Illegal Detection of Building Setback Line Using Augmented Reality

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1.Introduction

Planning Support System (PSS) is an approach for application of computer-based techniques in urban design [1)], which is systematic, dynamic and interactive [2)]. Currently, PSS has been mainly applied in future development prediction [3) 4) 5)], spatial planning [6) 7)], urban infrastructure location [8) 9)], and urban landscape design [10) 11)]. However, most of the current PSSs only support visualization running on Virtual Environment (VE), lack of the perception and interaction with the real world.

Augmented Reality (AR) is a technology which is possible to combine digital models with the physical world [12)]. It can generate a composited view with a combination of virtual world and real world in which the user can be located. The core advantage of AR applications using mobile devices (such as smart phones, tablets) is that everybody who holds a smart phone can access AR using APP. For implementation of reconstruction in high density built-up environment, there are a lot of complicated planning regulations, which residents are difficult to consider how to follow [2)10)]. We used AR technology to develop a Planning Support Tool using mobile devices to effectively check if design alternatives are matching those regulations or design guidelines. In this paper, illegal detection of the building setback line [13)] is taken as example by combining VR building models, building regulations with a real site. Through the tool, residents can interact with VR building models using mobile devices, to further understand design proposals and planning regulations in real construction site. As for urban managers, they can also verify whether the building model meets the building regulations, to improve the efficiency of public participation.

2. Research Objectives

In this research, firstly we develop an AR-based Planning Support Tool (AR-PST) for visualizing VR building models and building regulations through Unity 3D platform integrated with Vuforia SDK. Secondly, through the AR-PST, public users can interact with the building models via manual touch and human-computer interaction, to check illegal detection function in real world. Thirdly, verify whether the AR-PST can improve users' understanding of building regulations by user experience testing.

3. Methodology

3-1. Building Setback Line[15)]

The building form regulation mainly includes boundary line of site, wall line, oblique line of road and oblique line of adjacent site in Japan [13)]. There are 12 land use zones with different Floor-Area Ratio (FAR) and Building Coverage Ratio (BCR). Each zone establishes what kind of development is permitted on the land and restricts building size and density by prescribing the numbers used to calculate the buildable area (FAR, BCR), height, and setback. This work focus on building setback line defined in City Planning Law (CPL) and Building Standard Law (BSL) [14)].

3-2. Augmented Reality Technology

Augmented Reality (AR) is the integration of digital information with the existing environment in real time. Unlike VR, which creates a totally artificial environment, AR uses the existing environment overlaid with VR information. Figure-1 illustrates the system framework of AR technology. AR is as a tool for detecting the real world and thus to efficiently interact between humans and computers. According to the object-tracking techniques, augmented system is divided into positioning, marker augmented reality services. In this work, tracking and virtual rendering system are employed to combine virtual world and real world. Simulation and haptic rendering system are employed for planning support which only developed for illegal detection of building setback line in the paper. AR technology can use the images in the real world to recognize points of marker for combination with VR, and extracts points, lines, corners, textures, and other features through camera images. Figure-2 shows an example of AR marker. AR marker is used to detect

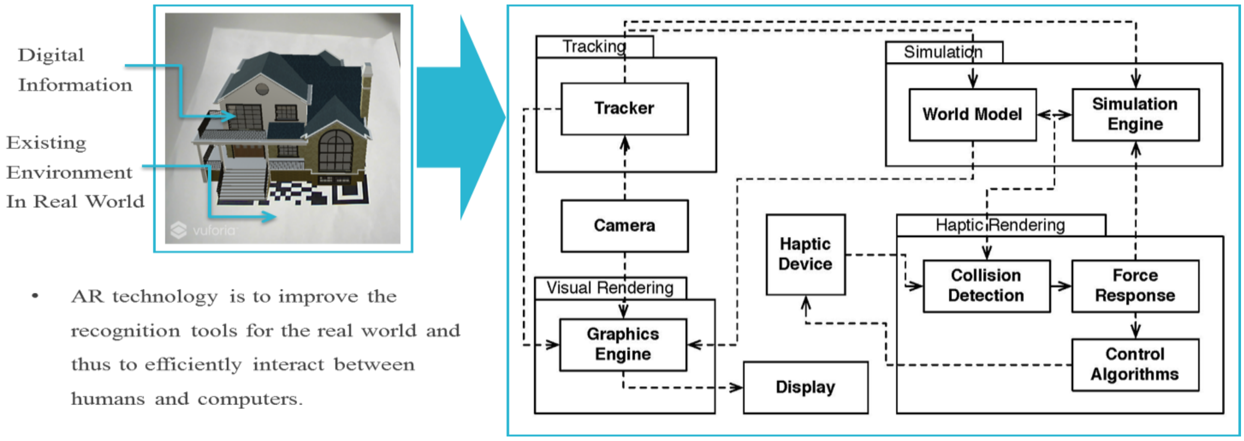


Figure-1 System Framework of AR Technology

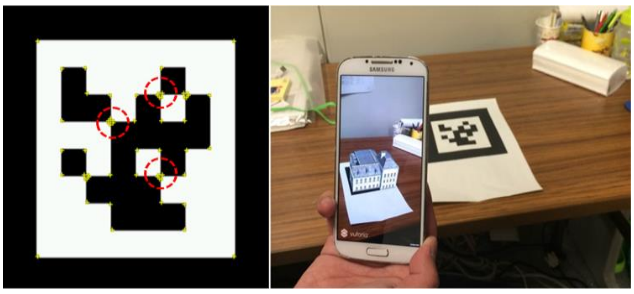


Figure-2 An example of AR marker

and recognize lighting, partial overlapping, and directions on the basis of an object's characteristics, and shows excellent performance [16].

3-3 User experiment

Since this paper is limited to illegal detection of setback, users experiment is designed for students who do not have knowledge on urban planning. The aim of this experiment is to check if the AR-PST based on AR technology is easy to use or not. Thus, the main contents of this test include the experience of functionality, contents, interactivity and fluency of the AR-PST, in which the accuracy of design alternatives are not checked.

4. Implementation of AR-based Planning Support Tool

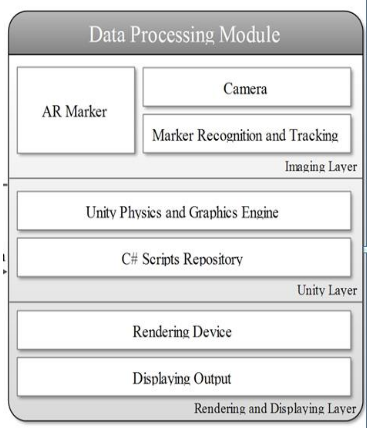
4-1. System Architecture

The AR-PST developed in this research uses marker augmented reality services as mobile application. Also, it is aimed to conveying 3D models or videos to real world through Image Targets. Vuforia Engine is utilized as development environment for mobile device. The development platform of this research used Vuforia SDK and Unity 3D, a games engine. Figure-3 illustrates the system architecture of the AR-PST to be developed in this research. For tracking and virtual rendering, a data processing module in Unity3D is used for target management. Cloud Target Database and Device Target Database are used for support planning work. The data transfer between the mobile devices and AR application.

4-2. 3D Modeling and Camera Setting

After preparation of the system development platform, the next step is 3D modeling. We used 3ds Max for creating different building models to meet the needs of building forms. The research imports the Unity Package downloaded as the matching coordinates, and registers a 3D object in ImageTarget Hierarchy, as shown in Figure-4.

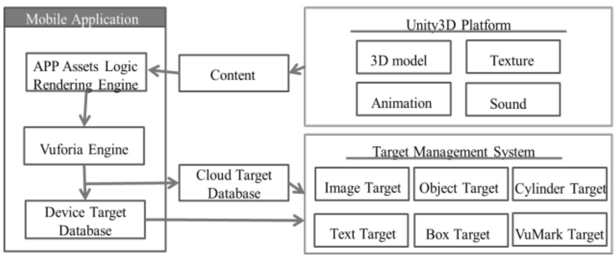
Secondly, sets AR Camera. The target can be set by script the codes. The target object to be detected will be imported



1)Tracking and Virtual Rendering

An example of AR marker

The lot of real site as AR marker, which can be recognized by camera and combined with virtual building model in unity3D.



2)AR-PST tool

Figure-3 System architecture of AR-PST

Figure-4 3D objects for AR

into project of the system, and the information of the target image will be saved in the ".xml" file. When the system needs to call the camera, the use of AR Camera can return a unique camera instance. The AR Camera can define the camera FRUSTOM's projection type, and shear the plane and viewport rectangle. It can be used as the background of the video scene, presented the picture to the background. When the system disables this background scene, the video will not have a background rendering effect. The system can set the parameters of AR camera, such as direction, device mode, mirror video background, world center mode and so on.

4-3. Collision Detection for Building Setback Line

In this work, the planning restriction of building setback line is shown in Figure-5. Collision detection is used for illegal detection in this research. There are four kinds of single collider in collision detection: Box Collider, Sphere Collider, Capsule Collider and Compound Colliders. There are numerous different combinations of collisions that can happen in Unity 3D. However, only Colliders and Rigidbody are used together to produce collisions. Thus, there are three Collider Combinations: Static Collider, Rigidbody Collider and Kinematic Rigidbody Collider. These colliders will become Triggers, when the IsTrigger property is checked in the inspector. Thus, Trigger is an alternative way of using Colliders. Figure-6 shows the state changes in collision detection using Trigger. Triggers have a unique set of three trigger messages that are sent out when a collision with a Trigger occurs. According to the configurations of the two colliding objects, the expected value from two Objects can be used verify whether the building model meets the building setback line.

5. User Experience Testing

5-1. Overview of Test Methods

The user experience testing can objectively reflect whether the AR-PST based on AR technology is easy to use or not. The results can be obtained by user cognition, operation experience, and communicating with the participants respectively [17]. The main contents of this test include the experience of functionality, contents, interactivity and fluency of the AR-PST. 20 participants of this user experience testing were students from Fuzhou University, and who were not studying urban planning in Feb., 2017.

Firstly, users can use the tablet to enter the initial page of

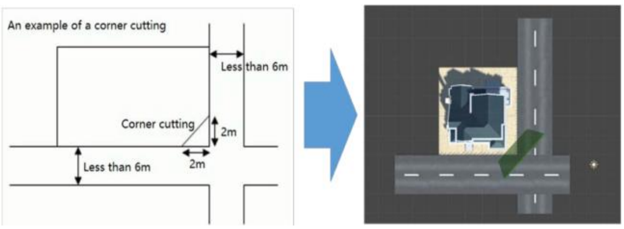


Figure-5 Building setback line in a corner

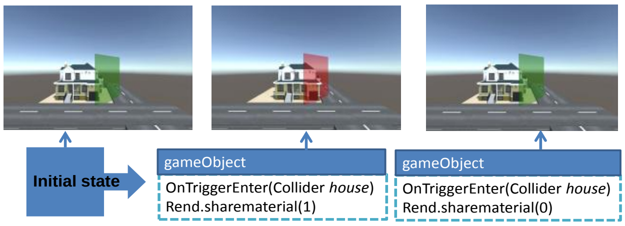
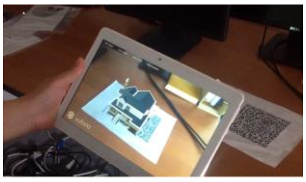


Figure-6 The state changes in collision detection using Trigger

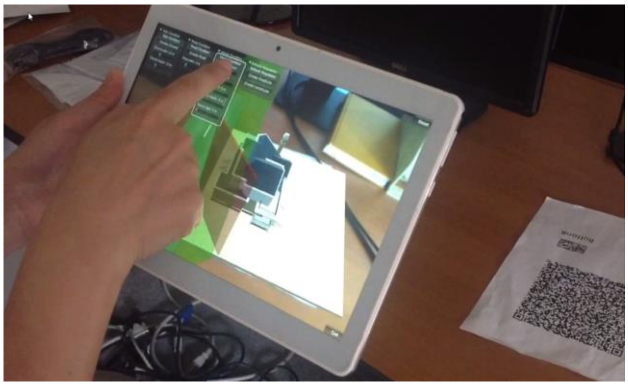
1) Scan the mark



2) Input the house

3) Locate the house

4) Show the parcel conditions



5) Apply the illegal detection of building setback line

Figure-7 The AR-PST for illegal detection of building setback line

Figure-8 The data used for user experience testing

Table-1 Participants' interest in the PST

No.	Test Item	Respondents
1	Understanding level of urban design above tolerable	17
2	Understanding level of building codes above tolerable	9
3	Like AR technology be applied to urban design	15
4	Belive the planning support tool based on AR technology very interesting	15

the AR-PST as shown in Figure-7. The initialization page will display the name and statement of the tool about the regulations of building setback and collision detection. Subsequently, the participants will enter the main menu interface and use the planning support tool in manual touch mode, and validate each functional module, then fill out the questionnaire. The real site is used for user experience testing, which is shown as Figure 8.

The questionnaire consists of three parts: basic information of participants, operation evaluation and feedback investigation. According to the understanding level of urban design, participants are divided into three categories: designers, hobbyists and beginners. The evaluation scales are divided into strongly satisfactory (A), satisfactory (B), neither satisfactory nor unsatisfactory (C), unsatisfactory (C) and strongly unsatisfactory (E).

5-2. Experimental Data Analysis

According to the basic information table of participants, it is easy to obtain participants' interest in the planning support tool, as shown in Table-1. From the table, it's easy to see that participants have a high understanding level of urban design, accounting for 85%; and only three participants don't understand urban design, they are beginners. However, the understand level of building codes is far lower than the understand level of urban design. Thus, the planning support tool based on AR technology may help to popularize building regulations. In this work, only building setback line is used for user experience testing which is very simple regulation for all participants.

Meanwhile, 75% of the participants liked AR technology be applied to urban design, and 75% of the participants believed the planning support tool based on AR technology very interesting. Moreover, through interviewed with participants who dislike AR technology be applied to urban design, and obtained the following results: two participants hold the idea that they are beginners, and they don't know enough about urban design; another three participants believe that AR technology is under developing, the research on the consistency between the virtual building model and the actual project plot needs to be perfected.

Through the operation evaluation and feedback investigation of planning support tool based on AR technology, the results are shown in Table 2. 90% of the participants believed that the planning support tool can help improve the communication efficiency between designers and users if using this tool for real site communication, and the degree of cohesion between the functional modules is very smooth. 85% of the participants can find the function module

Table 2. The results of operation evaluation and feedback investigation

No.	1					2			3			4			5			6				7						8			
Test items	Evaluate the functional module that interests participants the most.					The tool help improves the communication efficiency between designers and users.			Find the function module successfully.			The tool can auxiliary the process of urban design.			The degree of cohesion between the functional modules.			The sensitivities of manual touch and human-computer interaction.				The characteristics of the tool caompared to traditional planning support systems.						Whether participants like the planning support system.			
Options	A	B	C	D	E	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	D	A	B	C	D	E	F	A	B	C	D
Respondents	8	10	2			18	2		17	3		15		5	18		2	16	4				9	4	7			13	5	2	
Proportions	40%	50%	10%			90%	10%		85%	15%		75%		25%	90%		10%	80%	20%				45%	20%	35%			65%	25%	10%	

90% participants believed that the planning support tool can help improve the communication efficiency between designers and users.

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85% partcipants can find the function module successfully.

65% participants like the planning support tool.

80% participants strongly satisfied with the sensitives of manual touch and human-computer interaction.

successfully, and 80% of the participants strongly satisfied with the sensitivities of manual touch and human-computer interaction. 75% of the participants held the idea that the tool can auxiliary the process of urban design, and 65% of the participants like the planning support tool. Interesting, interactivity and flexibility are the main characteristics of the tool compared to conventional planning support systems with only virtual environment. The interesting shows that the planning support tool can display the text description building regulations in the form of 3D space model, and is easy to understand; it can be used in the professional teaching of urban design. Interactivity is the excellent manual touch and human-computer interaction, and the dynamic display of design scheme. Flexibility is that the tool is easier to change the visual angle for display than the traditional planning support system, and easy to edit building model in real time.

6. Conclusion

The proposed Planning Support Tool (AR-PST) based on AR technology can realize the combination of 3D virtual model and the real world. In this work, AR-PST only support user for checking the illegal building setback line by detection function.

The tool allows users to better understand and evaluate building designs under the regulation framework in real construction site, so as to help improve the communication efficiency between designers and users. The results of user experience testing indicate that the AR-PST has creative functional design and good interactivity, which can easily find the required functional modules and auxiliary the process of illegal detection of building for setback line. In the future, it is necessary to apply the AR-PST which proposed in this research to practical cases, so as to analyze the usable space of buildings based on all planning regulations, and determine its relationship with the building form controlling, study on the regulations of building form and the use of the possible space.

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拡張現実技術を用いた建築セットバック確認ツールの開発に関する研究

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本研究は、建築基準法に基づいて実際の敷地に適用される建築形態規制を用いて建物の適法性を検証するために、AR(Augmented Reality)を用いて携帯端末用のシミュレーションシステムの開発を行う試みである。Unity３D や Vuforia のスクリプトプログラム言語を利用して、建築線のセットバックの確認機能を開発した。

具体的には、携帯端末のカメラにより実際の敷地を計測し、設計中の仮想建物を敷地の座標に合わせて仮想空間に配置させ、敷地の条件に合わせてセットバックを適用した場合、セットバックのラインを幾何的な形により可視化し、利用者はセットバックのラインを移動することを可能としたシステムである。敷地において実際の建物がセットバックの規制に違反した場合には、開発したシステムを用いて自動的にチェックできるようになっている。実際の敷地に適用した規制のチェックには、 学生を対象にシステムの実験を行い、システムの有効性を検証した。本研究は、行政における建築確認審査業務を想定したが、大学における都市計画の関連業務の教育に利用できるシステムとしても開発したので、今後の研究では大きな展開が期待できる。

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