A Design Framework for Designing Tangible Interaction for Collaborative Use

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ABSTRACT
This paper describes a framework (under progress) for designing tangible interaction for collaborative use. Four design aspects/themes should be carefully exploited, if one wants to design a tangible interaction system intended for collaborative use: space and spaciality, tangible manipulation, embodied facilitation and representations and their expressiveness.

Categories and Subject Descriptors
H.5.m [**Information Interfaces and Presentation**]

General Terms
Design, Human Factors,.

Keywords
Tangible User Interfaces, Tangible Interaction, Design, .

1. INTRODUCTION
Tangible User Interfaces (short: TUIs) have become a hot topic in HCI. Until quite recently research was mostly technology-driven, focusing on the development of new systems. A change in focus can be detected from the special issue of Personal & Ubiquitous Computing on "tangible interfaces in perspective". Yet there still is a lack of theory, why "tangible interaction" works and what exactly is important to it [5]. And although cooperation support might be the most important generic feature offered by TUIs, this issue has attracted even less attention. Often people seem to assume that cooperation-specific advantages of physical environments are simply inherited by tangible interfaces. But a union of advantages from physical and digital worlds does not come automatically. We should know which properties of physical environments to maintain or explicitly exploit. Otherwise we risk destroying the resources relied upon in collaboration and diminishing positive effects of co-presence of human actors.

In my PhD thesis [10] I assembled findings from CSCW, work studies, communication research and design disciplines regarding social effects of physical, manipulable 3D media, identifying several lines of reasoning arguing for positive effects of TUIs on collaboration. Part of this project have also been empirical studies of cooperative situations supported by tangible media and a redesign study of a TUI. Ongoing work consists of distilling a design framework from the thesis results while broadening its scope to tangible interaction. This framework is introduced in the remainder of this paper.

Tangible interaction encompasses a much broader scope of systems or interfaces, which are not restricted to controlling *digital data* via manipulation of tangible objects (one can control real devices as well) and to the placement and relocation of tokens, what has been criticized as an imitation of interaction methods from the screen and neglecting the richness of embodied action [2, 4]. Therefore it seemed productive to address this larger design space, which also yields a higher number of systems to consider, leaving the somewhat artificial confines of any definition of TUIs behind.

1.1 Designing for collaboration
Some argumentation may be necessary about why to consider collaborative use. Many researchers agree that TUIs are especially suited to support collocated collaboration and report productive, enjoyable group processes. The number of TUI-systems aimed at collaborative scenarios – often design or group learning situations – documents this belief. Research is also acknowledging that social interaction is an inherent and important part of everyday life and of getting work done. E.g. museum visitors often come in groups and group interaction (also with strangers) plays an important role in the visit experience [3,8]. In work situations implicit communication and coordination, both co-present and distributed in time and space, can be found even in at first sight seemingly individual work.

Designing FOR cooperation is analogue with the understanding within interaction design that one cannot design an experience, only for it – one can create opportunities for experience. Similarly we cannot force people to cooperate, but we can induce it and create a „force field" encouraging collaboration. The framework presented here aims to help in creating such "force fields" by offering "design sensitities" [3] and some (soft) guidelines.

1.2 Tangible Interaction

Albeit refraining from a strict definition, we do need some shared understanding of what is meant with tangible interaction. In literature one can find different characterizations of tangible interfaces and of tangible interaction in the broader sense:

- Physical representation & manipulation of digital data [14], respectively interactive couplings of representational physical artefacts with computationally mediated digital information [9]
- Input by physical manipulation with hands, this being sensed, followed by system feedback. The more embodiment (spatial ties of in/output) and metaphor used in shape or movement, the more tangible [7]
- Bodily interaction with physical (graspable) objects [4]
- A combination of real space and real objects with virtual displays ([1] on Interactivating Space)
- Interactive systems, physically embedded within real spaces, which offer opportunities for interacting with tangible devices, and so trigger display of digital content or reactive behaviors ([3] on interactive spaces)

These do match nicely with my framework, although the frameworks aspects were originally developed in a different way (combining results from literature analysis, theory review and own empirical work).

2. THE FRAMEWORK

2.1 The four aspects / themes

Tangible Interaction Systems for collaborative use should carefully exploit

- Tangible Manipulation
- Space and Spatiality
- Embodied Facilitation
- Representations and their Expressiveness

These aspects each again consist of three to four more specific aspects. These aspects lead to a varying number of concrete guidelines. Within the scope of this paper, only a selection can be presented. First I will explain the four themes. References to the characterizations of tangible interaction are written in italics.

2.1.1 Tangible Manipulation

Tangible interaction is bodily interaction with physical (tangible) objects/devices. Input is done by physical manipulation.

This is more than using only physical props within Virtual Reality worlds or using mouse & keyboard. It is also more than simulated haptic feedback. Tangible interaction is direct manipulation of physical objects. These physical objects ARE the interface (and not just an intermediary tool) and ARE interaction objects.

In addition tangible interaction is about the kind of action and interaction taking place – it is bodily interaction, using the hands in varied ways and often interacting with the entire body - and also on the reaction of the objects.

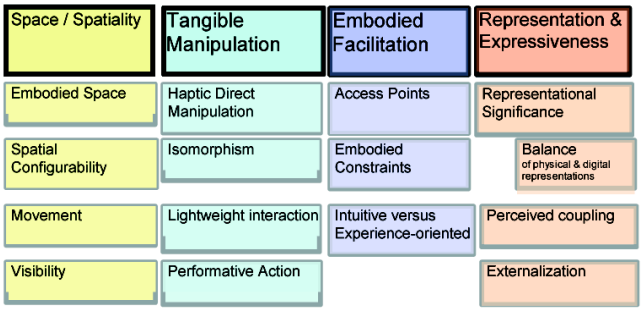

Figure 1. The complete framework with subthemes. (Representational significance and Balance are interconnected topics, handled as one subtheme)

2.1.2 Space and Spatiality

Tangible interaction systems are physically embedded in real space and combine real space with virtual displays.

Real space is 3D. It is inhabited, lived space (not abstract coordinates). Phenomenology talks of situated space, which receives orientation from an embodied here. "Situated space" further means that every room is marked by its atmosphere, the previous usage experience and its surrounding context. Situated space resembles the notion of places [3].

"People and physical space are made of the same stuff, but people and virtual space are not" [13, p.308]. Humans are spatial beings. Our perception is tightly coupled with action and movement. The body is a reference point for perception and thinking.

Space also offers a multitude of qualities or resources, like distance between objects, size, closure and openness, the ability to be filled with material entities, allowing movement and so on.

2.1.3 Embodied Facilitation

The space of the system is both a literal one (*tangible interaction systems being physically embedded in real space*) and metaphorical (the system space). Both are spaces for interacting in, allowing some movements and prohibiting or hindering others. We can interpret systems as spaces or structures to act and move in, thereby determining usage options and behavior patterns. They enforce social structures and direct user behavior.

Sometimes we stumble upon unintended side effects of design regarding social interaction, e.g. not sharing information, reduced awareness etc. This theme proposes to utilize these phenomena by intent. One can learn from didactics and facilitation methods how structure, both physical and procedural, can be shaped to support and direct group processes. This starts with arrangement of rooms and seating, provision of work materials, and goes on to deliberate adoption of game-like interaction rules. Both interaction design and didactics/facilitation can be interpreted as designing spaces for interaction and experience [12].

With Tangible Interaction Systems structure is not only in software, but also physical. They can truly embody facilitation methods. The way we can read and interact with representations is part of this structure.

2.1.4 Representations and their Expressiveness

Tangible Interaction is about physical representation of data.

Tangible objects stand in for - respectively represent - digital functions and data, or they represent other physical objects (and interact with them), or they simply stand in for themselves (with tangible appliances this can be the case). Often there are hybrid ensembles (or collections) of physical and digital (but perceptible) objects, each with different (representational) qualities.

Representations communicate to us; they have expression. In interaction we „read“ and interpret representations. In interaction we act on, modify and create representations, permanent and fluent ones.

3. Selected Sub-Themes

Figure 1 shows the complete framework with the subthemes. Within this paper and due to the work in progress nature of the framework only a few themes and resulting guidelines can be presented in detail. I chose giving different details on these, with some only presenting the subtheme and giving the guidelines, and explaining a selected few with short examples.

3.1 Tangible Manipulation: Haptic Direct Manipulation

Guidelines around haptic direct manipulation suggest to

- Allow users to grab, feel & move the “most important stuff”
- Make tangible interaction the dominant mode of interaction
- Be pragmatic, usability goes first (no dogmatism about haptic directness)

3.2 Tangible Manipulation: Lightweight interaction

Lightweight interaction means to allow “conversation with the material”. Users should be able to express and to test e.g. design ideas quickly, without cognitive overhead. This encourages participation and gives everyone similar chances. Guidelines supporting this are:

- Give constant, legible feedback
- Allow small iterative steps

3.3 Space and Spatiality: Embodied Space

We encounter objects and people in space. They have material presence (and demand our attention) - we meet them face to face, feel their aura and resonate with them [15]. Concrete space is always situated: we experience and create places [3]. This implies multisensory experiences, also in the embodied sense that space always surrounds us. Social effects of sharing space are intimacy, social nearness and a higher tendency to cooperate. Being in the same place is a reciprocal situation where seeing implies being seen. This creates both vulnerability and trust [15].

Guidelines around the theme of embodied space suggest to

- Enable co-presence of people & objects
- Exploit the relation of the human body to space (embeddedness, distance, left-right back-forth, big-small, enclosed-open)
- Turn space into places

3.4 Space and Spatiality: Movement

There is currently only one specific guideline

- Support bodily interaction

Bodily interaction is experienced as *enlivening*. It heightens the inner activity level, stimulates mental energy, creates mental-bodily engagement. Bodily interaction is *expressive*. It is part of expert skill, and also is a means of personal self-expression. Bodily interaction is highly *performative* and often a part of implicit coordination with other people. Bodily interaction is *observable*, fostering group awareness and attracting attention.

A bigger interaction space enforces more & larger movement and thus intensifies interaction. It also encourages more expressive gesture. Movement leads to bodily appropriation of space (taking ownership). The dynamics of group discussion often can be read from bodily interaction rhythm (see e.g. [6]).

Figure 2. Visitors at a city festival dancing on the clavier within the nightly “Sensoric Garden” installation

Figure 2 shows the clavier path, one installation from the “Sensoric Garden”. This was the result of a one-year student project, being an ensemble of interactive installations installed in a public park during a festival in Bremen and open during night hours [12]. Walking along this path (thereby interrupting light sensors) triggered colored spotlights where one walked and different drums and beats.

Here the expressive & performative aspects of interaction are salient. This is part of the fun of interaction. People try out different things, walking back and forth, using their umbrellas to trigger light sensors, jumping and dancing. We could observe people dancing for extended periods of time and dancing in groups. The picture demonstrates that it also seems to be fun to interact as a group. As the light sensors are located directly beneath corresponding spotlights and the designers had taped stripes on the floor to highlight the clavier analogy, it was intuitive to understand general concept. Yet for a good performance practice or skill is needed.

In the assessment of two different versions of the EDC, a system for participatory urban planning relying on an augmented game board, I also found movement to be a crucial element [6]. The different size of the system versions had marked effects on group behavior. With the larger system we observed large gestures, people taking ownership both bodily and mentally and a very lively group. The group using the smaller system used only short, tiny gestures and behaved almost timid and quiet, not appropriating the system space. This is visible in posture. Whereas the first group often leaned out wide over the system, the

second tended to lean back and to use self-blocking postures (elbow on table and chin leaned upon while drawing).

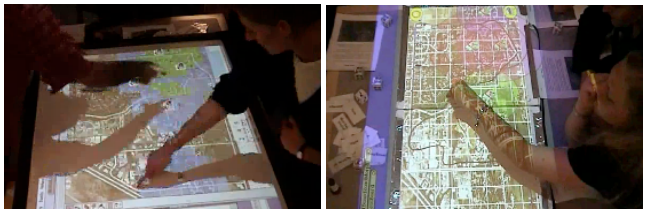

Figure 3. Comparing movement and posture of user groups at two system versions of different size [6]

A big interaction space necessitates big movements. In this study we could observe how bodily interaction seemed to trigger engagement and mental movement. The visible movement (on the video of the sessions) gives a reliable indicator for the discussion intensity and imagination taking place, while quietness is linked to phases of reflection & abstraction. Big movements also enhance expressiveness (gestures). In the EDC study we found gestures to be important for building a shared mental image. These big movements and gestures also were important in fostering taking ownership of system space.

3.5 Space and Spatiality: Visibility

Central guideline here is:

- Ensure visibility of 1) objects 2) actions and 3) effects

Visibility makes actions observable and improves legibility. It contributes to account-ability [13]. Because of the implicit force to be able to explain publicly visible actions, people tend to reflect more what they do. Seeing actions while they are being done and seeing prepraratory movement aids anticipation and improves (peripheral) awareness, supporting coordination. Seeing an action and observing the effect also enables learning by observation. Reciprocity (seeing and being seen) is important for social interaction. Visibility of objects provides focus and shared reference points. It calls for attention.

In the EDC evaluation it was salient how people would always talk and explain when they were sketching a solution idea. The drawings gave visible traces of actions, while gestures served as non-permanent, slowly fading memory help. Without visibility of emerging ideas (one system version had no sketching facility), the shared mental image suffered, resulting in insecurity and less thorough discussion of alternative solutions. Yet both system versions effectively served as a focus for discussion, creating a shared (bodily and mental) orientation.

3.6 Embodied Facilitation: Access Points

Access points refers to the options people have to access and actively manipulate the system. Access is an issue of power, highly influencing group dynamics. Guidelines are:

- Give multiple points of interaction
- Give equal access and no privileges
- Implicitly produce a shared transaction space, that is a space where the participants action and attention areas overlap (usually the forefront of bodies)
- Allow for simultaneous action

In assessing the EDC [6] we found that privileged access of facilitators to system functionality in the facilitated participatory session affected the power play. Changing the system to a setup, where crucial system function could be accessed from the table (where the group was sitting) established equality and enabled everybody to take over system control.

4. ACKNOWLEDGMENTS

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