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Method to Manage Building Construction Safety Using Photogrammetry

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Abstract: Various facilities such as safety railings and safety nets are used to prevent safety accidents at construction sites. As construction progresses, additional safety facilities may need to be installed or existing facilities may be damaged, so continuous management is required. To manage safety facilities, it is best for safety managers to check them directly, but there are parts of the site that cannot be checked directly. This study proposes a method to identify the installation status of safety facilities using photogrammetry. A drone is used to take photos and a three-dimensional model is created using these photos. By reviewing the implemented model to determine whether safety facilities are installed, it is possible to secure the safety of construction sites.

Key words: construction safety, photogrammetry, drone, digital twin

1. INTRODUCTION

Safety accidents in the construction industry account for a high proportion of all industries and are very costly. According to the 2021 Industrial Accident Status Analysis[1], the number of occupational accidents in the construction industry was 11.396 out of all industries (26,888), accounting for about 42.4%. Within the construction industry, workplaces with less than 5 employees accounted for 11,396 accidents (45.8% of the construction industry) and 191 fatalities, accounting for 23.1% of the total, out of all industries (828).

According to the Heinrichs Theory of Accident Occurrence (also known as the Domino Theory)[2], accidents can be prevented by eliminating unsafe behaviors or unsafe conditions rather than birth defects or personal flaws. Construction site managers take various measures to prevent accidents, such as safety training and safety facilities. However, since construction sites are built over time and site conditions are constantly changing, unsafe conditions can occur continuously. Eliminating unsafe conditions If you can continuously manage the changing conditions of a construction site, you have the opportunity to reduce the occurrence of safety accidents.

Using photos, videos, or 3D scans of the changing site to create a 3D model of the actual site can help identify unsafe conditions when compared to 2D drawings or CAD models. In this study, we propose to implement a 3D model of a building under construction by photographing it with a drone and utilize it to perform safety management.

2. DIGITAL TWIN

2.1. Digital twin and CAD (computer aided design)

A digital twin is an object (object, space, environment, process, procedure, etc.) that exists in reality that is represented as a digital data model on a computer so that it can be replicated and react to each

other in real time [3]. It is possible to verify the situation that may occur in the real space in advance through various simulations (simulations) in the real space.

Digital technology can be utilized in various ways in the field of architecture. By comparing the actual appearance of a construction site using a digital twin with a virtual reality model created in CAD, it is possible to identify safety management targets and risk factors.

Most 3D CAD models only show the structure and the completed state, which is necessary for construction progress, but insufficient for safety management. Information on safety facilities to prevent safety accidents and temporary facilities to support construction are also implemented in virtual reality, and it is possible to determine the risk of safety accidents by comparing and analyzing information extracted from on-site photos or videos.

Information for creating a digital twin model can easily be used to check the progress of internal and external construction sites with drones or 3D scanners, and safety facilities, loaded materials, and temporary facilities that are not displayed in 3D CAD models can also be identified.

2.2. Digital twin and construction safety

Simulating the virtual occurrence of safety incidents in a digital twin can help prevent real-world accidents. It is almost impossible to experiment or simulate safety accidents on a real construction site. In the virtual reality of the same digital twin as the site, you can simulate the loading of materials, the layout of pathways, and the movement of workers to prevent safety accidents on the actual site by generating safety accidents and analyzing the causes.

Virtual simulation can also be used for safety education at construction sites, as it can analyze the process of safety accidents, follow-up measures, countermeasures, and causes with little time and cost [4].

To utilize a digital twin, a 3D model of the building under construction is required. The interior and exterior can be photographed using a drone[5] or 3D scanner and converted into a 3D model using photos or point cloud data.

Photographs taken by drones are converted into 3D models using photogrammetry software, such as Pix4D Mapper [6], which is used in this study. Pix4D Mapper can synthesize photos with geolocation information to create a 3D model. In this way, exterior and interior shots of the construction site can be used to understand the progress of the site and identify unsafe conditions. In addition, safety accidents can be prevented by removing unsafe elements and simulating them using digital twins and extended reality models.

2.3. Safety management model using digital twin

A digital twin model for safety management at construction sites is composed of the following.

(1) 3D modeling implementation technology

3D modeling technology is required for the construction site progress using photos and videos. At the construction site, video data is acquired using drones or 3D scanners, and photogrammetry software such as Pix4D Mapper is used to implement the photos into 3D models. In this way, an efficient way to capture the outside and inside of construction sites and implement 3D models is needed.

(2) Construction site digital twin implementation

A digital twin that fuses a virtual reality model that models the construction process of a construction site with the actual site appearance[7] should be implemented. Virtual reality or augmented reality models can be built using 2D drawings or 3D CAD models [8], and extended reality models can be developed using Unity 3D and UnReal game engines [9].

It is also necessary to develop a safety management system that can simulate risk factors and prevent safety accidents according to the movement of construction site workers. In the virtual reality model of the digital twin, safety accidents can be simulated, and preventive measures can be proposed for follow-up and accident prevention.

3. APPLICATION OF SAFETY MANGEMENT MODEL

3.1. Modeling target

The target of 3D modeling is a building that has been abandoned due to long-term suspension of construction. It is located in Aewol-eup, Jeju-si, and was constructed in 2000 as a type 2 neighborhood living facility, but construction was suspended in 2004.

3.2. Photographing with a drone

The drone was used to capture the entire front, back, left and right sides of the building from about 30 meters above the floor level of the building, facing the center of the building as shown in Figure 1. The drone model used was a DJI Mavic 3, which was manually adjusted, and a total of 76 photos were taken and used for modeling.

Figure 1. Photos taken by a drone

3.3. 3D model conversion

Pix4D Mapper was used to convert the photos into a three-dimensional model. Figure 2 shows the arrangement of the captured photos. The drone was rotated around the building to capture all parts of the exterior of the building, although the photos were not uniformly spaced by manually taking photos around the perimeter of the target. When the photos are imported into Pix4D, they are automatically geolocated and placed, and the user can adjust the position on the screen to see where the photos were taken. Once converted to a 3D model, the photos that generated each coordinate can also be reviewed and modified.

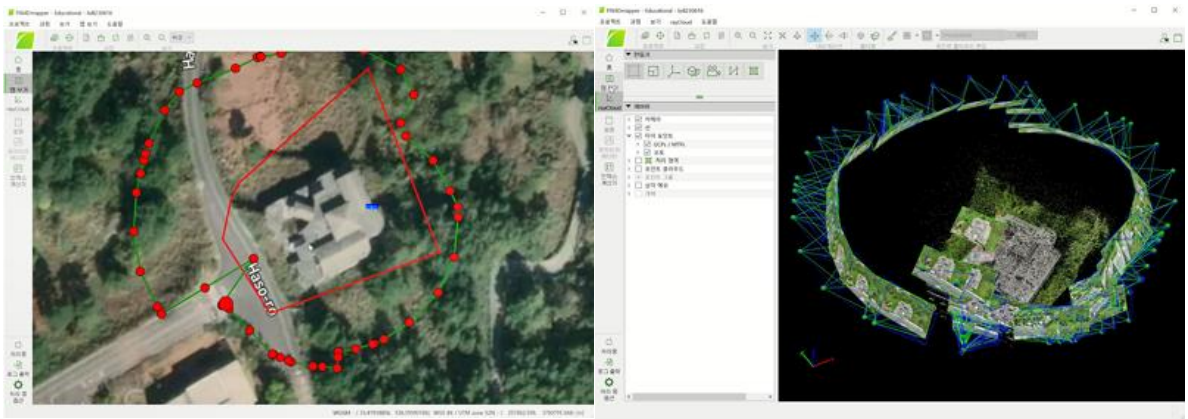

Figure 2. Layout of photos in Pix4d Mapper

Figure 3 shows the converted 3D model in Pix4D, and the current colors are also represented in the photo. Since the building is not under construction, it has been converted to a green color due to the presence of trees around it.

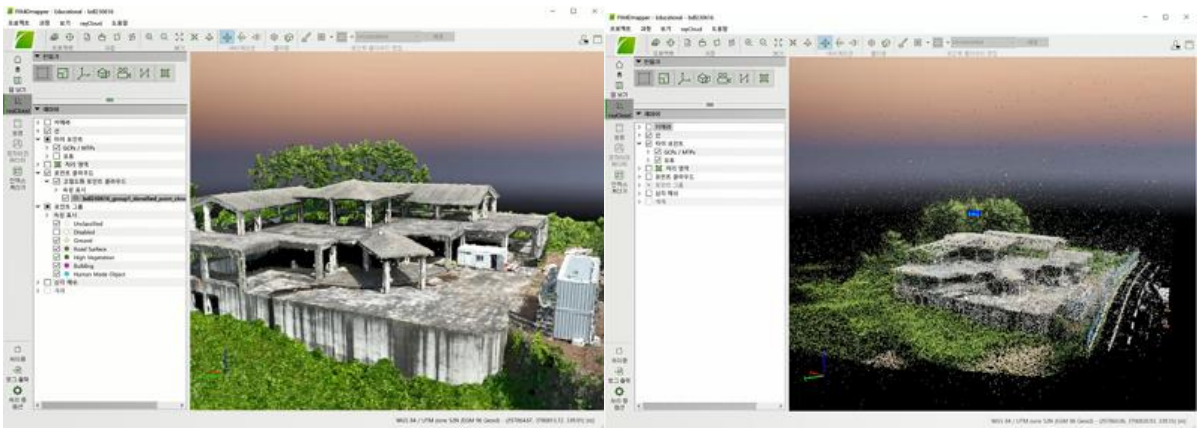

Figure 3. 3D model created by Pix4d Mapper

3.4. Cross-sectional analysis

SketchUp can import and edit files in OBJ format. You can remove unnecessary parts of the building and review the cross-section. Since only the exterior of the building was photographed by the drone, the roof, columns, and exposed floor are visible, but the interior, which is not photographed, appears as an empty space.

Figure 4 shows a cross-section, showing the walls and floor. Since the construction of this building has been suspended, the temporary facilities for construction have been almost removed except for the field office and warehouse. In order to proceed with the subsequent construction, safety facilities must be installed. By analyzing the cross-section, you can see where there is a risk of falling on the high floors, and you can see that safety railings should be installed to prevent falls.

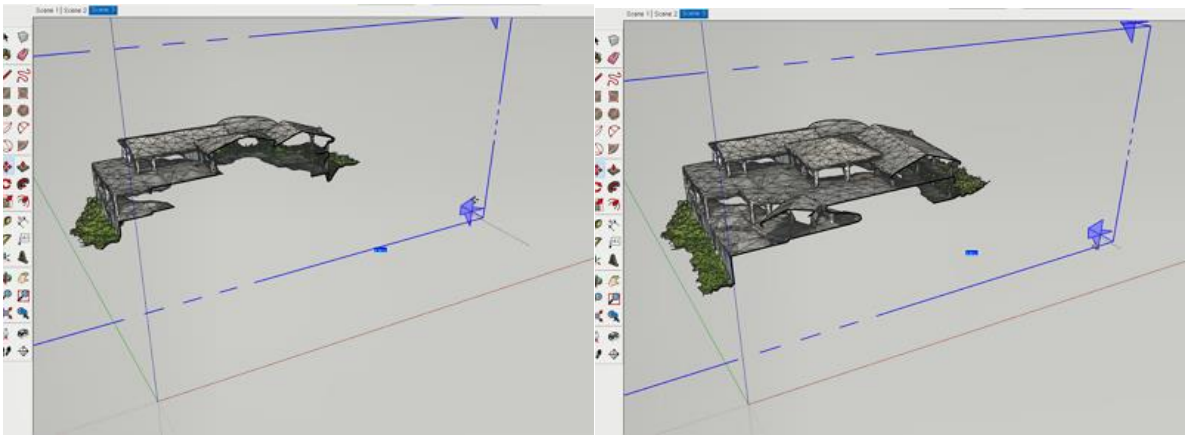

Figure 4. Cross-section analysis in SketchUp

4. CONCLUSTIONS

Architecture is the process of creating a design for a building on paper or in a virtual space and then constructing it on the ground. Digital twin is the most suitable technology for construction because it connects virtual space and reality. In this study, we propose a safety management plan for construction sites by implementing a virtual model that is part of digital twin technology.

Photographs taken by drones have location information and can be used to create 3D models. Pix4D, a software that uses photogrammetry technology, was used to build a 3D model and converted to a file format that can be viewed in SketchUp.

In SketchUp, the 3D model can be edited and the model created from the drone photos can be examined from different perspectives. In particular, through cross-sectional analysis, the corners of the building can be checked, and in the case of a building under construction, safety facilities can be reviewed.

By supplementing the 3D model analysis method in the future, it is possible to identify and respond to risk factors that cause safety accidents and major disasters at construction sites using digital twins in advance, and save costs and time for responding to safety accidents by applying construction site safety accident simulation. In addition, photos of buildings under construction and realized 3D models will help to manage construction progress and secure construction quality.

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