A DESIGN APPROACH FOR TANGIBLE USER INTERFACES

Bernard Champoux (Associate Researcher)
Dr Sriram Subramanian (Assistant Professor)
Department of Computer Sciences
Human Computer Interaction Lab
University of Saskatchewan
Saskatoon, Canada
bjc489@mail.usask.ca
sriram@cs.usask.ca

This paper proposes a mechanism to design Tangible User Interface (TUI) based on Alexander's (1964) design approach i.e. achieving fitness between the form and its context. Adapted to the design of TUIs, the fitness-of-use mechanism now takes into consideration the potential conflicts between the hardware of the artifact (electro-mechanical components) and the form of the user's control (Physical-ergonomics). The design problem is a search for an effortless co-existence (fitness-of-use) between these two aspects. Tangible interface design differs from traditional graphical interface design as unsolved conflicts between hardware and ergonomics can deeply affect the desired interaction. Here we propose a mechanism (in the form of eight questions) that support the design by defining the boundaries of the task, orienting the hardware (electro-mechanics) and ergonomics of the design space for various sub-tasks and finally fitting the different components of the hardware and physical- ergonomics of the artefact to provide a component level fitness which will delineate the final tangible interfaces. We further evaluate the effectiveness and efficiency of our approach by quantitative user evaluation.

Tangible user interface, tangible computing, design approach, collaborative design.

INTRODUCTION

A research direction in Human-Computer Interaction that has re-surfaced in the last decade is the use of physical real-world artefacts to represent and control digital data. Tangible user interface is the popular term used to refer to such computing systems that use physical artefacts as representation and control of digital data (Ullmer and Ishii, 2000; Dourish, 2001). Research in tangible user interface has broadly focused on developing systems for various application domains and proposing different frameworks to classify the different systems. Systems have been developed to exploit tangible user interfaces for desktop metaphor (e.g., Neurosurgical Props from Hinckley, 1994), virtual reality metaphor (e.g., Cubic Mouse from Frolich and Plate, 2001) or mixed reality metaphors. (e.g., DataTiles from Rekimoto, 2000). Frameworks have been proposed based on the type of interaction supported (continuous vs. discrete) (Ullmer, 2002) and level of mapping between the physical artefact and digital data (Wensveen et al, 2004). However, to make tangible user interfaces a viable real-world interface by truly targeting users' needs, a mechanism to facilitate the design of tangible interfaces and their prototyping is required. While software engineers have mature *software thinking*, referring to the functionalities' structure and software interface in the desktop space, a *tangible thinking,* referring to the dynamics' structure in the real-world space, is still in its infancy.

PURPOSE OF THE DESIGN MECHANISM

The problem in the development of TUIs based on desired user interaction is to maintain, during the process, a balance of the various trade-offs between the appropriate set of interactions required for the task and their compatibility with the available sensor technology. How to combine hardware and their usability constraints to create a tangible interface? The mechanism proposed in this paper, when used by a team of experts, aims to provide a workflow in this process and would result in a *set of clear and coherent decisions*, i.e. clear specifications and/or a functional diagram that works coherently with the necessary tasks. Structured through eight questions in three phases: defining the boundaries (BO 1-2-3-4), orienting the components (OC 5-6) and fitting the components (FC 7-8), the mechanism will ease the location of problems that occurs during the development, facilitate their identification with the mechanism terminology (boundaries, orienting and/or fitting problem) and help their formulation i.e. asking to the right expert the right question. Finally, a completed process will be the starting point to craft a S-Type (specifications) prototype to verify the co-efficiency between the required tasks, their interaction and the needed mechanicals components. The design team will then know how well the fitness-of-use has been achieved and will be able to use their answers to the questions as a checklist. We believe this approach to be an excellent solution to propose "tangible thinking" to students and to help experts in managing their projects. Figure 1 summarizes the eight questions and the next section presents the fitness-of-use problem.

Defining the Boundaries	Orienting the Components	Fitting the components
BO 1: What should the user experience? BO 2: What are the human tasks? BO 3: What would the artefact represent and control? BO 4: What are the conventions? • Physical Ergonomics • Electromechanical	OC 5: a) What is the nature of the interaction for each sub-task? • Continuous • Discrete • Assembly b) What are the electro-mechanical and physical ergonomic constraints for this task? OC 6: Does the sub-task need any relational interaction?	FC 7: What are the relations between the objects and the actions? FC 8: What is the task order when using the artefact?

Figure 1: The eight questions

ORIGIN OF THE 8 QUESTIONS

Designing a computer-enhanced object with a precise task in mind can become quite complicated in the absence of a specific workflow, especially when working in teams. These eight questions arise from literature reading and experiences of designing interactive systems and/or smart objects. People are sometimes very tempted to design a form right away. There is, a priori, nothing wrong with this as long as the designer is aware of the specific electro- mechanical constraints involved in the development of the artefact. However, when working with an idea, dealing with a functional diagram is far more easier (and cheaper) than constantly changing the real things.

THE FITNESS-OF-USE PROBLEM

Every design problem begins with an effort to achieve an appropriate fit between two entities: the form in question and its context (Alexander, 1964). A form is the desired solution to the problem and the context defines the problem (see Figure 2). The appropriate fit between the two entities results in an object with symmetry of use properties: effortless contact between the form and the context. (See Figure 3).

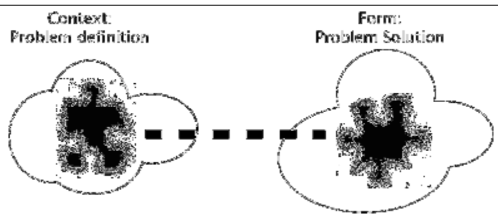

Figure 2: The original fitness problem

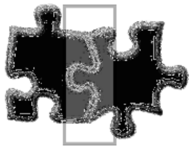

Figure 3: Symmetry of use: Frictionless co-existence between a form and its context.

In TUIs, this symmetry of use should occur between the physical artefact (form) that represents and controls information and the application (context and the suitable interaction) that defines the digital information: Fitness-of-use (see Figure 4). This is also evident from the MCR-pd interaction model proposed by Ishii and Ullmer (2000), which highlights a bridge between the physical world of atoms and the digital world of bits.

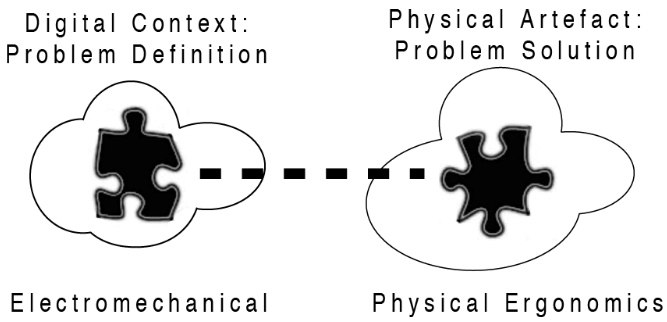

Figure 4: The Fitness-of-use problem adapted to TUI design

This fitness-of-use problem is confounded by the potential conflict between the hardware (electromechanical components like sensors and actuators that go into the physical artefact) and ergonomics (how the user will use and control the artefact: the interaction) of the design space. The problem is to find out what sensors fit into the artefact and how to fit them so that the ergonomics of the artefact are not compromised. The user's ability to control the artefact is dictated by the ergonomics, which in turn are dictated by the interactions required by the task. In contrast, the ability of the artefact to control the digital information is dictated by the electromechanics. Thus, the fitness- of-use problem is also transformed into finding a frictionless co-existence of the physical ergonomics of the artefact and its electromechanics. Achieving the fitness-of-use in TUI design aims to create "a vehicle by which the user acquires/constructs a meaning" of the application (Kaptelimin et al., 1981). In order to do so, our mechanism will define the core structure of a physical artefact by addressing the fitness-for-use problem between the appropriate set of interaction needed for the task and their compatibility with the available sensor technology. The potential interactions that occur during the use of the physical artefact highly influence the core structure of the device. Any change in the interaction style signifies a change in the core structure.

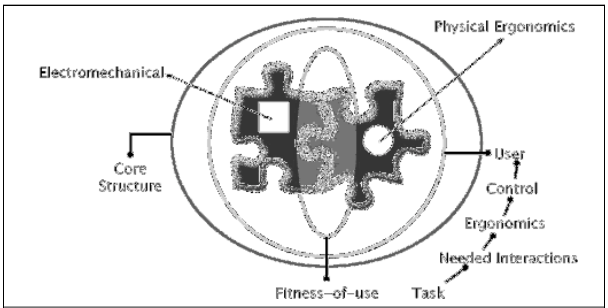

Figure 5: The physical artefact's core structure.

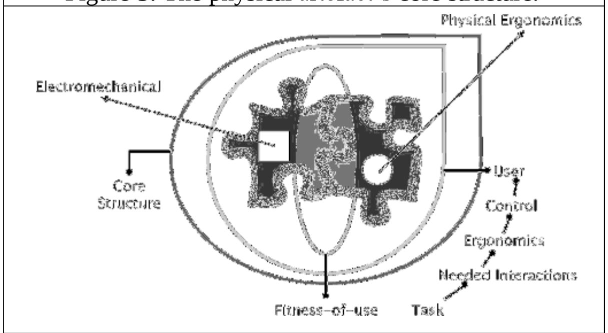

Figure 6: The physical artefact's core structure changed because of a different interaction style.

In this paper, we investigate the conflicting spaces of tangible interaction to achieve this fitness-of-use through eight questions in three phases: defining the boundaries (BO 1-2-3-4), orienting the components (OC 5-6) and fitting the components (FC 7-8). The desired fit needs to be *defined* through the attributes of the interaction, such as information about the tasks, user experience and context (physical and digital) of interaction. The first phase defines the various electromechanical