PIBA-DIBA or How to Blend the Digital with the Physical

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Abstract

Blended interaction often is about blending the physical with the digital. In contrast to common discussions of blending that focus on the commonality of the input domains we focus on the unique features of interacting with physical and digital artifacts. We propose PIBA-DIBA lists (Physical Is Better At – Digital Is Better At) that capture the strengths of using the physical and digital realms in blended interaction design. Thus, PIBA-DIBA lists can act as a collection of "optimality patterns" that are focused on the uniqueness of both realms and can help in the analysis, design and evaluation of blended interaction designs.

Author Keywords

Blended interaction; Digitality; Physicality; PIBA-DIBA lists; function allocation

ACM Classification Keywords

H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces: Theory and methods.

Introduction

Blended Interaction can be defined as the interaction in physical environments that are augmented with digital technologies to blend the power of digital computing with our capabilities to manipulate physical things or our existing work practices around physical artifacts

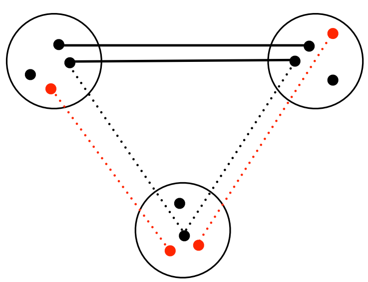

Figure 1. Conceptual Blending of two domains (or input spaces) forming a new domain (the blended space). Shown in red are the projections of unique features from the input spaces.

(e.g. [8]). The goal of blended interaction is to leverage users' knowledge about the real-world while preserving the power of digital computing.

Designing for blended interaction requires solving many trade-offs between which objects and interface elements are better left tangible in the real world and which should be instantiated digitally. The concept of blended interaction is based on the theory of conceptual integration networks [1] borrowed from cognitive science that describes how two (or more) domains (or *input spaces*) are blended in the mind to form the understanding of a new domain (the *blended space*; figure 1). Crucially, the blended space can contains (a) common elements from the two input spaces, (b) elements that occur only in one of the input spaces, and (c) emerging features that cannot be found in any of the input spaces and are unique to the blend.

Blending theory can be successfully applied as an *analytical* tool to existing or proposed blends as has been shown for hybrid physical/digital environments by, for example, [5,8]. But can the theory be also used as a *design* tool that prescribes how the input spaces can be successfully combined into a blended space? The theory does propose a set of constraining principles of how a blend can be arrived at. Fauconnier and Turner [1] call them "optimality principles". One example is the *topology principle* that states that for "any input space and any element in that space projected into the blend, it is optimal for the relations of the elements in the blend to match the relations of its counterpart". Another, the *web principle*, states "Manipulating the blend as a unit must maintain the web of appropriate connections to the input spaces easily and without additional […] computation" (p. 163). One may criticize the optimality principles as being too generic and vague to be helpful in interaction design. To alleviate this, one could try to formulate more specific optimality "patterns" that have been proven useful in frequently re-occurring blends, e.g. the blend of physical interaction with digital interaction. A second point of critique may be that as blending is often discussed in combination with metaphor [5], the focus shifts to the common structure between the domains (as illustrated by the web and topology principle), i.e. away from those aspects that are unique to the input spaces and that are also projected into the blend.

Our study tries to address both of these critiques. It is about optimality patterns that focus on the successful blending of physical interaction with digital interaction and that stress the unique properties of these domains instead of their common features. In our research we were inspired by MABA-MABA lists ("Men Are Better At – Machines Are Better At") that have been used by ergonomists from the early 1950s on [2] to allocate functions between humans and machines. From the perspective of blended interaction design, we are aiming towards optimality patterns that suggest which parts of the interface are to be implemented digitally or physically. Based on our experiences in designing tangible interfaces, on observing users' behavior in working with hybrid tangible-virtual sketching applications [7] and evaluating the literature on how we perceive, think and interact in physical and digital worlds, we recently introduced PIBA-DIBA lists as a tool for designing interaction with hybrid physical/digital interfaces [4,6]. Here, we present a revised version of the PIBA-DIBA lists and would like to discuss their usefulness as a method for user interface design.

Physical Is Better At – Digital Is Better At

A systematic distinction of Physicality and Digitality was introduced by Gjerlufsen and Olsen [3]. Based on the work of the philosopher Unger, they determined basic qualities of both worlds:

- Physical matter (atoms) – binary substance (bits)
- Spatial extent (extension within physical reality) – non-void extent (memory space)
- Spatial position (unique) – ubiquitous (no unique position)
- Spatial locality (surrounding objects) – referential locality (object references, links)

We developed this framework further by adding a fifth dimension *interaction alphabet* and specified these dimensions into more concrete lists of key advantages of physical and digital/virtual objects.

The following lists are intended to direct the designer's focus of attention to beneficial aspects of using digital and physical objects that otherwise go unnoticed because we take them for granted or focus too much on the commonalities of physical and digital interaction. Applying the lists allows assigning functions, e.g. from a requirements list to either the digital or physical realm during the design process.

Physical Matter – Binary Substance

Physical objects consist of real matter (atoms) while digital objects are made of bits. That has immediate consequences for being directly manipulable and whether users can apply their real world knowledge to the interaction. For instance, the natural laws of physics apply to physical objects, whereas the design of virtual objects may or may not obey these laws.

We propose that the Physical is better at:

P11. Intrinsic mechanical properties of physical object (e.g. shape) are easy to perceive and manipulate by the user.

P12. Physical objects are easy to grasp (both mentally and physically selected at the same time).

P13. Physical objects provide instant passive haptic feedback.

P14. Physical objects are unique.

P15. Physical objects need no operating system to function.

P16. Physical objects are robust against adverse environmental conditions.

Digital is better at:

D11. Intrinsic visual properties of digital objects (e.g. texture, color, label, visual shape) are easy to manipulate by the digital system.

D12. Digital objects can be easily processed by digital algorithms.

D13. Digital objects can be created from nothing and can be created as copies of other digital objects.

D14. Digital objects can be saved easily, reset to their initial state, and deleted.

D15. Constraints on the handling of digital objects can be easily set.

D16. Digital objects easily allow abstraction and their specification can be (temporarily) incomplete.

Spatial Extent – Non-Void Extent

Thus dimension concerns the spatial presence of physical objects in their "natural environment" compared to virtual objects that consist of invisible bits.

The spatial extent of virtual objects is mediated by technology. Their visibility depends on display size, their complexity on the size of physical storage devices.

Physical is better at:

P21. Physical objects are immediately perceivable (i.e. without technical equipment) by the user.

P22. Users can apply their sensorimotor skills to the manipulation of physical objects.

P23. Adding complexity to physical objects, e.g. adding details and textures, does not increase the required storage space.

Digital is better at:

D21. Digital objects cause only minimal costs for maintenance and storage.

D22. Digital objects require virtually no storage space, i.e. storage space does not depend on the geometric size (but on the complexity) of digital objects.

D23. The behavior of digital objects is not constrained physically.

Spatial Position – Ubiquitous
While physical objects always occupy a unique space that cannot be occupied by other physical objects, digital objects can be omnipresent when distributed across digital networks. The different degrees of spatial presence of physical and digital objects affect how users can interact with these.

Physical is better at:

P31. Extrinsic mechanical properties of physical objects (e.g. position, orientation) are easy to manipulate.

P32. When interacting with physical objects, action and perception space are united and perfectly aligned.

P33. The global reference frame in the physical space is the same for all users.

P34. Physical objects afford parallel space multiplexed control, i.e. physical objects are accessible at the same time.

P35. Physical objects are inherently three-dimensional. There is no extra effort required for constructing three-dimensional representations.

Digital is better at:

D31. Digital objects can be easily sent to remote locations (e.g. via digital networks)

D32. Synchronizing across remote locations allows for distributed manipulation of the same digital object (e.g. joint editing of documents in shared web-based word processors)

Spatial Locality – Referential Locality
The position and arrangement of physical objects affect the meaning an object assumes in the interaction. The context of digital objects is defined by their links to other digital objects. Spatial locality is less important for digital objects than for physical objects.

Physical is better at:

P41. Physical constraints may encode semantics (e.g. you must unlock a door before you can enter the room).

P42. Users can easily arrange objects in order to encode meaning (e.g. inserting a sheet into a folder).

The in-box example

This example describes a possible use of PIBA-DIBA lists in interface design. The in-box is part of a business app-lication described in [4]. Its aim is to collect invoices, which are represented as physical balls. Physical balls were used, because they are easy to grasp both physically and mentally (P12). As they are also unique (P14), the user can focus his or her attention onto a particular invoice by taking a ball out of the bowl and open it to access the invoice's content on a screen. Invoices are pre-filtered into new, returned and urgent invoices. The status of each invoice is indicated by colored LEDs inside the balls. The colors can be digitally re-assigned, so that new or urgent messages can digitally "bubble" from the bottom to the top of the ball stack without the need of physically re-arranging the balls (D11, D12). In order to support the user to find particular invoices, we included a digital search field (D12) underneath the bowl into which search keywords can be entered. After typing a keyword, matching invoices are indicated by blinking and 'bubble' to the top for easy access by the user.

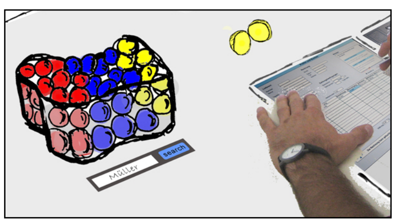

Figure 2. Example: in-box bowl (left) with invoice balls [4].

Digital is better at:

D41. Digital objects can easily create complex hierarchical or network structures by means of digital references.

Analog Interaction Alphabet – Digital Interaction Alphabet

The manipulation of physical objects generates continuous analog data about their position, shape, temperature and so on. If a computer rapidly processes this data, a smooth and productive interaction may ensue. When using virtual objects, analog manipulation may be more cumbersome but discrete manipulation may be very efficient.

Physical is better at:

P51. Users are capable of generating a lot of analogue information fast by moving their body (gestures) or manipulating physical tools.

Digital is better at:

D51. Digital systems offer means to easily enter and display discrete numbers, signs and words.

Using PIBA-DIBA

PIBA-DIBA lists might help to combine the two worlds of product design and software engineering. Product designers are typically involved in building physical artifacts (even if they are at first simulated in a CAD program). Software engineers are involved in building digital artifacts (even if they use physical interaction devices to achieve this). Both are experts in their domains and can achieve marvelous things by programming bits or assembling atoms. They achieve great mastery in their respective domains, but can be heavily biased (because of their knowledge and experience) by seeing only the PIBA (product designer) or DIBA (software engineer) aspects of the world.

Enter the interaction designer, who might be grown up in one of these domains or is half an expert in both. PIBA-DIBA lists may help in both cases. In particular they might be helpful

- in creating complete new designs where the physical and the digital are blended to achieve new forms of interaction, e.g. the hybrid tangible-digital touchtable described in [4] (Figure 2). PIBA-DIBA lists sensitize the designer for the consequences and ramifications of particular design decisions and also provide arguments for defending design decisions. They may also serve to systematically access the product's costs (e.g. space, storage, energy).
- in redesigning existing applications. An interaction designer can use PIBA-DIBA lists to analyze the functionality of an application and to (re-)allocate functions based on this analysis.
- in evaluating design ideas and designs. The lists may help to foresee the consequences of different design decisions that vary on the continuum between pure physical interaction and pure virtual interaction.
- in designing hybrid prototypes during product development to decide which parts of a prototype should be physically or digitally implemented.
- in teaching and education, sensitizing students for different aspects of PIBA and DIBA and enable them to make better and informed design decisions when creating blended interactions.

Although PIBA-DIBA lists are promising, a number of questions are still open: Are PIBA-DIBA lists in its present form useful enough for designers? How can we enhance them by providing useful examples? Would a design FAQ (e.g. on typical design problems and their solutions) based on the PIBA-DIBA assumptions be a better way to support designers? How much "methodology" needs to be created around the lists to create a meaningful workflow in the design of blended interaction between the physical and the virtual?

Outlook

While this paper gives an overview of the PIBA and DIBA principles, more detail is available that supports the single items in the list, but for which the space is not available here. In designing blended interaction these principles need to be weighed against each other and many trade-offs need to be regarded to arrive at an acceptable blend depending on the particular contexts of design and use.

While much of the principles on the PIBA side reflect advantages over traditional graphical user interfaces, recent developments of touch tables and projected interactive surfaces show that the digital "catches up". Previous advantages of the physical, e.g. the unity of action and perception space (P32), can be to a high degree of similarity achieved using digital objects (at least when they are flat). The PIBA-DIBA lists will need to be adapted over time as current developments indicate that it is the relative advantages of the physical that get more and more colonized by the capabilities of the digital. We will need to keep the lists in synch with technological development and this also means to incorporate further research pitting digital interaction against tangible interaction. In the end, however, we believe that a set of irreplaceable physical advantages will remain.

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