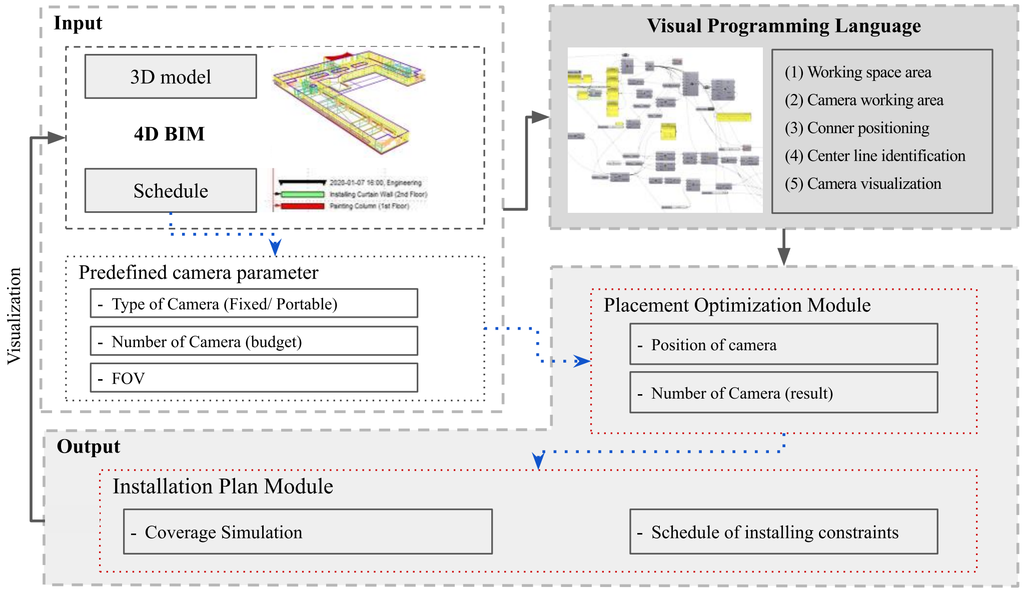


Figure 2. The framework for camera installation planning in construction

activity working area (i).

$$N_i = \frac{\text{volume of activity working area}}{\text{Camera working area}}$$

The camera position is represented by the values of X, Y, and Z coordinates. The (X, Y) variable is coordinated in the 2D working area, while Z is the camera's height.

(2) $0 \leq Z \leq H$ (H- the height of the wall)

The author analyzes two kinds of cameras (fixed and portable cameras) to assess the camera location. Following O'Rourke's theory [16], the fixed cameras were placed in the corner of the activity working area. For the portable camera, the software uses VORONOI grid logic to create the optimized centerline working field. Then the place is set to lay at the centerline.

3.3 Step 3- Installation Plan

After completing step 2, the planner made a final inspection by simulating camera network activity. It helps planners visually predict the monitoring area. This simulation also allows planners to adjust camera position and visibility. Due to construction nature, the construction process has not completed a number of potential camera installation locations identified in step 2. For example, the potential wall that has camera placement is construction. Therefore, the need to schedule cameras installation according to activity progress. Camera planning can also be beneficial in considering moving completed work areas to operating areas. It contributes to cost savings for contractors and still perform best.

3.4 Step 4- Visualization

Finally, the camera position and installation plan can be visualized in 4D BIM. The information can be communicated with related work crews (safety manager, supervisor) in a construction job site in various channels, including mobile devices.

4 Case study

To validate the proposed framework's applicability, the authors performed a case study planning for sample building's interior work. In the case study, the progress of constructing three rooms is evaluated, shown in Figure 3. The initial stage of the camera plan is conducting in Figure 4. The planners (1) insert the 3D model and room space volume box. Then, they (2) choose the camera type for usage purposes. For each type of camera, the permeameter inputs are the difference. The 360-degree camera can be adjusted by the height from the ground, range of view. With the fixed camera, the planner can choose the Conner position, height from the ground, rotation angle, and the working window. After visual programming analyzing, the results are illustrated in Figure 6.

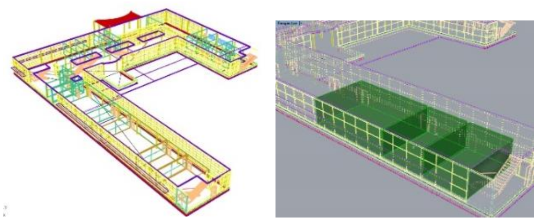


Figure 3. The case study project

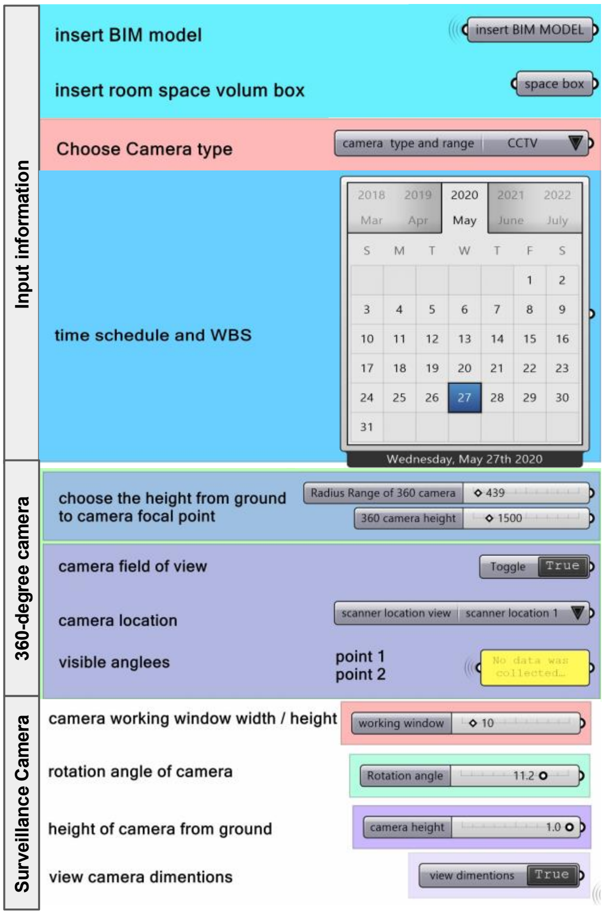


Figure 4. Input information

Figure 6(a) shows the results of 360-degree camera placement. Therein, the blue range is the visible view, and the red area is block view in Figure 5, and 6(b) describes the camera view simulation. The schedule of camera planning also presents in Figure 4 as the day installation.

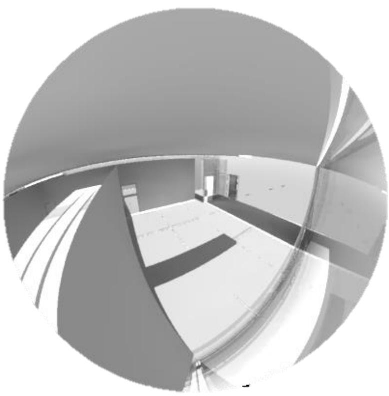


Figure 5. Fixed camera simulation

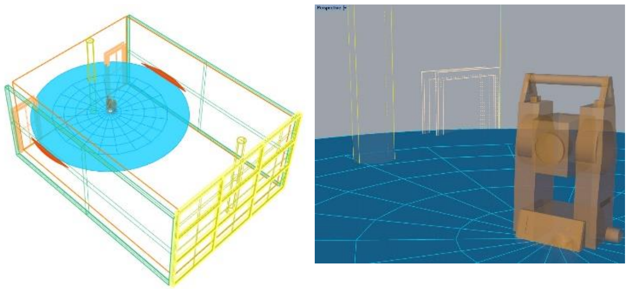


Figure 6. 360-degree camera coverage result

5 Discussion and conclusion

Establishing camera installation planning to collect visual data based on dynamic construction site requires significant manual and labor-intensive tasks. Most construction provides original installation plans without considering the progress. The study proposed a framework for camera installation planning using 4D BIM and VPL. To validate the proposed framework's applicability, the case study was conducted considering the project's construction planning. The results showed camera selection after task purpose. The system also visualizes the camera plan in 4D BIM, simulating camera view. Proper camera placement is expected to collect adequate video/image data quality and successfully support vision-based monitoring tasks.

Several research challenges need improvement. For example, the study considers the level of detail following the weekly or monthly schedule. Moreover, the case study uses two task monitoring and quality inspection. Future studies need to examine activity-based visual data. Moreover, the delay is a critical issue when implementing the construction phase. It may affect camera installation plans.

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