# AUGMENTED REALITY TECHNOLOGY BASED WIND ENVIRONMENT VISUALIZATION

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**Abstract.** Considering the outdoor environment at the initial stage of design process plays a significant role on future building performance. Augmented Reality (AR) technology applied in this research can integrate real world building morphology information and virtual world ventilation information seamlessly that rapidly and directly provides designers information for observation and evaluation. During the case study of “2017 Shanghai DigitalFUTURE” summer workshop, a research on augmented reality technology based wind environment visualization was carried on. The achievement with an application software not only showed the geometric information of the real world objects (such as buildings), but also the virtual wind environment has displayed. Thus, these two kinds of information can complement and superimpose each other. This AR technology based software brings multiple synthetic together, which can (1) visualize the air flow around buildings that provides designers rapid and direct information for evaluation; (2) deal with wind-environment-related data quantitatively and present in an intuitive, easy-to-interpret graphical way; and (3) be further developed as a visualization system based on built-in environments in the future, which contributes to rapid evaluation of a series of programs at the beginning of the building design.

**Keywords.** Environment visualization; Augmented reality technology; Fast response; Outdoor ventilation.

## 1. Introduction

The creation of a livable urban space environment has gradually become the theme of today’s architectural and urban planning disciplines. The study of microclimate such as the urban wind environment has also become a remarkable topic of academic concern. As an important factor of urban microclimate, urban natural ventilation plays an important role in the diffusion of air pollutants, the elimination of heat island effect, the perception of thermal/wind comfort in open space as well as the wind safety of high-rise buildings. Thus, the response to climate change in urban planning and architectural design is particularly urgent at this moment.

T. Fukuda, W. Huang, P. Janssen, K. Crolla, S. Alhadidi (eds.), *Learning, Adapting and Prototyping, Proceedings of the 23rd International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2018*, Volume 1, 369-377. 

On the other hand, with the advent of the digital age, a deep discussion of the meaning of architectural form has been aroused. “Performance Building” provides a new perspective for this topic, and presents the “formal meaning” transformation in architecture - Form Follows Performance (Yuan et al., 2016). Most researches and practices indicate that the initial stage of design decisions has a significant impact on future building performance. At this stage, taking the wind speed, wind direction and architectural form, opening, orientation and other parameters into the design considerations, will generate the passive wind environment design strategy, which can effectively create a comfortable microclimate environment by using the natural ventilation (Daniel and Rafael, 2016; Zheng, 2017).

Most research and practice has shown that decisions at the early stages of design have an extremely important impact on the future performance of the building (Oxman, 2009; Attia et al., 2013). In recent years, wind environment based passive design strategy can effectively use the natural flow of wind to create a comfortable micro-environment. However, the wind environment may not convenient to employ by architects because of its invisibility and complexity. Although with the development of technology, wind environment can be evaluated by frequently-used wind tunnel experiments and computational fluid dynamics (CFD) simulations, , while the simulations requires relatively professional knowledge, complex simulation settings, and plenty of time and cost. These restrictions led to less than 1% penetration of the architectural wind environment in the architecture industry (Hong, 2015). On the other hand, these results tend to be interpreted and analyzed by professional engineers, and then provided to the designers with some suggestions.

Visual design, on the other hand, is the key for architects to share design perspective and collaborative design. A more intuitive visualization platform is even more essential to the architectural design industry that today needs to effectively handle digital information. Seichter et al. (2004) applied augmented reality (AR) in urban planning so that designers can understand urban spatial parameters in three dimensions to load mass scale more quickly and convenient to make decisions.

At present, most of the traditional modes of education in Chinese architecture are displayed through blackboards, printed books as learning materials and computer screens, which bring a large amount of texts and data to the audience (Cheng et al., 2014). However, the lack of visual elements may make students more difficult to understand the design thinking, especially the environmental performance design. Unless specifically for students to set up a series of environmental simulation software courses, such as Fluent for wind environment simulation, Ecotect for daylighting and energy consumption calculation as well as other simulation software. If students were not experienced to these software and the utilizing of simulation results, the designed architecture might not be well considered and sustainable.

In contrast, once integrated with the AR technology, three-dimensional perspective of the built environment can be superimposed on architecture. Designers can observe and further analyse the environmental performance of the designed buildings from various angles by simply scanning the markers with a camera connected with a customized application installed in the computer or smart phones. By superimposing the dynamic video of the wind environment simulated in the processor onto the scene, the students can well observe and understand the impact of the building on the environment from multiple perspectives, which contributes designers to find effective methods to optimize the designing scheme (Behzadan et al., 2015).

Therefore, in recent years, lots of universities and research institutes have already focused on augmented reality technologies and developed extensive applications in fields of medical, education, military, industrial, advertising, games and tourism fields (Mochida et al., 2008; Behzadan et al,. 2015; Daniel and Rafael, 2016). The widespread application and rapid popularization of mobile AR terminals also provide beneficial reference for the three-dimensional innovation of building and environment 3D performance display. Based on the above concepts, this study mainly focuses on the application of AR technology in the field of architecture, introducing the visualization method and process of building wind environment based on AR technology. Furthermore, according to the case study of “DigitalFUTURE Shanghai 2017” summer workshop, with the application of Unity3D game development engine and Vuforia software, an application for visualizing building wind environment with AR technology has been developed. It conveniently displays the outdoor natural ventilation around buildings.

## 2. Methodology

### 2.1. AUGMENTED REALITY (AR) TECHNOLOGY

The goal of augmented reality technology is to superimpose computer-generated virtual objects, scenes or system prompts into real scenes to enhance the real world scene (Zhu et al., 2004). The technology can be applied to the virtual world of real-world information through the computer system to effectively improve the user’s perception of the real world and interactive experience. Based on computer science and technology, invisible information, including built environment, can be simulated and then superimposed with the virtual information applied to the real world, perceived by human senses, so as to achieve beyond the sensory experience of reality (Irizarry et al., 2013). In this condition, in the same screen or space, both real and virtual world display together. On the other hand, with the recent rapid development and continuous improvement of computer technology, augmented reality technology is changing the traditional technical methods from many aspects. It is changing the way human observe and feel the world. Ronald Azuma indicated that augmented reality should have three specific characteristics (Mahapatroa and Khilar, 2012). First characteristic is the integration of the virtual scene and real scene, which means augmented reality does not completely replace the real world information. Instead, it relies more on the real world. Relying on computer technology, virtual objects such as pictures, videos and 3D models are generated to integrate with the physical world. The Second one is characterized as 3D Registration. Augmented reality real-time tracks camera’s attitude angle for calculating the camera’s influence location and the registration location of virtual scene in real world. It aims to achieve full integration of the virtual scene and the real scene. The last one is real-time interaction, which refers to the user can obtain the corresponding feedback information through the real world timely.

AR system does not need to display the complete scene, but due to the requirement of analyzing a large number of positioning data and scene information to ensure that the computer-generated virtual objects can be accurately positioned in the real scene (Zhu et al., 2004). Hence, AR system generally contains the following four basic steps (Figure 1): (1) obtain real scene information; (2) analyze the real scene and camera location information; (3) generate a virtual scene; and (4) merge the videos or directly display.

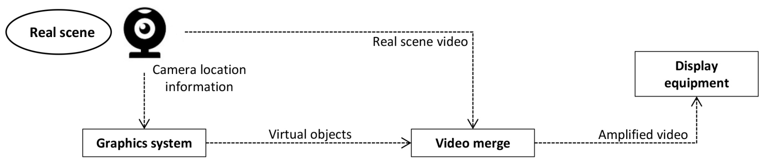


Figure 1. AR System Flow.

2.2. BUILDING DIGITAL MODEL COMBINED WITH CFD SIMULATION ANALYSIS

Fluid scene reconstruction is the emphasis and difficulties in augmented reality technology research. Fluid has complex motion characteristics, and there is also the problem that the topological structure changes with time and space during movement, which increases the difficulty of reconstruction of the fluid scene. Thus, the general scene reconstruction method is no longer suitable for the fluid. At present, researchers usually employ the physical properties of the fluid for its surface reconstruction, such as reflection and refraction. Some of them try to reconstruct water by measuring the amplitude of light refracted from the water by means of adding some chemical dyes or fluorescer to the water and then using special camera equipment. On the other hand, wind can be visualized with the application of smoke wire test and scour experiment in wind tunnel (Zheng et al., 2017). However, these kinds of method and technology require advanced or specific equipment as well as sophisticated experimental setups that may be not universal.

Recently, the method of fluid simulation is mainly with the help of computational fluid dynamics. However, the development of virtual and AR technology has spawned a novel human-machine interaction platform, which visualizes the trajectory of the wind and projects it into the real physical world. These visualizations are not intended to measure or mimic the real wind environment, but rather to promote people better understanding and communication by observing complex wind phenomena (Wang, 2009).

2.3. APPLICATION OF VUFORIA AND UNITY3D

Vuforia(TM) is a product of Qualcomm Connected Experiences, Inc. It is a development tool for developing augmented reality applications for mobile devices. It features cross-platform support for iOS and Android, as well as Unity3D extensions. The AR application applied in this research can be generated by several steps as below:

1. Design the building model;
2. The model is imported into ANSYS FLUENT software, meshing, parameter setting and simulation for obtain outdoor wind environment as csv file;
3. Export ventilation data into Unity3D to generate wind environment model;
4. Upload identification images in Vuforia;
5. Download the image unity package;
6. Import the image unity package in Unity3D and import the generated Unity3D wind environment model; and
7. Generate apk.

## 3. Case study in "DigitalFUTURE Shanghai 2017" workshop

During the "2017 Shanghai DigitalFUTURE" summer workshop, a research on augmented reality technology based wind environment visualization was carried on. The achievement with an application software not only showed the geometric information of the real world objects (such as buildings), but also the virtual wind environment is displayed. Thus, these two kinds of information can complement and superimpose each other. This AR technology based software brings multiple synthetic together, which can (1) visualize the air flow around buildings that provides designers rapid and direct information for evaluation; (2) deal with wind-environment-related data quantitatively and present in an intuitive, easy-to-interpret graphical way; and (3) be further developed as a visualization system based on built-in environments in the future, which contributes to rapid evaluation of a series of programs at the beginning of the building design.

### 3.1. INTRODUCTION OF PROCESS

According to Figure 2, the phases employed in the workshop "wind environment visualization" mainly include design, obtaining environment data, generating APP and virtual wind environment visualization with identification image.

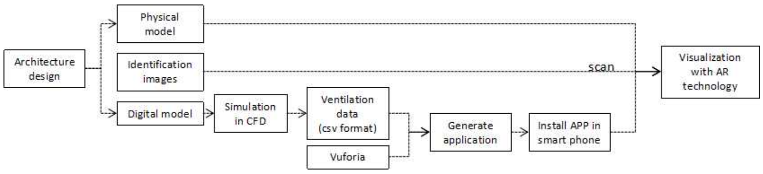


Figure 2. Phases of Generating AR APP for Visualizing Wind Environment.

### 3.2. MODELS APPLIED AND CORRESPONDING CFD SIMULATION RESULTS

Models have been designed in advance, and some of them have been 3D printed as shown in Figure 3, which left model is designed with multiple-cavity, while the right three models are designed according to twist concept. On the other hand, their surrounding wind environment has been simulated in CFD respectively.

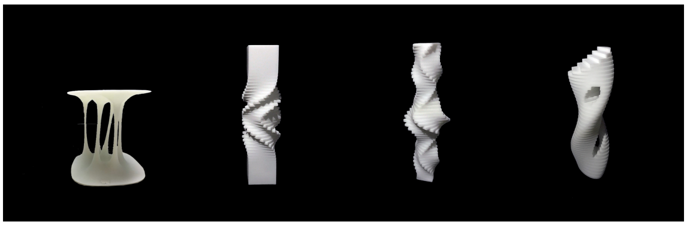

Figure 3. 3D Printed Models.

## 3.3. APP GENERATION, INTRODUCTION OF RELATED CODES AND KEY TECHNOLOGIES

### *3.3.1. Tracking Registration Technology*

In this study, tracking and registration technology is the camera as a tracking object. The tracking technology based on computer vision uses the camera to acquire the image of the real scene, and employs the algorithm of machine vision to fuse the virtual object with the real scene in the same video or image. Hardware sensor tracking technology through mobile smart phones and other portable devices to obtain the location of the device and mobile information. In addition, artificial identification images (markers) were applied in this study. The strong marker based tracking registration technology needs to place a marker in advance in the real scene as an identification mark. The purpose of employing the marker is to quickly and efficiently detect the presence of the marker in a complex real scene, and then register the virtual scene in the space where the marker is located.

The marker used in AR technology is normally simple. A marker can be a rectangular block with only black and white colors, or an artificial marker with a special geometry (Hou and Xu, 2017). In this case study, black words on white panels were applied as markers, such as “Digital FUTURE”, while different markers were designed for each models differently. These patterns on the markers indicate various virtual objects with different information.

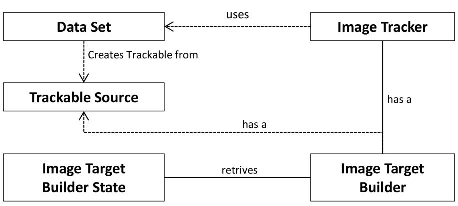


Figure 4. AR Virtual Button Coding Example.

### *3.3.2. Display Technology*

Visual may be the most important and direct information transmission channel between human and the external environment. Therefore, the display technology is one of the key technologies in augmented reality. The role of display technology is to combine computer-generated virtual information with the real world in which the user is located. Display technology in AR display system usually includes helmet display, handheld displays and projection display. This research was mainly based on the handheld display (mobile smart phone). Smart phones generally have a built-in camera, GPS function and magnetic sensors, etc., while most of them have a large high-resolution display screen. Small size and convenient to carry contribute to become the ideal AR development equipment.

### *3.3.3. Achievement*

With applying Vuforia software and Unity3D game engine, the SDK has been generated for installation in one Android mobile phone. Once the camera the identification images (markers), the supposed invisible wind environment became visualize on screen.

Figure 5. Wind environment visualization based on AR technology.

## 4. Conclusions

Augmented Reality is a new technology that can integrate real world building morphology information and virtual world information seamlessly. In the real world, the entity information, including visual information, might be difficult to be experienced in a certain time and space. However, with AR technology, these information can be simulated by computers and further superimposed into the real world that can be sensed by human. In this condition, the real environment and virtual material data is integrated in the same space in real-time.

Considering the outdoor environment at the initial stage of design process plays a significant role on future building performance. AR technology applied in the research can integrate building morphology information in real world and virtual ventilation information seamlessly that provides designers rapid and direct information for observation and evaluation. Based on the CFD simulation results, the invisible wind environment can be visualized on the mobile portable end to depict the movement trajectory of the wind around the building, which qualitatively provides the designer with information to evaluate the design strategy.

Therefore, it can deal with wind environment data such as wind speed and surface wind pressure quantitatively and help the interpretation of professionals and non-professionals in an intuitive and augmented reality way. For the next phase of real-time dynamic architectural design process of environmental visualization to get through the path, it will be possible to become the early performance of building design through the performance of a handheld tool.

## Acknowledgements

This research is funded by the National Natural Science Foundation of China (Grant No.51578378), the Special Funds for State Key R&D Program during the 13th Five-year Plan Period of China (Grant No.2016YFC0702104), the Sino-German Scientific Research Program (Grant No.GZ1162) and Science and Technology Commission of Shanghai Municipality (Grant No.16dz1206502, Grant No.16dz2250500, Grant No.17dz1203405).

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