# Understanding the Characteristics of Metaphors in Tangible User Interfaces

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**Abstract**

The idea of metaphors has been a central and popular element in the design practice of graphical user interfaces. While the principle is commonly applied and discussed in the field of Graphical User Interfaces, its usage in the field of Tangible User Interfaces (TUIs) is not yet fully understood.

This paper analyses the principle of metaphors in TUIs, based on the main definitions of interface metaphors being discussed in literature. Our aim is to identify the characteristics describing a metaphor in TUIs and to propose a concept that can be used in TUI design activities. Using the example of the so-called "ColorTable", we discuss how the principle of metaphor based on source and target can be applied to the particular context of TUIs. From our insights, we propose a concept of TUI metaphors which links the physical, the digital, and the application domain of TUIs.

## 1 Introduction

Through the concept of Tangible User Interfaces (TUIs), we are able to go beyond the limitations of desktop computing and to create new applications based on interactions with a physical environment. TUIs can provide the same computational capabilities as desktop computers, but are able to offer the richness and familiarity of physical actions. Using the physical objects and space provides social benefits, such as, collaboration (e.g., Hornecker & Buur 2006), and offers new types of human experience and understanding through interactive representations mixing physical and digital elements (e.g., Klemmer, et al. 2006).

Due to this particular mixture of physical and digital interactions and representations, we are faced with a new complexity related to the design of TUIs. Although a number of design guidelines and conceptual foundations are proposed in literature (Shaer & Hornecker 2009), we still lack of an explicit workflow for designing, describing, and evaluating the tangible interaction space.

The idea of metaphors has been a central and popular element in the design practice of graphical user interfaces. The most common and popular definition is based on a cognitive approach, considering a metaphor as a basic mental operation. It was formulated by Lakoff and Johnson: *"A metaphor is a rhetoric figure, whose essence is understanding and experiencing one kind of thing in terms of another."* (Lakoff & Johnson 1980). In 1987, Johnson provides an even more specific definition, stating that a metaphor is *"a pervasive mode of understanding by which we project patterns from one domain of experience in order to structure another domain of a different kind* (Johnson 1987)*."* Afterwards, the concept was intensively elaborated and discussed to become a key component in the design of graphical user interfaces. The idea was caught by several TUI researchers, claiming that the physical properties of objects and space are particularly interesting for metaphorical links (Fishkin 2004, Hurtienne & Israel 2007, Svanaes & Verplank 2000).

In this paper, we investigate the cognitive approach to metaphors in the field of TUIs. Our aim is to understand the characteristics of a metaphor in TUIs and to propose a description that can be used for designing and evaluating tangible interactions. We consent that a metaphor is a strong concept, which has a great potential in the design of tangible interactions. We believe that metaphors will allow us to better specify a workflow for the design of TUIs, which will improve the way users are experiencing and understanding them.

To understand the characteristics of metaphors, we first describe a complex TUI, the ColorTable, as well as one of its features. Through analysing this feature, we will extract the different types of sources and targets that can be found in TUIs. We will propose three types of metaphorical links, which make use of five types of patterns from three domains. We finish with our conclusions of how the three types of metaphorical links may help us in designing TUIs.

# 2 The ColorTable

To be able to study the concept of metaphor in TUIs, we take the ColorTable (Maquil 2010) as example. The ColorTable is a TUI enabling the collaborative discussion and debate of different ideas and concepts around urban planning projects. It is a tabletop interface presenting a collaborative planning and discussion space – users are motivated to share their ideas and visions by moving colour tokens of different shapes and colours on the table. The tokens enable users to set urban elements such as buildings, streets, pedestrian flows, or ground textures. The table view uses a physical map, which is augmented with digital information to provide a top-down view onto the project site. A vertical projection renders the scene against a background, which is produced by either a video stream, a panorama image of a view onto the site, or a see-through installation and creates a perspective mixed reality view.

One of the features of the ColorTable is the creation of roads (Figure 1). It was implemented to allow users to discuss and decide on the types of transport, speed and concurrency. They could define different types of roads and flows of animated objects moving on a given path.

Roads are created in three steps: First, the users select one of the predefined types provided on small cards. Second, they assign this type to a colour by placing it on a dedicated colour region. Third, they create the road itself by positioning rectangular objects at both endpoints on the map. Between these two points, a cubic Bézier curve is projected, which can be controlled by rotating the rectangles. Each colour differentiates a different type of road (e.g., highway, normal road, cycle path, footpath, or railway). Both the top and the perspective view show a coloured stripe of variable width to visualize the respective road. The animated objects are visualized as moving dots on the table and as flip frame animations on the screen.

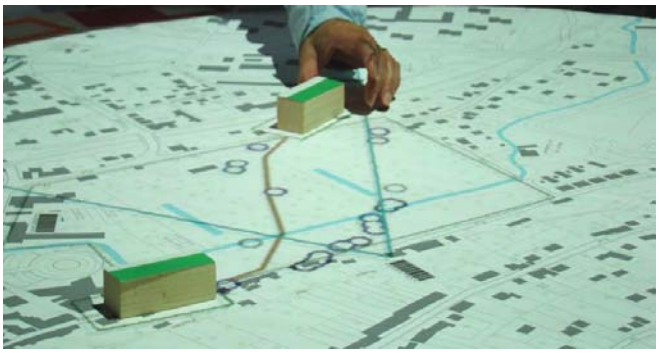

*Figure 1: Creating a road by positioning two rectangles on the physical map*

Applied to the feature of positioning roads, this means that we are analysing the metaphor: *creating a road on the site* is *selecting a card, assigning it to a colour, and placing two physical tokens on the map*. The unknown functionality of creating a road in an urban space can therefore be understood through projecting patterns provided by the card, the colour region, two rectangular tokens, the projected line, the paper map, and the tabletop. From these elements, we can understand that, for instance, a line is controlled through its two endpoints, that these can be moved freely in 2D and that the positions on the table are interpreted based on the section and the scale given by the map.

# 3 Sources and Targets in TUI Metaphors

The two domains that are mentioned in a metaphor definition are commonly called the source and target domain of a metaphor. The target is the original idea, a new or complex concept, to which the metaphor is referring to. The source is the borrowed idea, a familiar concept that helps us in understanding the target (Lakoff & Johnson 1980). The mapping from source to target is called the metaphorical projection (Kuhn & Frank 1991).

In the context of TUIs the source domain uses characteristics of physical objects and tangibility to refer to familiar concepts. As Fishkin (2004) points out, this context is particularly appropriate for applying a metaphor-based design approach, because of the high number of physically afforded metaphors: *"A designer can use the shape, the size, the*

*colour, the weight, the smell, and the texture of the object to invoke any number of metaphorical links."*

The target domain is the unfamiliar structure in and around the TUI that needs to be explained to the user. As described in (Blackwell 2006), the interface can be seen as some representation that helps the user to understand the abstract operations and capabilities of the computer. This is often considered as the target domain, which is presented as is it was something else that the user might already understand.

We agree with seeing the interface as metaphorical representation of the operations and capabilities of the computer, but believe that in TUIs, and especially mixed reality (MR) based TUIs, we are faced with a whole series of different sources and targets that are mapped through a metaphorical projection (see Figure 2).

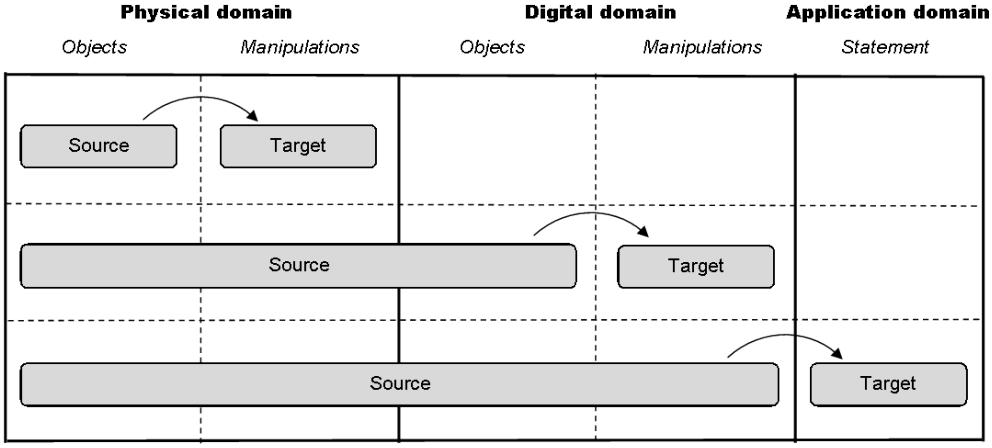


*Figure 2: Three different types of metaphorical links in a TUI*

The first type of domain which is unknown to the user, concerns the physical manipulations that can, or should be done with the TUI. In the case of the ColorTable this is to understand the area where objects should be placed (i.e., the tabletop), and that they can be moved or rotated. The patterns used in this metaphorical link are, for example, the flat bottom side of the objects, the flat tabletop, and the directional form of the rectangles.

When the physical manipulations are understood, they become part of the source and help the user to understand the digital manipulations. The physical objects and the characteristics of the digital representations give guidance on how the computational operations can be controlled. In our example, the user can observe that the line is drawn between the two rectangles and that their direction is always adjacent to the line. These physical and digital patterns support understanding how lines are computationally represented and controlled.

Finally, a third type of unfamiliar domain which can be found in a TUI is the application domain, i.e., the purpose for which the TUI is used. The feature of manipulating lines is on this stage used by the user to represent a road and to explain the vision of the types of

transport in the future urban planning projects. The source of this metaphorical link is formed through patterns of the representations provided by mainly the digital objects, such as the curved shape, the texture, the width, and the moving flows of cars, bikes and pedestrians.

When designing a user interface, we need to address all three types of targets and explain them to the user by, for instance, creating patterns for metaphorical links. In the case of tangible interaction, the physical and the digital world are closely integrated, and the same type of pattern is considered in multiple types of metaphorical links. Characteristics of physical objects explain as well the physical manipulations, and the digital manipulations, and represent a statement in the application domain. Digital objects are, in a similar way, used to explain the digital manipulations and the application domain. This interrelation of the physical and the digital across several layers requires that we need to adjust:

- considered patterns of a same TYPE, so that they are integrated in a common (object) design, and
- considered patterns of a same METAPHORICAL LINK, so that they complete each other for explaining a target

Note that our model on TUI metaphors is closely related to the concept of affordances (Gaver 1991) dealing with the perception of action possibilities by individuals. We prefer to use the term of metaphor since it is better described in literature and more generalizable across fields.

# 4 Conclusions

By introducing three types of metaphorical links in TUIs, we have added a new aspect to tangible interaction design. Our concept shows the interrelations between the physical, the digital and the application domain of a TUI using metaphorical projections. We propose to create a more specific workflow for the design of TUI based on the particular characteristics of metaphors and patterns used in the source and target domain. We believe that through such a model we are able to better explore the design space of a new technology as we better understand the consequences of design decisions.

In our future work, we further formalize the description of tangible user interfaces by taking into account the mental models and sensory motor experiences of the users. We seek to identify the characteristics of metaphors and the involved patterns which require less mental efforts for the users. We investigate how such a description can be used in activities of design and evaluation, in order to define a design process for TUIs. In a user centric design process, we will develop and evaluate different types of tangible metaphors for knowledge intensive applications in order to experiment on the more efficient workflow of design activities in TUIs.

**Acknowledgments**

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