Mastering digital materiality in immersive modelling

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Abstract
This work in progress paper describes four approaches of mastering digital materiality when modelling in immersive environments. The approaches emerged during a design study among four design students who used an immersive modelling system for two weeks all day long. All approaches imply different means of substituting the missing material constraints. In summary the study suggests that there are as many ways to master digital material as there are designers who use it and that immersive modelling can generate genuine forms on a high creative level.

Keywords
Digitality, materiality, constraints, immersive modelling, tangible interaction, virtual reality.

ACM Classification Keywords

General Terms
Design, Experimentation, Human Factors, Theory
Introduction

Materiality describes the material and tangible character of a medium and can be regarded as a genuine characteristic of tangible interaction [4]. Whether materiality must be physically tangible or can also be evoked by the potentiality of practical instantiations is an issue of ongoing discussions [6,7].

Regarding the use of digital systems which usually employ immaterial representations (e.g. graphics, video projections), it has been argued that the material character of the underlying hardware influences the potential uses of the medium [1,3], i.e. that “bits cannot escape the material constraints of the physical devices that manipulate, store, and exchange them”.

In product design materiality allows to externalize inner pictures and to start a reflective conversation between external and internal representations [7,8]. Rosner points out that “several scholars of craft and design (...) observe structural qualities [in material interactions] that are often not immediately ‘visible’ and become accessible only through continued practice with the material” [7, p. 1157].

This work in progress paper investigates the material properties of immersive virtual environments and describes four approaches of mastering digital materiality. The approaches emerged during a study among four participants who used an immersive modelling application full-time for two weeks. The aim of this study was to seek a degree of mastery matching professional standards of working with physical material. Compared to previous studies [5,9] this study lasted significantly longer and left more time to each individual participant to develop their ideas and models. The four participants were bachelor design students with at least two years of experience in product design.

The immersive 3D Sketching Application

The study was set up in an immersive five-sided CAVE [2] with 2.5 m edge length, employing a rendering cluster and an optical tracking system. An immersive sketching application was used which allowed free-hand drawing and modelling by means of three tangible interfaces: a stylus, a two-handed tool for Bezier-curve extrusion as well as a pliers tool (Figure 1) [5].

![Figure 1. Tangible tools for immersive sketching and modelling: a stylus, a pliers tool and a two-handed Bezier-tool.](image)

The stylus allowed drawing virtual ink directly into the virtual environment, following the movements of the stylus tip. The width of the stroke was scaled according to the force by which the user pressed the frame of the stylus. The two-handed Bezier-tool allowed the extrusion of a Bezier curve in 3d space by moving two handles controlling the curve’s control points. If the user pressed both handles, the curve was extruded along the path of the user’s hands.
The pliers tool allowed its users to grasp, reposition and release virtual objects by simply moving the physical pliers to the virtual object, pressing a button below the pliers’ frame, moving it and releasing the button at the desired position.

**Approaching immersive Design**

During the first days of the study, the students investigated the features of the immersive modelling environment. Early after the first day the missing physicality (i.e. physical constraints) as known from sketching on paper and modelling with physical material became apparent and were cause for discussion among the students and tutors. The following days, students examined various means of substituting the missing physicality either by physical patterns, ropes or guardrails (Figure 2).

![Figure 2](image2.jpg)

*Figure 2.* Students’ approaches to master the virtual materiality during the first week of the study using physical objects and patterns.

Other approaches included visual aids, particularly a visual grid which was projected into the CAVE and divided the design space in cubical subregions (Figure 3).

![Figure 3](image3.jpg)

*Figure 3.* Virtual grid used to visually structure the immersive environment.

The location of the physical/digital seam was the same in all approaches; the virtual material (virtual ink) was most of these approaches were not used in the second week of the study; some were further elaborated. Students reported that the aids helped them to approach the virtual medium but had not led to the desired results in terms of precision and controllability.

**Four Approaches of mastering the digital material**

After the intense examination of the immersive space, the available modelling tools and various approaches of forming the digital material, the students intensified the work on their particular designs during the second week of the study. They developed individual strategies of crafting the digital material and achieving a satisfying degree of mastery. The missing physical materiality and the missing physical constraints were still an issue for all four students and each student developed an individual strategy of substituting them.
in all cases extruded at the tip of a virtual cursor which in turn was directly controlled by a tracked physical object.

**Approach I: physical constraints, digital source, manual arrangement**

After experimenting with various physical objects one student decided to use a physical pendulum to generate virtual forms. The pendulum was hanging from a stand and had a tracking target attached to its lower end. Once set into motion it circulated horizontally around its centre of gravitation in decreasing radii. The stand was taken into the CAVE so that the student could observe the movements in situ. When the student wanted to materialize the movements she pressed the button of the 3d pen which triggered the extrusion of virtual ink. After one cycle she released the button which stopped the extrusion. This action was repeated several times and generated next-to-perfect circular elements of different radii (Figure 4). When the swinging of the pendulum came to an halt the student collected all circles she wanted to use and moved them to save space within the CAVE using the pliers tool. Then she started the procedure again and generated the next set of circles.

In a second working step the student arranged the circles and 'welded' them together into a set of singular shapes like a sculptor or goldsmith. The resulting shapes were then transferred as files to a desktop CAD system where they were stretched, multiplied and arranged into basket-like shapes. No artificial shapes were created in the CAD system, all elements originated from the extrusions of the physical pendulum. After the CAD processing the shapes where transferred back into the CAVE again and final adjustments were made manually such as the connection of lines between the elements (Figure 5).

![Figure 4. Approach I: physical pendulum creating virtual circles.](image)

![Figure 5. Approach I: drawing connecting lines onto the adjusted model.](image)

Finally the objects were rendered for presentation purposes using the CAD software (Figure 6). One object was chosen to be printed by means of a 3d printer (Figure 7).
Approach II: visual constraints, free-hand modelling

Attempting to apply pouring and holding metaphors in immersive design, one student decided to use virtual objects as constraints for his modelling techniques. In a first step he created exemplary basic containers, e.g. pots, using desktop CAD software. These objects were then loaded into the CAVE and served as visual constraints for further modelling actions. In a process lasting up to an hour per object, the student drew numerous elements, e.g. lines, curves or hair-like elements, which touched the virtual object but never cut through it (Figure 8).

In order to save time, only half of each object was modelled in the CAVE. The remaining half was generated by means of a revolution function when imported into the CAD system (Figure 9).
Approach III: visual constraints, free-hand modelling

Similar to the second approach the third student created virtual objects as visual constraints to guide the manual sketching process. Differing from the former approach, in this case the constraining objects were objects to be contained by the final models, e.g. books to be contained in a bookshelf or fruits to be contained in bowls (Figure 10).

The model was then sketched around the objects using surface modelling functions of the sketching application, e.g. Bezier-curve or stroke extrusion functions. After the principle shape of each object was created, the constraining objects were removed and the models were further refined in the CAVE as well as using desktop CAD tools. The principle shape of the objects remained unaltered throughout all modelling steps (Figure 11).
Approach III: resulting objects (renderings), bookshelves (left) and fruit bowls (right) with constraining objects removed.

**Approach IV: physical constraints, one-to-one copy**
The fourth student worked primarily in the physical domain. She decided to build a physical tool which allowed her to copy the outline of physical objects by scanning the surfaces with a tool tip attached to a telescopic arm. On the other side of the arm an optical tracking target was attached which controlled the position of the virtual cursor (Figure 12).

When moving the tool tip across the surface and pressing the stylus button, a shape inverse to the movements of the tool tip was extruded in the virtual environment (Figure 13).

**Conclusion**
Apparently the immersive sketching environments provided all students with enough opportunities to develop individual modelling approaches. It may be assumed that these four approaches are neither exhaustive, nor do they cover all possible immersive modelling techniques. It can be expected that - as in the physical domain - the number of possible modelling techniques is almost unlimited and depends primarily...
on the experience and skills of the user. In this regard it can be assumed that immersive modelling offers significant potential for interested users to further develop individual design skills and strategies.

Based on the results of this study it should be clear that progress in immersive modelling can not only be achieved by enhancing the tangible sketching tools (e.g. in terms of precision, response time, weight). To successfully use immersive modelling techniques it is also necessary to develop individual strategies on a conceptual level which help to compensate for the missing physical materiality and constraints.

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**REFERENCES**


