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Augmented reality potentials in design curriculum

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ABSTRACT: Having been investigated for over decade, Augmented Reality (AR) technology is still perceived by many professionals as being inaccessible. In this article, the author describes an approach adopted for its integration into a design and architecture curriculum. The author presents the process and results of implementing the integration, and illustrates the challenges of introducing AR, including the acceptance of this technology by students, and issues pertaining to AR system development. Feedback from the study has revealed that sound AR systems could be conceptually or prototypically created by non-AR specialists. It was also advocated that the implementation of AR would increase the industry adoption of these tools and the emergence of a new generation of design and architecture students with a strong awareness of AR concepts and technology.

INTRODUCTION

In the current digital age, students entering higher education expect to be exposed to appropriate cutting-edge Information Technology (IT) that would potentially benefit their future career profession. As one advanced type of IT, Augmented Reality (AR) technology can create an augmented workspace by inserting content from the virtual space into the physical space where individuals work [1]. This is compared against Virtual Reality (VR) where users are immersed into a totally virtual world.

AR technology has matured to the point where it can be applied to a much wider range of application domains such as design, architecture and construction. Very few AR applications are noted in the areas of design and architecture because AR technology is still perceived by many as being inaccessible associated with various development challenges. Certain efforts have been made in integrating Virtual Reality into the existing curriculum of architecture and the built environment [2][3]. In contrast, no similar efforts have been noted for the application of AR in design and architecture education.

In this article, the author presents an approach adopted for integrating an AR module into the curriculum of design students at the University of Sydney in Sydney, Australia. The design computing programme at the University of Sydney is one of the largest providers of design computing education in Australia. This integrated approach aims to increase students' motivation and encourage them to apply AR concepts and technology to their discipline in a focused manner. A study was implemented by applying this approach to the design term projects of 28 second-year design computing undergraduate students in the unit *Collaborative Virtual Environments* and nine graduate students in the unit *Computer-Supported Cooperative Design* across two semesters within one year. The approach adopted for this integration is examined in this article with an analysis of end results of AR implementation. This study shows that current AR technologies, if integrated appropriately within the design and architecture curriculum, demonstrate strong promises to provide a foundation for a new class of solutions for the architecture industry.

Augmented Reality

Augmented Reality (AR) allows a user to work with real 3D environments while visually receiving additional computer-generated or modelled information about the task at hand. Such displays can enhance the user's perception of the real environment by showing information that the user cannot directly sense when unaided.

Augmented Reality is typically based on efficient and appropriate media representations of digital contents (eg wireframe, text, video, etc), interaction devices – input (eg mouse, data glove, tangible, etc) and output metaphors (eg visual display, auditory, haptic, etc) that is natural to use, a precise tracking system (eg vision-based, GPS, etc) to provide accurate position and orientation information to keep a virtual scene in sync with reality, and exhaustive computing power (eg mobile computers, standalone server) to cope with the real-time requirements of AR. It is envisaged that AR technology can improve the current state-of-the-art of architecture visualisation, design process and building construction processes.

INTEGRATION APPROACH

There are typically three methods to make education a research activity as follows:

- Bring one's own research into the classroom by setting lecture topics that are relevant to a certain research area;

- Make the classroom a platform for research on education;
- Apply certain research findings in the literature of education to improve one's teaching.

The integrated approach presented in this article is based on the philosophy of the first method, but further advances it by incorporating large-scale research-oriented term design projects.

Figure 1 depicts the overall flowchart of the approach to integrate Augmented Reality into the design and architecture curriculum. The initial incorporation of computer subjects into the academic programme is an established method within the existing design and architecture programmes. As soon as students become familiar with these topics, they could be further integrated into other subjects. Currently, elements of these computer subjects appear in many modules throughout the programme such as 3D modelling, design programming, principles of ArchiCAD and AutoCAD, etc. The adoption of this approach provides opportunities to assess the perceptions for new technologies and appraise their potential applications.

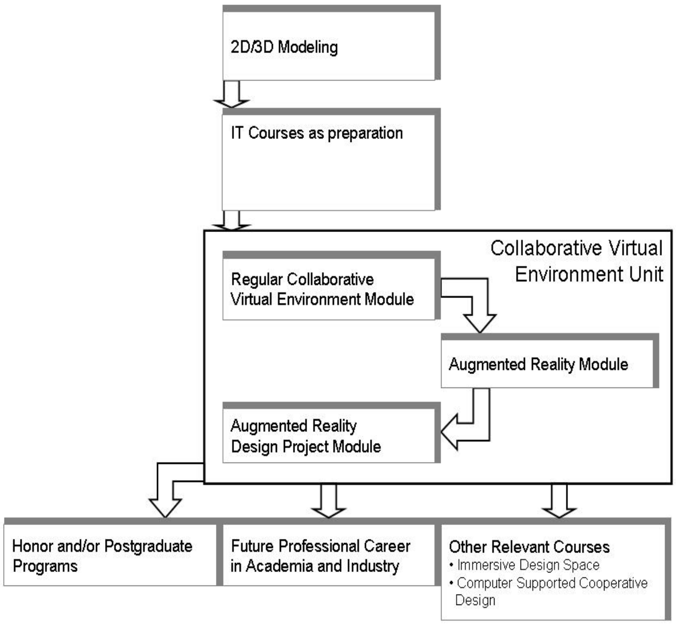

Figure 1: Flowchart of the integrated approach.

An immediate implementation of the integration approach is the developing of visualisation, specifically that which is Augmented Reality-based, as a topic area in design and architecture. Initially, a standalone AR module was developed to consider the long-term possibilities of integrating AR within the broader design and architecture curriculum. The AR module was included in the second year undergraduate unit *Collaborative Virtual Environments*, and the graduate unit *Computer-Supported Cooperative Design*.

This module mainly consists of two parts: lectures and a term design project. Lectures of the AR module were designed to introduce students to the theoretical aspects of AR, hardware and software technologies, as well as spatial cognition and related human factors. Demonstrations were also created from example applications developed in both academia and industry to enrich the lecture contents. The term design project is predominant and provides opportunities for students to practice their research abilities with the knowledge learned in lectures. They need to go through the entire project cycle: problem statements, conceptual design, prototyping, development, testing and usability evaluation, as well as hands-on use, customisation and the testing of existing AR software/toolkit. The subject-specific tutorial materials in the AR module were developed that could speed up the process of skill/knowledge acquisition and enhance the appropriate applications of AR technologies in their term design projects. Modifications of the same module would also be appropriate for inclusion in other units such As *Immersive Design Space* and *Designing Virtual Environments*.

There are three major benefits from the integration: it can prepare certain students for their future research project in honour and postgraduate programmes. It can benefit students for their future career in either academia or industry. It can also prepare students for the study of other relevant units.

INTEGRATION: STUDENT PROJECTS

The goal of group-oriented term design projects for students is to obtain an understanding of the state-of-the-art of Augmented Reality (AR) and Collaborative Virtual Environments (CVE), an insight into the technical issues involved in constructing an AR-based CVE for cooperative architectural design, and an idea of the future potentials in this field.

Project Requirements:

Students need to examine the available AR technologies, and to select and apply appropriate approaches for the development of an interactive simulated environment. Specifically, students were asked to identify and articulate an open problem in areas including architecture and engineering design, urban planning, design collaboration, team communication, mobile construction collaboration and decision making, constructability review, and then specify/develop a sound AR system (mechanisms and strategies) by determining system architecture, hardware (display, input device, computing device, tracking device, etc), software development (media representation, platform, toolkit, etc), interfaces and functionalities formulation. Application scenarios of their solutions also need to be developed and elaborated.

Samples of Students' Projects

Students' projects have varied according to their own interests along their projected future careers. Some students have worked on the conceptual design of AR systems for a specific problem or scenario in architecture industry, assuming that technology and funding are available. Some students even physically developed AR prototypes and then implemented experimentations. The term projects enable students to practice their knowledge in an academic manner and conference papers are planned for some high quality work. Student projects have demonstrated a concern of applying technology appropriately for the needs of their professions. Samples of students work are presented as below covering areas of urban design and planning, interior design, disaster response and mitigation, etc.

Sample 1: Intelligent Agent-Based AR System for Urban Design

One group of students developed a visualisation and simulation framework for an intelligent agent-based AR system, which allows designers to analyse design issues within a real and familiar workspace. This framework combines augmentation concepts (AR, intelligent agents, tangible interface) into one collaborative platform. The system incorporates AR/VR dual viewing modes. The AR mode superimposes 3D visualisations of structures/buildings within an urban area onto a tabletop where the mixed scene could be viewed through head-mounted displays. Designers could manipulate virtual elements through tangible interface by having such a bird's-eye view. In addition, the system allows users to switch to the VR mode where an immersive walking-through experience can be generated by enabling a first-person perspective by fixing the user's view onto a selected agent's view in the virtual world. Such dual modes could increase the user's awareness by providing them with multiple views of the area rather than limiting them to a particular perspective. Intelligent agents are also incorporated into this system to simulate the movement of different objects in an urban area. Dynamic objects such as pedestrians, traffic and sunlight are represented by avatars in the virtual urban design. The behaviour of these avatars is governed by an agent architecture that can effectively sense both the real and the virtual world. Simulation allows users to evaluate the impact of designed environment on these dynamic objects. Interaction with the virtual urban design could be realised through a data glove, which provides a tactile and intuitive interface for browsing menu and manipulating virtual objects in a tangible manner. For example, this would involve *dragging* a virtual structure from the virtual menu to the desired position and tweaking it either directly or through an attribute menu for adjusting its parameters.

Sample 2: Prototype Implementation of AR for Urban Planning

This project entails the concrete implementation for some ideas described in Sample 1. Students developed an AR-based planning system that allows participants to acquire more detailed visual information from virtual models, as well as real time manipulations on the layout design in a real and familiar workspace (see Figure 2).

Figure 2: Screenshot of an AR system for urban design.

The system set-up enables the delivery of the design idea across a group of designers in a discussion room with a large projection screen instead of head-mounted displays, hence allowing for more social interaction. They also conducted a pilot study to evaluate the effectiveness of their system against the traditional method (wood block method) on the task of the reestablishment process of a residential and commercial complex at Millers Point in Sydney. The experimental results shows that although some technical difficulties in their system introduced negative performance factors on the outcome, all the subjects believed that the system holds significant potentials in urban design.

Sample 3: Augmented Reality for Outdoor Design

One group of students proposed the creation of an AR system that facilitates the building and planning of smaller structures (such as streetlights and street furniture) and park/public garden landscaping. Rather than visiting the site then drawing plans back at a desk, or viewing a 3D representation in a room, their system allows architects, designers, landscapers and urban planners to insert objects into their proposed location in the real world (see Figure 3). This allows them to see human movement around planned structures, and the effects of light/shadow.

Through head-mounted displays, participants could see a composite image of the virtual object and the real world into which they could add objects with a tablet PC. The system allows designers to collaborate off paper or screen and design in a real environment. It has further applications into other more specific and general design and urban planning areas.

Figure 3: A virtual bench is positioned onto the proposed location in the real environment.

Sample 4: Augmented Reality-Based Mixed Design Space

In this project, students proposed a conceptual design of a collaborative virtual environment aimed at architectural and interior design. Their conceptual design could help architects and interior designers produce effective solutions while designing and constructing their own works.

This system actually consists of two spaces: the Augmented Reality space for architects in designing exterior of a building, and the Virtual Reality space for interior designers in designing interior of a building. The two spaces are adjacent with each other and could communicate through certain virtual interfaces. As such, their system allows the creation of a complete building from interior to exterior. In the Augmented Reality space, the architects can design the exterior of the building while visualising the external parts. The Virtual Reality space allows designers to view objects in real-life sizes, that is, as if the interior designers actually standing inside the room while they are creating. They could also move fixtures, fittings and/or furniture around freely with the touch of a finger. In doing so, they would not have to move actual heavy physical objects around to find the most suitable place in the room. This project gives it the advantage of allowing architects and interior designers to interact and collaborate with each other in the entire design process.

Sample 5: Augmented Reality for Construction Disaster Response

One group of students recognised that a large volume of coordination and communication information needs to be aggregated, presented and assessed among diverse rescuing groups in construction disaster responses. They developed a framework that incorporates AR technology to facilitate effective coordination and the communication of critical information among diverse rescuing groups by improving their situational awareness. This AR-based collaborative virtual rescuing platform aims to provide an effective means by which parties in the construction disaster area could effectively communicate with various command centres concurrently, as well as provide access to auxiliary information transmitted from sources such as satellites and radar. Three focus areas – the command hierarchy, communication protocols and communication interference – were identified and incorporated into the framework after analysing typical construction disaster response procedures. Their project also identified properties that the physical/technological implementation of this AR system would need to possess so as to tailor the framework suitable for use in the majority of conceivable construction disasters. They also justified the AR system architecture (eg hardware for communication and positioning, visualisation interface, software platform, etc) that enables the system to be operational under real conditions.

FEEDBACK FROM STUDENTS' PROJECTS

All students were requested to reflect on the effectiveness of their end results and submit their reflective feedbacks in written form. Information was gained about their shared experience of applying AR to a design project. Focus groups can be useful after the term design projects have been completed to assess the impact of integration. Focus group meetings were hosted soon after the students had presented their completed projects at the session of *Design Project Critique*. Their evaluations on reasons why the AR technology could be applied and integrated into their future professional practice were that AR could:

- Extend the traditional forms of collaboration and visualisation;
- Improve communication for those people not familiar with interpreting 2D plans, sections and elevations;
- Enable a client to not only see his/her project in the context of its surroundings, but also to be able to interact with it;
- AR technology offering interactivity can be practically run on personal computers, including laptops, typical of those in use in many offices;
- Enhance the image of a professional practice through the use of cutting-edge technology when submitting feasibility studies to clients. Students identified how AR could be usefully employed by planning authorities considering a development proposal. For example, they considered that AR could be usefully applied for future development strategies by those responsible for the management of a site of buildings such as a hospital. They perceived its potential applications in developing client briefs, marketing and even training;
- Facilitate the discussion of ideas and options (constructability review) prior to construction. The use of interactive technology in the initial stages of project design can enable issues concerning constructability to be highlighted early in the design process;
- AR technology could be generally used for many different applications beyond architecture. Examples include disaster response, entertainment, etc;
- Attract funding and investment sources.

Other views that emerged from the student feedback were as follows:

- Students reflected that linking AR to their professional practice project was very useful as they had a detailed understanding of the problem they were trying to solve;
- The theoretical aspects of AR should continue to be an integral part of the approach, complementing AR skill acquisition;
- The implementation of an AR-related term project should continue to be an integral part of the approach, which could prepare students for the honours programme and postgraduate study by giving them research experience.

For their final presentations, students presented their AR projects, which were assessed by a panel of two staff members with backgrounds in CVE and AR/VR. The assessors observed how the students attempted to integrate their AR systems appropriately into the identified problems and provide feedback/suggestions to their projects.

SUMMARY

In this article, the author outlines an approach to integrate AR into the design and architecture curriculum, which makes it more accessible in teaching and learning. Samples of students work are described to demonstrate the quality of students' work in the term of design projects. The qualitative feedback from this study provides lessons that can be used to determine a correct integration methodology between the two subject areas (design/architecture and AR). It was also revealed that sound AR systems could be conceptually or prototypically created by non-AR specialists. Students advocated that the implementation of AR would increase industry's adoption of these tools and the emergence of a new generation of design and architecture students with strong awareness of AR concepts and technology. Unit tutors noted that some students spent longer time on learning how to use the AR software/ toolkit, which affected their focus on the innovative design of AR systems for articulated design and architecture problems. Therefore, the future integration of AR into the design and architecture curriculum will encourage students to focus more on visualising the interface for various architectural designs.

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