TANGIBLE AUGMENTED REALITY:
A NEW DESIGN INSTRUCTIONAL TECHNOLOGY

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ABSTRACT: This paper discusses the proposed idea of using Tangible Augmented Reality to gain design knowledge since information sharing has been limited by one way receiving knowledge without enough response and interaction in the learning process. The new instructional technology is not only available through visual cues, but also opens up multi channels from different cues. It describes some guidelines for space utilizing between buildings and followed by a scenario. The proposed system offers three levels of information which affects aspects of individuals experience of space as they move the digital contents in the real environment.

KEYWORDS: Tangible augmented reality, tangible user interface, augmented reality

RéSUMÉ : Cet article examine la proposition d’utiliser la Réalité Tangible Augmentée pour acquérir de la connaissance en design puisque l’échange d’information, dans le processus d’apprentissage, a été limité à une réception de connaissance à sens unique manquant de réaction et d’interaction. La nouvelle technologie d’instruction n’est pas qu’accessible par signaux visuels, mais ouvre aussi à de multiples canaux de différents signaux. Il décrit des directives pour utiliser l’espace entre les immeubles, suivies d’un scénario. Le système proposé offre trois niveaux d’information affectant des aspects de l’expérience individuelle de l’espace pendant qu’ils déplacent le contenu numérique dans l’espace réel.

MOTS-CLÉS : Réalité tangible augmentée, interface usager tangible, réalité augmentée
1. INTRODUCTION

*Instructional Technology* is a comparatively new field dedicated to applying what is empirically understood about how humans learn (Reiser 2001). It also improves upon performance to the design, development, implementation, and evaluation of learning and performance support of products, processes, and environments (Reiser 2001).

The term *instructional technology* was initially separated from the term *educational technology*. *Educational Technology* was defined as “a complex, integrated process, involving people, procedures, ideas, devices and organization, for analysing problems and devising, implementing, evaluating and managing solutions to those problems, involved in all aspects of human learning” (Molenda 2003). Instructional technology was applied to situations in which learning is purposive, controlled and centred on problem-solving processes.

There is no doubt that the advent of new technical innovations and computer-assisted methods will increase and that there will be more methods to facilitate students’ learning in the future. There is no doubt that these technological means and methods do play an increasingly important role in helping the learner in the modern educational context as well (Januszewski 2001). In recent years, the traditional notion of the classroom has been expanded and evolved; virtual space has taken its place alongside physical space. For example, Tangible Augmented Reality (TAR) has been used in educating children in the museum to understand the volcanic explosion through a media called *the magic book* (Billinghurst, Kato and Poupyrev 2001). However, little research efforts have been made towards using TAR technologies for learning in high education. Therefore, it is necessary to investigate the benefits of current TAR in the educational context of learning in the field of design that are based on corresponding learning theories that utilize TAR systems for design-learning.

2. TANGIBLE AUGMENTED REALITY

Tangible Augmented Reality (TAR) is usually a combination of a Tangible User Interface (TUI) and an Augmented Reality (AR) system (Chen and Wang 2008). The use of an AR system allows learners to see a three-dimensional presentation of the graphics. Moreover, the specific interface makes it possible to manipulate the pieces in a direct and intuitive way—instead of using a mouse or a keyboard.

In recent years, Augmented Reality has emerged as an important medium for education and entertainment (Schnabel 2009; Billinghurst, Kato and Poupyrev 2001; Freeman and Steed 2006). *As the number of people building AR applications grows, it becomes increasingly apparent that a need exists for more efficient development tools.*
Although Computer-Aided Design (CAD) applications have become designers' inevitable tools for expressing and simulating innovative ideas and concepts, designers still face certain problems when they replace traditional materials and mock-ups with 3D CAD systems. For instance, for certain intangible problems, designers are unable to physically interact with testing products in early stages of the design process. As design environments move from physical world to a virtual one, designers are confronted with emerging intangible problems. In contrast, as realistic as it can be, the rendering fidelity on monitors cannot provide the realistic tactile feelings of design models, yet foam models or other physical prototypes can. In addition, it is unlike 2D scale renderings and 3D physical mock-ups, 2.5D perspective drawings have lost a cue for the perception of absolute size. According to these reasons, inexperienced designers might be inclined to mistakenly comprehend 3D CAD design. Therefore it is essential to afford the haptic sensational channel during design learning process. A touchable and graspable interface based on 3D CAD data, augmented foam (Lee et al. 2004) has been proposed to apply AR technologies to physical blue foams. Using augmented foam, a blue foam mock-up is overlaid with a 3D virtual object, which is rendered with the same CAD model used for mock-up production. A method has been presented to correct occlusions of the virtual products by user's hand. For instance, augmented foam was tested for a mug design (see Figure 1). Designers were able to inspect and evaluate the design alternatives interactively and efficiently.

**FIGURE 1. GENERAL-PURPOSE AR (A1~A3) AND AUGMENTED FOAM (B1~B6): (A1) PLANE MARKER (A2) VIRTUAL OVERLAY ON A PLANE MARKER (A3) VIRTUAL OVERLAY ON A TABLE, (B1) AUGMENTED FOAM WITHOUT VIRTUAL OVERLAY, (B2) AUGMENTED FOAM WITH VIRTUAL OVERLAY (VISIBILITY PROBLEM), (B3) AUGMENTED FOAM ON A TABLE, (B4~B6) AUGMENTED FOAM WITH CORRECTED HAND VISIBILITY (VARIOUS COLOUR CUPS) (LEE ET AL. 2004).**
There have been also some attempts to integrate familiar analogy techniques with efficient digital environments that allow designers to interact with digital information seamlessly and intuitively during early design processes. Examples of them are Tangible User Interfaces (TUI) for urban design (Ullmer and Ishii 1997; Underkoffler and Ishii 1999), Augmented Reality systems for urban planners (Billinghurst and Kato 1999; Buchmann et al. 2004) and 3D simulations for feasibility studies (Freeman and Steed 2006; Keawlai 2008; Fisher and Flohr 2008). In many design processes, physical interaction and tactile information are advantageous, or even critical. In particular, architectural design involves several realms of sensory experience which interact with and fuse into each other. The Irish philosopher and clergyman George Berkeley associated touch with vision and assumed that visual apprehension of distance and spatial depth would not be possible at all without the cooperation of the haptic memory (Houlgate 1993). From his point of view, vision needs the help of touch, which provides sensations of 'solidity, resistance, and protrusion' (Houlgate 1993). Therefore, if sight is separated from touch, it could not have any idea of distance, or profundity, nor consequently of space or body (Houlgate 1993). Jan Gehl considers human scale and interaction are successful architecture (Gehl 1987). Hence, a good design process should involve multi-modal sensational channels to the designers. The issue of architecture and urban design is mainly space. Many philosophers (Gibson 1962; Casey 1997) dealt with space as a fundamental dimension of our being and acting in the world, and they realised that, to properly understand space and its connection with human feelings and actions, it is necessary to overcome the vision of it as pure individual objects, and to start seeing it as overall dimension for interaction and experience (Tuan 1977).

3. BENEFITS

When technologies increase the possibilities of visualization, it aids students to better understand abstract concepts. For instance, students can manipulate learning objects on computers through graphic displays in ways never before possible, and can communicate their results and conclusions in a variety of media to their instructors, students in the next classroom, or students on the other end of the world. For example, using technology, students can collect and graph real-time weather, environmental, and populations data from their community, use the data to create colour maps and graphs, and then compare these maps to others created by students in other communities. Similarly, instead of reading about the human circulatory system and seeing textbook pictures depicting blood flow, students can use technology to see blood moving through veins and arteries, watch the process of oxygen entering the bloodstream, and experiment to understand the effects of increased pulse or cholesterol-filled
arteries on blood flow (Garrison and Anderson, 2003). With the incredible fast
development of technologies, current instructional technologies seem have
much more offer beyond only colour maps or graphs and motion pictures, one
of these options is to use Tangible Augmented Reality.

As mentioned before, Tangible Augmented Reality has become a new
instructional technology. The benefits of using Tangible Augmented Reality
makes learning more efficient based on the combination of visual and tactile
cues. The information involved in design process typically consists of compli-
cated elements such as concepts, constructs, principles, scale, spatiality and
propositions. Practice is the application of that knowledge to solve problems.
Practice can also contribute to the knowledge base through information gained
from design experience, development, utilization, management, and evaluation.
In particular, there is a lot of abstract knowledge such as understanding spatiality in the design domain. The purpose of instructional technology is to affect
and effect learning. The reason that TAR can become one option of instruc-
tional technology is because it creates the opportunity for students to learn
design in experiential activities. Furthermore, using TAR might eliminate the
gap between the interaction with a natural environment and the interaction
with a computer system. TUI uses objects of the natural environment as an
interface to the computer. Thus, the real world and the virtual world are com-
bined. This intuitive mode of interaction simplifies the communication between
man and machine, especially for unpractised users. Moreover, TUI can be used
by several persons simultaneously because it is not restricted to one screen or
one keyboard. This makes the technology especially during team work, it can
benefit from a three-dimensional presentation and a direct way of interaction
because this increases the realism of environment and simplifies its controls.

Many urban design tasks concern the spaces between buildings as well as the
buildings themselves. No one will sit down in front of a drawing board or CAD
screen and spend months designing the column of air between buildings. Archi-
tects talk of tectonics as if the earth moves for them every time they put up a wall
and it seems natural that people usually pay less attention to invisibleness or the
airy-fairy (Gehl 1987). Space gets chopped up and generally taken away from us
in cities, however, the moment people begin to lay out buildings in multiple units,
the moment they build houses and the repetition of the shapes starts to create
patterns. Therefore, inevitably people begin to consider what happens when
someone looks out of their window at their neighbor’s home, or what the pattern
of car parking might be, or why people are allowed to own their home right up
to the threshold of the bricks and mortar but no further. The spaces between
the houses become just as important as the buildings themselves (Gehl 1987).
Therefore, it is essential to educate current designers to pay more attention to the
spaces between buildings, rather than the buildings themselves, and also how to
understand and analyze space utilization between buildings. However, most likely
the spaces between them get trashed. Nobody seems to care if a medieval church is overshadowed or if the sun is blotted out.

4. PRINCIPLES AND SCENARIOS

Tangible Augmented Reality offers at least a cycle of involving two sensible movements through the design process, from visualization to tactile sense which brings out realistic experience in the place. Place is a space which is invested with understandings of behavioral appropriateness (Tuan 1977). Although we are located in 'space', we act in 'place' (Harrison and Dourish 1996). Therefore if the design process can provoke more interaction for designers, then it will help them to understand the relationship between buildings. In this way, the space between buildings can be better utilized. Such sites should receive adequate sunlight and not be completely overlooked by neighbouring houses. The following discussion describes some example principles which are according to the Rushcliffe Borough Council (2008). These principles are illustrations to demonstrate how TAR will benefit the learning of them. The next section presents proposed TAR prototype with a detailed discussion.

Firstly, there should be adequate space to accommodate at least a single car beyond the edge of any walkway or highway subject to the requirements of the car parking standards (Rushcliffe Borough Council 2008). Figure 2 shows an unorganised car parking space. The relationship between street and car parking is being ignored in this part. But using TAR could bring the direct sense for people to understand that the space is not enough for car parking, for example, when users see the number of cars increase, then they immediately can view the decrease from the space. Hence they can understand why the guidelines have to be set in certain dimension.

**FIGURE 2. PARKING AREA.**
Secondly, the minimum rear garden area for 1 and 2 bedroom units should be no less than 55 sq metres, excluding any space required for a garage or car standing (see Figure 3a) (Rushcliffe Borough Council 2008). Rear garden which functions as a natural environment is the essential element for residential area. Unfortunately this has been frequently decreased to satisfy the demands of high density residential areas.

Then, all other new dwellings should incorporate a rear garden area of not less than 110 sq metres for detached properties and 90 sq metres for semi-detached (see Figure 3b) and terraced properties excluding any space required for a garage or car standing. TAR can show to the users with row data from one building to the other, so when they manipulate the position of the different objects, they can see how it affects with the distance with immediate feedback. For example, when the user manipulates the house object and its distance from other houses, the screen would give immediate response with digital information shown on the screen corresponding to the movements from the users. In addition, when a user makes changes to the location of a house, this can significantly change the amount of available rear garden area that is available, and this must be taken into account due to council regulations. Here the user could visualise how the distance could change the space between the objects and receive immediate feedback.

**Figure 3.** (a): Relationship between rear garden and bedrooms; (b): Distance between windows to dwellings (Rushcliffe Borough Council 2008).

The minimum eye-to-eye distance for a space to the rear of the dwellings where the windows of habitable rooms face each other should be not less than 30 metres (Rushcliffe Borough Council 2008). It is hard for people generally to understand the relationship between the distance and the space, but with the aid from TAR, users can see how the distance affects the area in order to change
the space usage. This can help user understand the relationship between a single element, such as volume, distance, or area, and the spatial relationship. Without the aid of TAR, the user will have difficulty forming an image in their mind of the spatial relationships involved, and will also be lacking any validation.

Where rear garden spaces are adjacent to communal or public open spaces, roads or footpaths, or are situated in key or prominent positions, a 2 metre high screen wall is to be constructed to suitable details.

In certain instances it may be appropriate to consider alternative standards to those set out above. This may be the case where it can be shown that an innovative approach to design is appropriate or where the site is within a historically significant environment including conservation areas and within the setting of a listed building where account must be taken of the character of the local area.

There should be not less than 10 metres (Rushcliffe Borough Council 2008) between the main window to a habitable room and the facing boundary of the plot (see Figure 4a).

**FIGURE 4.** (a): distance between a main window to facing boundary of the plot; (b): distance between a main window to a habitable room facing a building (Rushcliffe Borough Council 2008)

There should normally be not less than 14 metres (see Figure 4b) where a main window to a habitable room faces a building of two or more storeys without a facing window to a habitable room (Rushcliffe Borough Council 2008). A greater distance may be required between buildings when due to orientation, a significant over-shadowing or over-dominant impact would result, for example, with three storey buildings. In this situation, TAR could easily create the vision for users to see how these different objects could impact on the space and influence on the design.
Rear garden spaces shall normally be enclosed by post and wire, close boarded or hit and miss type fencing. A personal sitting out area to the rear of each dwelling should be provided and screened by a solid wall or fence of at least 3 metres (see Figure 5) in length and 2 metres high. Hedging of approved species with fencing should also be considered. With the assistance of TAR, these conditions could be delivered to the users in a more sensible way since the users understand better with a combination of visualization and haptics.

**FIGURE 5. REQUIREMENTS FOR A SOLID WALL (RUSHCLIFFE BOROUGH COUNCIL 2008).**

In summary, the above principles are discussed within the connections between two objects. Apparently, it is straight-forward to understand the relationship between two buildings and also not difficult to follow these principles when these figures are presented with numbers. However, architecture and urban design is much more intricate than this. When the scenarios get complicated, such as there are usually more connections between people, places and buildings and there are some objective of the advice to ensure that every new dwelling is provided with an acceptable amount of beneficial outdoor space with suitable means of enclosure to provide a private area within which to undertake normal outdoor activities. Particularly, if one relationship between the buildings also connects to another link, the scenario could be difficult to imagine from drawings. For example, when single scenario starts to combine together, such as the Figure 4a with Figure 4b being arranged together, then suddenly the relationships are not only just to satisfy the distance with habitable rooms from one side, depending on the other buildings' orientation, the issues of privacy, shadowing, etc. have to be considered as well. If the stories of building are different, then it makes the situation even more complicated and difficult to be imagined/understood. Therefore, TAR is envisaged to be much more helpful since it not only offers visualization, but creates the opportunity for designers to interact with physical objects in order to identify the different
relationship from different objects. The next section presents proposed TAR prototype with a detailed discussion.

5. PRINCIPLES AND SCENARIOS

The framework for the TAR system contains three levels of functions: distance, 2D area and 3D volume. The initial interpretation for the urban area can be provided with the raw data for the distances of the spaces between different objects. For example, a 2D map can be projected to the screen using Graphic Interface. The raw data could be pre entered into the TAR program. The physical objects are then arranged to be positioned in the initial plan. When a designer starts to observe the relationships between buildings, streets and rear gardens, the distance data can be visualized/presented with level 1 function according to the specific relationship between objects. This could provide designers/learners with instant feedback and relevant results with real scale in a real scenario. Users could interact with the physical objects as they would do with a physical model in a design studio. Data is calculated and the results are immediately projected to the corresponding location through Augmented Reality technology.

The second level deals with data/information based on the area. Users modify the size of the buildings or other objects in order to obey the guidelines from the design, meanwhile they can also decide if they want to maintain the information from level 1.

The third level is to consider the space into three dimensional representations. The view would be seen as in Figure 6 which creates the spaces between objects. If users want to look closer at a particular scenario in the design, they could choose to set off the different objects into one color which are not related to this scenario. In this way, the users would not be confused with information overload from the screen.

For example, the Figure 6 shows different heights of buildings which result in multiple spatial relationships. TAR could allow users to see the distance between different building, the arrows (show in Figure 6) pointing from one building to the other can guide the users and help them to understand the spatial relationships that are present. The blue area in Figure 6 highlights the area between the buildings according to the movements and modification made by the user. Furthermore, the user should also consider the void between the buildings, so they might like to consider the third level of space between individual objects.

There are several major components in this proposed system (see Figure 7): the tangible interface, the database system, and the data processing through the computation from context sever. Firstly, users will interact with the system from a tabletop surface, with the Charge Couple Device (CCD) digital camera as means
of input. The projector is used as output. The camera could detect all changes to transfer all the movements to the computer. Then the computer calculates all the results and projects them to the screen.

**FIGURE 6. AN EXAMPLE OF LEVEL 3 VIEW.**
6. SUMMARY

The aim of the using Tangible Augmented Reality (TAR) is to evoke the new instructional technology into design learning while enjoying the design activity. This new instructional technology is not only available through visual cues, also opens up multi channels from different cues. Thus, it unifies the advantages of engaging multi-sensory of TAR into the experiential design learning activities. This paper discusses the potentials of using Tangible Augmented Reality to gain design knowledge. This paper also describes some guidelines for space utilizing between buildings and followed by a scenario. The proposed TAR system framework is also presented, which offers three-level graphic representation. Moreover, the TAR system is capable of including the perspective view from the third dimension in a natural way.

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REFERENCES


