Studying Architectural Massing Strategies in Co-design

Mobile Augmented Reality Tool versus 3D Virtual World

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Researchers attempt to offer new design tools and technologies to support design process facilitating alternative visualization and representation techniques. This paper describes a comparison study that took place in the Department of Architecture, at the Istanbul Technical University between 2016-2017. We compare when architects designed mass volumes of buildings in an marker-based mobile Augmented Reality (AR) application with that of when they used a collaborative 3D Virtual World. The massing strategy in the AR environment was an additive approach that is to collaboratively design the small parts to make the whole. Alignment and arrangement of the parts were not the main concerns of the designers in AR, instead the functional development of the design proposal, bodily engagements with the design representation, framing and re-framing of the given context and parameters become the discussion topics.

Keywords: Augmented reality, virtual world, massing strategies, protocol analysis

INTRODUCTION

The practice of architectural design is changing rapidly with the prevalent use of technology. Through the advancements on virtual worlds, parametric tools, computer aided design tools, interactive three dimensional (3D) simulations for spatial design development, architectural ‘massing’ study become possible in digital environment. The advanced digital tools that would support architectural massing study is a growing research area (Sun et al. 2013; Donath and Lobos 2008, see also, Khan and Loke, 2017 for a review). In architecture, massing refers to the consideration of building volume and/or breaking up enormous volumes. In a massing study, different principles for generating architectural shapes and spaces would be demonstrated such as additive or subtractive form generation principles (Krupinska 2014). The external architectural form is decided through the massing studies, in particular, visual area, partitioning, fenestration, faced articulation and the overall topology of the design proposal are extensively articulated.

The employment of 3D modelling tools in design process would provide designers opportunities of exploring new types of architectonics that may not require continues reconstruction, in contrast to analogue tools such as sketches and physical models, which ‘involve considerable redrawing, tracing and scale model making’ (Achten and Joosen 2003). Although the employment of the physical model mak-
ing and sketching in the design process have been extensively studied in the individual cases (Janke 1978; Goldschmidt 1988), and also in the group processes (Schön 1985; Ward 1987), there is a lack of study that compares designers’ massing strategies in Augmented Reality (AR) and Virtual Reality (VR) in a collaborative design context.

The recent mobile Augmented Reality (AR) technology has the potential to offer new opportunities for co-designers as a new design platform where the physical and visual models are superimposed during the architectural massing study. In this paper, we present a comparison study that is conducted in the Department of Architecture, at the Istanbul Technical University between 2016-2017. We investigate when architects designed mass volumes of buildings in an marker-based mobile Augmented Reality (MAR) application with that of when they used a collaborative 3D Virtual World, Second Life.

ARCHITECTURAL MASSING AND MODEL MAKING

Architectural massing refers to the considerations of three dimensions (3D) of a building envelope that would define an interior space or the exterior space (Jacoby 2016; Thompson 1999). The consensus on the definition of ‘massing’ appears to the centre on the idea of “the physical volume or bulk of a solid body, or a grouping of individual parts or elements that compose a unified body of unspecified size” (Burden, 1995, p. 48). Massing study is also known as “mass reduction, additive or subtractive spaces, or facade articulation” (Stamps, 1998, p.825).

Architectural design is widely accepted as a dynamic and complex process that starts with massing study (Akin and Moustapha 2003; Leyton 2001). During architectural massing study, spatial arrangements of shapes and forms and the relationships of the design proposal with the surrounding context are studied. During design process, architects make models as a “means of exploring and presenting the conception and development of ideas in 3D” (Nick, 2014). Massing study through model making has the potential to facilitate the presentation of the materialisations of design ideas, by getting as close as possible to the actual appearance of the design proposal. Model making in particular, can help with the creative process of visualizing 3D space directly by helping the inspection of the complex visual relationships (Porter and Neale 2000).

The research shows that massing process improves the management of the overall design process through strategies that rely on the use of regulating elements in the analogue and standard CAD situations (Akin and Moustapha 2003). Architects do not have to rely on only the standard CAD situations, as researchers attempt to offer new design tools and technologies to overcome the complexities by alternative visualization and representation techniques. With the recent developments on digital design tools, model making takes place on the computer screen during the early phase of architectural design process, such as using Building Information Modelling tools, parametric tools and recently VR and AR applications.

Researchers developed a hybrid virtual environment system and direct visual editing techniques for architectural massing study, investigating quick modelling and the implementation of physics for an effective design experience (Chen, 2011). Donath and Lobos (2008) discussed the phenomenon of the envelope design for high-rise buildings, proposing digital tools in the early stages of a massing study that “helps to reduce the working time, increases the confidence on the generated solution and it also contributes to the exploration of several alternatives in a short time” (p.108). Woodbury and Chang (1995) developed building technologies for massing studies that facilitate the exploration of the many possible approaches to massing. In their massing technologies, there were two types of massing objects: those that enclose functional spaces and those that stand for compositional concepts. In contrast to those studies, we focused on the design strategies of architects during massing study in the early phase of design process when they employ two different digital environments.
**METHODOLOGY**

In this paper, we compare architectural massing strategies of six designers when they are using two different emerging digital design technologies using protocol analysis: (1) co-design with a marker-based mobile Augmented Reality tool (MAR session) and (2) co-design in a Virtual World- Second Life (VW session). Protocol Analysis has been widely used in design studies (Gero and Neill 1998; Suwa and Tversky 1997) and in collaborative design studies (Gabriel and Maher 2000; Gül and Maher 2009).

The participants of the study were the final year architecture students in Istanbul Technical University. During the sessions, they were given two different design briefs with similar complexity including similar construction area requirements and mixed-use programs (office - residential and commercial). Each session that was recorded on videotape lasted 30 minutes. During the experiments, the designers’ actions and speech were video-taped and protocols were produced. Then these protocols were studied and encoded by using a specific coding scheme that has been developed for this research.

Segmentation: The data of the research consists of continuous stream of video and audio. Since the aim of the research is to understand the massing strategies of designers, there is a need for a thorough investigation of designer’s physical activity and externalizations. The hybrid segmentation strategy that is based on ‘who’ is doing ‘what’ action during the sessions was applied in order to understand the behaviour of co-designers (as explained in Akin and Moustapha 2003; Gül, 2007). The hybrid method was based on two research: (1) Gero and McNeill (1998)’s definition: ‘flag the changes in actions and intentions’, (2) Maher et al. (2005)’s definition: ‘flag when there is a change in the ‘who’ and ‘what’ items.

Coding Scheme: Finally, the segmented protocols were examined by using the coding scheme, as shown Table 1. We focus on the utilized massing strategies to model the design representation that was captured from the design dialogues and video recordings of the designers. Thus a ‘massing’ class that includes discussions on regulating elements, spatial relationship (spatial adjacency, arrangement, alignment, gesturing), referencing (ego-
centric, allo-centric), design approach (part-whole), architectural tectonics (program-form-materialization), framing and reframing given problem parameters and context, and visual inspection is developed as the coding scheme, as shown in Table 1.

**Experiment Apparatus**

First, a marker-based mobile AR application was developed using Unity3D game engine with Vuforia AR plug-in. Vuforia AR plug-in offers a set of target objects' library, object recognition and extended tracking, as shown in Figure 1. First, a set of marker images are defined in the Vuforia AR library, and then the data set of the image targets was uploaded in the Unity 3D platform. The AR environment was enhanced for the collaboration with a physical model and a wide-shared visual display for supporting the design activity (for more details of the AR system, please see Gül et al., 2016).

In the marker-based mobile AR design session (MAR), participants were given the basic primitives for the massing study; cube, sphere and cylinder objects that are associated with markers on the physical model. The designers were able to operate dragging, rotating, scaling and changing the colour of the basic 3D geometries on x, y, and z axes. One of the tablets’ view was shared and projected on the glass-table, and both designers were able to control the commands for creating and editing the geometries using the AR interface on their tablets. Figure 2 shows an instance from the MAR experiments where two designers were working together.

In the second phase, designers collaborated in a multiuser collaborative 3D virtual world, Second Life (SL). A virtual island, VirtualITU, in Second Life was given to designers to build an office tower, as shown in Figure 3. SL is an object-based design environment, which provides designers with the basic 3D geometries such as, cube, sphere and cylinder etc. with wide-range of editing capabilities. Figure 3 shows study participants working remotely, sharing the SL design platform.

**RESULTS AND DISCUSSIONS**

The results of the analysis show that utilized mechanisms of collaborative massing activity have some differences in each design environments. Table 2 shows the duration percentages of the massing activities that are measured based on the coding scheme. The particular differences are observed as follows: the duration percentages of regulating elements (alignment (37,6%) and adjacency (22,4%)), form and materialisation of the architectural tectonics (26,97% and 10,81%) are higher in the VW session. The duration percentages of the framing (7,22%), reframing (11,56%) and referencing of the global relations based on environmental features (allocentric 26,44%) and referencing of local relations based on one’s current location (egocentric 16,19%) and program (21,39%) related articulations and gesturing (12,57%) are higher in the MAR session. The time spent on the visual inspection of the design proposal (67,73% in MAR and 85,71% in VW) is the highest in both design sessions. The results and findings are reported as follows:

In the MAR session, during the experiments, designers started with introducing new objects onto the scene, (modelling activity starts with registering the markers) and then, they assigned an architectural function to each object on the screen referring num-
The development of the Marker-based Mobile Augmented Reality Application in Vuforia Developer Portal

For example, D1 (designer 1) said:

[...I load the first marker, OK. Save it... Our first cube, number 1, that would be the podium level of the shopping mall].

Participants of the study did not articulate the overall building mass at once. The affordability of designing in the MAR environment might have an impact on this strategy. Since the MAR tool affords the manipulation of one basic geometry at a time, thus the massing strategies was to manage the small parts to make a whole building. In short, an addictive massing approach was observed.

In the MAR session, the main regulating element was the boundary lines that was the periphery of the neighbour buildings, park and road boundaries. The designers indicated those boundaries as the extension lines of the alignment by pointing gestures while they were adjusting the size of the proposed building blocks by altering the X and Y coordinates for the desired alignment (visually inspecting the design proposal at the same time) in the MAR session.

The significant difference is observed in the ‘gesture’ code, as shown in Table 2 (12.57% in MAR and 0.35% in VR). Here, gestures are the hand movements of the participants that are employed to explain the spatial relationships of design ideas playing the role of extension lines in a sketching activity. For example, the designers gestured by pointing on the model when they indicated a street direction or a park area as the alignment axis for the building mass. In addition, another type of gesturing that is bodily movement and touch screen gestures occurred when a designer wants to reflect and elaborate an idea, particularly the visual inspection of the design proposal through bodily movements (bending, leaning etc.) was observed. Co-located working and the presence of the physical model might also have an impact on this finding that requires further investigation.
In the VW session, during the experiments designers discussed about the design ideas and proposed architectural tectonics as a whole building mass, rather than articulating ideas on collection of small parts. For example, D2 said:

[...let’s have a building, like a box... that would be large on ground and with some cantilever parts on the upper floors facing to the sea].

Once they decided on the design proposal by verbally articulating what the finish building would look alike, then they spent the rest of the given time for constructing the model in 3D world. Thus, we observe making of the model in VW started with the consideration of the whole building mass. They decided the overall building tectonics in their imagery in consensus, then, they did some task allocations on making the mass one by one: One designer would be looking at the top view monitoring what the other designer is doing by examining spatial relationships and the visual appearance, such as size, form, texture and colour.

VW of the study, Second Life (SL), is an object based multiuser virtual world with some build and edit tools. As mentioned earlier, the inbuilt making of model features of SL consists of primitives of the basic geometry such as cube, sphere, cylinder and prisms as well as some complex forms such as torus, tree objects etc. An object building starts with dragging a basic cube onto the scene, then designer needs to scale, rotate, move and change its size, shape, colour, materials as s/he wishes. In SL, the VirtualITU island consists of some landscape features such as a lake in the middle with several hills around and flat areas as well as some buildings to be the context for design activity. The existing buildings in SL played an important role that was to provide a sense of scale as well as being the precedent, the designers altered the size of their proposed design entities by taking into account of the size and the style of the existing buildings in the island. The main regulatory element is the existing context, in particular the volume and height of the existing building and vista points in

<table>
<thead>
<tr>
<th>DURATION</th>
<th>MAR %</th>
<th>VW %</th>
<th>MAR Mean D.</th>
<th>VW - Mean D.</th>
<th>MAR- SD</th>
<th>VW -SD</th>
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<td>10,47</td>
<td>11,11</td>
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<td>14,285</td>
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<td>ARRANGEMENT</td>
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<td>18,81</td>
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MAR: Design in Marker-based mobile augmented reality session, VW: Design in Virtual World (Second Life) session, Mean D.: Mean duration in seconds, SD: Standard deviation of duration

Table 2 Durations percentages, mean and standard deviation of the codes in MAR and VW sessions
The landscape become consideration points for the design proposal in SL. The alignment of the parts and the spatial adjacency of the design proposal in the context become an important topic of discussion and activity during the VW session. The alignment and arrangement activities become important as internal regulatory features. That means when they model the 3D design proposal, designers engaged with the individual parts of the mass in relation to a prior building part. Higher duration percentages of alignment and arrangement also indicate this finding. In addition, designers spent considerable time for the visual inspection by flying over the design proposal in SL.

FUTURE REMARKS

Although the initial results of a study presented here focuses on the massing strategies of architects, it is a part of a larger research effort dealing with the impact of place and representation types on designers’ activities and sense of presence. The results of the comparison study indicated that the affordances of the design features of the studied environments have an impact on the designers’ massing strategies. A further study will be conducted to design and evaluate more on the use of AR based collaborative design environments providing varied 2D and 3D design objects (ability to draw and make notes on the representation and providing more geometric primitives and library of customized building elements) to understand the effects of the affordances of the interfaces on design behavior. Additionally, there are a lot more characteristics of a user not explicitly focused in this study that could be of importance, e.g. novice vs expert in design with AR, level of familiarity of the tools, learning effect and so on. The long-term goal of this study is to empirically measure the essential influencing factors on interaction during basic design tasks, to establish the foundations for typical user behavior in more complex design scenarios.

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REFERENCES

Achten, H and Joosen, G 2003 ‘The digital design process - reflections on a single design case’, Digital design, 21st eCAADe conference proceedings, pp. 269-274

Akin, O and Moustapha, H 2003, ‘Strategic use of representation in architectural massing’, Design Studies, 25(1), pp. 31-50


Dunn, N 2014, Architectural Model Making, Laurence King


Jacoby, S 2016, Drawing Architecture and the Urban, Wiley, Chichester, West Sussex


Sun, Q, Lin, J, Fu, C, Kaijima, S and He, Y 2013 ‘A Multi-touch Interface for Fast Architectural Sketching and Massing’, *CHI 2013: Changing Perspectives*