PUPPETEERING ARCHITECTURE

Experimenting with 3D gestural design interfaces

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Abstract. This paper documents and analyzes a set of experimental prototype applications for interaction with 3D modeling software through body movements. The documented applications are the result of two workshops dedicated to exploring the potential of 3D motion tracking technology in architectural design. The larger issue the work addresses is how one can create tools that allow us to bring our intuition and our talent for 'craft' into the digital design process and in how far tapping into the expressive powers of our body movements may provide new possibilities in this respect.

1. Introduction

It has often been pointed out that current CAAD systems are particularly weak in supporting the early stages of design (Knight et al. 2005; Gross 1996; Richens 1992). Among the most important (and perhaps most obvious) conclusions most researchers in this field came to is the need to make the interface as intuitive as possible, ideally to make it "disappear" altogether.

The goal put forward in many such projects was to come to a mode of interaction similar in ease as the traditional sketching. Sketching by some researchers is taken literally as the two-dimensional activity it is when one uses a pen or pencil on paper. A number of programs for conceptual design provide sophisticated sketch-recognition capabilities that enhance the sketching process (Schweikhardt and Gross 1998). Another branch of research takes the notion of sketching less literally. Their aim is to provide 3D modeling capabilities that can be used as simply and intuitively as a pencil without actually resorting to a pen as the input device (Kurmann 1995; Pratini 2001). Nevertheless, both approaches emphasize our capability to express ourselves through continuous (mouse-, resp. pencil-)

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movement rather than through typing keys on a keyboard or clicking buttons on a computer screen.

We may infer that an underlying premise of choosing the more fluid type of movements in the mentioned examples is that it allows us to interact with the computer in a more direct or more intuitive way. This notion can be taken further by exploring gestural interaction. Whereas in the sketching or mouse-movement paradigm the free movements are still limited to a plane, in gestural interaction, they can happen in space.

This paper documents and analyzes a set of experimental prototype applications for interaction with 3D modeling software through body movements. The documented applications are the result of two workshops dedicated to exploring the potential of 3D motion tracking technology in architectural design. The first workshop was conducted at our institute with a group of architecture students during one week in June 2006, the second with a different group in the winter semester 2006/07.

The larger issue the work addresses is how we can create tools that allow us to bring our intuition into the design process and in how far tapping into the expressive powers of our body movements might provide new possibilities in this respect.

2. Giving Form

> The apprehension and giving of form is a dynamic process, rather than a static code; giving form gives works their meaning. Of course the givers of form are the hands. […] Through the hand, workmanship involves execution, and expression involves workmanship. (McCullough 1996, p 8)

Computers are thought of as tools for the mind, rather than the hands (McCullough 1996, p 17). But ever since graphical user interfaces were introduced, this has started to change. The notion that operating a computer has something to do with craft, as McCullough writes, is not outlandish. In fact it makes perfect sense. Homo faber, the species that makes things, has evolved to refine their talent for craft. And while manual labor is currently mostly thought of as a job that is not well paid, in the context of information technology manual labor can also be seen as a particularly rich and precise way of expressing ourselves and thus potentially transferring this rich information to a computer.

Current developments in computer interfaces, resp. in consumer electronics, certainly point in that direction: touch screens, the tablet PC, the Palm organizer, Apple's forthcoming iPhone - all replace the traditional buttons by smooth, continuous surfaces for user input. Conceptually the advantages are clear: the smooth surface that also doubles as a screen has much greater flexibility for user input. It can be used to process continuous strokes rather than just individual clicks, making it possible for the user to make more nuanced, personal input, such as handwritten notes or sketches.

Actually touch screens have been around for a long time and pen input, in the form of the light pen, was already used by the very first CAD pioneers (Sutherland 1963) and thus by far predates the mouse as an input device. But until recently these input technologies were confined to niche markets. One can only speculate about why they took so long in becoming more widespread. The main reason is probably that for the great majority of computer applications, mouse and keyboard are perfectly sufficient input devices. The average computer user has little need for the more nuanced and direct types of input. Therefore the market share of touch and sketch technologies has traditionally been marginal. And because in computing technologies it takes large numbers to drive down cost, they remained rather expensive.

Now it seems that this is starting to change. Quite possibly this change has been brought about by the sophistication of graphical user interfaces (GUI). Fluid transitions between different states of the screen have long been proven to make it easier for users to maintain a mental map of the screen content in their minds (Card et al. 1999, p. 30). More and more, today's interactive applications and graphical user interfaces are respecting this fact. Shunned as mere 'eye candy' by some purists, the popularity of these effects probably reflects a desire of our perceptual apparatus to see things behave in an analogue, life-like fashion. When there is 'life on the screen' (Turkle 1997), when interface elements resemble physical objects rather than abstract information as we manipulate them, we seem to enjoy dealing with them more. It is only natural, then, that there is also a desire to reciprocate these fluid graphical effects of the GUI on the input side. Thus the renewed interest in tablet or pen input doesn't come out of the blue. It is the logical consequence of our increasingly object oriented GUI metaphors. Current technological developments in this area, such as multi-touch interfaces (which are also advertised as part of the above mentioned fothcoming Apple iPhone) show this growing interest in more natural ways of human computer interaction and offer fascinating glimpses into unprecedented ways of working with computers (Han 2005).

As a perhaps unintended consequence of this quest for natural interaction, craft is back. The computer is more and more turning into a tool for both the mind and the hand.

If our analysis is correct we are currently witnessing a technology long in the making that is finally becoming mainstream and giving craft an unexpected comeback. But we can also look further into the future. Tablet and touch screen interfaces are a step towards more fluid interaction, but the development does not have to stop there. Our evolved bodily skills are not limited to sketching. Humans are good at doing things in three dimensions. To really take advantage of these skills our user interfaces have to be fully three dimensional as well. Arguably this is especially true for the three dimensional activity of giving form.

3. Background: Motion Tracking Technologies

In order to create three dimensional user interfaces and thereby bridge the gap between physical and virtual environments one needs to perform some sort of tracking of our body in space. Several technologies for tracking have been developed, including magnetic, mechanical, acoustic, inertial, optical and hybrid tracking (Bowman 2004). Among these, optical tracking systems currently reach the highest level of precision. This explains their widespread use in character animation as well as in medical applications. In both fields, sub-millimeter accuracy is needed to achieve the level of nuance and detail that has become standard practice.

The biggest disadvantage of optical systems is the problem with occlusion that can only be countered with a high redundancy of cameras, leading to the other major disadvantage: the rather high cost of the hardware. Another problem is that in order to track well, the field of vision of the cameras should be free of glare and reflections, limiting the types of environments such set-ups can be used in. Nevertheless, today's state of the art systems are typically rather simple and hassle-free to set up and use.

Besides speed and precision, their main advantage over most of the other mentioned technologies is that the user can be completely untethered from the computer, moving and behaving naturally (except for the markers they have to wear). For this reason optical motion tracking has been used in a number of artistic projects with dancers (Kaiser 2002). In the projects presented in this paper, a six camera VICON 3D motion tracking system was used in connection with the modeling and animation software Maya.

4. The Workshops

As we have described elsewhere (Hirschberg 2006) 3D motion tracking can be put to different uses in architecture. In the workshops described in this paper the goal was to find novel ways how one can interact with respectively give form to a virtual model. In the first one, which took place in June 2006, the topic of puppeteering was used. The second one was titled Formotion and addressed the topic of form through motion head-on.

4.1. PUPPETEERING ARCHITECTURE

When looking for new ways to apply a technology it is easy to get trapped in conventional ways of thinking. It is one thing to declare that giving form should happen in three dimensions and quite another to come up with concrete ideas of how this could be done in a meaningful way. In order to stay away from the common notions of computer aided design tools such as coordinate systems or object snap, the analogy to puppetry was chosen as a playful approach that put more emphasis on narrative than on the creation of form. This proved to be successful as many of the gestural interfaces the students produced contain rather novel interactive features.

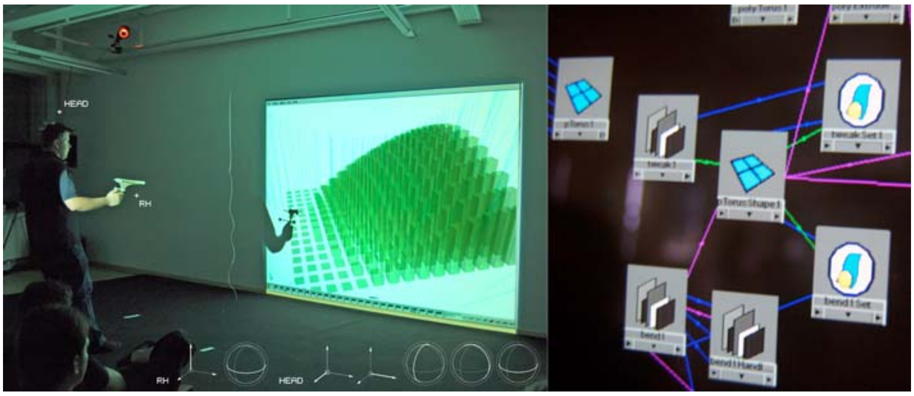

Figure 1. Project Student A: Interacting with a field of green cubes in different modes. Main control with object in right hand, switching of modes and adjusting parameters with head gestures (nodding, shaking); right: Linking of parameters and objects in the Maya hypergraph interface.

Figure 2. Project Student A: sequence of interactions in different modes, switching of modes is controlled by nodding or shaking head.

Technically the students developed their applications on the basis of an existing real-time interface between the VICON 3D motion tracking system and the modeling and animation software Maya, making use of the MEL scripting language.

The reference to puppeteering was used in the workshop as a way to give the work of the students a certain inspiration and direction while at the same time opening them up to new ways of conceiving of the interaction with a computer. The analogy was also appropriate as most students used just one object with markers to control their model, tying the X, Y, Z coordinates and the three angles by which the object's position is defined in space to various functions or properties in the modeling system.

Puppeteers can be seen as giving form to the movements and the interactions between the puppets they control. While puppetry per se has very little in common with the way architects tend to design (or for that matter sketch) spaces, what interested us was its narrative dimension. To control their puppets a puppeteer makes highly artificial and awkward movements, yet they are held together by the narrative of the play the puppets enact. Just so we wanted the students to steer clear of conventional approaches that tend to focus on individual gestures that trigger individual actions but rather focus on the overall sequence of events and the drama the movements create. Their final presentation was labeled as a performance rather than a presentation of their project. In fact it was only then that we brought the question into the discussion whether they thought that their puppeteering interface could also be used as a way to construct form.

4.2. RESULTS OF THE PUPPETEERING WORKSHOP

The workshop was designed as an open experiment. Figures 1 through 4 give some impression of the work produced. Some of the students' performances were very entertaining, though not everything worked as planned. Thus the above mentioned element of craft was clearly present: things happen live, one has to act at a certain moment, the skill of the operator was in some cases as important as the application.

Some interesting ideas the students came up with:

Mode Switching: Many projects support switching between different modes of interaction by some extreme movement: a high z-coordinate, so the operator would reach up high with their marker object, or an extreme angle, so they would turn the marker object upside down. In one project the switching was triggered by nodding or shaking of the head. This was meant to prevent unintentional mode-switches and usually worked reliably.

Two Marker Objects: Some students used two marker objects in parallel, thus potentially controlling twelve parameters at the same time. While interesting in their complexity, these projects were more confusing for an unexperienced user. Even when the second object was only used to control the interaction mode of the first one or the camera view, handling two marker objects at once still demanded a lot of concentration and was not exactly intuitive for first time users.

Accompaniment: The performance idea was taken literally by many students in that they chose some music as accompaniment. One student went even further in that he set his project performance both to a music score and to a keyframe animation. Thus the modeling environment to which he controlled his object was changing along with, yet independently of his actions. In a sense he had replaced the intentional mode-switching with a continuous loop of modes that merged into another.

When the projects were discussed as ways to design form rather than as virtual puppeteering environments, new questions and ideas came up. Rather than being permanently linked to a parameter with one's body, many expressed a desire to be able to grab and release objects, and thus to be able to move around the scene without influencing it.

Figure 3. (left) Student B: controlling spin, size and edginess of space flowers; (right) Student C: The fight with the flying mustache – a dramatic confrontation.

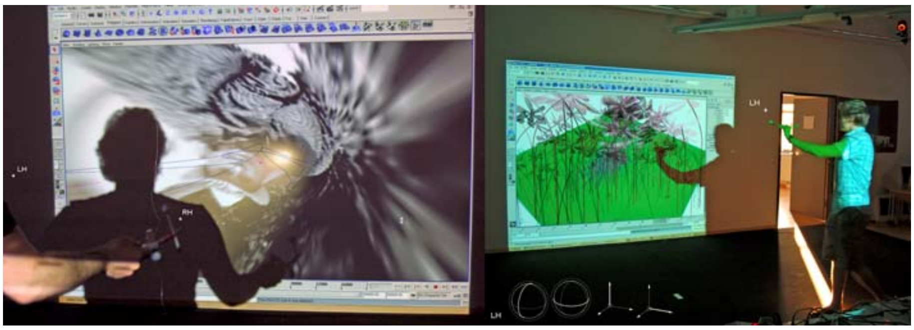

Figure 4. Student D: controlling a particle field with two hands. Student E: watering virtual flowers with one hand.

Most students felt that controlling many parameters at once would be something that one would get better at with practice. But at this point nobody thought it would make sense to spend too much time learning to better work with their interaction patterns. They felt that in order to get people to practice with them, the logic of the 3D motion interface should be more forthcoming and intuitive to begin with.

4.3. FORMOTIONS

The title of the second workshop describes rather well what it was about: formotion can be read as the short version of form through motion, or formation by motion. The main difference to the first workshop was that students could use a head mounted display during their interaction with the virtual model. As a warm-up assignment, they were asked to draw a piece of furniture into space (Figure 5). As could have been expected, the resulting spatial sketches were rather clumsy. When compared with conventional 2D sketches of the same object (Figure 5, left), they revealed a lack of finesse and precision. Nevertheless, when they were processed further with additional modeling operations, these clumsy space drawings turned out to be interesting starting points and revealed some interesting qualities. Once they were rendered they looked very interesting and unique. (Figure 5, right; Figure 6). These qualities, however, had more to do with the intrinsic beauty of human movement (which we explored in more depth in: Hirschberg 2006) than with the fact that they were meant to be pieces of furniture.

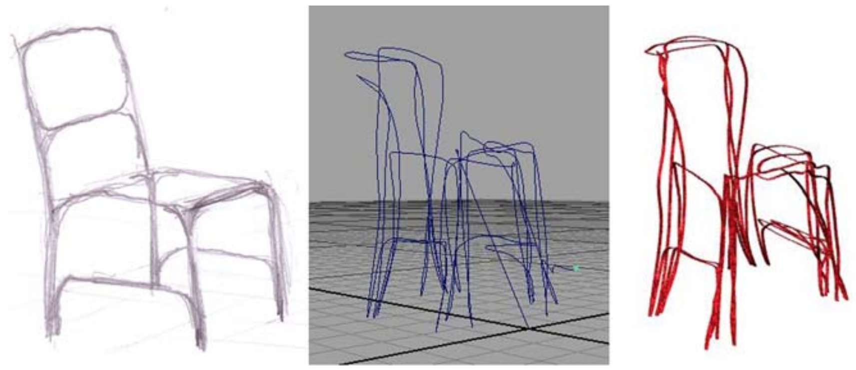

Figure 5. Freehand Sketching into Space. As a way to get to know the system, students tried to sketch a chair in space. Here shown as a handsketch (left) in the Maya modeling environment (middle) and as a rendering (right).

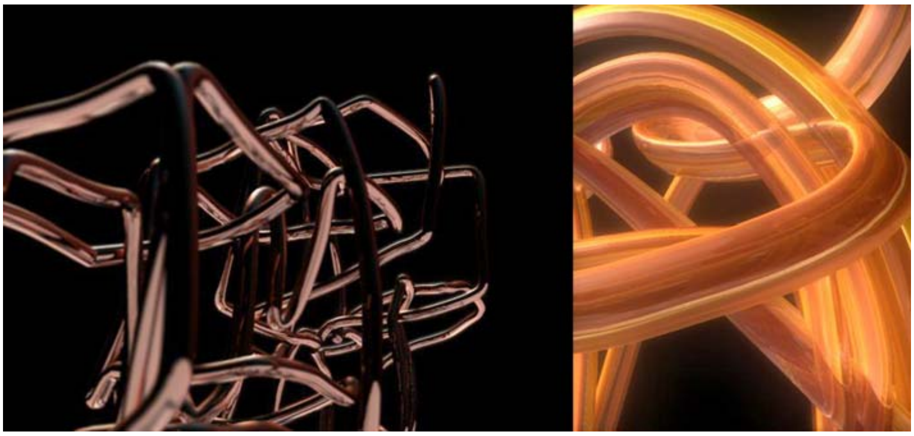

Figure 6. The space drawings of the furniture objects were developed further in Maya and revealed some surprising aesthetic qualities.

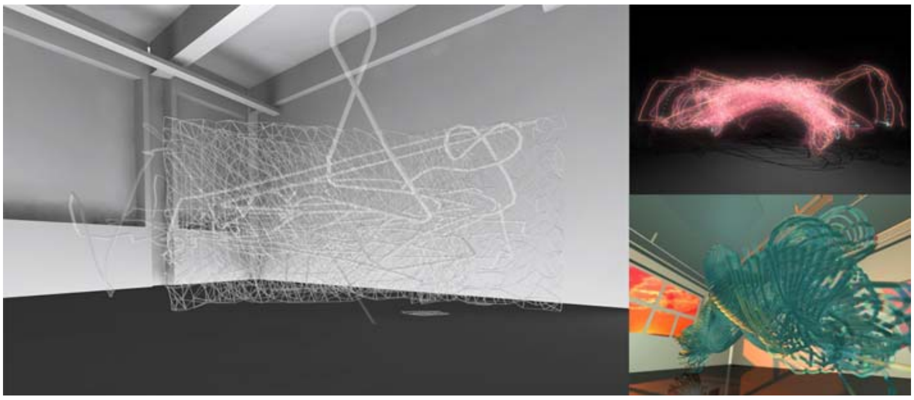

Figure 7. Augmented daydreaming: Using the virtual model of our lab as the setting, students had to come up with a scenario of how they could interact constructively with a virtual model.

4.4. BEYOND SKETCHING

Some sort of sketching in space is probably the most obvious initial idea one might have about a 3d interface for a design tool. But despite their quirky esthetic qualities, the chair sketches suggest that, when operating in space, sketching might actually not be the most successful metaphor. This echoed some of the desires expressed at the end of the puppeteering workshop: that it wasn't nice to be permanently linked with a model. The ideas the students came up with instead were often inspired by less refined movements: pushing and pulling, blowing… It turned out that the dynamics engine of Maya provides some very effective modes of interaction, that the students experimented with in their Formotion projects.

One idea put forward by the teachers was to conceive of the role of the computer in these projects as enabling 'Augmented Daydreaming'. The immersive feeling of being able to physically walk around a virtual model and the possibility to interact with it in the soft and indirect ways the dynamics engine allows really brought out this feeling in the students. Of course it is very difficult to describe or convey the nature of such immersive, interactive experiences with static images. Yet they do give an idea of the variety of the works produced (Figure 7).

Beside the dreaminess, some projects also featured real inventions. One student differentiated between pushing and pulling by turning his hands around, thereby triggering the force field attached to his hand's position to change direction (Figure 8). This turned out to be very effective and was also immediately understandable for other users who picked up on it almost instantly.

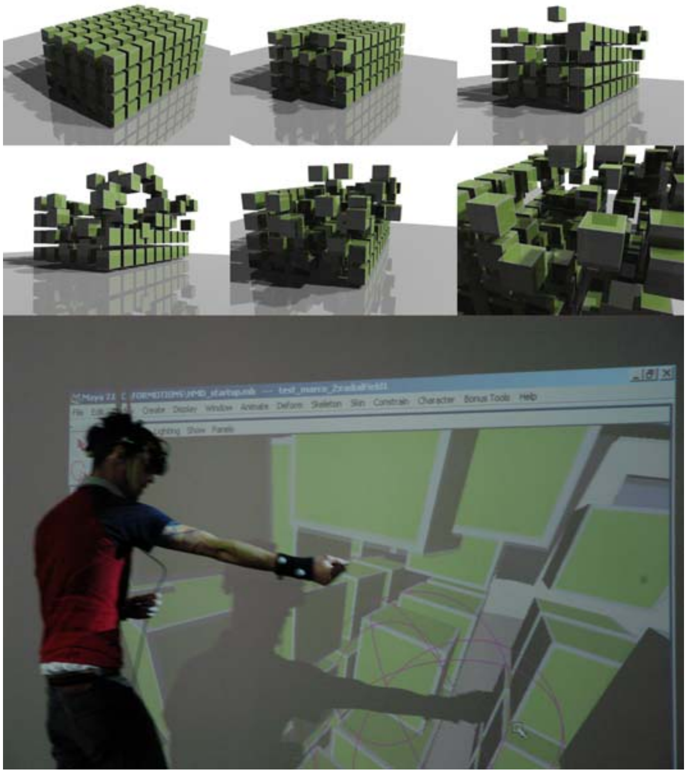

Figure 8. Student G created an environment to move around boxes in space, differentiating between pushing and pulling by turning his hands 180 degrees, which proved to be a very successful gestural metaphor that people picked up easily

One student worked on spheres with a wind field, effectively shaping a soft, ephemeral object with a virtual blow dryer (Figure 9). There is something quirky about operating a virtual blow dryer, but as a way to define large, curvy shapes it seemed to be very practical. It reminded one of experiments in wind channels that are done in car design, with much less overhead, of course.

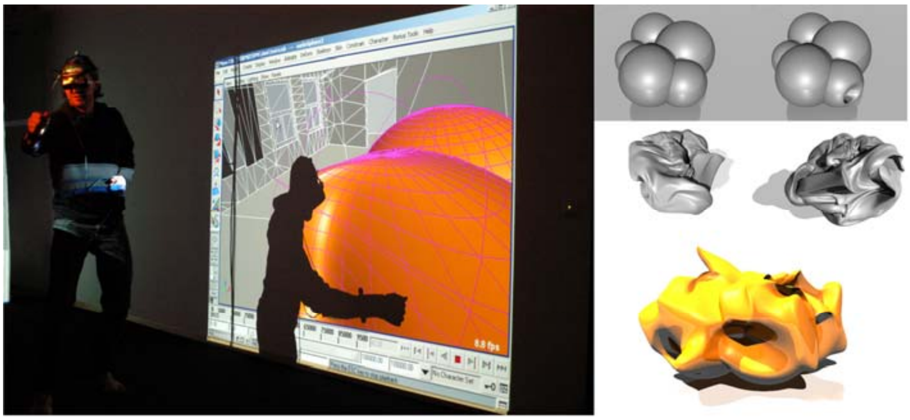

Figure 9. Student F shaping a soft, ephemeral object with a virtual blowdryer. On the right are different stages of the interaction: the initial arrangement of spheres, intermediate and final stages of different sessions

5. Conclusions

In this paper we described two workshops that explored 3D gestural interaction with virtual models, making use of an advanced optical tracking system. Our investigations are based on the assumption that the current trend towards continuous movement as input in human computer interaction will yield more intuitive interfaces and that eventually such interfaces will not be confined to a surface but take full advantage of our bodies' ability to move in space. The goal of the workshops was to experiment with these technical possibilities and thereby come to a clearer idea of how such gestural interfaces might eventually work.

Given the 'indirect' approach and the limited time of the workshops, the projects presented in this paper are obviously not meant to be understood as fully fledged gestural design tools. Nevertheless they provide some valuable insights. They show that by linking our movements with a modeling environment in intricate ways it is well possible to control many parameters at once, but that it is difficult to make this control intuitive. They also demonstrate how craft may become an important aspect of digital design again. They particularly seem to confirm the trend towards physical based behavior as a successful interaction metaphor for design: using a virtual blowdryer to shape an object was more successful than drawing an object with a line in space. In this way, the experiments we described are indicative of the potential of gestural interaction in design and provide ample reasons why this area should be explored further.

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