Tangible User Interfaces
- Classification -

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Abstract

This paper summaries the classification framework for Tangible User Interfaces that was presented by Ullmer and Ishii and later extended by Hoven and Eggen.

1 Introduction

The number of application of Tangible User Interfaces (TUIs) has been growing over the last few years. Although there are just a few applications which are commercially available it is obvious that TUIs are an alternative to the traditional Graphical User Interfaces (GUIs) to bridge the gap between the digital and the physical world. To break down the rank growth Ullmer and Ishii have presented a model to classify TUIs in 2000. They did some minor changes on the model in 2001 but the base framework of the characterisation of tangible interfaces has remained the same and reached a grand acceptance.

The classification model presented by Ullmer and Ishii has been extended by Hoven and Eggen in 2004 for their work with associative TUIs and personal objects.

This paper gives an overview of the classification of TUIs. The framework as well as the extension are introduced. At the end an alternative model based on application domains is briefly presented.

As it is just a short report focused on the classification, it is expected that the reader is familiar with the different instances of Tangible User Interfaces which have already been developed.

There are no specific references as the whole report is fully based on four papers which are listed at the end.

2 Terminology

Most of the terms in the context of Tangible User Interfaces have not reached a widespread consensus yet. As a well defined terminology is important – and common for scientific areas – especially to characterise a system, the following terminology should be considered:

Iconic and symbolic The difference between *iconic* and *symbolic* signs is the fact that *iconic* signs share some representational properties with the objects they refer to. This is not the case for *symbolic* signs. For example representing a person with a shape of the form of a head would be *iconic*. On the other hand representing a person with a form of an apple would be *symbolic* as an apple shares definitely no representational properties with a person. *Phicons* is the short form for *physical icons* and beside their existence in the physical world they are similar to GUI icons.

Tokens and reference frame *Tokens* are the physical elements which can be manipulated and used in the so called *reference frame* or physical interaction space. For example in the Bricks system the *bricks* are the *tokens* and the *ActiveDesk* is the *reference frame*.

Containers and tools *Containers* and *tools* are both subsets of *tokens*. *Containers* are *symbolic tokens* to which media can be assigned. A perfect example therefore are the mediaBlocks. *Tokens* which represent digital operations or functions are called *tools*. The "wind tool" in the Urp system serves as an example.

3 Key Characteristics

Before talking about the key characteristics of TUIs the interaction model for tangible interfaces – the so called "model-control-representation (physi-

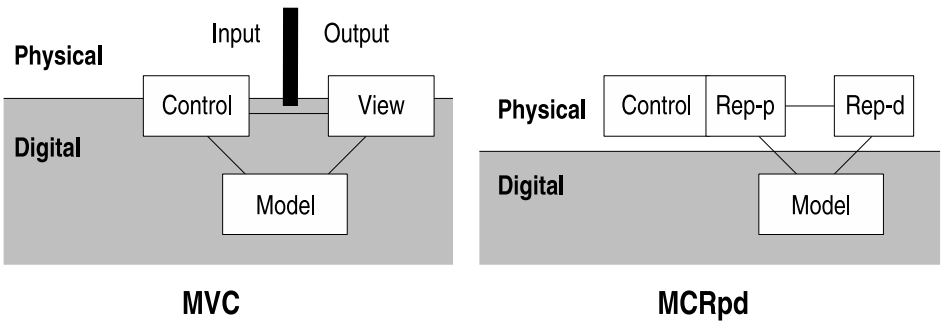

Figure 1: GUI and TUI interaction models.

cal and digital" short "MCRpd" – must be introduced. The MCRpd model is derived from the well-know "Model-View-Control" ("MVC") model. In the MVC model the major part is digital, only the input and ouput devices, which are strictly separated, are physical. In the MCRpd model only the *model* itself is digital, all other parts are physical. The *view* is divided into two subcomponents: The *physical representation* and the *digital representation*. The input and output devices are not separated any more what in fact marks out a tangible user interface.

Based on the MCRpd interaction model four key characteristics of tangible user interfaces can be specified. Therefore the three relationships between the physical representation and the other components play a major role.

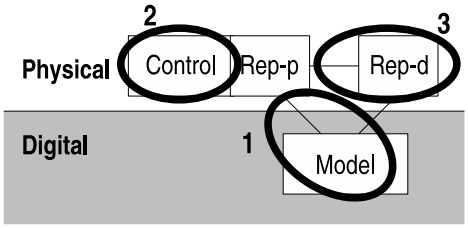

Figure 2: Key characteristics based on the interaction model.

1. **rep-p – model** The way the physical representation is coupled to the underlying digital information (*model*) is the central characteristic. A token for example can represent a data container but graphical geometries could be bound to it as well and performing a tool might result in digital computations.

2. **rep-p – control** How is the physical representation controlled? By user interaction? By motor? On a planar surface or in free space? The answer to those questions is the second characteristic.

3. **rep-p – rep-d** Frequently the representation is not only of physical nature but includes a digital part (mostly graphics and audio) as well. The relation between physical and the digital representation is an important characteristic of TUIs.

4. The fourth characteristic is not directly derived from the model. It concerns the physical state that partially embodies the digital state of the system.

4 Classification

Based on the key characteristics discussed above Ullmer and Ishii presented a classification in 2000. They split up the different TUI systems into four categories (for examples see Table 1):

Spatial *Spatial systems* are systems which interpret the position and orientation of tokens in a reference frame. Very common in this category are systems encompassing iconic tokens on a horizontal surface.

Constructive Systems with a *constructive* approach belong to this category. Such systems are similar to the classical LEGO where modular elements are coupled (mechanical) together.

Relational In *relational systems* relations between different tokens are created. The tokens can associate digital information which are put into a context with the relation of the tokens among each other.

Associative *Associative systems* are similar to *relational* in the way that they associate tokens with digital information, but the tokens do not have any relation to each other.

<table>
<tr><th>Spatial</th><th>Constructive</th><th>Relational</th><th>Associative</th></tr>
<tr><td rowspan="2">Bricks
metaDESK
BuildIt
Urp
InterSim
InfoBinder
Twin Objects
Illuminating Light</td><td>Blocks
BBS
IModeling</td><td>Marble Ans
Lego Wall
mediaBlocks
musicBottles</td><td rowspan="2">Voice Boxes
POEMs
WebSticks
Passage</td></tr>
<tr><td colspan="2">AlgoBlock
SAGE
Programming Blocks
Triangles</td></tr>
</table>

Table 1: A few examples of TUI instances.

Of course, the borders of the groups are not strict and the classes are not mutually exclusive. Most of the systems can be classified into a main group, but other aspects of the system might belong to another group. In addition there are definitely some TUIs which are a mix of *constructive* and *relational* systems.

It is interesting to observe that most systems of the *spatial* and *associative* group are *iconic* and systems of the *constructive* and *relational* group are *symbolic*. Further more *relational* and *associative* systems work mainly with *containers*.

This framework for classification has been changed in 2001 by Ullmer and Ishii. In fact, they just omitted the *associative* category; they mentioned already in 2000 that they are "less confident of the utility of this category".

Three years later Hoven and Eggen extended the framework because of the omission of the *associative* category and their work in the area of personal objects (Digital Photo Browser). In the extension the focus is on the token with its associated digital information. The main classification is based on whether the tokens have a personal meaning to the user or not. Subgroups are made on the fact of whether the associations are flexible or fix and whether they are iconic or symbolic.

Digital associations	**Fixed (1)**		**Flexible (n)**	
Physical object type	**Symbolic (tool)**	**Iconic (tool)**	**Symbolic (token)**	**Iconic (token)**
No existing mental model, mostly multiple users ⇒ **Generic object**	Bricks metaDesk Urp musicBottles Triangles	BuildIt Light Illuminating Urp	MediaBlocks WebStickers InfoSticks	
With existing mental model, mostly single user ⇒ **Personal object**			Passage	POEMs Phenom Living Memory Box

Table 2: The extended model with a few example.

5 Application Domains

Another approach for the categorisation of Tangible User Interfaces relies on the application domains. The TUIs are categorised based on the question "what kinds of tasks are tangible interfaces good for?". At this place the different domains are not explained in detail but just listed to give an idea for the different possible domains:

- Information storage, retrieval and manipulation
- Information visualization
- Modelling and simulation
- Systems management, configuration and control
- Education, entertainment and programming systems

6 Conclusion

It was seen that there is not only one single model to classify TUIs. Two main models were presented during the last few years. The framework introduced by Ullmer and Ishii is well defined and covers the whole area of tangible user interfaces. The model presented by Hoven and Eggen is based on the work done by Ullmer and Ishii and has a strong focus on associative TUIs. Although the use of personal objects instead of generic objects might become more and more important in the future it is discussable whether this is the most important characteristic of TUIs.

Why is there not only one single classification model? Is it because TUIs are still a new research area? Is it because there are lots of prototypes but only few commercial applications? So the area of TUIs is more a playground with toys than a serious scientific field? Is it even possible to classify TUIs, as TUIs are so widespread and a single instance can combine lots of aspects?

In my personal opinion there have been developed already lots of nice and funny TUIs. But would I really use them in my everyday life? I don't mind taking the photo album from the shelf! I'm sure there are domains where TUIs could be very helpful, for example in modelling and simulating complex systems, in the medical environment or as an aid for handicapped persons. But applications within those domains are extremely individual and specific and live a life behind the scene. This leads to my opinion that it is more important to have a well defined terminology to be able to describe and characterise a system in detail than a single model to classify each TUI instance.

7 References

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