Designing a shape-changing interface: A customizable interactive tree

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ABSTRACT
This paper details the design process behind the creation of a shape-changing interface as part of a semester project in Interaction Design. Our self-chosen theme of the semester was "making the invisible visible". The paper describes a physical, interactive design and its capabilities. The original goal of the project was to make users aware of their indoor climate by sensing CO2 levels and changing the design accordingly. Because of this original goal, the design is based upon the metaphor of a tree shedding its leaves. As the CO2 levels rise, the tree sheds its leaves.

Though the end-result sprung from a guiding case of trying to make users aware of their indoor climate, the project evolved into becoming a possible platform for other designers to build upon through customization of the interface. This paper serves as inspiration and a call to other designers to embrace shape-change in their design work, as well as exploring ambiguity in the interpretation of the design.

Author Keywords
Interaction design; Shape-changing Interfaces; HCI; Ambiguous design; Organic interface; Design

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces, Output Devices and Interaction styles.

INTRODUCTION
The goal of this project was to explore and experiment with physical form, capabilities, materials and aesthetics in order to create a physical interactive design whose aim is to "make the invisible visible". One of the main challenges of HCI is the pursuit to align the user's and the designer's mental models of how a design is supposed to function. With the detailing of our process, our hope is that other designers will explore shape-change as a means to create meaningful and interesting interactions for users to experience by staying open to interpretation and finding new purposes with the interface over time. The domains in which we sought to found our design in are shape-changing interfaces and ambiguous design, both of which we will outline briefly.

Shape-changing interfaces
Shape-changing interfaces are physical interfaces which change shape, according to Rasmussen et al [3]. Though mechanical systems have been around for hundreds of years, they are usually perceived as rigid and static. Shape-changing interfaces allow designers to create user interfaces which uses physical change in shape or form in order to communicate its purpose, which in turn allows for interesting, meaningful and hedonic interactions. The main functional purpose of applying shape change is to communicate information. This allows the information to be communicated in a physical, tangible way by changing the physical interface to convey said information in an expressive manner [2]. Exploring the field of shape-changing interfaces through interaction design is one way to illustrate how they can integrate into and benefit from different use contexts. By doing so, we may gain an understanding of how shape-changing interfaces can enter and improve people's lives in new and unexpected ways.

Ambiguous design
Interaction designers who develop systems in Human-Computer Interaction (HCI hereafter) often focus on developing systems which have a single, clear, and specific interpretation of what the systems are for, how the systems should be experienced and how they should be used. New domains from different fields such as arts, public environments, and new techniques in HCI are converging to suggest that multiple, competing interpretations can co-exist profitably. An ongoing key issue in HCI is interpretation, and a general agreement on how a system should be interpreted is that the system should only have a single, correct way to be interpreted and that designers should communicate that exact interpretation to the users of the system [4].

According to Sengers and Gaver it is often appropriate to convey a clear and specific interpretation to a system. However, they argue that it is not always a problem when designers and users have different interpretations of a system design. Even if an interpretation problem occurs, the solution might not be to accommodate a single

correct interpretation [4]. This inspired us to create a physical, interactive interface which embraces ambiguity in the interpretation of the design.

MAKING THE INVISIBLE VISIBLE

When thinking about what it means to make the invisible visible, we asked ourselves how to do so and what it might teach us. Why even bother trying to make the invisible visible? "The invisible" is a world around us which we cannot see but holds much information which influences our daily lives in profound ways, like the negative effects of a poor indoor climate. With our design, we sought to bridge the gap between the world we can see and the world we cannot see. We explored three different interaction styles as the foundation for our design to make the invisible visible to the user; having the interface act neutrally to the information it conveys; having it instruct the user to perform an action; provoking the user by way of adding/subtracting elements to the interface. We pursued the latter of the three and constructed a mechanism which allows for detachment of a paper disc, which serves as a geometric representation of a leaf, while using a central magnet to allow users to reattach leaves to the structure.

USING A TREE AS A BASIS FOR THE DESIGN

With the design of our interface, we aimed at creating an organic association [2] by basing the design on a tree, but a challenge in this regard is that users might not grasp this expressive association because the interface is too mechanical. Therefore, we sought to find a balance between aesthetics and technical functionality with our design. The partial aims for the physical, interactive design was to make something that opens, closes and detaches to create the illusion of a tree shedding its leaves. This was achieved through an extensive, iterative prototyping process.

PROTOTYPING

Our design process was characterized by a curious exploration in diverse directions trying to make prototypes of open, closing and detachment mechanisms working independently before combining them. Our starting point revolved around the idea of building a mechanism from the ground up [Figure 1 & 3], before trying to retrofit our ideas to an existing mechanism in the shape of cocktail umbrellas [Figure 2]. Our initial, physical prototyping and exploration into concepts of open, closing and detachment mechanisms led to the final mechanism, with which we returned to a completely self-constructed prototype. Winther and Vallgårda argue that given the design of shape-changing interfaces is still in its infancy, the initial form giving may be characterized as more exploratory investigations, whereas later stages of the process closer to an actual product will include more normative and defining decisions [5].

Figure 1. Early prototype made from felt and straw. The felt retracts when two strings are pulled.

Figure 2. Functional prototypes made from cocktail umbrellas with strings.

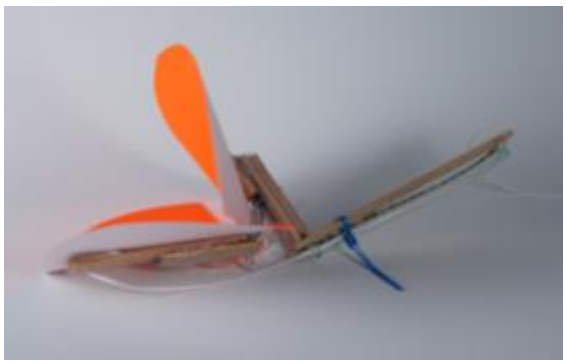

Figure 3. Early, functional prototype of an opening mechanism.

This is very much in line with our own experiences throughout this project. Much time was spent exploring which materials we could use and how we could put them together in a way in which we could feasibly use them. A testament to our creativity is the number of ways in which we have taken some kind of material and shaped it to our needs in spite of its intended use. For example, we used soda bottles to make plastic cones for attaching a mechanism to an actual tree rather than 3D modelling and printing our own first. We used cocktail umbrellas as possible flowers for our tree since they are already a de facto open/closing mechanism. This kind of exploration of everyday materials forced a creative process to take place throughout the entire project duration.

The base mechanism

After around 150 iterations of parts for an open/closing mechanism, we settled on a version [Figure 4] made from foam board and round wood. The entire unit somewhat resembles a slice of pineapple which folds over on itself. We discovered that the outer layer of the foam board was highly durable and would not tare after being stress tested for hundreds of uses so the upper surface is kept as one solid layer. Our design functionality goals were to make something which opens, closes and detaches. If we take a step back and evaluate our final mechanism, what is it really? It is two half-circles, one half of which folds over on the other when a string is pulled. If we look at our mechanism from that perspective, it would fall under the shape change type of orientation [2] because what the half-circle does is change its angle from one to another. One of the half-circles changes orientation to create the effect of the mechanism closing and therefore changing its shape. Through this type of change, we distort the original shape through changes in direction, while the original form is still clearly recognizable [Figure 6]. When paper leaves are attached to the tree's crown, the aesthetics resemble that of a real-life tree in size and volume [Figure 5].

INTERFACE CAPABILITIES

An Arduino Mega micro controller controls 25 servo motors on the tree. Each servo motor can be controlled very precisely in 180 steps across the 180-degree spectrum. The Arduino can be programmed to animate the tree in practically countless ways when sensing an input, like for example CO2. The interface has a total number of 125 mechanical bases grouped in clusters of five (a grouping as such is nicknamed a "bouquet" by the authors) with a servo motor each. It is possible to open and close five bases on each bouquet, which allows for many shape-change combinations. All 125 bases can for instance transform from an opened position to a closed position synchronously or individually one bouquet at a time. Another possible combination is that five bases can open and close asynchronously in a time-delayed manner across the crown of the tree, meaning that some of the bases transform in a slow movement while other bases transform in a fast clap-like movement.

INTERPRETING THE INTERFACE

We have designed and built an interface that we believe holds the possibility to be able to communicate the state of the indoor climate, but we have no perception of whether that is true, or how the user will interpret it, due to the lack of any kind of evaluation. Since our interface can change its shape and generate millions of different visual expressions, we image that it can possess a great many interpretations. Of those, it is highly improbable that there is a single, specific interpretation that is more correct than all the others.

Figure 4. The final base mechanism, which is replicated 125 times on the final tree.

Figure 5. The final interactive prototype in context, pictured with 125 paper leaves attached.

Figure 6. The final interactive prototype without leaves – the aesthetics have changed dramatically.

A general approach when evaluating and testing in HCI is to test against the designers intended interpretation of the system. When a system designed for multiple interpretation has to be evaluated, this can no longer be seen as a sufficient approach. It might seem straightforward to use reinterpretation as evaluation measurement, but this could lead to the conclusion that every system designed with multiple interpretation is a success, because almost every system can trigger interpretations unknown and be used in unintended ways. Sengers & Gaver argue therefore that "*designing systems to support a rich range of interpretations does not abdicate the designer from responsibility for the eventual success of the system*" [4]. Instead of the general evaluation principle in HCI, designers should create their own set of

evaluation principles that fit the goals of the system design. Since user evaluations were out of the scope of this project, we encourage others to explore evaluations of the design.

CONCLUSION

By constant explorative iteration in pursuit of a simple mechanism whose function reacts to different inputs, and thus creates different outputs depending on the specific use case, we have created a physical interactive design which serves multiple purposes. We have demonstrated one of these purposes by trying to make the invisible visible with the case of indoor climate, by provoking potential users to act based on the output of the interface. Additionally, we presented the capabilities of the interface, which may inspire other designers to use our physical interactive design as a toolkit for further design exploration.

Should any students choose to build upon the work presented in this paper, our hope is that would lead to the discovery of many interesting interactions with and interpretations of the interface, finding new purposes for the design. Though our focus was centered on the concrete design goals of making something open, close and detach, we discovered that the transformation between endpoints in the transition of the basic mechanism is what changes a mechanical system to an animated shape-changing interface.

As Interaction Design students ourselves, we encourage other students to find inspiration in our design and process, and explore ambiguous design and shape-changing interfaces themselves in order to aide users in their everyday lives.

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A short video demonstrating the tree running a sequence can be found by following the link:

https://youtu.be/f7X10wbnH4M

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