# Let's Get Physical:
# Tangible Interaction and Rapid Prototyping in, for, and about Design

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Workshop aim: Following decades in which design computation was almost exclusively the domain of software, today many investigators are building hybrid systems and tools that, in one way or another, bridge the divide between physical "real world" artifacts and computational artifacts. On one hand the rapid rise and popularity of mass-customization, rapid prototyping and manufacturing raises questions about the kinds of software systems and tools that might make these hardware technologies useful in designing. On the other hand, advances in microcontroller and communications technologies has led to a wave of embedding computation in physical artifacts and environments - that is, tangible interaction.

The "Let's Get Physical" workshop calls for position papers that populate in this space of hybrid computational-physical systems, particularly in relation to design. Topics might include (but are not limited to) the following:

1. systems, methods, and tools for rapid prototyping and manufacturing in design
2. tangible interaction with design software
3. design methods for tangible interactivity
4. toolkits for tangible interaction design

Workshop #1, Second International Conference on Design Computing and Cognition
Eindhoven , The Netherlands July 8, 2006

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# Musical Instruments
## *Tangible Interaction with the Intimate Interface*

Position paper for the Workshop
**Let's Get Physical: Tangible Interaction and Rapid Prototyping in, for, and about Design**
**DESIGN COMPUTING AND COGNITION Conference 2006**

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Musical instruments are extreme examples of precise, expressive and versatile interfaces. When played by a skilled musician, profound and complex interaction can take place. This is a great source of inspiration for making electronic interfaces more sensitive and effective.
With the transition to the use of electronics as a sound source, a new type of non-mechanical instrument was needed. The limitations of the mechanical systems (ie, the length, thickness and tension of a string is directly related to its pitch and timbre) have also gone, which means that there is almost total freedom in the design of the instrument. In fact there is so much freedom that new guidelines and approaches to design for this complexity have not yet been established. With the introduction of the communication protocol MIDI in the mid eighties, the *control surface* or interface was increasingly detached from the *sound source* – splitting the 'instrument' in two as it where. In the last twenty years many developers have worked on creating new instruments, both new interfaces as well as new forms of sound synthesis. These instruments show that it is becoming possible to create new instrument forms, unrestrained by mechanical limitations, fitting to the player at the close, even *intimate* level.

Due to the decoupling of the sound source and control surface, a lot of *feedback* from the process controlled was lost (and later found when explicitly designed in). In electronic musical instruments, the main sense addressed is the auditory through the sounds produced and there is visual feedback in some cases. But the touch feedback from the sound source is hardly used, the feel of a key that plays a synthesised tone will always be the same irrespective of the properties of the sound (the device can even be turned off entirely!). Compare this with the feel of quite similar keyboards on the piano and the harpsichord, or the differences in the touch of an pneumatic organ or an electronic one.
Musicians traditionally rely strongly on their sense of touch when playing acoustic instruments, which helps them to control and articulate the sounds produced. In these cases, there are three sources of information for the player:

- kinaesthetic feedback: the internal sense of the players own movement (proprioception)
- passive tactual feedback, the shape of the instrument and the elements touched (strings, keys)
- active tactual feedback, through the vibrations or other changing properties of the instrument

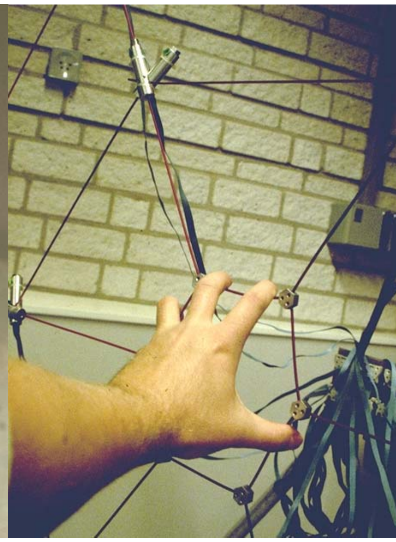
As with other electronic systems in general, players of electronic musical instruments such as synthesizers lack the information channel of active tactual feedback, unless it is explicitly built into the system. Due to the decoupling between control surface and sound source through the MIDI protocol, players are not inherently in touch with the means of sound production. The third feedback modality of a traditional instrument as mentioned above is missing. However, this decoupling can also be used as an opportunity because of the two-way nature of the link between interface and sound source, by designing and applying the active tactual feedback.

Ever since the Theremin, gestural controllers have been popular in electronic music. However, from the three feedback modalities mentioned above now only one remains, the proprioception. It is therefore more difficult to play accurately.
Research has been carried out about addressing the sense of touch in order to restore the relationship between that which is felt and the sounds produced. It is an important source of information about the sound, and the information is often sensed at the point where the process is being manipulated (at the fingertips or lips). This immediate feedback which supports the articulation can be described as articulatory feedback.

The development of musical instruments in the successive technological stages show clearly how the instrument becomes more invisible, less physical, often 'easier' to play, but harder for the player to express him or herself with. This is because *effort* is actually often a good thing. When playing the instrument, the physical resistance is a source of information about the process of playing and articulating sound. The lack of physicality must be compensated for, by including haptic design, ie. force feedback and vibrotactile feedback.

The difficulty of playing traditional instruments is related to the physical nature of the sound making process, and this process determines to a large extend the design of the instrument. With electronic instruments the form factor is free, so it becomes possible to take the human as a starting point and develop ergonomically more optimal instruments. Total freedom however is difficult to design from, as there is often no concrete function to dictate the form. The functions are abstract (in sound, but also in other interactive systems) so the form has to 'follow the function' in other ways. Metaphors are often used (but they have their own limitations), or translations from one modality to another in an almost synaesthetic way.

In the presentation some recent new electronic instruments will described, starting from hand held or worn interfaces such as a glove, to bigger scale instruments that still enable an intimate connection between player and the interface. Primary examples are the new interfaces which the author has developed together with some of the main pioneers in this field such as Michel Waisvisz (The Hands) and Laetitia Sonami (The Lady's Glove). It is also possible to augment traditional instruments with electronics. An example of such a *hybrid* instrument is described, the Meta-Trumpet the author has developed for Jonathan Impett.
In addition to the intimacy, the other important lesson learned from musical instrument design is the importance of the role of the sense of *touch*.
As examples of larger scale instruments, two instruments are described that the author has developed with Atau Tanaka, which extend the scale of intimacy to the architectural or even global scale.


# A PHENOMENOLOGICAL DESIGN METHOD FOR TEXT INPUT AND OTHER TECHNOLOGICAL ARTIFACTS

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***Abstract.*** *Design practice in the Human-Computer Interaction (HCI) tradition often focuses on developing a task-based model of behavior and extrapolating system requirements from this model. Some tasks, however, are too complex to model. Consider the problem of text input beyond the traditional desktop and laptop computing paradigm. Natural, seamless, efficient and comfortable text input is a complex activity involving the translation of language into psychomotor rhythms acting on a spatial topology. Accurate models with appropriate emphases are difficult, if not impossible, to construct. Fortunately, as this paper shows, we may make informed design decisions not by modelling, but by leveraging phenomena. In this design study I leverage the patterns of language and innate tendencies of the human typist to create an imprint of text input activity on a technological artifact.*

## 1. Introduction and Motivation

Frustrated with multitapping text into your cell phone? Thumbs tired from mini-QWERTY? Don't have 40 hours to learn Twiddler chording? Don't want to get hit by a bus when crossing the street and entering graffiti into your PDA? Haven't quite mastered the interpretive dance or hand motions required for your gesture-based system?

Imagine walking down the street on a Saturday, comfortably and effortlessly recording your thoughts directly to your blog. How are you doing this? In other words, how can we effectively design an off-the-desk text input device that facilitates blind text input for extended periods of time? As one computer science/HCI professional suggested to me, we could model a hand in a computer. Or we could create an algorithm which maximizes or minimizes certain language parameters. Or we could assemble a panel of experts, including linguists, interaction designers, cognitive scientists and ergonomists to analyze the problem and propose solutions. But why model or analyze a complex activity, at the risk of missing an important factor or misplacing an emphasis, when you can leverage tendencies innate to the activity? A phenomenological design approach can reveal and tacitly incorporate solutions which aren't apparent upon analysis or modelling. Furthermore, a phenomenological method supports the notion of *natural*, as opposed to *idealized*, interaction. Here "natural" refers to a response well-located within the participant's being. "Idealized" refers to interaction as it "should be" as determined by a model, calculation, designer or expert stakeholder.

## 2. Axioms

This phenomenological design method relies on the following beliefs, held as principles for the sake of the study:

(i) Accurately modelling complex human activity is statistically impossible.

(ii) It is possible to imprint an activity on an artifact.

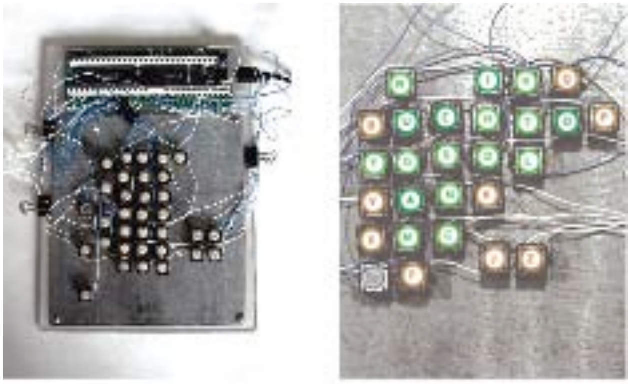
(iii) Collective intelligence can emerge through individual transactions.

## 3. Design priorities

The text input device considered here is intended to afford extended periods of comfortable and efficient blind input. It is to be designed for the person-on-the-street, as opposed to the technological elite. For this reason, I prioritize easily-understandable, non-strange designs which leverage legacy devices. The device should be immediately usable while channelling expert, blind operation over time. It should fit with the body ergonomically. English language text input is prioritized. I do not have the space to include the rationale behind my decision to constrain the text input device to a one-handed keyboard at this time. Suffice to say that these priorities led to such a constraint in the design possibilities.

## 4. Initial design study

I devised a pilot study with the following ingredients: a functional, reconfigurable keyboard (Fig. 1), a phrase set representative of the English language (MacKenzie 2003), and ten participants. The reconfigurable keyboard is not a prototype design, but a prototype design *tool* to serve as an artifact for the imprinting of activity. Participants were encouraged to rearrange magnetic character keys around a two dimensional metal plate and change the heights of keys using small magnetic risers to suit the phrase they were typing. In this way, the phenomena of typing shapes the device.



*Figures 1 and 2.*

The Reconfigurable Keyboard, v. 1 *and* Example of Triangular Layout

In keeping with the person-on-the-street audience for this object, study participants were chosen from a wide range of ages and livelihoods. In opposition to the reality of many HCI studies, readily-at-hand computer science and engineering students were deliberately avoided. Ages ranged from 21 to 64 and included a first-grade teacher, an arborist, a home renovator and a sculptor. All participants were English speakers and used their right hands.

## 5. Results

The primary purpose of this study was to determine the effectiveness of the method. Study participants were both able to enter text into a laptop computer using the reconfigurable keyboard and rearrange the keys. Study structure, such as order of events and timing, were sound. The study resulted in qualitative results informing design and some consistent imprinting.

Most participants used conscious strategies to organize the keyboard, particularly by partitioning characters according to type and allotting certain types of characters to individual fingers. Some participants (three of ten) worked more automatically, seemingly developing a phenomenological dialog between language and the keyboard.

A triangular layout often emerged, particularly among the participants working more automatically. This layout tended toward a right triangle with the non-hypotenuse sides on the top and left. In these layouts, letter frequency correlated to finger strength. Often common di- and tri- graphs were placed adjacent, allowing for a rolling hand motion while typing. See Figure 2 for an example.

In addition to self-devised home rows, the peripheral boundary of the layout was often used by participants to guide finger placement. Most participants used the various key heights as tactile landmarks. Interesting topographic patterns emerged.

Due to the desktop nature of the design tool, a majority of participants used hand stabilization strategies particular to being seated at a desk. This phenomena pointed to the next phase of the design study.

## 5. Phase Two

The second phase of this study has recently begun. I am using the same phrase set and study structure. The design tool has evolved to a functional reconfigurable keyboard which lays on the surface of a purse or messenger bag. Study participants can use their own bags or use my preconstructed one. In each case, the belongings the participant has carried with them remain in the bag or are placed inside. If necessary, small bean bags are inserted to add stability.

*Figure 3.*

The Reconfigurable Keyboard, v. 2

## 6. Conclusion and Questions

As designers of novel technologies, we must often devise design methods appropriate to our framing of the problem. We are guided by our designer's instincts and our methods are refined through experience. This study points to a design method which combines design axioms, priorities and decisions with an evolving phenomenological method.

Have other workshop participants experienced phenomenological results through their work? What design problems could benefit from a phenomenological method?

The study thus far indicates that a text input device configured as a one-handed keyboard can be constructed as an imprint of human activity. The study also indicates that in order to find an imprint using this method, designers should encourage participants to abandon conscious analysis. Although conscious key organization strategies can give us an insight into how participants remember the location of keys, in order to capture an imprint of human linguistic, cognitive and psychomotor structures, participants should be encouraged into a state of automatism, or focused, unconscious improvisation. Another way to describe this state is to say that participants must "back-brain" the activity and enter into a feedback loop between the phrase set and the keyboard.

If it is true that human activity unconsciously channelled can facilitate imprinting onto a technological artifact, how do we encourage this behavior in our study participants? How do we discuss it within our professional community given that a vocabulary describing this state is lacking, soft, or considered suspect, particularly in the HCI literature?

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# NATURAL INVERSE: PHYSICALITY, INTERACTION AND MEANING

*Extended abstract*

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## 1. Introduction

Many of the novel tangible artifacts that have recently emerged are exciting, inspiring, fascinating – inviting you to touch and interact. The interweaving between computers and artifacts can create mesmerizing products that draw you to interact with them. And to ensure an interaction is a success, it is the responsibility of the designers to first understand what the physical nature of these products has to offer and how this physicality can be exploited to create meaningful interaction.

In designing a tangible artifact, it does not necessarily have to be totally different, or, 'out of the world', from what we already have and use today. In fact, today's ordinary artifacts, which include everyday appliances and devices, can teach us much about the interactions that we sometimes take for granted.

Exploring an artifact can be a positive experience if it allows users to recover from mistakes, be it on an everyday artifact, or a novel tangible one. Allowing users to recover from mistakes, or at the least reduce the effects of them, is such an important role in interaction. Without easy recovery users may avoid exploration, but with it users feel safe, knowing that their actions will not lead to failure. The presence of an 'inverse action' supports this recovery.

## 2. Inverse action as we all know it

The ability to inverse, or undo an action really helps users to recover from mistakes and to carry on with their task, hence sustaining them in an interaction. In Graphical User Interfaces (GUI), undo or redo assists users in tracing back one and more of their previous action(s). In computer supported cooperative work (CSCW), undo is found to be an integral need of users that must be supported by a system (Abowd & Dix, 1992). Whilst in direct manipulation (DM), the ability to inverse or undo proves to reduce the risk of getting it wrong the next time (Shneiderman, 1982).

In our own study, we have looked at everyday physical artifacts – appliances and devices, to understand what makes interaction natural and fluid (Ghazali & Dix, 2005a). From our findings, simple artifacts such as a dial or a knob on a speaker, which allows an inverse action, reduces the risk of getting it wrong for those who do not have complete understanding of an artifact, or to be precise, the understanding of the relationship between the physical state of the artifact and its underlying logical function. Furthermore, if the inverse action is 'natural', that is exploits the normal responses of our motor system, then users can recover virtually instinctively often unaware they have made an 'error', avoiding breakdown.

## 3. Inverse action in tangible design

The inverse action has proven to be an integral part of interaction in our design studies of the Cubicle (Block et al, 2004). The Cubicle is a small device shaped like a cube and in ours studies was used to control a media application. In order to study users ability to infer how to interact with it, the mapping between the device and its effects were deliberately manipulated. Despite a lack of understanding of the mappings, the participants were able to react appropriately to feedback and successfully complete tasks and moreover enjoy the experience. The 'natural inverse' property, which is one of the key features of physicality, has helped participants in their interaction with the Cubicle (Ghazali & Dix, 2005b).

The natural inverse property in tangible design also gives flexibility to users in creating their own understanding of the physical artifact and its mapping. In the VoodooIO Gaming Kit (Villar et al, 2006), participants can freely define the functionality of a number of physical controllers such sliders, knobs and buttons,, and are also free to place these controllers anywhere on a canvas, in any way they like. What is interesting to note is the way the participants placed the slider on the canvas. We would have thought the slider would be placed like a typical slider, on a horizontal plane, with its minimum end on the left and the maximum on the right. This would automatically expose the conventional learnt meaning of its mapping. Nonetheless, participants placed sliders many ways, including vertically and diagonally with its minimum and maximum at either end. The natural inverse property means that when the participants interacted with these oddly placed sliders, they were able to apparently effortlessly interact with these, despite their unconventional layout and allowing them to quickly create an understanding of the new mapping.

## 4. Its importance

A physical artifact, which is positively designed would encourage user to keep on interacting with the artifact besides creating a meaningful interaction. The natural inverse property does not just contribute in reducing the risk of getting it wrong, but also injecting a positive encouragement in the exploration – getting to know the unknown. A physical artifact with the property of natural inverse also gives flexibility to user in the creation of meaning between the artifact and the underlying functionality.

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# TANGIBLE INTERFACES FOR VIRTUAL REALITY BASED PRODUCT DEVELOPMENT

*Two approaches based on rapid prototyping*

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**Abstract.** Two approaches are introduced to integrating Tangible User Interfaces (TUIs) in Virtual Reality (VR) environments by using Rapid Prototyping (RP). In the first approach, objects created with RP are augmented kinesthetically by means of force feedback. In the second approach, hybrid objects with physical and virtual components are used. Both approaches are still in a very early development stage. Possible applications are usability testing in early phases of the product development, simulation of assembly and disassembly situations and basic VR interaction techniques.

## 1. Need for Tangible User Interfaces in VR based Product Development

Virtual Reality (VR) methods are often being used in early phases of the product development to make it possible for the user to experience geometrical, technological and physical properties of a product as well as characteristics which affect its environment (Spur and Krause 1997, p. 31). Unfortunately today's VR systems can not sufficiently display the tactile and kinesthetic characteristics of digital objects. Direct interaction with digital objects, e.g. grasping and manipulating, is hardly possible at present, because interaction is usually mediated by input devices such as data gloves and pointing devices. With gesture based interactions, the interaction has no haptic aspects.

For these reasons purely physical prototypes produced by means of Rapid Prototyping (RP) are often used in early phases of product development to predict tactile and kinesthetic product properties. Compared to virtual prototypes, physical ones have a number of disadvantages, especially a) the high production costs of large physical models, b) the restriction of the model’s size to the diameter of the RP machine, c) the inflexibility of the physical object's shape (compared to the potential geometrical dynamic of virtual objects). Merging physical and virtual objects may combine the advantages of both "worlds" within one object. Tangible User Interfaces (TUIs) represent such an approach in Human-Computer-Interaction (HCI). TUIs couple digital objects and functions with physical objects and properties (Ishi 1997, Fitzmaurice 1996, Ullmer 2001). The possibility to directly manipulate without input devices is one of their most important characteristics. Users can directly sense, reach and manipulate a tangible object in its extrinsic properties (position and orientation in space, size) and intrinsic properties (shape, color, mode), without having to consider artificial interaction techniques given by the system.

Two approaches are described for integrating physical prototypes of interactive products into VR environments, which can be described as spatial TUIs in Ullmer's and Ishi's (2001) MCRpd interaction model. Well designed, these can share most of the advantages of physical and digital objects (table 1) and thus extend the range of displayable object properties and modalities.

Both approaches use physical objects made by means of RP. The first approach focuses on purely physical objects that are kinesthetically augmented. The second approach uses what I call hybrid objects which consist of both virtual (graphical) and physical elements.

TABLE 1. Advantages and disadvantages of physical and digital (virtual) objects (see also Dreher 2005, p. 17)

| Advantages of physical objects | Advantages of digital objects |
|---|---|
| - Direct physical interaction (grasping, manipulating) without need for input devices<br>- Combination of visual and haptic interaction channels (leads to large interaction bandwidth)<br>- Manipulatable with either hand<br>- Spatially distributed (space multiplexed, no explicit communicating/switching of the input focus necessary)<br>- Per se integrated perception and action space (supports sensomotor coordination, sense of orientation and motor memory)<br>- Haptically rich surface<br>- Expresses physical affordances | - Easily changeable and highly flexible<br>- Graphically representable<br>- Very low production and changing costs<br>- Low storage-, transportation and maintenance costs<br>- Costs not dependent on geometrical object size |

| Disadvantages of physical objects | Disadvantages of digital objects |
|---|---|
| - Hard to change intrinsic properties (shape, colour, state/ mode)<br>- High manufacturing and changing costs<br>- High costs to realise dynamic functions (e. g. mechanics)<br>- Costs rise with object size<br>- Limited lifetime<br>- Storage-, transportation and maintenance costs | - No physical interaction<br>- Graphical representation does not reach that of physical objects (in particular the depth perception is reduced, since the focus is always at the projection surface)<br>- High costs for haptic representation<br>- Limited compatibility<br>- Migration problems |

A problem which results from bringing physical objects into virtual environments is *occlusion*: virtual objects which should be seen by the user before a physical object are in some cases partially covered by the physical objects (figure 1). This problem exists in all VR Systems with wall or table projection (e. g. Holobench, CAVE) and can hardly be solved. Occlusion can substantially limit the illusion of virtual objects.

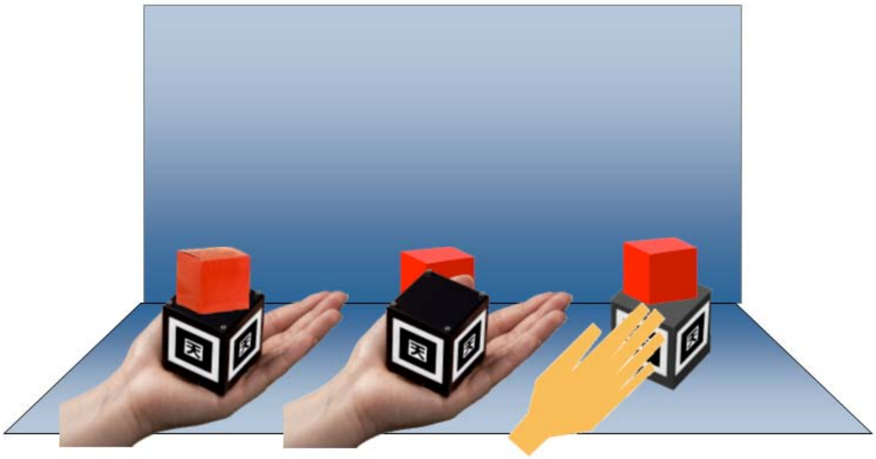

*Figure 1.* Three representations of the same model: physical object, hybrid object with occlusion, virtual object.

## 2. Kinesthetic Augmentation of Physical Prototypes

The first approach to unifying physical prototypes and virtual environments is a modular kinesthetic augmentation system that can hold different interchangeable objects (figure 2, Krause 2005). It couples two force-feedback arms with a jointly used end-effector, the physical prototype, using form factors for easy interchangeability. This construction plus an additional drive and encoder within the end-effector provide six degrees of freedom (DOF) in output and input and can transmit forces applied on them from within the virtual environment. The workspace of the device is 168 W x 127 H x 65 D cm. The average time lag when applying force feedback to the end-effector is below 1 millisecond.

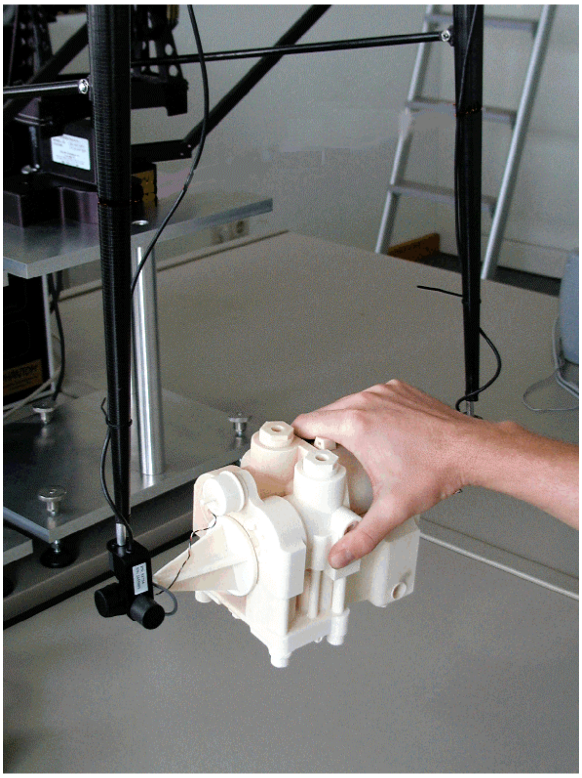

*Figure 2.* Two coupled 3-DOF actuators holding a physical prototype (from Krause 2005)

This solution is suitable for evaluating prototypes, where forces in input and output play a critical role, e.g. in collision detection and physical interaction with the environment. For unifying input and output space in a next step, the system will be integrated into a Holobench environment using a lightweight overhead construction which does not block the view of the projected VR scene. The physical object will be placed and digitally integrated directly into the virtual environment.

## 3. Hybrid prototypes in Virtual Environments

In the second approach, for low production costs and better flexibility in terms of intrinsic properties, the prototype is split into virtual (graphical) and physical elements. Elements such as handles and knobs which provide controls to the prototype or which have important haptic properties for the interaction, are produced by means of RP. Elements, such as flat surfaces or displays, where the haptic characteristics are not relevant, are displayed as virtual graphics, seamlessly attached to the physical element. In terms of Ullmer and Ishi's definition (2001) the physical representation of the object, directly controls the extrinsic properties of the digital representation. The assumption is that the user builds a mental model of the object as a unit of physical and virtual elements. Such hybrid objects can combine many of the advantages of physical and digital objects specified in table 1, in particular:

- Direct physical interacting (grasping and manipulating)
- High geometric flexibility and changeability of important parts of the object
- Low manufacturing costs
- Costs almost independent of geometrical object size

Figure 3 shows hybrid, purely physical and virtual variants of the same model. In a first attempt these were integrated into a virtual environment by means of magnetic tracking. Problems arise due to non linear distortions of the measuring data. Thus, when moving the hybrid object, its graphical and physical elements shift in the user’s view. This problem can be reduced by more precise methods, for example optical tracking.
The second solution is suitable for the evaluation of prototypes which have only small graspable parts (e.g. handles and knobs) where geometric changeability is crucial.

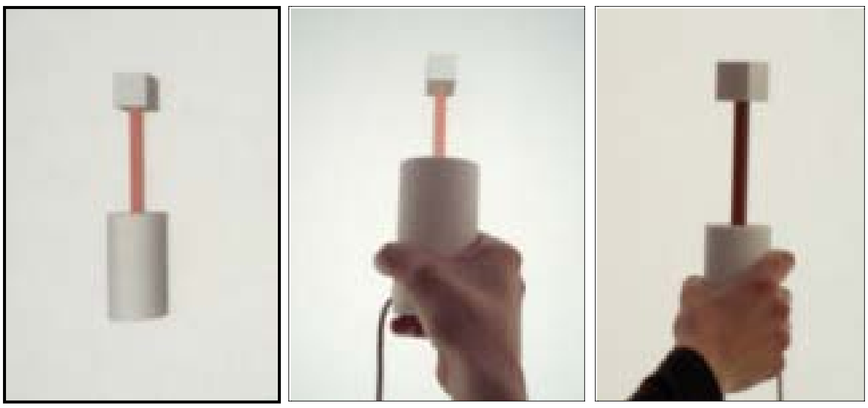

*Figure 3.* Virtual, hybrid and purely physical variants of the same model.

## 5. Summary and Outlook

Despite the problems such as occlusion and shifting, the approaches presented for integrating prototypes into virtual environments are promising for the evaluation of product characteristics in early phases of the development.

In order to estimate the comparability of such tangible interfaces with real products, comparative usability testing should be performed. Measuring user's performance and accuracy in basic manipulation tasks is a good point to start with.

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# TRISKIT

*A software-generated construction toy system*

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**Abstract.** Triskit is a modular construction toy system designed to be outputted from acrylic sheet stock on small laser cutters. Even the best commercially construction toys (e.g., LEGO; K'NEX) are limited in that users have access to only the parts provided by the manufacturer. We wanted a construction system that comes with software for easily generating itself. This paper presents the design process that led to the Triskit system and initial results in using the materials with 10- and 11-year-old students.

## 1. Introduction

Play with any well-designed construction toy system—such as LEGO Technic, K'NEX, or Lincoln Logs—and you develop an understanding of what makes the toy a *system*. Parts fit together in sensible, predicable ways, there are unit dimensions and normative interconnect methods, and a coherent visual and tactile experience emerges. Over time, you may conceive of and then desire a part that does not exist in the building system. But you know that it logically could exist as a legitimate element. Of course, commercial vendors do not typically publish their systems' design drawings, so it is hard to realize your component.

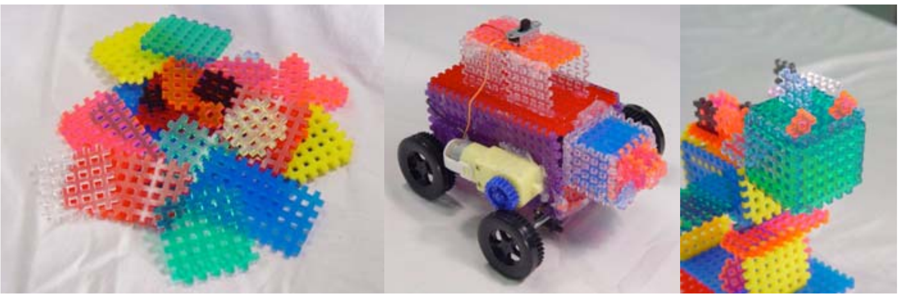

*Figure 1:* Triskit components; child's motorized car; dinosaur sculpture

This limitation motivated the development of the Triskit construction toy system. We desired a set of components that we could easily manufacture, and for which we could provide the specifications to other end users, allowing them to create parts that would automatically become part of the Triskit system.

Figure 1 shows our results: the Triskit components, a motorized car built by 12-year-old, and a dinosaur sculpture designed by an undergraduate in our lab. The remainder of this paper describes our design process, our Java-based software tool for creating Triskits, and reflections after working with a group of 4th- and 5th-grade students.

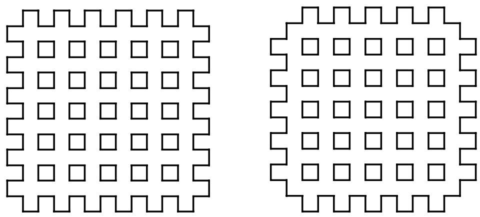


*Figure 2.* type-A and type-B Triskits.

## 2. Design Process

We selected 1/8” acrylic sheet stock as our base material, because it is relatively inexpensive, reasonably sound, and comes in pretty colors. Also, the laser cutter in our lab (a Trotec Speedy II with a 45W laser) can cut through it nicely.

As experienced LEGO builders, we took inspiration from this system. We wanted to be able to build models comparable in size and function to a typical motorized LEGO construction. We liked the fact that LEGO bricks are self-mounting; that is, a brick connects to another brick without the use of a specialized connector component.

In prior one-off projects we had done with our laser cutter, we used tab-and-slot designs to join parts. We generalized this approach and developed the first Triskit “waffle,” which later became known as the “type-A Triskit” (Figure 2, left). (The Triskit name itself comes from our parts’ resemblance to the popular snack cracker.)

When playing with our type-A Triskits, we quickly realized that the hole-slots on each Triskit face would be offset when two type-A Triskits are joined. This led to the design of the type-B Triskit, which has its edge fingers offset by a half-step (Figure 2, right). With type-A and -B

Triskits, we were able to build 4-sided rectangular structures with aligned holes.

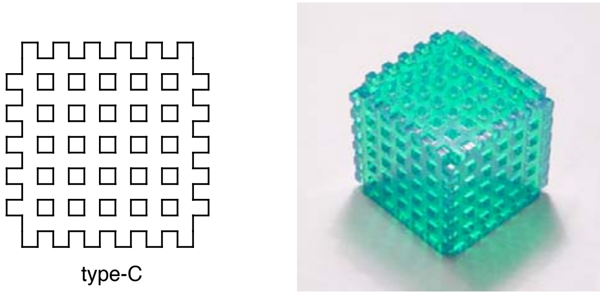


*Figure 3:* type-C Triskit and cube built from 6 identical type-Cs.

We then tried to close the 4-sided rectangles by putting Triskits on their two open faces, and realized that we could not. This led to the development of the type-C Triskit, which has type-A fingers on one pair of opposite sides and type-B figures on the other. We were now able to build the cube (Figure 3).

At this point, we felt like we had a design that was worth playing with, and we set off to develop software to easily generate variants of our 3 Triskit types.

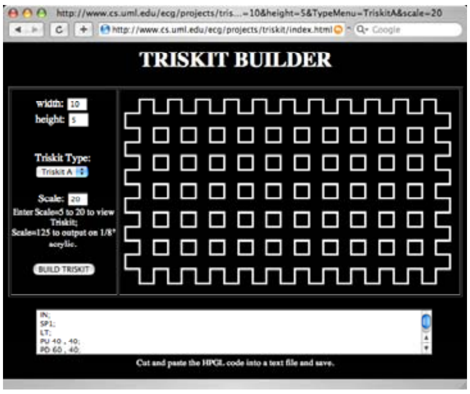


*Figure 4:* Triskit Builder Java applet.

## 3. Making Triskits

The first Triskits were drawn directly into a vector-based draw program (CorelDraw). After we had worked out the basic design and dimensional units, we built a prototype software tool in Microworlds Logo. As the Logo turtle nagivated the screen and drew the Triskit, its movements were captured as HPGL[1] commands. The HPGL code was saved as a text file, which was then imported into a blank CorelDraw document and printed to the laser cutter.

We then developed a Java applet to do the same. After specifying the Triskit features (dimensions and type), the "Build Triskit" button displays the Triskit on the screen and generates the HPGL code for manufacturing it (Figure 4).

## 4. User Testing

We conducted a workshop with 4th and 5th grade students at a local school, meeting for an hour twice per week for a total of about 20 sessions. We introduced the Triskits at the beginning of the workshop and used them as the primary building material for the duration.

The children found the Triskits challenging; it was not evident to many of them how they should fit together. After there were a few models underway in the classroom, however, things got easier.

We realized that the Triskits do not hold together particularly well. This led to some quick improvisation. We tried screws and nylon cable ties to hold them together. 6×32 machine screws fit snugly in the hole-slots on each Triskit face, but the kids did not seem to like using them. Finally, we introduced hot glue guns, and things became a lot happier. A project model designed by one of the children, and representative of the group, is shown in Figure 1 (center photo).

One surprise was that several children did not constrain themselves to the right angle geometry inherent in the Triskit parts. They cut them, glued them at angles, and otherwise treated them as casually as necessary to obtain the effect they desired.

The Triskits do not include any parts to support motion (e.g. gears and axles). To allow the kids to motorize their models, we purchased generic plastic gears and wheels, metal axle rods, and gear motors.

We showed the children the Triskit Builder software on one occasion, but it did not seem terribly relevant to the children's goals (building a motorized model). In retrospect, the Triskit system differs fundamentally from other software-based building systems—e.g. Designosaurus (Oh *et al.* 2006) or HyperGami (Eisenberg *et al.* 2003). In these systems, the primary development is done on the screen; with Triskit, the main work is with your hands.

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[1] Hewlett Packard Graphics Language, a vector-based drawing language originally designed for HP pen plotters. See `http://en.wikipedia.org/wiki/HPGL`.

## 5. Concluding Remarks

At present, the Triskit system is more satisfying for creating static, sculptural models (e.g., the dinosaur of Figure 1) than structurally sound models with moving mechanisms. After having designed the Triskits, we have an even greater appreciation for the power and sophistication of the LEGO Technic system.

One of the biggest challenges is getting the tab-and-slot connectors to work reliably. This is compounded by our discovery that 1/8" thick acrylic plastic varies significantly in its nominal dimension. Using 6×32 screws could work, but the children we tested with were not keen on that approach. We might have better luck with 1/4" plastic, or a more significant re-thinking of our approach.

We underestimated the time it takes for the laser cutter to produce a Triskit. The internal hole-slots create is a lot of cutting per piece.

The Triskits are presently limited to rectilinear forms, but as noted a number of kids found ways around these restrictions anyway. Creating diagonal shapes (e.g. triangles) would be relatively straightforward and could add a lot to the system, even in its primitive state.

The Triskit Builder applet works nicely, and it is quite easy to generate Triskits of varying dimensions. We would like to better integrate the applet with the overall software toolchain.

Looking ahead, we realize that we don't have to do everything with our laser. By combining Triskits or their descendants with inexpensive, off-the-shelf parts (e.g., screws, common plastic gears), we could have a building system that is powerful and flexible.

## Acknowledgments

Martin Meo led the design of the Triskit system. Andrew Chanler solved the cube problem by inventing the type-C Triskit. George Doyle implemented the Java applet version of the Triskit Builder. David Ceddia co-taught the robotics workshop along with co-authors Fred Martin and George Doyle. Michael Piantedosi created the Triskit dinosaur shown in Figure 1, and photographed all of the models shown in this paper.

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# TANGIBLE TOOLKITS

*Integrating Application Development across Diverse Multi-User and Tangible Interaction Platforms*

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**Abstract.** We are creating unified programming tools that allow developers to easily build applications for many different tangible platforms, and that can accommodate the continued evolution of the underlying sensing technologies. The Synlab API extends across several media table object-tracking platforms, RFID tagged object interactions, manipulable displays and multi-touch surfaces.

## 1. Introduction

While the digital realm enables a range of media content to be stored and manipulated, the promise of truly malleable digital information is limited by the means through which we can access the digital space. The interfaces that lie between our everyday physical environment and the digital world remain dominated by displays coupled with single-channel input devices (mice, keyboards). While these platforms are well suited for many desktop and mobile applications, it has been long acknowledged that they do not necessarily meet the needs of a multi-user application space in shared physical contexts such as living rooms, meeting rooms, classrooms and public spaces.

Over the past decade, researchers in areas such as tangible and ubiquitous computing have begun to address these needs by developing interaction techniques that can more seamlessly bridge the physical and digital worlds. Applications have been demonstrated across a range of domains, such as design and simulation, media content browsing, game play and learning. The technologies used to track people, objects and interactions in physical space range from computer vision, to infrared or ultrasonic sensing, radio frequency identification, and more.

In many cases however, the technologies used are not yet ready for prime time. Tangible application prototypes often demonstrate interaction methods that cannot be achieved using any single commercially available technical solution. As a result, they frequently use combinations of technologies or customized hardware setups, which in turn require custom communication and programming protocols. The complexity and cumbersome nature of the hardware setup makes application development for these novel platforms an arduous task that is mostly undertaken only as small-scale projects within user-interface research labs.

As the underlying technologies continue to change and develop, we can simultaneously mature the field of tangible interaction design by creating unified programming tools for developers. These tools could enable the creation of applications for many different kinds of tangible platforms while accommodating continued technological evolution.

## 2. Tangible Toolkit Research

The use of application programming interfaces (APIs) and toolkits is not new in software development, and enables programmers to rapidly create applications for computer interfaces that use traditional input/output devices. The concept has also been explored by some ubiquitous and tangible computing researchers. Many of these toolkits support low-level tangible interface design, allowing designers to assemble components such as sensors and actuators into hardware prototypes that can be interfaced to software applications using event-based communication. Notable examples include Crickets (Martin et al. 2000), Phidgets (Greenberg et al. 2001), iStuff (Ballagas et al. 2003), and the Calder Toolkit (Lee et al. 2004). A related area of toolkit research has focused on single-display groupware, such as multi-touch tables. Examples include DiamondSpin (Shen et al. 2004) and the SDGToolkit (Tse et al. 2004), which support touch or stylus-based user interactions rather than customized tangible objects.

In the Synaesthetic Media Lab at Georgia Tech, we are working mid-way between these approaches to develop an integrated application toolkit (the Synlab API) that allows developers to build applications for a range of tangible platforms and technologies. Our approach is similar to the Papier-Mâché toolkit (Klemmer 2003) which provides an event-based model for application development using RFID-tagged, barcoded, or computer vision identified objects. However we are extending our API to include a broader range of tangible platforms and technologies, such as acoustic-based object tracking media tables, tilting tabletops, spinning screens and more.

## 3. A Unified Toolkit for Tangible Platforms

The Synlab API is rooted in the creation of an API for the TViews media table, a multi-user display platform that supports interaction through the identification and real-time tracking of a virtually unlimited set of tagged objects. Early tangible tabletop applications were built using computer vision technology, and demonstrated the value of such platforms in design fields like urban planning and holography (Underkoffler et al. 1999). The computer vision setup was cumbersome and unreliable, requiring carefully calibrated cameras to be placed above or beneath a projection surface. The TViews system moved the sensing into the interaction surface using an electromagnetic tag-based approach, which eliminated some of the unreliability resulting from line-of-sight interference but still required an overhead projected display. The second generation of TViews uses an acoustic sensing method that works through a transparent surface, allowing a display screen to be embedded within the table (Mazalek 2005).

*Figure 1.* Role-playing and pente games running on different implementations of the TViews table which use electromagnetic sensing (left) and acoustic ranging (right) to locate the tangible objects on the display.

While each of these tabletop object tracking technologies is very different from a hardware perspective, they all provide the same basic functionality to application developers. For this reason, it is important to provide an API that hides the details of the underlying technology and allows developers to create end-user applications independent from the particularities of the technical solution used. The initial API for the TViews table provided a typical event-based system for application development. Tangible objects placed on the table trigger system events (e.g. object added, updated or removed) that are received by listening applications.

Since its initial creation as a media table programming toolkit, we have extended the Synlab API to include additional technologies and platforms, including RFID object tracking, multi-touch surfaces, and manipulable displays such as a tilting table and spinning screen. The latter two were constructed by PhD student Hyun Jean Lee, and allow users to interact with media content through physical actions exerted on the display surface, e.g.

tilting or spinning. The Synlab API can also be extended to support custom events for specific devices or platforms. For instance, the tangible objects on the acoustic-based media table support add-on input/output devices such as buttons and LEDs, which make use of custom input events (e.g. button press) and bi-directional messaging from applications (e.g. commands to turn on an LED). Figure 2 illustrates how applications interface with underlying tangible platforms via the Synlab API.

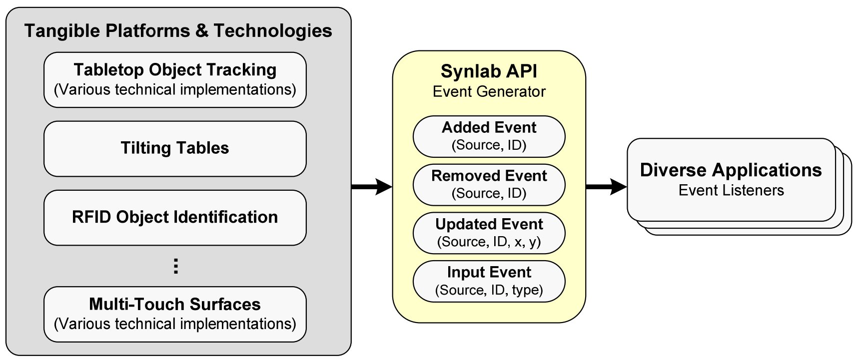


*Figure 2.* The event-based Sylab API supports application development across a diverse range of tangible platforms and technologies.

## 4. Application Examples

In parallel with the development of the Synlab API, we have also been creating media applications. Several examples are mentioned briefly here. Additional information can be found at: http://synlab.gatech.edu.

For tangible media tables, we have been exploring media content management applications, including geographic media browsing, photo sorting and digital storytelling. Many of these applications can also run on multi-touch surfaces without requiring changes to the application code. We are also developing tabletop board games and a multi-player role-playing game that makes use of custom tangible interaction objects, such as game characters, action tools and dice. For the tilting table, we are developing geographic map and biological data browsers. We are also exploring tracking of everyday user interactions with RFID-tagged objects for visualization and simulation of user activities in online social spaces.

In the future we plan to continue developing applications and extending the Synlab API to incorporate additional platforms and technologies.

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## FORM GENERATION

*The value of physical objects in digital design*

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**Abstract.** As physical objects continue to be used by product designers and architects, despite the ubiquity of sophisticated digital alternatives, perhaps it is time to re-assess their function in the design process and how physical and virtual design practice may be better integrated in the future.

### 1. Introduction

Despite the availability of sophisticated and flexible digital alternatives, physical processes such as sketching are still preferred in architecture and product design for generating form in the early phase of the design process (Stappers and Hennessey 1999). Although many digital tools for representing and manipulating form, such as computer aided design (CAD) and rapid prototyping (RP), have been incorporated into contemporary design practice, their application has been confined to developing rather than generating form (Broek, Sleijffers and Horvath 2000). While the inherent ambiguity of sketching may afford the generation of unforeseen possibilities through emergence, this same ambiguity inevitably means that sketches lack rigour in their description of form. Conversely, while digital representations are able to supply this rigour, they in turn require a degree of pre-structuring (Stiny 2006) that is felt to conflict with the unstructured nature of early phase design activities.

For many designers then, digital design is a hybrid of physical and virtual processes; sketching, in combination with hand-modelling, is used to capture and assess ideas, while CAD and RP are employed to develop them.

Aside from the need to pre-structure designs when using digital representations, digital tools are also criticised on the grounds that they place a perceptual distance between designers and their ideas. Much research effort has gone into devising technological means to ameliorate this perceived defect, often by citing more intuitive interfaces or by attempts to make virtual designs tangible through haptic solutions. So far none of these solutions have been accepted in design practice on the same scale as CAD.

The appeal to intuition is not as convincing as it might at first seem, and what is regarded as an intuitive interface by designers who were trained in pre-digital practices may be unnecessarily limiting to those who follow. When the car was invented it was initially known as the horseless carriage (viewing the new technology through the paradigm of the old), if the interface design of modern cars had followed the allegedly intuitive path they would have been equipped with reins, a whip and a simulated view of the rear end of a horse rather than a steering-wheel. The argument for haptics seems equally flawed. Designers often realise form by carving and sanding a block of foam, whereas an often cited haptic solution (the Sensable device) simulates sculpting clay with a stylus (Sener, Wormald and Campbell 2002). The application of force feed-back in many haptic solutions is also distinctly punctual (used here in the sense of acting at a point). Tactile assessment of a design is made by palpation instead: using the whole of the hand in intimate contact with the surface of a form, not by prodding it with a stylus.

So, as CAD has become acculturated (Jabi 2004) amongst newer designers and physical, craft based processes are still being employed in digital design, it seems entirely possible that a re-assessment of how both hand and machine-made physical representations are used alongside virtual representations, could result in a methodology that would integrate physical models more effectively into the early phase of the design process.

## 2. Sketch Prototyping

At The Open University we are beginning to look at a possible methodology which would combine the informality and speed of sketching with the tactile and visual qualities of physical models. We have typified this, at the moment hypothetical process, as sketch-prototyping. For sketch-prototyping to be usefully integrated with digital representations in the early phase of design it would, in addition to being as informal and arbitrary in use as a traditional sketchbook, also require:

- No pre-structuring

- Free flow of information from physical to virtual and virtual to physical

- Low cost and / or ubiquitous equipment

- Speed rather than accuracy, tolerance of ambiguity

If this were achieved, sketch prototyping could be used to bridge the transition from the unstructured nature of sketches to the more structured nature of digital representations of form. It would also enable the palpable assessment of digital designs earlier in the design process with down-stream benefits for both assessment and development decisions. Furthermore, sketch prototypes, as physical manifestations of digital designs, can be thought of as digital representations in themselves. If, in modifying a physical object by hand, those modifications were reflected in the virtual representation, sketch prototypes could be seen as a form of digital interface - working on a physical object would then be synonymous with editing a digital file.

It is also possible that the inherent inaccuracy of hand-mediated sketch-prototyping could afford a level of ambiguity (and emergence) that is felt to be missing from the more structured approach of on-screen digital design.

## 3. Outline of the enquiry

Initial work on this enquiry focuses on establishing the kind, quality and quantity of information that is actually useful to designers when generating form, when moving digital information between physical and virtual representations. This may include a study of cognition in vision, and an analysis of how sketching, modelling and CAD have functioned in the design process to date. The questions raised by this enquiry centre around:

- What are the differences in function between the sketch and the model? When is one more appropriate than the other? How does/should information flow between them?

- How accurate does this information need to be? Is an informal photogrammetric, digital modelling based approach more useful than laser-scanning?

- What level of abstraction / ambiguity would aid form synthesis when mediating between physical and virtual representations of digital designs?

## 4. Summary

Adopting a hand mediated approach to digital design might encourage traditional designer's 'ownership' of digital representations (working with the digital is often perceived by traditional designers as something that is given over to technicians). In addition, although newer designers are accustomed to working with on-screen digital representations they may be losing valuable physical form manipulation skills. It is possible that re-integrating useful aspects of older form manipulation processes with newer, flexible digital practices may be to the benefit of both.

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# INTEGRATION OF TANGIBLE INTERACTION AND RAPID CAD MODELING IN 3D FORM DESIGN

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**Abstract.** This paper presents a new form design method for tangible interaction and rapid geometric modeling. A design platform has been discussed to support iterative and concurrent development of ideas, tangible physical modeling and interaction, and rapid transfer of the physical models to CAD models. Constructing (or updating) a CAD model from a working physical model plays a key role in rapid product development processes.

## 1. Introduction

In the early product form design stage, designers are concerned with testing and sharing design concepts, sculptable soft-models with clay, wax, gypsum, polyurethane (PU) forms and so forth are used in a similar way to 2D sketches to quickly communicate, evaluate and record ideas. By using soft prototypes made from easily carved materials they can develop form design in 3D very intuitively because physical models and tangible interaction are available. At this stage, making aesthetically pleasing proportions and combinations of various design forms is very important, rather than accurate geometry.

Note that the design process is iterative and incremental and designers often discuss and present their ideas during the process. Based on a full range of physical feedback including tangible interaction, designers can develop physical models by sculpting but the process is enhanced by the use of its corresponding CAD model. For example, the CAD model is required for photo-realistic reflection rendering with material properties and lighting environment in order to evaluate the concept. The CAD model is also needed as a backup model because physical modelling processes are not good at the undo operation. When designers decide to go back several steps, it is difficult to restore a previous model by the opposite physical operations of adding or removing materials. If a backup model is available, another soft-model can be re-produced by Rapid

Prototyping. On the other hand, the backup model can serve as a preserved master model to support a concurrent modelling process. That means that multiple designers can try different form developments simultaneously from the same starting model. The CAD model can be easily utilised as a quick means of communicating temporary (working) form designs with geographically distributed colleagues. Thus, the use of updating CAD models can not only save lead-to-market time, but also provide more freedom for the design process. Therefore, form design activities need a platform to support iterative and concurrent development of ideas, tangible physical modelling and interaction, and rapid transfer of the physical models to CAD models. Constructing (or updating) a CAD model from a working physical model plays a key role in rapid product development processes.

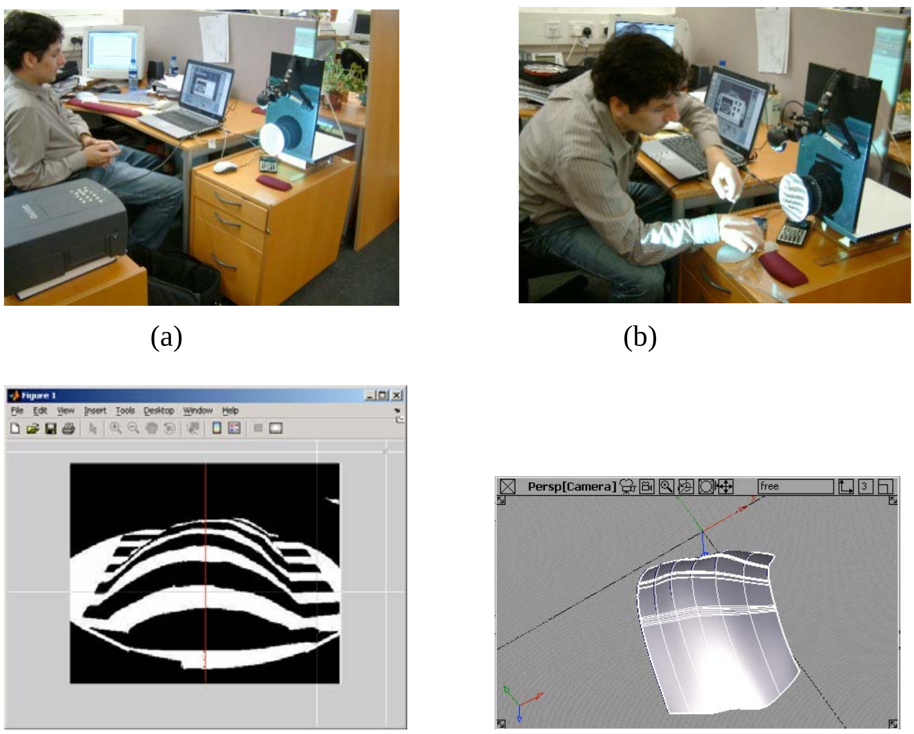
## 2. Related Works

Reverse Engineering techniques [VMC97] have been considered effectively as one-off operations for generating models or geometry from scanned 3D data clouds. However, these techniques have a variety of limitations when applied to form design. Surface modelling using an enormous amount of scanned point data (104 - 108 points) is time-consuming and requires expert modelling skills [LH00]. This step is usually not automated and involves frequent manual interaction with the user even with a well-developed surface modelling software packages. In addition, any small perturbations may need a re-scanning of whole object again because little work has been done on reverse engineering to provide model/surface local updating with measured points. This will not only require more time for modelling, such as 1-2 days, but also change models for unchanged regions [CGM04]. This is undesirable. Some research in the automotive industry shows the advantages of working with profiles especially when free-form surfaces are involved and techniques for 3D reconstruction from profiles lines are being investigated.

## 3. New design Method

In order to support incremental and rapid form design process, we propose a new hybrid modeling environment to directly integrate physical (soft-model) and virtual (CAD) modelling processes. Instead of using traditional RE techniques such as using 3D cloud data, a novel single image-based CAD modeling approach is proposed utilizing profile lines to create an initial CAD model corresponding to a physical model and then updating it locally and easily. Our initial work [PWQ03a] [PWQ03b] has indicated that it is possible to modify a CAD model easily from a sculpted 3D model having profile lines on the surface. This environment can support both surface design and evaluation. The proposed techniques being less time consuming, make communication richer, impose less computational burden and are easier to use.

In principle, the proposed surface development and modeling is based on a single image of a local region from a Digital camera (design object can be put on a rotary platform). After changing the physical model, a single image of the modified region can be taken. Camera internal parameters and external setting-up parameters will be transferred to construct/update the corresponding CAD model. By matching profiles on CAD models and their corresponding image with physical models, the system will automatically update CAD models in minutes. In this way, the modeling process is incremental as form design develops. We propose an optical projection of profile lines onto the surface according to the specific model geometry (See Fig 1).




(a) (b)

(c ) (d)

*Figure 1.* Design process

These profile lines can be designed with varied grid lines and patterns to reflect the size of a clay model and its corresponding surface features. The profile lines were projected via a LCD projector (Fig. 1a). While the designer developed a 3D physical model with soft material, the profile lines on the 3D surface keep changing consistently (Fig. 1b). During this modeling process, at any time, a CAD model can be created corresponding to the working physical model. For example, when the designer took a photo through a Web camera (see Fig. 1c), the profile lines on the image were used to measure the changes in 3D. As a result, a 3D CAD surface model was created (Fig. 1d). Afterwards, any small perturbation on the physical model would result in the changes of only some of the profile lines in a small region, locally updating the earlier CAD surface model would be much easier and appropriate for the application.

## 4. Discussion

This paper demonstrated a new method for supporting tangible physical model development and rapid CAD surface modeling. Some research issues are still under investigation, for example, how to construct or update 3D CAD surface from captured images, what is the best design interface for tangible interaction and surface modeling.

## Acknowledgements

The authors would like to thank Dr S. Lim for his discussion on this research in the CAD research group, Brunel University.

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# WIZARDRY AND THE TANGIBLE USER INTERFACE

*Using Wizard of Oz studies for Tangible Environments*

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**Abstract.** This paper provides a summary of the current research on the use of Wizard of Oz studies with tangible user interfaces. It then describes a simple study that introduced a new use for wizarding with children in the design of tangible interfaces. Three findings are presented and ideas for extending the work are presented.

## 1. Introduction

One of the major challenges for the design of tangible user interfaces is the trade off between the investment of time needed to create environments and the possibility for that environment to be unsuitable for use. To assist in rapid design, several methods are used including the design and evaluation of concepts and the use of low tech prototypes (Lin and Khooshabeh 2003). One method that is often used is the use of a Wizard of Oz Study.

### 1.1 WIZARD OF OZ STUDIES

In a Wizard of Oz study, some or all of the interactivity that would normally be controlled by computer technology is ‘mimicked’ or ‘wizarded’. This allows the designer to ‘see how’ the design works with target users without having to have all the functionality in place. Originally developed to deal with the complexities of recognition based systems (Dahlback, Jonsson and Ahrenberg 1993), the WoZ method is also well suited to tangible and ubiquitous technologies. In a traditional Wizard of Oz set up (shown in Figure 1), there is a human wizard who manipulates the interface independently of the subject of the experiment. The method was first used by (Gould, Conti and Hovanyecz 1983), although it was only named Wizard of Oz when it was described by (Kelley 1984).

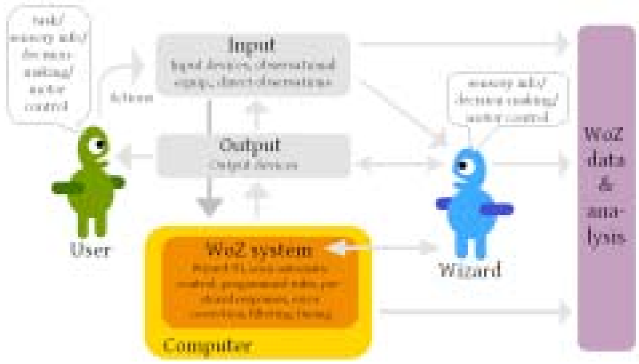


*Figure 1. Wizard of Oz setup ((Höysniemi and Read 2005)*

1.2 USES OF WIZARD OF OZ STUDIES

The first Wizard of Oz studies date back to the 1980's (Gould, Conti et al. 1983), (Kelley 1984). Until recently, the Wizard of Oz method has been mainly used to design and collect language corpora in speech-based systems (Dahlback, Jonsson et al. 1993) and user behaviour in multimodal user interfaces (Coutaz, Salber and Balbo 1993).

More recently, there has been a tremendous growth in the use of WoZ in various fields of Interaction Design including perceptual user interfaces (Landay, Hong, Klemmer, Lin and Newman 2002), ubiquitous computing (Lin and Khooshabeh 2003), virtual reality (Robertson and Wiemar-Hastings 2002), help systems (Maulsby, Greenberg and Mander 1993), and games (Höysniemi, Hämäläinen and Turkki 2004). In addition, advanced WoZ systems are being implemented (Pettersson and Siponen 2002) and new user groups, especially children (Robertson and Wiemar-Hastings 2002), have taken part in WoZ experiments.

Since 2000, there have been an increasing number of reported studies on using the method with tangible user interfaces. Two particular studies are those by (Andersson, Höök, Mourão, Paiva and Costa 2002) that used a Wizard of Oz method to gather the gestures needed to operate the Sen Toy, and by (Montemayor, Druin, Farber, Sims, Churaman and D'Amour 2002) which used a wizard to turn lights on and off in an augmented physical space.

As long ago as 1987, Tom Landauer applauded Wizard of Oz as a highlight in HCI but recommended that studies needed to be carried out to further investigate the usefulness of the method (Landauer 1987) Recently, studies by (Höysniemi, Hämäläinen et al. 2004) and (Read, Mazzone and Höysniemi 2005) have investigated the use of Wizard of Oz with children.

## 2. Using Wizards in Design of TUIs

The present study was designed to investigate a new use for the Wizard of Oz method. The study took part in the context of a museum with physical objects being attributed with behaviours.

The study involved six children; the first three children (the wizards) were initially introduced to a functional tangible environment. This environment had RFID technologies and wireless sensors that were used to augment a helmet and two swords. The three children were able to play with these pieces and investigate the effects, When a child put the helmet on, the computer played battle sounds from the historical era, when one sword was picked up, the adjoining smart board displayed battle scenes and gave the impression that the battle was coming towards the child, and the other sword being picked up caused a light in the room to flash on and off. If the two swords touched one another, as in battle, blood curdling sounds were heard.

The children played with the artifacts and were then shown how the 'system' was programmed to react to the play. The same children were then introduced to a different set of historical artefacts; these comprised a WW2 gas mask, a Davy lamp, an old radio and a pack of cards. The children were then tasked to decide what should happen when these devices were played with and, with the help of the researcher; they constructed a Wizard of Oz environment that would mimic the interactions. This required the children to create the reaction effects and map out on a grid the actions and reactions so they could act as wizards. Whilst the children were designing their environment, two adults also designed their own version of the play space.

Once the wizards were ready, three different children came into the room and played with the WW2 artefacts in the wizarded environment (with the first three children acting as wizards). The session was videotaped and excerpts will be played at the workshop. Following the videotaping, the children and the adults sat together to watch the video tape and comment on the designs and the experience.

The use of wizarding in the design threw up several interesting points. Firstly, there was a lot of evidence to suggest that the children doing the wizarding had a better idea than adults about what the children might do with the artefacts. This suggests that children should be involved in the design of tangible interactions. Secondly, the children wanted to wizard much more than was possible, and were disappointed to only be able to wizard very simple reactions. This was backed up by the children that used the second wizard prototype who quickly lost interest in the environment. It seems that for a wizarded, or real, tangible environment to be evaluated, a lot of functionality needs to at least appear to be happening. The third major finding was that the addition of a random feature in the wizard environment greatly improved the experience. The children designed the environment so that on touching the radio, random sound files from the era played, and this was a great success.

The researcher intends to do a much larger study along similar lies with four different teams of children doing the wizarding and with four teams of participants. This may be completed by the time of the workshop.

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