The Values of Tangible User Interfaces: How to discover, assess and evaluate them?

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Since the introduction of Tangible User Interfaces, in the beginning of the 90s, a generation grew up interacting with computers. At the same time the context of computing changed dramatically: from a device used almost exclusively by specialists, it evolved to a general device that plays a dominant role in our societies. But where does this leave TUI? In many respects, the idea of tangibility plays a marginal role in Human Computer Interaction. It makes sense to re-evaluate the intrinsic values of TUI design. This paper proposes to research the appropriate metrics to do so.

Keywords: Tangible User Interface, comparative research, metrics, physical representation, metaphor, embodiment, token. .

1. INTRODUCTION

In their seminal CHI paper ‘Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms’ of 1997, the authors, Hiroshi Ishii and Brygg Ullmer, inspired by the collection of the historic scientific instruments at Harvard University conclude that: “users of the past must have developed rich languages and cultures that valued real haptic interaction with real physical objects”. (Ishii, Ullmer, 1997).

Figure1. Historic Scientific Instruments at Harvard University (Department of the History of Science website 2017)

They proposed a relatively new view on Interface design with emphasis on this real haptic interaction, the Tangible Interface (TUI). This implicated that the dominant interface system at that time, based on mouse, keyboard and screen input, was seen as lacking that kind of 'rich languages and cultures'. 'Tangible Bits' showed a way out, a direction for the emerging field of interface design, a way that promised radical change. In their vision, interacting with computers should cater more to the 'human' skill to manipulate objects manually, and thus would be more intuitive, effective and fun.

In a variety of different institutes and in a broad range of domains, TUI were prototyped and researched. Tangibility was a keyword and seen as one of the possible innovations for Human Computer Interaction.

In the last two decades, the field and context have radically changed. We have to bear in mind that at that moment in time, in 1997, desktop computers were generally used but the Internet, introduced in the first half of the 90s, was only available to hardly 2 percent of the world population.

(see: www.internetlivestats.com/internet-users/)

Another innovation that changed perspective on HCI since 1997 was the introduction of the touchscreen. This proved to be a versatile interface concept that provided many applications with an, easy to use, intuitive, input system. The smartphone became, in less than 10 years, a general device that can be used for a variety of functions and has penetrated the market in an impressive way, now owned by a large part (30%) of the world population (see www.statista.com/statistics/330695/number- of-smartphone-users-worldwide/)

In this paper we ponder the values of TUI in this rapidly changing context. We want to determine what qualities are likely to be of relevance in what situations and in what domains they are likely to make interaction more effective and intuitive. To do

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so, we posit that there is a need to discover, assess and evaluate the values that TUI have.

To do so we propose tests that will be quantitative as well as qualitative: performance and experience are equally valuable to our research. The outcome will hopefully lead to an increased awareness of the values of TUI. More practically, it will point at realms and technologies that are likely to benefit from a tangible interaction approach. But first we have to determine what TUI are.

2. HOW DO WE DEFINE TUI?

Ishii and Ullmer (Ishii, Ullmer, 1997) set out to bridge the gap between the technology, the bits, and the world around us, the reality to which the bits referred: “Tangible Bits allows users to ‘grasp & manipulate’ bits in the centre of users’ attention by coupling the bits with everyday physical objects and architectural surfaces.” (Ishii, Ullmer 1997). Later, they narrowed down their definition stating that, among other restrictions, in TUI there is no distinction between the input and the output device.

However, within the scope of our research, this narrower description is problematic. Over the years, the term Tangible User Interface has been used for a wide variety of systems and there have been many developments and new prototypes, which lead to confusion. It can be argued that smartphones are tangible and provide feedback. So are smartphones tangible interfaces?

Fishkin (2004) starts from the paradigm Ishii and Ullmer introduced: "a user uses their hands to manipulate some physical object(s) via physical gestures; a computer system detects this, alters its state, and gives feedback accordingly."

Fishkin approaches TUI as a spectrum, rather than what he calls a 'binary' description that tells us whether or not an interface can be seen as a 'real' TUI. He proposes a taxonomy for TUI based on their embodiment and metaphorical quality. For our research, we adopt this taxonomy. We see TUI as a variety of systems where graspability, the possibility to manipulate them with our hands, is one of the vital elements. We classify TUI by their metaphorical quality or the way they embody certain interactions. Our aim is to analyse the different properties of TUI. It is of less importance whether or not the TUI in our research is a 'real' tangible Interface according to stringent definitions.

3. TUI IN COMPARATIVE STUDIES

The 'real haptic interaction' Ishii and Ullmer referred to has inspired the research and production of a number of tangible interfaces like the urban planning tool Urp, that added a number of properties like the angle of the sun and how airflows (wind) can affect an urban plan (Underkoffer, Ishii, 1999). SandScape, a tool for landscape architects, allowing real-time manipulation of objects and sand combined with video projections, works with more or less the same technology.(Girot, 2010).

TUI were particularly successful in music interfacing, with for instance Reactables, a collaborative musical instrument based on the manipulation of objects on a table (Kaltenbrunner, 2006). Another promising domain for TUI is education, where the intrinsic value of TUI might be preferable to Graphical User Interfaces (Revelle, 2005).

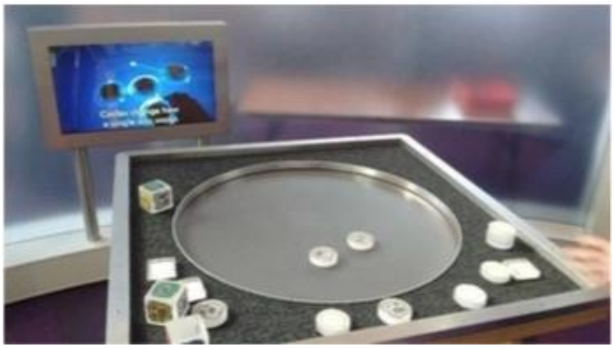

Figure 2. Reactabes at 2017 Newcaslte Maker Faire (Nemeth)

Literature on the evaluation of TUI is varied: some assume that a TUI has advantages over GUI (Fitzmaurice and Buxton, 1997; Fitzmaurice et al., 1995; Zuckerman et al., 2005), others state the opposite (e.g. Horn et al., 2009; Marshall et al., 2010). We found no clearly defined and widely accepted metrics to assess the values of a TUI. TUI have not been exhaustively compared to other interfaces, empirically tested. A relatively recent comparative study (Zuckerman et al., 2013), where a TUI is tested in the same circumstances as an equivalent GUI, suggests that users prefer the TUI version. Remarkable in this study was that, according to a majority of respondents, the usability of tangible interfaces was regarded as inferior to the GUI. It was apparently the subjective experience of the TUI, that motivated them to prefer it over the GUI.

From our background investigation we have concluded that user performance is often separated from TUI usability: users might prefer something that is less usable because there are other properties they value over the quick performance of a certain task. It might just be that using a TUI is more fun, appeals more to the intrinsic human values of the user.

Also, if there is a conflict between measured user performance and users’ stated preference, it seems there is a problem with the metrics or the experiment itself. One of the issues with most of the experiment settings, as we conclude from literature, is that the experiment settings are not purposeful, many tests would benefit from a more practical and clear task description. We believe that a careful assessment of performance and usability can give added value to the definition of the metrics of research.

Another issue with a number of testing situations is that tests rely either on quantitative research, measurable results, or on qualitative research, the result of questionnaires asking test subjects to respond about their experiences. It might make sense, in the domain of interface design, to test both: to combine the result of observations, measuring accuracy and speed of a performed task with questionnaires about the experience of test subjects so representation and ease of use can be assessed.

To measure what a worthwhile interaction is, we need to establish metrics, define standards of our research. Our starting approach, would be to look at intuitiveness, ease of use and effectiveness (see Tullis, Albert, 2010).

3.1 User Groups

A substantial part of TUI research is centered around special user groups. It makes sense to make a (re)assessment of these user groups. What user groups are likely to benefit from TUI? For what users a specially designed TUI is just not appropriate?

There is another complication we would like to address: users have been changing over time. Users of 2017 have different skills and a different context than users in 1997. This means the attitude towards for instance tangibility might have changed over time. Might the more 'natural' properties of an interaction have appealed to a user with no prior interface experience, for a user in 2017, having used a variety of interface systems, this might be altogether different. For our research we will mainly focus on a contemporary user, with sufficient experience with interfaces.

3.2 Physical Representation

Part of this research is aimed at a defining property of a TUI: the physical representation and the advantages for the user. This property of TUI has a history well beyond interface design. Tokens, embodied objects that symbolize a certain task or action have been used for ages. The (mostly tangible or visual) properties of an object that assures the user of the status of a system seems to be imprinted in our DNA.

There are examples of successful physical representation for real world applications, where safety, legal issues or token representation is necessary, like in air traffic control and railway traffic systems. In air traffic control centres physical ‘strips’ are still used to track planes by Air traffic and ground control centres. One way railway tracks still use tokens to signify to drivers the track is cleared to drive on: there exists only one token per track, the tokens are handed over from driver to driver.

A 'conceptual framework' for TUI in this context has been devised, the TAC paradigm. This is a system based on the token quality and constraints of TUI. We will categorize applications for our research according to the TAC paradigm to give an idea of the token value of the interface. (O. Shaer 2004)

4. TUI TO THE TEST

We propose to look for the value of TUI and define metrics to do so. In order to achieve this we suggest comparative tests with TUI and GUI. A number of preliminary tests with common interfaces can be set up. There are everyday examples where users are familiar with both tangible and graphical interfaces. In games like chess, most players, not only the accomplished ones, are used to playing the game in different ways:

- The classic -tangible- way of playing chess on a board with pieces

- On paper in diagrams in for instance newspapers or chess books

- Digitally in various shapes or forms, be it against a computer or against an opponent somewhere else in the world

Scrabble is also played as a board game, digitally and on paper. This renders both games, played all over the world by a variety of users, an interesting test subject for our research.

It makes sense to assess carefully how players approach the different ways of playing their games: why, where and in what contexts they choose for a specific way of playing the game.

In these tests it will be possible to gather quantitative and qualitative data. We can measure what the players' results are using various interfaces, even playing against the same opponent. We can also investigate how players are playing: how long it takes to make a move, for instance, or how many obvious mistakes are made.

In our qualitative research we will ask players to fill in questionnaires to assess what their experiences and preferences are. We will also make use of video registration for observational analysis.

Following this, real world applications will be tested. To narrow the scope, applications will be selected where the sense of touch and our ability to use our hands to manipulate and handle physical objects are exploited, and the end results make sense (see Dourish, 2001). We will test an existing graphical user interface and devise a tangible alternative. We will test the interfaces in a real life setting. Alternative we will test a GUI for an application that traditionally has been tangible.

These tests will allow us to gather qualitative and quantitative data. These results will be used to assess what are the metrics, the elements of TUI that can be measured and be helpful in assessing whether or not a TUI is appropriate, whether it really provides opportunities for the 'real haptic interaction' Ishii and Ullmer envisioned.

5. CONCLUSION

Many researchers are, like us, inspired by everyday objects, by the idea that simple objects can perform complex tasks. In TUI, this idea has its own set of dynamics. To this day, the repercussions are not exhaustively researched nor defined.

Our aim is to investigate TUI in this context. And to do so, we aim to empirically test TUI. The result, an analysis of the mechanisms at work in this realm of tangible interaction and an overview of metrics and values, will hopefully contribute to a purposeful design process and more straightforward TUI research.

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