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An Empirical Study on Tangible Augmented Reality Learning Space for Design Skill Transfer

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Abstract: Tangible augmented reality (TAR) technology opens a novel realm which integrates the computer-generated elements into the real word. Its applications into design education have been explored with a limitation to this entire area. TAR offers an innovative learning space by merging digital learning materials into the format of media with tools or objects which are direct parts of the physical space. It is therefore conceived that such combination opens new perspectives in teaching and learning. This paper presented and evaluated one TAR system to improve the pedagogical effectiveness of experiential and collaborative learning process in urban design education. The results from the experiments were analyzed under a previously developed theoretical framework, which show that TAR can enhance the design activities in some collaborative work.

Key words: tangible interface; augmented reality; tangible augmented reality; design learning; physicality

Introduction

The empirical study presented in this paper focuses on supporting tangible augmented reality (TAR)-enhanced learning practice based on experiential and collaborative learning theories. Technically, this empirical study was based on the platform, TAR-based urban designer. As a traditional learning method, wood block was selected as the benchmark to be compared with this TAR system. The most unique and possibly the most powerful characteristic of this learning space is that it affords a first-person form of immersive or semi-immersive experiential learning. This method in urban design learning is not based upon third-person knowledge normally communicated in lectures, where students learn with no opportunity to directly experience what they learn on their own. The qualitative learning outcomes from third-person and first-person learning are very different. A preponderance of third-person learning means that student learning outcomes are usually shallow and retention rates are low. This formulates the assumption that has been tested in the study presented in this paper. There are three identified measurements for validating the improved learning outcome and enhanced knowledge transfer: assessment on the quality of designed solutions, questionnaires, and protocol analysis. Special questionnaires and associated data collection strategies can be developed based on a wide range of related literatures which address learning theories and its associated testing techniques. The approach of protocol analysis can be used to supplement the lab experiments to closely examine students' social learning processes (e.g., assessment of social interaction) by capturing episodes of collaborative learning activities. Selected experimental results and interpretation which supports the discussion of applying the framework to the TAR system, were also presented in this paper.

The goal of this study is to evaluate a functioning TAR system for urban design learning or any similar

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learning problems. It examined the benefits of using TAR technology in design education as well. The possibility of misinterpretation among the participants could be reduced by providing more detailed visual information on design artifacts, which not only give better understanding in design structure for the study, but also promote inspiration in solving more specific problems. This can also encourage the learning in the collaborative space in order to improve the overall learning efficiency and productivity. This study also identified the strength/weakness of TAR systems involved in the design activities for learning. Therefore, the study explored the capacity of TAR concept and systems for development in similar fields.

1 Role of TAR in Design Learning

Learning activities vary with a broad diversity of learning processes underneath. These can be basically classified into two categories: constructive and analytical. Current design education involves the critical need to integrate analytical and constructive learning sequences. There are proven benefits from interleaving theoretical and practical learning[1], and there is a growing need for innovative teaching and learning concepts and technologies which can support such integration.

From the technical perspective, the TAR concept can bridge this gap between the theoretical and practical, and focus on how the real and virtual can be combined together to fulfill different learning objectives, requirements, and even environments. Constructive activities are aimed at building real components, analytic activities at cognitive understanding of virtual components[2]. From the perspective of learning activities, this concept facilitates the bridging between direct and practical experience learned from constructive activities and symbolically communicated experience learned from analytic activities[3]. More specifically, TAR can become a link for connecting physical mock-up experience (from constructive activities) and abstract modeling (from analytical activities) in the context of architectural education[4]. For example, textbooks are generally well organized according to the level of readers. Textbooks may involve many elements such as concepts, rules, analogies, and imageries so that information may be stored in long-term memory. TAR systems enable learners to use one learning style based on printed materials and to access additional information using Augmented Reality (AR).

TAR systems can utilize multimedia for learning, while simultaneously exploiting the advantages of printed learning materials. In TAR systems, markers/tags can be added to the text to identify information related to the descriptions in the text, and are detected with an image-processing tool, such as ARToolkit[5]. 3D geometric learning has been considered especially effective when used in Augmented Instructions, because texts are limited to two-dimensional presentations[6].

2 Previous Work: the Framework

The framework[7] was developed as a theoretical process for applying TAR concept and technology in the field of design learning. This framework bridged the connections between four knowledge domains from cognitive science, design process, TAR technology and learning theory. The framework shows that TAR systems which combine traditional tangible user interfaces with AR technologies become an input into learners' brain.

Cognitivism[8] uses the metaphor of the mind as a computer: information comes in, is processed after the stimulus and the learners are viewed as an information processor (like a computer). The brain can be viewed as the processing continuum which involves thinking, memory, consciousness, etc. These are the behaviorism[9] that brain responds to environmental stimuli. It reflects the observation through watching and the corresponding tactile feedback. This procedure brings out the concrete experience to the effects of physicality which mentally impact learners. While learners participate in the design activities, the typical design activities form the features of design development which inherit the consecutive cycle.

For TAR systems, the initial mental image/model can be gained from reflective observation (AR) and tactilely from tangible feedback (tangible interface). For each cycle along the design process, learners follow the thread of presenting, testing, and re-imaging responses to a set of related problems. This continuous and combined feedback from visual and tactile channels promotes the abstract conceptualization to be formed. Following the above procedure, the active experimentation can be converged. The response can result in possible benefits of expressive, playful, reflective, situated and interactive learning activities from TAR systems.

Students usually work better if they are within a common workspace instead of working in separate locations. Figure 1 depicts the shared communication cues in the space between them. These cues include gaze, gesture, and nonverbal behaviors.

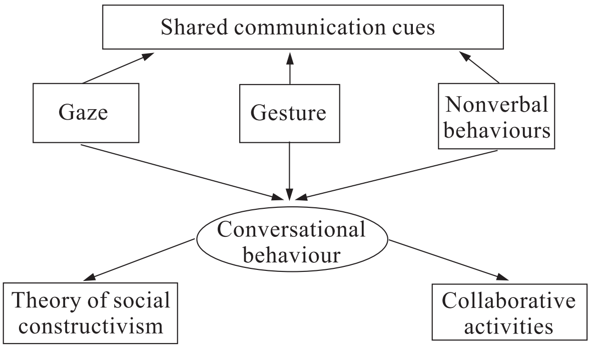

Fig. 1 Shared communication cues

The approach of protocol analysis could be used to analyze the social learning outcomes and effectiveness from the use of TAR systems. Design thinking can be induced from the behaviors captured from the oral communication, including verbalizations, drawing and gestures (Fig. 2).

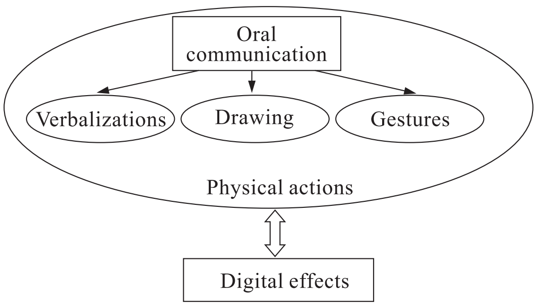

Fig. 2 The approach from physical action to digital effects

Learning outcomes can be compared with the current method of how design is taught that typically consists of lecture-based and a follow-on studio where physical objects/props such as wood block mock-ups are used to convey meaning. The lecture part offers very limited interactive space for concrete experience. In a classroom setting, students work better if there are some interactions which are established in their natural workspace instead of merely working with computers. Students using TAR are envisaged to promote their interactions and event processing modules for state update by the context server and TAR. Through this design process, students can be actively involved in the design activity to develop critical design skills and knowledge rather than passively fed in a normal lecture.

It should be identified the extent to which students can make learning progress in skills, knowledge, or attitude, with and without the experience of the TAR system for certain design activities identified in the framework[9].

User acceptance plays a vital role in the way a system is used and perceived. This naturally affect the way a user perceives and interacts with a system and is a good example of why learners cannot simply take solutions from one context and expect them to work in another. Even small user studies in actual work settings, are rare in the field of TAR and it is believed by the authors that this can be largely ascribed to the design methods commonly used within the field. Therefore some questionnaires need to be investigated before the actual design to ensure the usability. Confronting a design for a new technology with tasks from real work rather than laboratory settings allow problems that otherwise would remain unknown to emerge. Testing the concept of providing augmented instructions together with such an apparatus in the real-world settings thus reveal the pros and cons of a design. The system, regardless of appearance, does affect the social context of the task simply by being introduced as a new element. However, this may not be a problem in the long run □ if the system has a positive influence on the task, user, and context, it will grow to be a part of the task as time and experience advance. This should be true for TAR as it has been true for other technologies, for instance, the use of computers for writing papers – few students and researchers today can imagine writing papers without the cut-and-paste functionalities of word processors. Likewise, instructions through TAR technology have the potentials to become a natural part of everyday life in many domains. Cognitive systems provide a way to study and think about TAR systems as joint cognitive systems acting in a goal-oriented and adaptive way. There is a lack of these fundamental aspects in most other perspectives.

3 A TAR Testbed

One prototype based on the framework was designed to examine how TAR system can help design learning as compared to the traditional way. This TAR-based design learning system could allow participants to acquire more detailed visual information from virtual models, as well as real-time manipulations on the layout design. Learners can use the system in visualising the actual design structures as well as creating a shared design workplace for multiple learners. With the design easily changed and updated, the overall design process can therefore be simplified and facilitated. In the study, two different scenarios are used for the wood block method and the TAR system respectively. Eight major steps as shown in Fig. 3 have been conducted in this study.

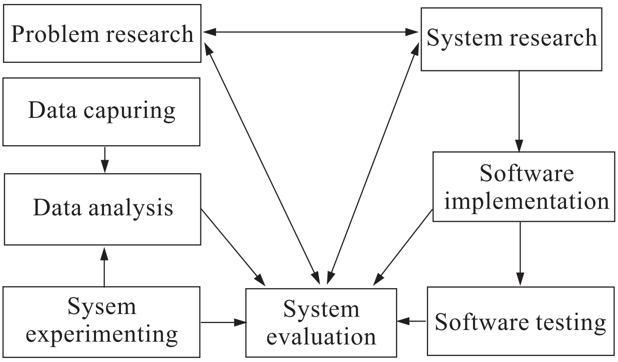

Fig. 3 Overall process

Firstly, the scope and requirements for the study were implemented in the section of problem research. Then it was required to construct a design system for specific problems. The study was chosen by using ARToolkit[5]. ARToolkit is a free AR application which is programmed by using C# language. In general, ARToolKit overlays virtual imagery on the real world objects. In details, ARToolKit captures images from the camera input, analyzes the image and searches for predefined patterns. If any pattern is found, the toolkit then overlays the corresponding virtual object over the real object. Corresponding to the system research, some functions like the modeling part should be done in the software preparation part. The virtual object was pre-modeled by using 3D modeling application, ArchiCAD. Users can quickly develop new model depending on the pre-defined requirements. The TAR system features some advantages which enable the development of the research as shown in Fig. 4. All input images are captured by one camera, the position/orientation is unique. Hence, it reduces the difficulty of view-point calculation if multi-cameras are required. Square marker patterns have been used to present multi buildings which provide the functionality of extendable marker collection. The software should be tested to ensure that the system can work properly.

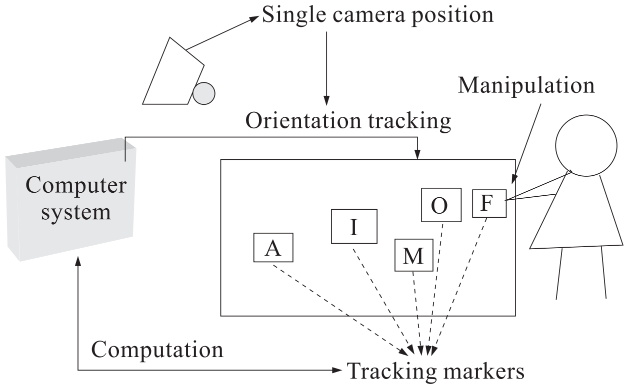

Fig. 4 System setup

4 Results and Discussion

This section interpreted part of the experimental results and reflected those results within the context of the developed framework from the perspective of the learning theories. From the results, some common issues are apparent for the groups using TAR. They all spent a lot of time for indication (while checking with screen) in both modelling actions and body movements. However, it seems that the TAR enables participants to develop the design ideas as the portion of design tasks. One scenario design was done by using wood block method as shown in Fig. 5. Figure 6 shows the result when the group used TAR to design the other scenario.

Fig. 5 Using wood block for urban design learning

In contrary to the TAR, there are many advantages over wood block method. Participants commented that

TAR has more detailing particularly in the texture of models. This certainly improves the visualization which increases the perception from the reflective observation. Secondly, they felt like the system mobility because they did not have to carry the entire collection of wood blocks around. This reduced the efforts for getting the tactile feedback so the participants can easily access the markers which provide more spaces for actions where they affected computation.

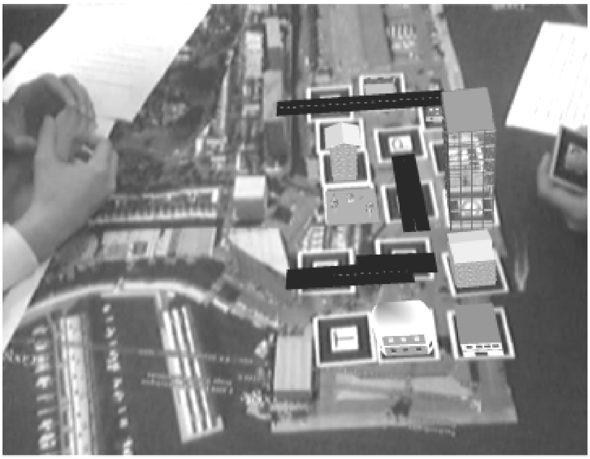

Fig. 6 Using tangible augmented reality system for urban design learning

In contrast to traditional learning method, the TAR system affords opportunities to capitalize on human's developing repertoire of physical actions and spatial abilities for direct system input and control. It highlights conditions under which concrete experience can be gained faster when both watching and feeling impact on learners' brain in the same pace. It should be emphasized that the TAR helps to improve the efficiency of design activities from certain learning aspects although it could also slow down process when certain usability issues arise.

Visualization plays an essential role when it involves the quality of explaining design ideas since it helps to explain ideas in a more detailed manner with visual aid, however, with traditional models users need imagination for each wood block. As mentioned in the framework, the initial image can only be formed when there is enough information perceived and constructed visually from reflective observation (from AR) and tactilely from haptic feedback (from tangible interface). Then followed by the cycle along the design process, participants can try to solve some specific problems by the consequence of presenting, testing, and reimaging[10]. Abstract concepts are then reinforced by this continuous combined feedback from visual and tactile channels.

5 Conclusions and Future Work

This study explored potentials for students to become more empowered with TAR-based learning. The user feedback of this study showed that all participants agreed that TAR systems featured significant potentials in future development for design learning. TAR can enhance the design activities in some collaborative work, because TAR systems can improve virtual representation of objects. It is promising and useful in design education for the learners to discuss the ideas which maximize the learning outcome as well as efficiency.

This study is an initial effort towards TAR applications in design learning and the results can become a basis for TAR in broader applications in education. The benefits for educators to become involved in the development of learning content associated with TAR systems are also substantial.

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