Speculative Precision: Combining Haptic Terrain Modelling with Real-Time Digital Analysis for Landscape Design

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Abstract

The Chair of Landscape Architecture – Professor Christophe Girot – asked its students to experiment with physical sand modelling combined with real-time digital analysis to develop speculative and precise landscape structures. The terrain models were formed in an iterative design process exploring various landscape scenarios. The digital analysis, which was displayed on a screen in front of the sand box, revealed functional considerations such as slope and water levels while the tangible sand box could be interpreted cognitively. With this method it was possible to quickly sample and evaluate both performative and poetic properties of several landscape topologies.

1 Introduction

Recent movements in "landscape urbanism" and "landscape infrastructure," make a plea towards a broadening of the landscape design discipline to include larger territorial systems (BÉLANGER 2012). While the architectural discipline is founded in the tectonic expression of buildings, landscape architecture seems to have forgotten its disciplinary origin of shaping the form of both rural and urban landscapes, being mostly oriented towards garden design. Both directions tend to neglect the physical shape of the earth's surface as an expressive material that has become modulated by natural and cultural forces over time.

Because computer modelling is still very time-consuming and difficult to learn, this paper will demonstrate a haptic method to design with the earth's surface, integrating the physic-cal, scientific, and poetic properties of a particular site in a single meaningful whole (GIROT et al. 2013). This method can open up a new form of "terrain intelligence" to the designer by physically demonstrating all the continuity and complexity of spatial relationships and proximities within surface structures. We perceive the craft of responding to – and shaping of – the earth's surface as a vital aspect of a resilient design approach. Therefore it should propose a new foundation for landscape architecture as a form-giving discipline for contemporary cities and landscapes.

The overall goal of the one-week workshop discussed in this paper and held in summer 2013 at the Chair of Landscape Architecture – Professor Christophe Girot – was to develop a variety of terrain modulations in an intuitive and informed way. All the students worked with a real site, which was located on a small peninsula in a mountain-lake with varying water levels of up to 20 meters due to the use of the water for the generation of electricity

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(see figure 1). The students were asked to only work in sand. Inspired by the work of the Tangible Media Group at the MIT Media Lab, the geometry of the sand model was captured using 3D image reconstruction technology (ISHII 2008). We developed our own software to analyse the resulting digital model. A simulation of water levels, along with contour lines, relief shading and slope information was provided to the students in real time on a screen above the sandbox (see figure 2). The combination of the haptic sandbox combined with the digital analysis led to highly informed spatial designs even though the students involved in this workshop did not have prior design experience.

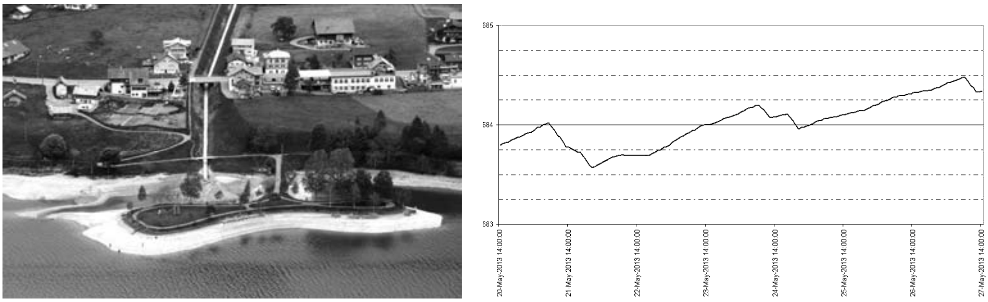

Fig. 1: Photo and water levels of the island in the Lungerersee, Switzerland.

2 Haptic Terrain Modelling

The transformation and modification of terrain through modelling is still a cumbersome endeavour because of complicated computer programs mostly controlled by keyboard and mouse. The critical relationship between the designer and the landscape becomes highly abstracted in a 3D computer environment. However, recent developments in haptic modelling and tangible interfaces show a great potential to radically change the way we design (PETSCHEK 2012; ISHII 2008). Going beyond the pencil and digital drawing boards, these new interfaces combine touch and intuition with the analytical power of the computer. Research projects by MIT Media Lab, like "Illuminating Clay" and "Sandscape", show how: "Users sculpt and manipulate digital information through tangible media like clay and sand, coupled with underlying computation for design and analysis"(ISHII 2008). The goal of these instruments is not to categorise and flatten a site's properties but to close the gap between the designer and the physical reality of a landscape in all its topological complexity.

To overcome the gap between the designer and the spatial landscape (created by modelling in an abstract computer environment), our workshop combined two different techniques: a physical interface and digital analysis. For the physical interface we used a sandbox because of its inherent material property: the rules of gravity and volume of the sand model are easily translated into actual landscape through scaling. The digital analysis was done in the computer after an iterative scanning-process of the sand-model with an interval of

20 seconds. The results of the analyses were then presented to the students and gave them direct feedback on how their designs will perform on the real site.

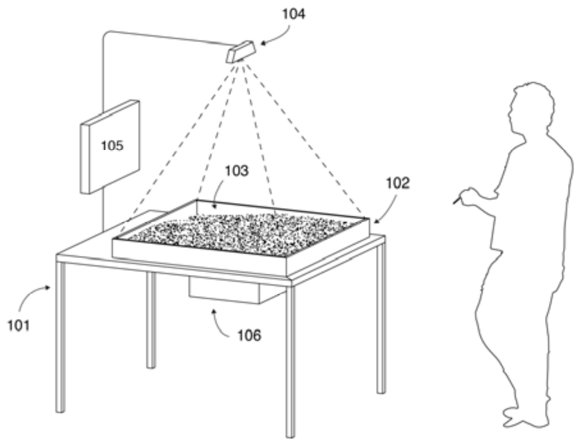

Fig. 2: Design of the haptic modelling interface. 101: Table, 102: Sand Box, 103: Modelling sand casted from a negative CNC milled model, 104: 3D scanner and RGB camera, 105: Display, 106: Computer.

2.1 Sandbox Interface

We decided to use highly precise topographic data to stay as close to the existing landscape topology as possible. This data was captured with our drone and processes into a 3D model by 3D photogrammetric reconstruction (FRICKER, WERNER et al. 2012). The topographic data was then translated in a negative site model at a 1:100 scale using a CNC milling machine (FRICKER, KAPELLOS et al. 2012). Subsequently a positive model was cast in modelling sand. Because we did not have precise topographic data of the lake-bottom, we used this sandbox to sculpt the bottom of the lake according to a few height-points we acquired from the local municipality. Interesting enough we realised that our sandbox was the easiest and fastest way to model the lake-bottom, instead of using a computer modelling program. After the initial modelling we ‘scanned’ the sand box with a series of 12 pictures and obtained the geometry with 3D photogrammetric reconstruction. This method proved to be more precise than the 3D scanner we later used for the real-time analysis. This digital model was then milled again so that we could cast the final landscape showing both the topography acquired with the drone as well as the under-water bathymetry. This method created a highly precise positive of the site’s topography as starting point for the transformations by the students. It also proved practical in the sense that once a modulation was exhausted, students could easily create an original starting point by re-casting the sand on the negative-model.

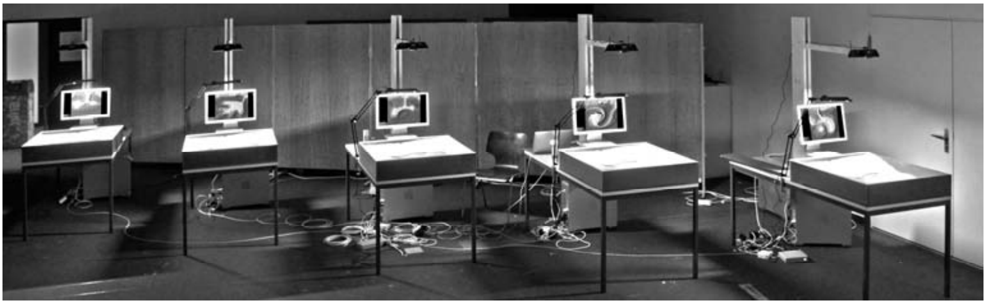

Fig. 3: Workshop laboratory showing 5 modelling stations consisting of the sandbox, a display, the 3D scanner and a computer.

2.2 Digital Analysis

The digital the model was acquired by a 3D scanner mounted above the model (see figure 2). To avoid any occlusion in the scanned geometry the use of a single scanner proved to be enough. We used the Kinect scanner that was developed by Microsoft for their game-console Xbox. It is readily available around the world and very cheap compared to professional market solutions. The scanner was connected to a computer under the table that took care of the processing of the incoming data-stream. We wrote our own analysis software that converted the raw scanning data into a 3D model, which was then used to analyse the design. First, the incoming data stream of 3D points was referenced to the model scale, after which it was converted to a digital elevation model (DEM). This DEM was then processed to display the various analyses onto the computer screen.

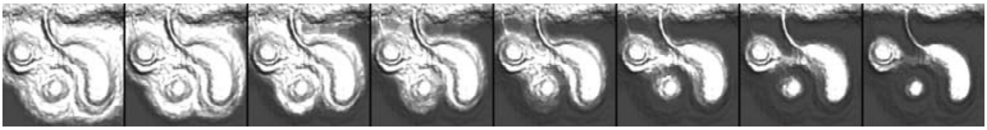

Fig. 4: Water level simulation of an intermediate design stage. The water levels in the lake vary up to 20-meters throughout the year.

The user interface for the 3D model was designed to provide two different views for the user; a perspective environment and a plan view of the model between which the students could switch at any time. The transparency of the water could also be manipulated to either display the water-edge or the continuous above– and underwater topography. In plan view the model used hill shading for the relief presentation (see figure 5). Because the water of the lake was used for energy production further downstream the water level varied 20 meter throughout the year. This became a focus point for all of the designs. It was here that the sand box proved exceptionally useful: the water level could be simulated in real time on the screen, giving students vital information on how their new landscape would function throughout the seasons. This meant that every design was highly adapted to the local topography despite its variability throughout the year.

Fig. 5: From left to right: Perspective view, physical model view captured with the rob camera of the 3D scanner, plan view with hill shading and water simulation.

3 Design Method

Before getting their hands 'dirty' in the sand box, the students made a site-visit to familiarise themselves with the locality and the scale of intervention. Features like the water-edge, the water level and the topology were looked at carefully. At this point they had enough information to start making their first sketch in the sandbox. Because the topography of the model represented the site in every detail, spatial relations and levels became intuitively understandable and easy to manipulate. Four students worked together on each sandbox, which although not ideal, proved to be an interesting experiment in collaborative design. Snapshots of the 3D model were made every 20 seconds and saved on a central server so we could discuss their progress while going back in time. These time-lapses were used during various discussions about their process and allowed us to critique their current and past iterations in a comparative manner.

Fig. 6: Students modelling (left) and presenting (right) their design.

Operations – additions and subtractions – applied on the existing landscape were to be compensated locally, minimising the transportation of material. These were easily simulated by not allowing the students to add or remove any material from the sand box. As a by-product of the 3D digitalisation, documentation and representation of their designs were readily available. Various perspectives, sections and plans were generated from the 3D model to support their arguments in the final presentation.

4 Results and Conclusion

With the method described above, it was possible to work analytically with a tangible media such as sand, stimulating the students towards speculative and precise designs. One of the biggest challenges of landscape modelling is that there is not yet an intuitive interface that is flexible enough to work quickly and incorporate an on-going design process. Learning a complex 3D program to benefit from the analysis normally takes up a lot of time, and results in static models that are difficult to change iteratively. Using sand to model the landscape provided a tangible interface that required almost no learning curve. Everybody already knows how to model in sand from his or her childhood. All the students had to do was to "play" in the sand box.

The resolution of the 3D scan proved to be accurate enough for this exercise at 1:100 scale. For larger scales however, when the z-levels get smaller, it would not have provided enough detail. Adding resolution with a better 3D scanner however would also impact computation time of the analysis, something we'd like to keep as small as possible to allow for the benefit of real-time feedback. At this workshop were able to break down the scanning cycle to about 4 seconds, something that needs improvement for true real-time interaction.

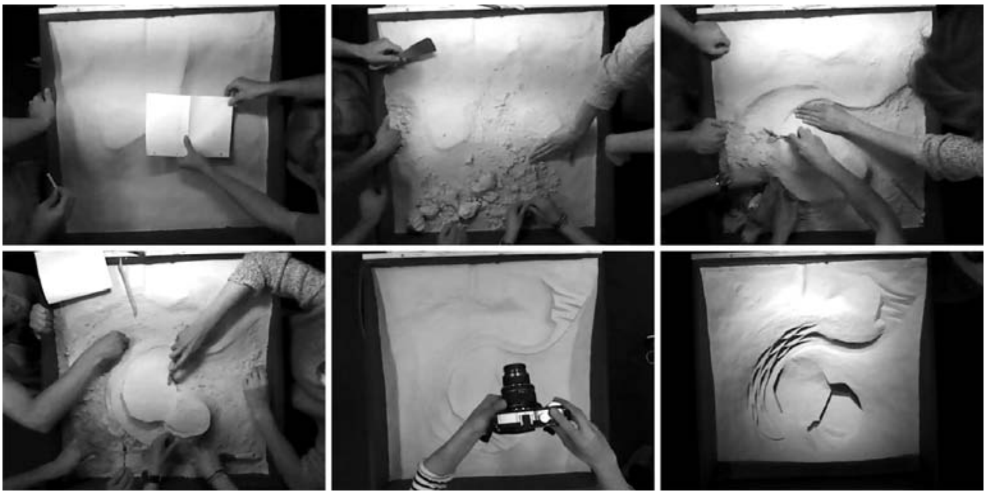

Fig. 7: Design process captured from the RGB camera of the 3D scanner showing the whole design process in 6 stages.

The disappearance of technology as demonstrated with this project enables a truly creative design process. It facilitates the designer to sculpt freely without limitations imposed by the geometric properties of mathematical computer surfaces. The resulting 3D model with the current setup does not allow a direct translation into construction drawings yet, but it is only a matter of time until the scanning technology has advanced to higher resolutions.

Further experiments have been carried out using a photogrammetric process to obtain higher resolution models. The scanning cycle for this method however is slowed down considerably. Work on this design instrument is continuing by Ilmar Hurkxkens at the Chair of Landscape Architecture in 2014 in the form of a one-year research project.

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