# Applying virtual reality technology to architectural design teaching

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ABSTRACT: The development of computer technology has gradually changed attitudes to architecture, including the methods and skills of the practice. Therefore, teachers of the subject must create the most effective environment for enabling students' study. In this article, virtual reality as applied to architectural design is discussed. A virtual architectural system was built that included immersive virtual roaming and interactive virtual roaming. This can make students experience an incomparable sense of reality and immediacy. By exploring the virtual building, students can fully realise the pros and cons of its design and, hence, identify necessary modifications so as to optimise the design.

INTRODUCTION

Architectural design is an old and mature discipline, with rich content and abstract concepts. Teachers of architectural design often use floor plans, profile maps and elevations, as well as other plane figures by which to show to students a three-dimensional stereoscopic construction. But, the effectiveness of these methods is often influenced by students' social experience, understanding and spatial reasoning ability. Hence, these factors can make communication between teachers and students more difficult [1].

Previously, teachers used mainly two-dimensional plans, elevations and profiles, so as to display a design. A small modification on a figure is likely to affect other aspects of the design on different figures. This approach is error-prone, and difficult for students to understand. Faced with this situation, teachers could make a miniature model of the design; but, this is burdensome and increases the time required for the design. However, architectural design using virtual reality can directly portray a three-dimensional design and modifications, and can do it quickly. This is a natural way to represent the design since it is unnecessary for students to transform repeatedly from two-dimensional graphics to a three-dimensional conception in the brain.

This article reports on a living virtual building developed using immersive virtual reality technology, which was used in teaching architectural design. The students can walk freely around and visit places randomly in the virtual building. This marks a great breakthrough for understanding, compared to the traditional two-dimensional designs, and overcomes the restriction with three-dimensional animations in that they can only be observed passively and are not interactive.

Traditional architectural design usually uses the method of transformation to go from two-dimensional to three-dimensional graphics. The designers of the two-dimensional graphics design have a narrow, un-integrated view of the design. New design ideas often are missed, when designers transform from two-dimensional to three-dimensional thinking. As the two-dimensional drawings or three-dimensional models reflect only part of the information about the building, they often cover up a number of design defects.

VIRTUAL REALITY TECHNOLOGY AND ARCHITECTURE

Virtual reality technology, introduced into building design, allows designers or owners an immersive experience of a building. Designers can construct a *virtual* room and can *move* around any way in the room. This aids understanding of the *pros* and *cons* of the building design. Changes can be made until the designer is satisfied. A virtual building is shown in Figure 1.

Figure 1: Virtual building roaming.

Virtual reality technology allows the artistry of a building to be displayed and highlighted. Space art here refers to the artistry from the use of space in and around a building. In the past, it was difficult to display space art in the design of a building. However, space art at the design stage can be displayed using virtual reality technology.

Therefore, the author argues that research on the use of virtual reality technology for teaching architectural design is particularly relevant. The study described in this article considers the effect on classroom teaching of an architectural design case study using virtual reality discussed also by Liu [2].

VIRTUAL ARCHITECTURAL DESIGN TEACHING

The work reported here had the following four steps:

- First, a formulation of the virtual architectural design specification, and production of the virtual architectural design.
- Second, production of the teaching assignments and the class design tasks.
- Third, implementation of the teaching tasks. Guidance was provided to students to complete the design tasks step by step. Communication was crucial among students and between students and teachers.
- Fourth and finally, after the completion of the design task, students were exposed to the virtual architectural scene to roam and interact with. They were expected to offer feedback about defects in the design and modify the design accordingly.

This work used a task-driven teaching method, which includes the process of *specification (task exhibition) - analysing (analysing task) - disambiguating (problem-solving) - questioning (evaluation and feedback)* (the starting point is shown in Figure 1). This approach helps students overcome limited one-way thinking, prompts them to use their knowledge and strengthens their innovative abilities [4].

*Step 1: Specification (task exhibition)*

In this step, the teacher creates a scene and sets the architectural design tasks. The teacher explains the new design issues that the students are to address using the virtual architectural design. Meanwhile, the teacher puts forward the overall design goal reflecting problems set for the students. The students use the virtual scene to solve the problems. This stimulates students' thirst for knowledge and the desire to explore problems.

*Step 2: Analysing (analysing tasks)*

The teacher's architectural design usually is complex, and contains too much information. Therefore, students cannot immediately come up with a modified design. Hence, it is necessary that the teacher leads the students to analysing the teaching assignment. The students can, then, decompose the whole design task into many small tasks. These small tasks must link with each other, so that, in toto, they meet the requirements of the total architectural assignment.

*Step 3: Disambiguating (problem-solving)*

In this step, the students use their initiative to actively explore questions and implement the small tasks one by one. The students need to establish the related links of each small task, to test and to verify the small tasks, and ultimately to complete the whole task.

*Step 4: Questioning (effectiveness evaluation and feedback)*

Learning is a process of unceasing introspection and improvement. Students should be able to objectively evaluate their own learning. For example, having finished some architectural design task, students should question whether they are satisfied with the results; which parts need further modification and improvement; and is there a better way to accomplish the learning, and so on. In addition to self-assessment, students need to evaluate the work of other team members, summarise the beneficial experience and analyse existing problems and related factors, so as to provide useful feedback [3].

Meanwhile, teachers should make an integrated assessment of the whole task-driven teaching process. Through reflection, students may make adjustments to a design, providing new knowledge and new experience, to strengthen and enrich their experience.

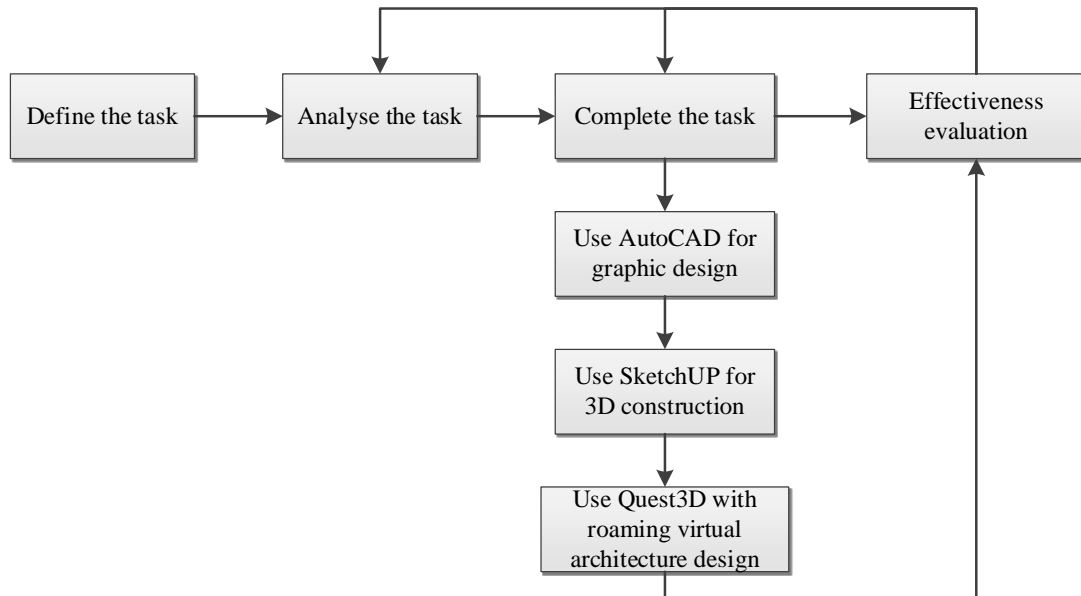The multi-step process is shown in Figure 2.



Figure 2: The architectural design teaching process.

Programming Language Used for Virtual Architectural Design Teaching

The virtual architectural system was implemented using a graphics package (3ds MAX), with rendering by custom software called shaders, which execute images on the graphics processing unit (GPU). This enables equipment and processes to be displayed more vividly, e.g. an internal flow channel, and a pump and valve can be portrayed as a three-dimensional arrow model, with the textured flowing liquid. An example of the code for this in the Cg (C for graphics) programming language is:

```
CGPROGRAM
……
v2f vert (appdata_base v)  //vertex function
{
v2f o;
o.pos=mul(UNITY_MATRIX_MVP,v.vertex);
//view port transformation by projection matrix
o.uv=TRANSFORM_TEX(v.texcoord,_MainTex); //texture coordinates
return o;
}
float4 frag (v2f i) : COLOR  //fragment function
{
float4  outp;
float4 defaultcolor = float4(0.6,0.6,0.6,0.26);
//define default color when texture is  hidden
float4 texCol = tex2D(_MainTex,i.uv);
//define texture and make assignment
//_MainTex_ST.xy corresponds to Tiling ，_MainTex_ST.zw corresponds to Offset
```

```
//changing _Lenth value by external scripts can realize texture animation effect
if(i.uv.y <_Lenth*_MainTex_ST.y)
outp  =texCol;
//with in _Lenth value display the texture
else
outp =defaultcolor;
//out of _Lenth value display the default color
return outp;}ENDCG
```

Building a Virtual Architectural Design

To produce a virtual reality simulation, it is first necessary to make and store the objects used to construct the simulation. The software chosen for this work was Vuforia AR (augmented reality) SDK (software development kit) from Qualcomm Inc. Vuforia supports a local or cloud database. These storage methods have their own strengths and weaknesses. Local databases do not need network support, are faster, but support only a limited number of objects that must be identified and made in advance. By contrast, the cloud database can support more than one million objects, but relies on a high-speed Internet connection. In the end, it was decided to use a local database. The images and other objects were uploaded so as to form a local dataset using Qualcomm *Target Manager,* which is the tool that manages the interface to the database (cloud or local) [5].

Objects can be added to scenes as needed. They can be placed where required and such features as lighting and texturing can be applied, e.g. Figure 3 shows a script written in the C# programming language for inserting a camera.
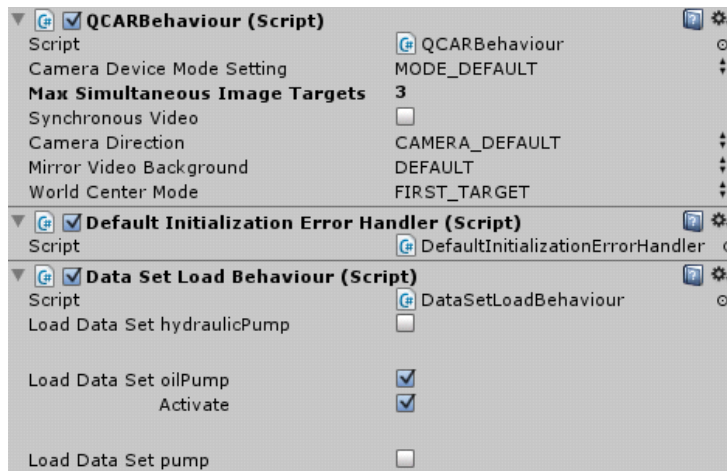


Figure 3: C# script for placing objects into a scene.

The modelling process was completed with 3ds MAX and the computer aided design package AutoCAD, from Autodesk Inc. [6]. The software package Cult3D was used to add interactive special effects. This includes animation, grouping objects and allowing motions, such as zoom and rotate. The interface is shown in Figure 4.
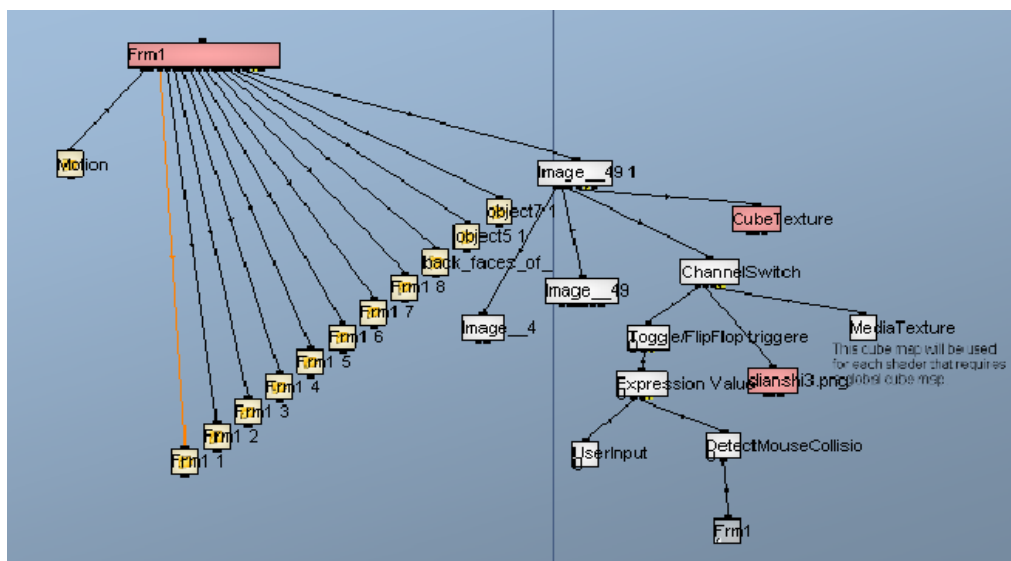


Figure 4: Interactive interface.

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CONCLUSIONS

To sum up, applied research on virtual reality technology in the field of architectural design teaching is important as it positively impacts on the teaching process and learning outcomes. It promotes an improved awareness of design in students, allows better optimisation of the design effect and improves the teaching of architectural design.

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