Towards Tangible Enactive-Interfaces

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Abstract

This paper compares the disciplines of Enactive Interfaces and Tangible User Interface design with the aim of showing that by considering the design knowledge of Tangible User Interfaces with the cognitive depth of the theories of enaction, a new type of "enactive tangible-user-interface" can be designed. Introductions to both disciplines are given, before a method of gauging the enactive potential of particular TUI's is described. Finally a discussion of the two disciplines' combination is given with such questions as, "are all tangible-user-interface's enactive?" and "are all enactive interfaces tangible?"

1 Introduction

Tangible User Interface (TUI) design is now a well-established field in comparison with the study of Enactive Interface's (EI's) which is relatively young. It is proposed here that it is possible to use the knowledge of TUI design for the benefit of developing EI's. Introductions to both TUI's and EI's are given in the following sections.

2 Tangible User Interfaces

TUI's, in Ullmer and Ishii's definition, are interfaces that "give physical form to digital information, employing physical artefacts both as representations and controls for computational media"[16]. Several frameworks for TUI design have been proposed, including the MCRpd model by Ullmer & Ishii [16] and the embodiment and metaphor based taxonomy of Fishkin [7] which will be discussed in this paper. First, as an introduction to the different types of TUI, four classifications of tangible interface instance are outlined below.

2.1 Tangible Interface Instances

In [16] Ishii identifies four general types of TUI with the categories: Spatial, Constructive, Relational and Associative. Spatial systems rely on the spatial interpretation of multiple physical objects within a common frame of reference. A typical case is the use of tangible blocks on a horizontal augmented surface, an example being the AudioPad system [13]. Constructive systems rely on the building-block principle, and involve using a number of objects that can be combined together, such as in the Blockjam system [12]. Relational systems couple digital information with a physical object, for example of the slot-machine programming system [14] that allows users to program a Logo 'Turtle' through the use of cards that represent commands. Associative systems are similar to relational systems with the difference that each physical-digital link is fixed, and there is no interaction between the objects. A good example of this type of system is the music-bottle project [9] in which individual bottles are linked with a sound that can be played by removing the bottles lid. A sub-category is defined for devices that are both Constructive and Relational. An example from this system is the bricks tangible programming project [10] as it relies both on linking digital information in a dynamic manner and on the constructive arrangement of its blocks.

2.2 Embodiment and Metaphor Based Taxonomy

A taxonomy has been developed by Fishkin [7] that uses the concepts of embodiment and metaphor to classify TUI's. The rationale of Fishkins's taxonomy is that tangible interfaces are a particularly broad area of research, and a simple binary definition to decide whether an interface is tangible is not sufficient. The solution is to create a two dimensional taxonomy that allows for a scale of tangibility. The two axes of this taxonomy are embodiment and metaphor.

Fishkin's definition of embodiment is effectively a measure of how close the digital output is to the input, and also to what extent the user thinks that the states of the system are inside the device. The scale is defined as ranging from 'Distant' (the output is removed from the input) through 'Environmental' (output is around the user) to 'Nearby' (the output is near to the input), ending up with 'Full' (the output device is the input device).

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The scale of Metaphor looks at how the use of the interface can relate through metaphor to a real-world concept. The scale ranges from 'No Metaphor' (no analogy to an existing object or action), to 'Noun or Verb' (the interface either looks like (noun) or acts like (verb) something else), to 'Verb and Noun' (the interface both looks and acts in a similar way to another object), finally to 'Full' (the user does not need to make an analogy because there seems to be no distinction between the virtual and physical systems).

Looking at the utility of this taxonomy, it is shown how it can incorporate Holmquist's theory of containers (objects to move digital information), tokens (icon-like objects used to access stored information) and tools (used to manipulate digital information)[8] as well as the 'object as' theory [17]. Of particular interest to this paper is the study that looked at how tangible interfaces have evolved within a particular task domain. It was found that in the three areas in which there had been multiple projects (children's storytelling, tangible workbenches and control widgets on an augmented desktop) the evolution of the field had progressed from the 'no-metaphor/distant-embodiment' corner of the taxonomy to the 'full-metaphor/full-embodiment' corner. It is proposed that this corner of the taxonomy is the one most likely to hold enactive-TUI's, as full-metaphor and full-embodiment are conducive to the transfer of enactive knowledge.

3 Enactive Interfaces

Enactive interfaces are a classification of interface that allow the expression and transmission of enactive knowledge. Enactive knowledge, as opposed to symbolic or iconic knowledge, is a form of knowledge that is stored in bodily sensori-motor responses. The handling of enactive knowledge via the means of an enactive interface can be considered a particularly direct means of communication between human and computer. Enactive interfaces are desirable because they allow the user to utilise their pre-conceived knowledge of interacting with the world when using the interface.

3.1 Criteria of Embodied Interaction

In his development of a theory for Enactive Instruments [1] Armstrong outlines a list of criteria for embodied interaction. These are summarised below:

1. Embodied activity is situated. The agent is situated in an environment.
2. Embodied activity is timely. Real-word activity requires real-time constraints.
3. Embodied activity is multimodal. Concurrent use of multiple sensory modalities with the possibility of cross coupling between the modalities.
4. Embodied activity is engaging. The agent is required by the system and is actively engaged with it.
5. The sense of embodiment is an emergent phenomenon.

Here we will only be considering the first four criteria as possible design aids, as emergent phenomena are something that can be seen to be a result of an embodied system, rather than something that can be designed for.

4 Comparison of TUI's and EI's

TUI's and EI's can be compared on two different levels, the first is to consider their general similarities and dissimilarities, the second is to make a deeper theoretical comparison using the criteria of embodied interaction.

4.1 Similarities

Both TUI's and EI's have a reliance on the haptic modalities. TUI's inherently have a haptic element due to their tangibility; even if the haptic modalities are not used for active sensory display, then they will at least be present in a passive manner for input. EI's are reliant on haptics in a slightly more subtle way as they deal in the transmission and storage of enactive knowledge, which is based on motor skills which are intimately linked with haptics.

TUI's and EI's are both multimodal in general. Multimodality is the third criteria in Armstrong's definition for embodied interaction so it can be assumed that EI's that support embodied interaction will also need to be multimodal. TUI's do not necessarily need to be multimodal, however in practice a large number of them are. A reason for this can be seen in the way that the standard haptic interaction of a TUI is usually augmented with visual and audio feedback thus creating a multimodal system.

4.2 Dissimilarities

The main difference between TUI's and EI's is in the form that they represent knowledge. Bruner [4] describes the three possible types of knowledge used when interacting with the world as symbolic, iconic and enactive. Symbolic knowledge involves conceptualization and abstract reasoning, iconic knowledge involves visual recognition and the ability to compare and contrast, and enactive knowledge is constructed on motor skills. Enactive interfaces work on the enactive level of knowledge, whereas TUI's are free to work within any of the modes. Because they are most often comprised of objects contextualised in a physical environment, TUI's inevitably rely to a great extent on the enactive level, however they tend to normally operate in the iconic or symbolic realms. An example of an iconic TUI is the 'Urp' urban planning system in which the tangible element takes the form of the buildings they represent. An example of a symbolic TUI is the Audiopad [13] which is designed for realtime music performance. The user manipulates radio-frequency tagged pucks around a tabletop, navigating interactive text-based branching menus that are projected onto the table's surface.

4.3 Comparison using Embodied Interaction Criteria

Using Armstrong's criteria of embodied interaction, as outlined in section 3.1, it is possible to see which of the criteria is applicable to TUI's.

Starting with the criterion 'Embodied activity is situated', it can be generalised that all TUI's are in fact situated given their tangible nature, and that in this respect both TUI's and EI's are similar.

The second criterion demands that embodied interaction is timely. By timely it is meant that real-world events require real-time interaction, so in the case of an interface, the interface would have to allow the user to respond in a timely manner, and not allow the flow of interaction to be broken. TUI's can differ from being very timely to not at all timely. An example of a timely system is the Illuminating Clay project [15] where you can change the input (the clay) and the output (the clay) immediately reflects the new state of the system. A non-timely example would be a TUI that didn't immediately update it's output in response to a change in the system or the users input.

The third criterion states that embodied interaction requires the use of multiple sensory modalities. As discussed in section 4.1, TUI's are in general multimodal, so in this respect they shall be regarded similar.

The fourth criterion is 'embodied activity is engaging'. In this respect, TUI's are different from EI's as they need not be engaging. It must be remembered that the concept 'engaging' not only considers the attention span of the user, and how occupied they are with the interface, but also by how much the interface needs the involvement of the user to function. A good example of a TUI that requires the user's ongoing attention is the topographic torch [2]. The topographic torch is an egocentric mapping device that displays the section of a map that refers to the area directly ahead of the user. This requires the user to move their body in alignment with where they are interested in.

From this comparison it can be seen that TUI's can differ from EI's in two respects, timeliness and engagement, whilst they are similar in the two respects of multimodality and situatedness.

5 Representing the Tangible-Enactive Space

It is proposed above that TUI's differ from EI's in two main aspects, timeliness and engagement. These are not simple binary states, but continua both from non-engaging through to fully engaging and from non-timely through to very timely. It is hence suggested here that it is possible to create a graph with 'engagement' for one axis and 'timeliness' for the second axis, on which it would be possible to place any TUI, with the result that it will be possible to plot how enactive a TUI is (fig. 1).

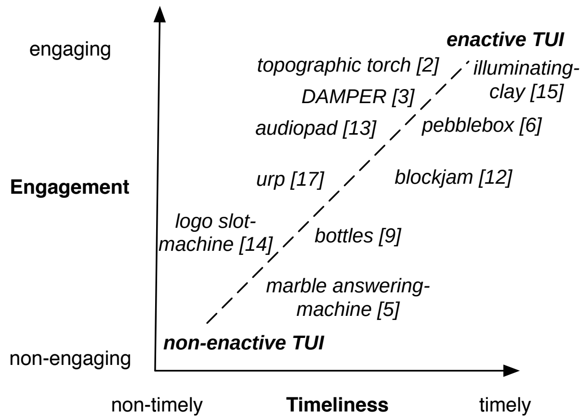

Figure 1: Graph showing the Tangible-Enactive Space, with project examples.

The utility of this graph is that designers of TUI's can gauge the enactive potential of the system they are designing, and modify their design so as to achieve the desired position within the tangible-enactive space. For instance the Logo slot machine [14] does not need to be fully enactive, as it is predominantly concerned with the symbolic manipulation of programming commands. Bishop's marble answering machine [5] is also placed in the non-enactive corner. The DAMPER [3] on the other hand, a tangible interface for music performance, benefits from being both timely and engaging and has hence been designed to enable enactive interaction. Similarly, the Pebble-Box [6] a musical interface designed for granular synthesis is placed in the enactive-TUI corner as it is both engaging and timely.

6 Discussion

When discussing the joining of TUI and EI theory, three questions come to the fore:

Does an enactive TUI make a better TUI? This is not necessarily the case. In some cases the ability for the transmission of enactive knowledge is desirable, however in some systems it is more desirable to create a purely iconic or symbolic system.

Are all TUI's enactive? The question of whether all TUI's are inherently enactive is answered to a certain extent by the Engagement vs Timeliness graph (Fig.1). The graph shows that only TUI's that are entirely unengaging or untimely are not enactive. Any TUI that is fully engaging and fully timely can be considered an enactive interface. So from this it is possible to see that only some TUI's make the status of being fully enactive (this can be seen as the 'strong' definition of an enactivity), and the majority are partially enactive ('weak' definition of enactivity), thus leaving only a small minority of TUI's that are truly un-enactive.

Are all enactive interfaces tangible? Although it is easy to jump to the conclusion that all EI's are tangible as in general a great deal are, it is possible to think of an EI that does not involve the manipulation of a tangible object. An example of this is a system that uses someone's free movement in space as input, for instance a typical virtual reality setup. The VR system allows the user to work in the enactive realm; although rather than utilising object manipulation skills it is possible to use a have a system where proprioceptive skills are more important.

7 Further Work

We are currently working on developing a series of musical interfaces that will be designed to explore the role of enactive interaction and how it can be built into TUI's. It is proposed that Fishkin's taxonomy be investigated with greater depth in regards to how metaphor and embodiment effect the enactive potential of these interfaces.

This discussion would be easier to carry out with a better understanding of what is, and what is not an enactive interface. It may be possible to get a better understanding of how to create an enactive interface by first trying to design a truly un-enactive TUI.

8 Conclusion

This paper has investigated the link between tangible user interfaces and enactive interfaces, showing how the two theories can be placed in a single design space. There is a lot more work to be done in this area and this paper will hopefully encourage further investigation into the link between the two disciplines.

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