3D TRANSFORMATIONS

3D Scanning, Digital Modelling, Rapid Prototyping and Physical Depiction

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Abstract. We investigate the creation and reinterpretation of an architectural design process using a variety of digital and physical media. We study how tools for design influence perception, comprehension and creation of spatial volumes within both Virtual Environments (VE) and physical realms. We explain how designers translate spatial volumes and communicate architectural design ideas by using VE and conventional models. In a series of reinterpretation of architectural meanings we examine the translation of three-dimensional design from virtual to tangible depictions and vice versa. We conduct a design-studio in order to explore issues of quality, understanding, communication and building of architectural compositions. VE can be an environment for design distinguishable and facilitating reality. We test this statement by interchanging both realms to that extent that the boundaries of each one are nearly dismantled. Virtuality and reality are both used in alternative form- and design-finding exercises in order to gain an overall conclusive design.

1. Introduction

Moving freely between media and realms the artists Man Ray expressed and communicated ideas in the pictograms he called ‘Rayographs’ (De l'Ecotais, 2002). In these, Man Ray ‘drew’ directly on photographic paper using light sources. Similarly, the architect Jørg Utzon and the artist Asger Jorn used virtual and real media to convey spatial expressions. Emulating a painting by Pablo Picasso, Asger Jorn used a ‘light pen’ and photography to re-present sketches by Utzon (Weston, 2002) (Figure 1).

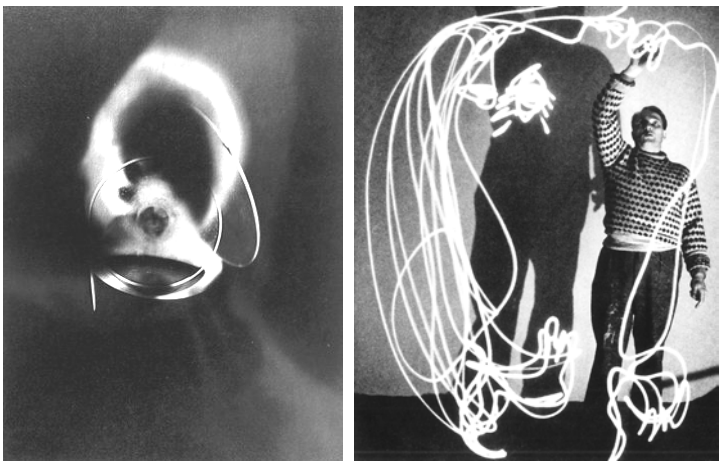

Figure 1. Left: Photogram by Man Ray. Right: Asger Jorn using a 'light pen' to sketch.

Inspired by their expressive methods to cross over different domains we initiated a simple spatial design-task. Architectural students were asked to develop a scheme using tangible and digital means for their design ideas. They engaged in repetitive interactions and reinterpretations of their designs from real to virtual and back to real. This process introduced the students to a new approach of design-creation and form-finding.

Architects use both physical and digital forms. The design of the Guggenheim in Bilbao for example, employed wooden and card models that were translated into digital form (Bruggen, 1999). Previous research suggests that spatial creations of architectural volumes are enhanced using virtual environments (Schnabel, 2003). With the re-representation from a virtual to a real model, shape and design are translated in such a way that they fit into the new media's characteristic. It appears that interactions between conventional and digital media are a multifaceted combination of the characteristics and possibilities introduced by of each of them. According to Kvan (2002) the quality of design and the depth of its form-finding are directly linked to its representations, communications and collaborations. Hence, if such characteristics and possibilities influence the reinterpretations that generate design information, then media interactions amplify the designer's opportunities (Herbert, 1995).

The objective of our experiment was to identify how designers translate spatial volumes and communicate design ideas by using Virtual Environments (VE) and conventional methods of three-dimensional (3D) depictions as in physical models. We investigated how tools for design influence perception, comprehension and creation of spatial volumes within both VE and physical realms. In a series of transformations and

interpretations of design steps and design explorations we examine the translation from tangible to virtual depictions of design and vice versa.

2. Transformations

We studied a creative process in a fictive design task that allowed the free generation and interpretation of form and space within an architectural context. In the setting of a design-studio we proposed a task only to translate, explore and manipulate a conceptual idea of a design using physical and virtual tools. An abstract spatial assembly was to be transformed from real to virtual environments and back in repetitive cycles. Thirteen members of a master's course at the *Department of Architecture, The University of Hong Kong* were introduced to the various tools and their potentials. All students had extensive prior experience using digital tools in design. After initial training and experimental exercises, the students were asked to start using an object of their choice or other inspiration for their initial expression. The students used a 3D-Scanner to translate their initial intention into a digital model. In the next step, the file was manipulated using a variety of modelling software, including a *Phantom Digital Clay* haptic feedback tool. The design rendered into physical form using a Rapid Prototyping (RP) process (Gibson et al., 2001). This cycle was repeated as students refined their designs until they reached a satisfactory outcome. At the conclusion, the students presented their designs using a final RP model and a digital projection showing the process they undertook. These steps are described in detail below.

2.1. CREATION

The students started the cycle with their series of actions choosing an object. There were no limitations, since an important part of the whole exercise and interpretation is the freedom of possibilities of each step (Brady, 2000). The objects chosen varied from a bottle of water, to a leaf from a tree, folded paper, parts of their own body and other objects. Some students chose not a tangible object per se but chose instead to work from a movement through space. This virtual 'object' described a dance, a rhythm or the form of an imaginary object. Thus the later set of 'objects' are already by their nature an interpretation of reality. Using the scanner, the objects or movements were digitized and translated into a virtual representation. These objects, real and virtual, provided the seed from which the cyclical design process evolved (Figure 2).

Figure 2. Objects used by students (real and virtual)

2.2. TRANSLATION

The initial translation of the object was accomplished using a 3D-Scanner *(Polhemus FastSCAN)*. Scanning is not a faithful replication of an object but a reinterpretation. Errors and occlusions are introduced that do not exist in the physical form. For example, dark elements of the scanned object are not recognized and therefore omitted in the digital representation. The speed of movement and repetitive sweeping of an area affects the quality of the scan. Exploiting these properties, the students made use of the 'shortcomings' to create new forms. For example, one student was inspired by the work of the Japanese artist Yayoi Kusama (Hoptman et al., 2000) who uses dots as the key element of her art. The student scanned folded newspaper with large black ink headlines and photos to intentionally create holes within the scan (Figure 3).

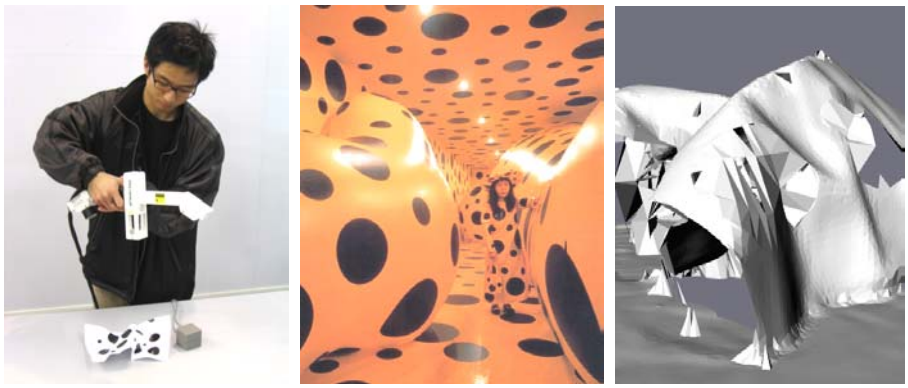

Figure 3. Left: Scanning paper. Middle: Artwork by Y. Kusama. Right: scanned output.

The software of the 3D Scanner allows through various settings different resolution, mesh-sizes and triangulation of the digital model. The export-function to a typical CAAD-file (such as *3ds, dxf* or *stl*) can manipulate the model in a range of different outcomes. The model can either be fragmented into several objects, melted into a low resolution scan or a cloud of points, which are either unconnected or connected by straight lines or curves. Student used these possibilities as tools to manipulate the original scan to an abstract arrangement of form and space within its virtual representation..

2.3. DIGITAL TRANSFORMATION

Once a scanned element was created, it was manipulated further using digital tools. This part of the sequence of translations required some technical expertise in modelling software. Several technical problems were encountered. The scanning process produced a very large number of polygons and points; as a result, the file-size of the exported scan was very large, requiring substantial processing power. The students used a *Dell Precision Workstation,* which is able to handle such file-sizes and compute such data. The 3D Scanner's software exports the model as a surface rather than a solid. Since solids were needed in the next phase of the studio, most students translated the model into a solid at this stage. Additionally some students reduced the amount of polygons, while other selected a part of the model and continued to work with their chosen selection only.

Various functions of modelling software (such as *Rhino 3D, FreeForm* or *Maya)* allow users to alter their design in expressive ways. Students explored a range of transformation techniques to explore their designs using the standard repertoire of CAD software such as Boolean operations, volumization, projection, extrusion, skinning, slicing and others.

At this stage of the design students moved beyond their initial forms and developed the concepts to achieve a new expression of their intention of design. The virtual representation of their work allowed the students to explore the spatial composition in a way, which they could not think of after choosing their object in the first phase (Figure 4).

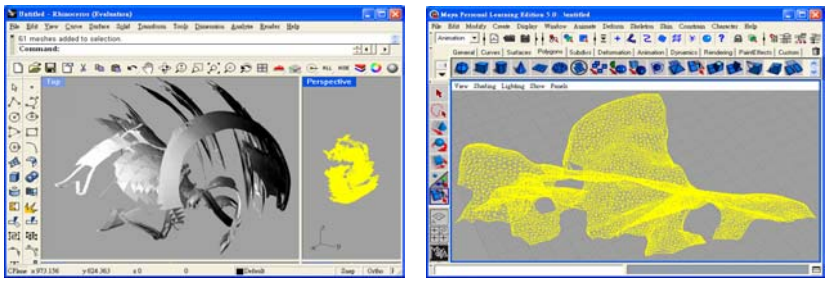

Figure 4. Screenshots of a design using modelling software (left: Rhino 3D, right: Maya).

2.4. VIRTUAL MANIPULATION

Architects explore their designs digitally and physically, using CAAD software in VE and employing physical media such as using clay, paper, cardboard, cutters and glue. Typically, these realms are treated separately as individual entities rather than integrated into a continuous process. In contrast, we wished to link directly between these two domains in this phase of our design-studio. Our students manipulated their models by using a haptic-feedback tool *(Phantom)* to alter their digital design. The combination of the force-feedback device with the modelling software *FreeForm* allowed students to explore their designs, merging virtuality together with physicality, the intangible with the tangible. The digital models were given the properties of physical clay. Students made changes to their design with the same ease as they would modify physical clay-models by cutting, carving, sculpting, smudging and pressing elements or adding additional forms (Figure 5).

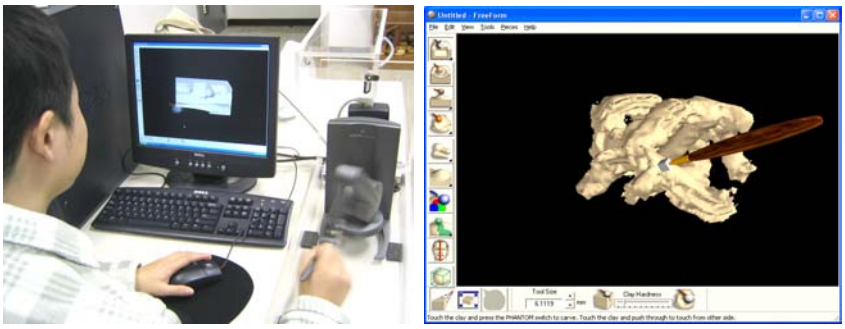

Figure 5. Left: Student using Phantom. Right: Screenshots of designs using FreeForm.

2.5. REALITY CREATION

Architectural designers use physical models as a means by which to interpret their designs. The phases described above enabled the students create and interpret their design from a physical object or movement to a design within VEs. In order to materialize the model back into a physical environment, students printed their models using a *Z402 System 3D-Printer* to obtain a physical object. With the re-presentation from a virtual to a real model, shape and design were translated in such a way that they fit into the new media's characteristic. At this point, the physical RP-models act as the tool for communication and abstraction of the design development (Figure 6).

Figure 6. Printouts using the 3D Printer.

2.6. PHYSICAL MANIPULATION

Students explored and developed their designs with conventional techniques of traditional model-making. However, due to the fragile properties of RP-models, there are limitations to the possibilities of modifications. Additional elements were added while other parts were removed or the models were divided into subparts (Figure 7).

Figure 7. Models were altered using conventional methods of model making.

This phase closes the circle from real to virtual back to real. One stage opened up to the next step. Each translation offered students the opportunity to explore and recreate the design, each medium facilitating different acts of interpretation or transformation. Having been through one complete cycle, the students were free to repeat any of the phases until they finish their design and assembled a final presentation.

2.7. PRESENTATION

The students recorded and documented the whole process development of their design so that they could communicate and comprehended the intention of the design as well as its outcome. Students used both web-based presentation as well as all models, including the original object and all interim products. In a final review, critics discussed and commented on the processes and outcomes of the students' works in a typical design-studio critique. This phase made it possible to communicate the intention, the transformation and the outcome of the design to broader audience. Since all students treated the above described phases in a different manner, the outcomes were of great variety. The presentations allowed the students on one hand to understand the impact of their own actions within the process, on the other hand to learn from other students' methods and their outcomes (Figure 8).

Figure 8. Student presenting his work during the final critique.

3. Discussion

Within our studio we successfully dismantled the boundaries between VE and real environment to an extent that both realms merged into the other. VE

can be an environment for design distinguishable and facilitating reality. Both realm were used and needed to achieve an overall conclusive design. A significant feature of our studio was to focus on multiple rather than single interactions. Digital and analogue media introduce new aspects to the design and are neither neutral nor transparent. Interactions in different media confront the designer with unique digital objects that arise from scanning and model manipulation. These artefacts force the designer to revisit previous interpretations of volume and space, and thus become sources for form.

Unlike the digitization of Frank Gehry's models that are translated as a facsimile copy (Bruggen, 1999), our process explored the opportunities offered in the transformation from one realm to another. The designer therefore could explore different possibilities of the design that were unique to each phase. Each medium was investigated by using its own strengths and weaknesses. The process of translation, such as scanning, was itself a creative act.

Scanning, and the subsequent triangulation of the form, translated the physical model into an altered design. As Panepinto (2001) points out, similar to the transformation from the digital to the physical realm accuracies and settings of the scanning process offer a variety of new design elements, which were not possible using other means: liquid conversions, facetted surfaces as well as manipulation of surface complexity or error generation are methods to reshape the physical model.

Previous research suggested, that spatial creations of architectural volumes are enhanced using VE (Schnabel and Kvan, 2001). Consequently we asked students to transform their design using VE and its supporting software. In this way the design-proposals could be examined in an inclusive and real scale fashion. Thus the preliminary proposals could be altered according to the intention of the designers.

According to Kvan (2002) the quality of design and the depth of its form-finding are directly linked to its representations, communications and collaborations. Thus it is therefore essential to re-represent the design in reality by the mean of a physical model. Schnabel and Kvan (2004) advocate that RP play a significant role in the design process that involves VEs and that produce physical representations on demand which contribute to the communication and exploration of form and space within an architectural context. However, as Kvan and Thilakaratne (2003) noted: "RP models do not lend themselves to conversation as they are fixed in form and fragile in material". In fact, the students could not modify their RP models following traditional techniques of model-building. Similar to the other earlier phases the students had to creatively adapt to the characteristics of this phase.

However, the physical models acted as the tool for communication and abstraction of the overall process of design.

Each of the phases is an essential part of the overall creation of design creation and addresses and expresses only certain aspects of the design. This enables a holistic discussion about design, form, function and architectonics, which is significant not only within the architectural education, but also in all other dialogues involving spatial representations. For all participants it was surprising, which creativity and spatial exploration of architectural forms and space these 3D transformations generated. The quasi trivialness of the starting point of the design development turned very quickly into a serious dialogue of space.

4. Conclusion

An experimental design-studio was successfully conducted employing tools and elements of the physical and virtual realms. Students created transformed and re-interpreted complex spatial designs by manipulating them within a 3D space. A series of solutions of both environments generate together understandable and rich spatial expressions.

Since VE play a vital role in the design and form finding of architectural creations, virtuality becomes, in that sense, its own reality that compliments physical realms. On the other hand reality is expanded into a new dimension without being duplicated the other environment.

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Apparatus

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FreeForm Modeling System, Touch-based modelling software for *Phantom,* SensAble Technologies Inc., Woburn, MA, USA, http://www.sensable.com

Kaiser Proview 60. Head Mounted Display, Kaiser Electro-Optics Inc., Carlsbad, CA, USA. http://www.keo.com

Phantom 1.5/6DOF high-fidelity, 3D force-feedback device, SensAble Technologies Inc., Woburn, MA, USA, http://www.sensable.com

Polhemus FastSCAN, Handheld laser scanner for 3D scanning based on magnetic motion tracking, Polhemus, Colchester, VT, USA. http://www.polhemus.com

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