Transformable Tangible User Interfaces

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ABSTRACT
This paper aims to give an overview of the Transformable Tangible User Interfaces by shedding some light on the motivation behind their creation, the approach that is commonly used in order to create them, the issues faced during their creation and three possible ways in which the users can interact with them. This overview is by no means an exhaustive one and is aimed to be for an audience who are familiar with tangibles.

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Transformable; interface; tangible; active tangible; passive tangible; shape changing interface.

ACM Classification Keywords
Design.

General Terms
Human Factors; design; theory.

INTRODUCTION
Tangible User Interfaces (TUIs) are interfaces that "*build upon our dexterity by embodying digital information in physical space*" [4]. The most significant component of these interfaces are tangibles which are "*manipulable physical elements that serve as representations and controls for digital information*" [11].

Pederson et. al. explain that initially, passive(static) tangibles were used due to the advantage that they offered over Graphical User Interfaces (GUIs) of providing a physical handle to the digital world [8]. However, it was quickly realized that while using such tangibles, there was always a chance of an inconsistency occurring between the digital and the physical model due to their uni-directional nature which allowed them to change the digital model, but not vice versa. Active tangibles, on the other hand are bi-directional tangibles which look to resolve the inconsistencies of passive tangibles by ensuring that if the digital model is altered then those changes are reflected in the physical world, and vice versa.

However, the GUIs still held an advantage over active tangibles because while each pixel on a GUI display is fully configurable, the tangibles are restrained by the physical limits of the materials being used to manufacture them. This led to the experts of the Human Computer Interaction (HCI) field coming up with the concept of a "*generation of materials that can change form and appearance dynamically, so that they are as reconfigurable as pixels on a screen*" [4]. Materials like these are envisioned to be used in creating interfaces which will allow the users to use their natural ability to interact with them as they would with any other everyday object. Interfaces that will have the capability of adapting to the user and not the other way around. Interfaces the likes of which we have never seen before: Transformable Tangible User Interfaces.

In this paper, I wish to give a brief overview of the Transformable TUIs (Transformables) research field. Rather than being exhaustive or trying to provide the solution for a particular problem, this overview will focus on a subset of the Transformables out there in order to give the reader an idea of what the current status of the research is and where it's headed.

PROBLEMS AND ISSUES

While in concept the idea of having a transformable tangible interface which will present to the users a physical manifestation of all the digital information in the best way possible and allow them to manipulate it by changing the form (shape) of the interface sounds intuitive, such an interface does not exist at this point in time.

The biggest hurdle facing the developers of Transformables is a lack of inherently transformable materials. While the developers can still create structures that are approximations of such materials using the currently available materials like shape memory alloys, piezoelectric ceramics and thermoplastic [3], the lack of materials tailor made for such purposes results in most products being clumsy, unaesthetic, not very robust and not much good outside of a lab.

While this problem is being dealt with by the material sciences, nanotechnology, mechatronics and computer science experts, it is fair to say that the progress has been slow [4].

While the field of Transformables is still relatively new, people have realized their potential and as a result a lot of attempts are being made to create approximations of them. However a problem that these “approximations” give rise to is that while there are a lot of them out there, very few of them actually consist of transformations which are intuitive or well connected for the desired response. This results in them suffering from a problem commonly known as the “Gulf of Execution”. This problem describes how a user might intuitively think that they have to execute a small set of actions in order to achieve their goals, in reality the set actions required to fulfill that goal is much bigger and complex [5].

In addition to all that, the fact that the field of Transformables is very recent and unexplored means that there is a complete lack of any kinds of standards or guidelines which results in there being very little consistency between any two interfaces. For example, while on almost all GUIs, a mouse pointer is meant to be moved around and a button is meant to be clicked, on a transformable interface the user might need to use their fingers as pointers or maybe use gestures to navigate around.

APPROACH FOR DESIGNING TRANSFORMABLE TUIS

Prior to diving in to the world of Transformables, it is essential to know the approach used to design such interfaces. Radical Atoms, the ideal Transformable described by Ishii et. al. does not exist yet [4]. However, using electrical components and some of the existing materials mentioned earlier, some of the properties of the ideal Transformable can be emulated. Using these properties, development of interaction techniques which will slot right into the Transformables equation once the ideal materials are available, can begin.

The approach detailed above, is described as the Vision Driven Approach by Ishii et. al. as it aims to work on a part of a currently unsolvable problem (the creation of a truly transformable interface) by proposing interaction techniques that could be used if we had truly transformable materials available [4].

This means that the transformable interface designers do not focus so much on the implementation of the transformable as they do on what could be done if a material with the desired properties was available.

WAYS OF INTERACTION

According to Coelho et. al. there are three distinct ways in which a transformable interface can be used [3]. This list of ways is not exhaustive but covers the most obvious ways in which a transformable interface can be beneficial and will give examples to show how some of the current Transformables out there have highlighted these ways. We will refer to the different forms or shapes of a transformable as states from now on.

States to Represent Function

A user can tell a lot about an object just from its shape. If an object is protruding from a remote control device, then intuitively we know it is a button and is meant to be pressed. If that button is in the shape of a triangle, then yet again intuitively we know that it represents the function “Play”. In this way Transformables offer a very efficient way of overcoming the problem that has plagued TUIs since the beginning: the problem of a simple intuitive interface being unable to scale to cover more complex functions [7].

However, it is essential to note that while Transformables give us the freedom to make the interface more intuitive, without carefully following standards or guidelines, it is entirely possible to create something which might seem very intuitive for the developer but wildly un-intuitive for the users.

SpeakCup is an excellent example of leveraging the properties of Transformables as the shape of the silicone body results in the object either recording sounds or replaying the previously recorded sounds [14]. This is very intuitive as the top of the surface, where seven holes are located, when turned in to a cup acts as a metaphor for the device “absorbing” sound and when the shape is changed so that the holes end up on the outside, it “releases” the sound that was absorbed previously.

Haptic Chameleon uses its shape transformation ability in a similar way as a circular dial corresponds to the ability to go through a video frame by frame, whereas turning the dial into square results in the function of that dial turning in that of going through the video scene by scene [6].

Origami Lights, while not seeming very useful other than as an art installation has similar affordances as changing the form of the tessellated matrix results in varying types of lighting patterns [2].

As it can be seen from the above examples, in theory, given the ideal transformable material, it could be possible to create a device that has just one button but can still allow the user to execute multiple functions. While that might affect the speed of the tasks being done, in instances where space needs to be preserved, something like that could be the best option available.

States to Represent Changing Data

A change in the shape (or texture) of the interface can also be used to convey to the user changes in the digital data of the system.

The Khronos Projector breaks the link between space and time in videos and allows the user to rewind or forward any part of the video being projected by physically manipulating the part of the screen it is being projected on [1]. In this case, the change in the shape of a portion of the screen results in the (data) image at that portion being rewound or forwarded.

Lumen is another example where the interface can be transformed in order to output changing data [9]. The user simply rests their hand on Lumen, an array of movable light guides that move in a 2 dimensional space in order to create shapes, images etc. While the light guides used in Lumen are relatively big in size, it is not that much of a farfetched idea to imagine the same concept being used on a much smaller scale (with smaller light guides) to make the "display" much more fine grained and thus much more accurate.

Programmable blob is a Transformable of a similar vein. In this case however, the user does not physically touch the blob of magnetic fluid floating on a special surface with electromagnets underneath it which allow the users to shape the blob into whatever they wish [12]. When coupled with a computer with a CAD program running on it, the blob can be recreated in the computer as a digital model. While at this stage, the interaction is uni-directional in that if the blob is manipulated, the digital model changes but the reverse isn't true. It would not require too much effort to make it bi-directional and allow the blob to convey the change in the digital model by changing its own shape in return.

States to Constrain User Actions

As mentioned earlier, the ideal transformable would be a substance that is as configurable as the pixels on a normal GUI. The reason why that is such a desirable property is due to the fact that it gets over one of the most often cited limitations of any tangible interface: physical limitations. However, while the inability to manipulate an object in any way we want is normally a disadvantage, in some cases it can be used to provide the users force feedback and help them learn the system and its affordances and limitations.

Topobo and GIFFI are two such construction toolkits that use motorized components, kinetic memory and the ability to physically program components in order to teach kids basics of real word physics such as balance, coordination and relative motion [10, 13]. In addition to all that though, the physicality of the components being used also acts as a natural barrier against any attempts to create physics defying structures, which would have been allowed on a normal GUI(unless there were specific checks in place against it). This ensures that users learn about the limitations in real world and are made to think creatively in order to get around them.

This way of using Transformables can also let the user know the result of their actions by giving force feedback and not allowing the user to do something that shouldn't be done. For example, if a user is trying to increase the volume on a system by turning a dial, increasing the resistance of the dial as it moves towards the maximum volume can let the user know that they are reaching the maximum without needing them to look at the dial.

CONCLUSION

From GUIs to passive tangibles to active tangibles, Transformables are the next step up. True Transformables will be bi-directional interfaces that will allow users to manipulate their corresponding digital model by letting them manipulate the physical interface itself. Any changes made directly to the digital model will also result in corresponding changes to the transformable interface. However, since a material which can allow users to change its properties whichever way they wish to, does not exist just yet, therefore, using the vision driven design approach, we ignore the part of the problem that we cannot solve yet, and work on a different part in order to come up with interaction techniques for interfaces made up of the ideal transformable material.

However, problems facing us in the development of such interfaces are the lack of appropriate materials, gulf of execution and a lack of widely accepted standards or guidelines.

In order to make up for the lack of the perfect material, structures made from electrical components and currently available materials(SMAs, piezoelectric ceramics etc.) are used as approximations of the ideal transformable material and allow developers to use them as placeholder and design interaction techniques that would be used if the ideal material was available.

The three ways in which we can use Transformables for interaction are using them to represent different functions, using them to represent changing data and finally using them to limit the user's actions or and help them learn about the system using force feedback.

FUTURE WORK

The field of Transformables is still a relatively new one and therefore there are a lot of areas that need to be worked on. While creation of some standards might sound like it will hinder the creativity of upcoming interfaces, it can also result in making the interfaces more intuitive and thus more user friendly. Experimentation with new materials should also be kept ongoing in order to assert the most desirable properties of the ideal transformable.

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