Regarding the Physical/Digital Seam in Design for Intuitive Interaction

Johann Habakuk Israel*, Jörn Hurtienne**

*Fraunhofer IPK Berlin, Pascalstr. 8-9, 10587 Berlin, Germany
**University of Cambridge, Trumpington Street, Cambridge CB2 1PZ, Großbritannien
johann.habakuk.israle@ipk.fraunhofer.de
j.hurtienne@eng.cam.ac.uk

Abstract: The design of user interfaces includes a function allocation between physical and digital interface elements. Even though this function allocation has a high impact on the interactive properties of the final product, methodological support for this step is still limited. With regard to designing the physical/digital seam, this position paper outlines some merging strategies and applies them to the analysis of two example products.

1 Introduction

Developing digital products means to design both physically (mechanically) and digitally (graphically) represented elements in the user interface, and to merge them in a single system. The decision about which parts of the interface are to be represented in which realm is often done intuitively, based on available interface elements, and only rarely on a systematic allocation of functions. For example, a 3d Tetris-like game could represent blocks digitally on the screen while providing physical access via mouse and keyboard controls or via a touch screen interface. It would be rather unusual that a developer of such a game would contemplate about the physicality of the mouse and the virtuality of the game blocks before designing the game.

With the emergence of new sensor capabilities and new approaches to human-computer interaction like tangible interaction or mixed reality, the possible design space in the physical realm grew extensively, staying high in the digital realm (cf. [UIJ05]).

In order to get a grip on the design of hybrid digital/physical interfaces, Hurtienne et al. [HIW08] suggested a methodological approach, starting with a PIBA-DIBA list (physical is better at – digital is better at). According to this approach, designers should decide whether to implement a certain function physically or digitally based on the advantages of each domain, while keeping the number of physical/digital seams reasonable low.

Applying the PIBA/DIBA list to the design of information displays with highly dynamic content would suggest a digital implementation, while a highly interactive medical application for analysing 3d medical datasets by an physician should be implemented via physical controls (cf. [HPG07]).

Although the list was not intended as a designing tool for intuitive interaction in particular, it can be found that when looking at the PIBA side, almost every entry aims at cognitive efficiency (this makes it relevant for intuitive interaction, as per Naumann et al. [Na07]). For example, with respect to the spatial position of interface elements: "When interacting with physical objects, action and perception space are united and perfectly aligned." The entries on the DIBA side almost entirely address the computational advantages of Digitality, for example: "Digital objects can easily be processed by digital algorithms." With respect to intuitive interaction, the design task is to merge both realms, maintaining physical control and computational power of the hybrid artefact.

In the workshop, we would like to discuss merging strategies and design principles, which do not focus on either the physical or the digital realm but on the seam regarding:

- States (state-less, state-full; in each state the device shows the same or different reactions to user input, e.g. menus, screens, modes)
- Mapping of physical controls to functions[1] (1:1, 1:n; per state/scenario; e.g. one physical key controls one or multiple functions)
- Spatial location and distribution of the interfaces (co-located, dis-located; congruent, incongruent arrangement)
- Synchronicity of action and feedback (both technically and conceptually)
- Unity of the interface elements as perceived by the user (represented as physical, digital/graphical, hybrid objects; often correlates to co-location)

These principles are well discussed in the literature (e.g. [SLC04, SWK04]). We would like to review this discussion with respect to intuitive interaction. With respect to these and other dimensions, which may evolve during the workshop, the questions to discuss would be:

- How less-physical can artefacts be designed, maintaining cognitive efficiency and supporting complex computational solutions? (Today, combinations of GUI/TUI interfaces might be the best practice.)

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[1] More precisely, the mapping goes from physical elements (e.g. keyboards or touch screens), where the user generates interaction token (e.g. commands or gestures) which are composed from an interaction alphabet (e.g. characters or tapping, double tapping, sliding) to the invocation of functions (the semantic layer, cf. [Ni86]). In this short paper, the discussion is limited to the mapping from physical controls to functions for simplicity reasons, but should be extended in the workshop.

- Are some mappings more “intuitive” than others? Are they task-, user- or domain-specific? (For example, co-located 1:1 mappings are supposed to support intuitive interaction better than 1:n or n:m, cf. [SWK04]).

- Learning effects: Are some mappings easier to automate than others? (Again, co-located 1:1 mappings might be the best solution with respect to automation.)

- Do design principles from the physical realm also apply in the digital realm? (Is it possible to simulate physicality by visual (graphical) means?)

We like to explain our criteria with respect to two very basic and common examples. Participants of the workshop are invited to investigate their examples according to these dimensions.

2 Example: One-to-one Mapping, Co-Location, Representation, Unity

The iPhone employs four physical controls and one touch-screen (with two spatial degrees of freedom, DOF; the accelerometer, which is also embedded in the device, is not discussed here, because it has no salient function associated yet). While the four physical controls are mapped one-to-one to single, frequently used functions (figure 1), all dynamic contents – such as web and mail client or custom applications – are controlled via the touch-screen. The mapping from the xy-coordinates to the functions is dynamic, depending on the screen contents.

Fig. 1: Physical controls of the iPhone (four 1-DOF controls, one 2-DOF control)

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Nevertheless, the locus of the physical control of a function and its visual representation is co-located on the "touch-screen". Manipulating the hard-wired physical controls requires only tactile attention (which facilitates cognitive efficiency, cf. [SS99]), while controlling the dynamic contents requires primarily visual attention, since the flat touch-screen provides no tactile cues. From the perspective of the design principles mentioned above, the iPhone complies to the design principles 1:1 mapping, co-location, unity and synchronicity but breaks the state-less criteria, because the xy-coordinates of the touch-screen are dynamically allocated to various functions.

Comparing the iPhone with a standard mobile phone reveals, that the latter employs considerably more physical controls. Each key is mapped to a single function, but the mapping depends, except for the volume control, on the current mode (menu). Furthermore, physical control and visual representation of functions are dis-located and the mapping require explicit explanation (e.g. an user manual section on "soft buttons", figure 2 right). Although the keypad provides some tactile cues, edges and travel, the dis-location and spatially incongruent arrangement makes it difficult to control the functions without visual attention. With respect to our design principles, the standard mobile phone also complies to the 1:1 mapping principle but breaks the state-less criteria and co-location.

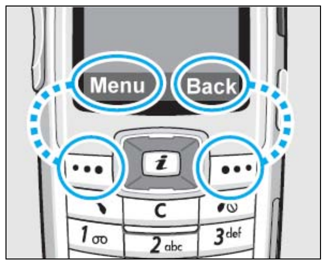

Fig. 2: Physical controls of a standard mobile phone (24 1-DOF controls) [2];
mappings explained in the mobile phone manual (right)

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[2] Regarding only spatial/physical degrees of freedom (DOF), see the note above for gestures and semantic mappings.

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According to our design principles, iPhone and standard mobile phones differ with respect to co-location and spatial congruency. Does this imply that one is more intuitive than the other? Can we at all define design criteria for intuitive use that are independent of specific users and tasks? While we would like to discuss these questions with the workshop participants, our main aim is to emphasize that consciously designing and placing the seam between physical and digital realm is relevant for intuitive interaction. Carefully tuning the physical and the digital into harmony represents a novel design problem that we need to become aware of. We believe that a new "seam-aware" design may discover efficient design solutions which are unknown so far.

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