A DESIGN OF LANDSCAPE TELE-SIMULATION SYSTEM USING UNMANNED AERIAL VEHICLE AND AUGMENTED REALITY

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1. Introduction

As an industry, which spends a lot of money and time, it is very difficult for the construction industry to change the design or to correct some errors after construction begins. It can be seen that once there is any flaw in the design process, many irreparable losses will be caused after the real project begins. Augmented Reality (AR) can effectively improve this kind of situation. By combining the virtual building model (design) with the actual target construction site, the AR image can be used to preview the landscape simulation scene on the project site, thereby reducing potential losses and improving efficiency.

Prior to the system designed in this paper, there has been a precedent for combining AR with the construction industry. There are also some practical cases, in which AR and Unmanned Aerial Vehicle (UAV) development technologies are combined. Stefanie et al. (2014) used AR to render real-time virtual 3D building models. Wang et al. (2015) used farm UAVs to help farmers analyse the status and provided a more efficient cultivation program where uses GPS-assisted AR systems for positioning. Due to the experience of UAV aircraft operators was limited to 2D displays, Ji et al. (2017) reinforced it with augmented reality technology. Jacopo et al. (2017) constructed a Visuo-Haptic Augmented Reality system with additional visual tactile sensors to help operators remotely detect nuclear radiation areas.

Although the combination of AR and construction industry has greatly improved the previous architectural design process, there are still many problems. Since the screen of the digital device limits the AR images, it will reduce the number of people participating in the review and the review-able angle.

In view of the above deficiencies, this paper proposes an outdoor landscape simulating review system that combines AR and UAV development technologies with telecommunication technology. The system uses the real-time video stream returned by the UAV camera to generate AR images on multiple devices, which expands the scope of the simulation review and increases the number of people involved in the review process, further improving the efficiency of the entire process.

In this paper, to expand the user experience in the outdoor landscape review and the efficiency of the whole process, a prototype system of landscape tele-simulation using UAV and AR based is designed. Firstly, the system will achieve the outdoor landscape simulation function from multi-angle, which is limited by device's screen before. Secondly, it transmits the simulated scene to the off-site device through telecommunications technology, allowing more people to participate in the landscape review at the same time, which improves the efficiency of the review process. This paper mainly presents the design flow of the system, the functional realization methods of each part, the outdoor verification of each module, and the expected function of the system after its completion.

2. Proposed Method

2.1. SUMMARY

In the intended design, the technology used in the system can be divided into three parts roughly. It utilizes:

- **Simultaneous Localization and Mapping (SLAM) based marker-less AR technology:** Real-time rendering of virtual building models in real-world environment
- **UAV developing technology:** to review designs from a number of manpower inaccessible perspectives
- **Tele-communications technology**: for real-time data transmission of AR images to participants who are off-site for better review results

We will combine these three technologies with the pre-prepared building model in the game engine Unity, and finally output an application for use on Android portable devices.

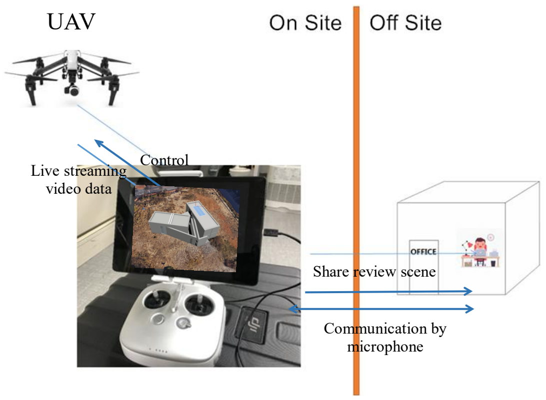

Figure 1. System schematic diagram in actual use.

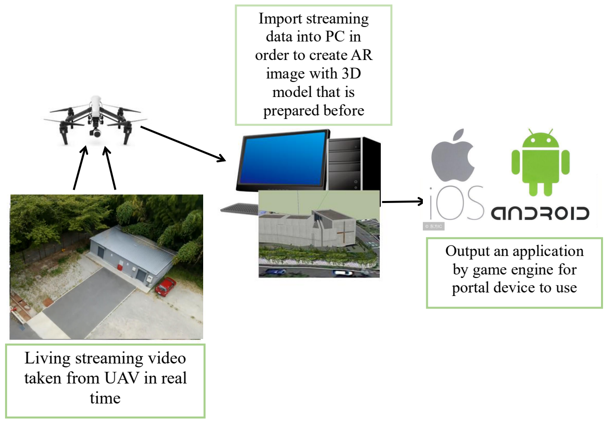

Figure 2. Development process diagram.

2.2. UAV SETUP

The UAV is actually a microcomputer that has many functional interfaces inside. In this designed system, the remote control interface and camera of the UAV will be mainly used. The remote operation function of the UAV is a basic function, so that the participants in the review site can see the higher and further review scenes by operating the UAV on the ground; and the UAV camera can return the streaming video in real time.

In this system, we need to connect the returned streaming video to the game engine Unity in order to synthesize AR image in next step. In UAV Inspire 1, which is used in this system, the Lightbridge component developed by DJI itself is responsible for the real-time return of the video stream, which is more stable and efficient than the Wi-Fi-dependent data transmission method.

2.3. SLAM BASED MARKER-LESS AR

2.3.1. MAKING 3D MODEL IN ADVANCE

Before using this system, you need to use the 3D modeling software (such as Autodesk Revit or 3ds Max) to create the 3D construction model that the system needs, and then import it into Unity for use. Although Unity can do simple modeling on its own, in order to ensure the details and precision, finally choose the method of importing Unity from other 3D modeling software.

2.3.2. AR TRACKING

AR technology can be divided into two categories: marker based AR and marker-less AR. Compared to the marker based AR, the marker-less AR does not need to arrange the marker in advance. It is more convenient by identifying and tracking the virtual models by recognizing features in the natural image. This tele-simulation system uses the marker-less AR algorithm based on SLAM technology. SLAM (SLAM in this paper refers specifically to the visual SLAM using only the camera as a sensor) refers to the technology of generating an environmental map while estimating the self-position without using the map. As a tool widely used in robotics engineering, it can make AR algorithm's tracking part more stable and less likely to be lost due to fast movement. In this system, Unity is used to transfer the 3D construction model, the AR image can be synthesized in real time after receiving the streaming video returned by the UAV, and users will be able to control the opening and closing of the tracking.

2.4. TELE-COMMUNICATION TECHONOLOGY

Different devices share the landscape review site through the network communication protocol, and the system needs to obtain the use rights of the device microphone to facilitate communication between users.

3. Functional verification of each module

In order to verify the function of each part of the system and the feasibility of the whole design of it, this paper also has carried out some verification tests.

3.1. SIMULATED FLIGHT TEST OF UAV

The software and hardware used in this experiment are shown in Table 1. This test is to verify whether the UAV can successfully transmit the video stream back to the portable device in real time. Since this set of equipment is located in the review system throughout the system design, the device can be connected to the remote controller of the UAV through the USB cable to achieve the controlling of the aircraft.

Experimental site was in Osaka University, Suita Campus, M3-411 (indoor).

Table 1. Hardware and software used in the test.

Hardware	UAV Inspire 1
	Android tablet Nexus 9
Software	Android Studio 3.0.1
	DJI mobile SDK

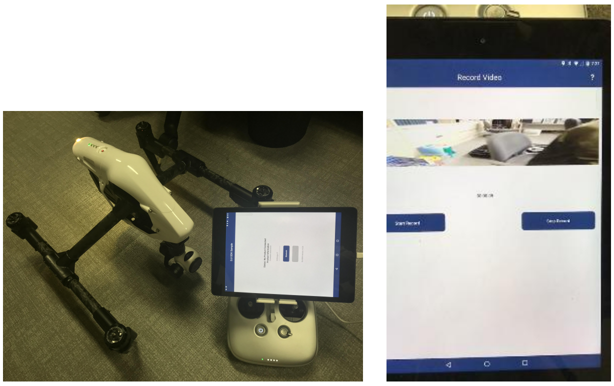

Figure 3. Device and video streaming transmission interface.

3.2. AR OUTDOOR APPLICATION TEST

The system will use the SLAM-based marker-less AR algorithm developed by KUDAN to achieve the outdoor review function we need. Since many factors can affect the accuracy of marker-less AR project, outdoor natural images contain fewer features than indoors, so it is necessary to conduct outdoor contrast experiments for the AR application. Due to the particularity of the SLAM benchmark, the SLAM-based mark-less AR algorithm does not place the 3D model at the given location, it will appear in the center of the screen by default. In the tracking process of this algorithm, a marker is used to let the user determine where the model will appear.

The place where the experiment was conducted was an open space next to the building, where is in the Osaka University Suita Campus. Figure 5 and figure 6 show the positional relationship between the open space and the building. Some specific distance and angle information is shown in table 2. We conduct five experiments on the 1st to 5th floors to test the stability of the algorithm outdoors.

Figure 4. Actual test site.

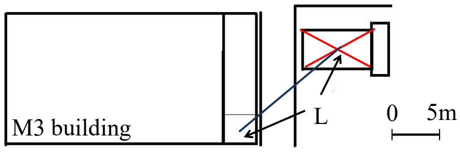

Figure 5. Plan view.

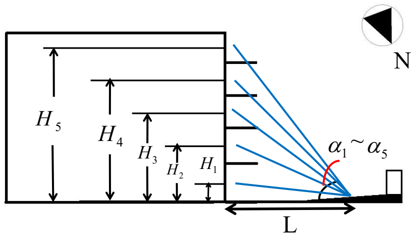

Figure 6. Front view.

The distance from the location of the experiment to the center of the target open space is set to L. The height of each of the five experiments is represented by $H_1 \sim H_5$. The angles from the camera to the target open space and the horizontal plane are represented by $\alpha_1 \sim \alpha_5$. After obtaining the above data, the value of α_1 to α_5 can be calculated by Equation 1:

$$\alpha_n = \arccos \frac{L}{H_n} \qquad (n = 1,2,3,4,5) \tag{1}$$

The measured and calculated data are recorded in the table 2. Figure 7 is the results of the five floors before AR tracking and after AR tracking started.

3.3. EXPERIMENTAL RESULTS AND EXPECTED RESULT

From the simulation flight test of the UAV, we can obtain the streaming video captured by the camera by accessing the real-time backhaul interface inside the UAV, and display it on the portable Android device. This video stream is transmitted back through the Lightbridge component. The method is stable and low latency and can be used for further real-time processing.

Table 2. Data measurement and calculation results.

Floor Height (H)	Meter	Angle (α)	Degree
H_1	1.7	α_1	6.046
H_2	6.7	α_2	22.658
H_3	10.3	α_3	32.691
H_4	13.9	α_4	40.894
H_5	17.5	α_5	47.475

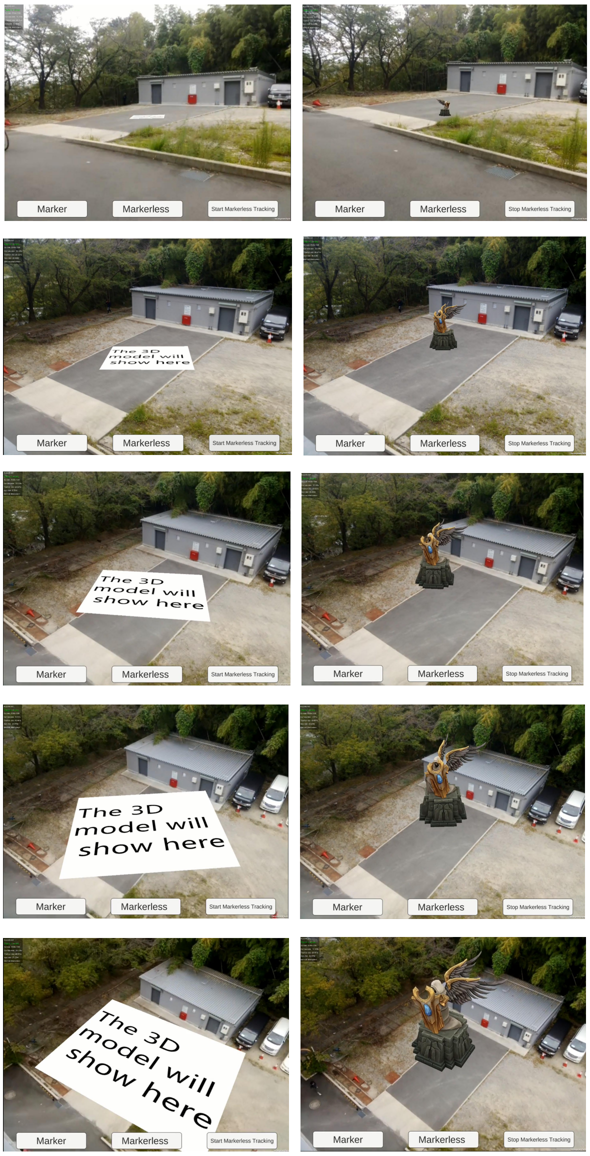

Figure 7. AR test results on each floor.

In the AR outdoor application test, we can get three conclusions: 1) The size of the 3D model generated later is related to the size of the auxiliary marker shown on the display. 2) From the first floor to the fifth floor, as the height increases, the angle between the device to the target plane and the horizontal line named α increases, the size of the marker becomes closer to the set value, and also the display size of the 3D construction model. Figure 8 shows the size and positional relationship between the marker and the 3D model in the game engine. 3) When the angle α is too small, the stability of the 3D object will be greatly reduced or even unrecognized (first floor). Due to the manpower limitation, it is hard to guarantee that only the experimental conditions of height without changing the angle are changed. From the above conclusions, it can be reasonably predicted that the 3D model will display the normal size when α becomes 90 degrees (i.e., the device is perpendicular to the horizontal line).

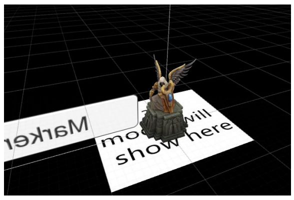

Figure 8. the size relationship between marker and 3D model.

4. Conclusion and Future Work

This paper proposes an outdoor landscape simulating review system that combines AR and UAV development technologies with telecommunication technology. In the system development part, we will develop a software application based on Android platform by using the PC-based game engine Unity as the total development platform. The program synthesizes the AR image by using the SLAM-based marker-less AR algorithm with the real-time video stream returned from the UAV, and then showing it on portable digital devices. Utilizing the camera of the UAV expands the visibility of the field; in the meanwhile, telecommunication technology allows more people to participate in the review process, which will make the whole process more efficiency than before.

This paper also verifies and compares the algorithms that will be used, and confirms the feasibility of the system. In the future, the author will begin the integration of the three technical algorithms on Unity to achieve the desired results in the design.

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