Physicality in Tangible Interaction: Bodies and the World

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ABSTRACT
What is the role of physicality in the type of interfaces and/or interaction styles that is being referred to as 'tangible interaction'? It refers to the physicality of the user's body and the physical world. This position paper gives a short introduction into 'tangible interaction', denoting systems relying on embodied interaction, tangible manipulation, physical representation of data, and embeddedness in real space. It then introduces a framework that contributes to understanding the (social) user experience of tangible interaction (as well as to designing these), proposing four themes and a set of related concepts, and discusses the roles of physicality in this framework.

INTRODUCTION
Tangible User Interfaces (TUIs) and Tangible Interaction are terms increasingly gaining currency in HCI. Through embedding computing in the everyday environment and supporting intuitive use these approaches [5, 7, 9, 28] share goals with other novel approaches to HCI. Design here requires not just designing the digital but also the physical, as well as designing new types of interaction. There is still a need for conceptual frameworks, that unpack why 'tangible interaction' works so well for users [8], unpacking user experience aspects, and offering principled approaches for research and design of these new hybrid environments.

Over the last two years I have developed a framework, contributing to filling this gap [15, 16, 17]. It offers four 'themes' or perspectives on tangible interaction, highlighting different aspects of the user experience and interaction. These build upon results from numerous studies (researched from the literature) on human interaction within physical environments and with physical objects, underpinned with theoretic (or philosophic) argumentation lines from e.g. phenomenology, distributed cognition etc. Themes are explicated with 'concepts', which summarize single aspects or arguments. At a more detailed level, which is still in development, concepts are translated into design guidelines (or rather: inspiring and thought-provoking suggestions – they are meant to be selected as adequate and interpreted). The framework focuses on how tangible interaction supports social interaction, but also addresses the overall interaction experience. The question I'll focus on in this position paper (which has gotten a rather quick sketch in need to be outlined in more detail and care…) is:

What is the role of physicality in the type of interfaces and/or interaction styles that is being referred to as 'tangible interaction'?

The position I'm taking here is that it refers to the physicality of the user's body and the physical world. As written earlier, my framework contributes to the larger research agenda of Embodied Interaction [8, 22, 28]. With his book on Embodied Interaction, Dourish [8] gave the most notable push towards a theory of tangible interaction and of its interaction experience. Yet when he emphasizes how social action is embedded in settings, he focuses on social construction of meaning. Physicality is a central aspect of Embodied Interaction, although often ignored. Even when Dourish talks about embodied interaction, it seldom becomes clear what it means to be embodied – the human body is strangely missing, as well as the materiality of the world we interact with and live in.

A BROAD VIEW ON TANGIBLE INTERACTION
Increasingly, computing is moving beyond the desktop and 'intelligent' devices spread into all fields of life and work. As argued in [16, 17], we chose to use 'tangible interaction' as an umbrella term, drawing together several fields of research and disciplinary communities. This deliberately broad view encompasses a broad scope of systems relying on embodied interaction, body movement as interaction means, tangible manipulation and physical embodiment of data, being embedded in real space and digitally augmenting physical space. It covers approaches from HCI, computing, product design and interactive arts. From the characterizations found in literature, we can distinguish three views:

- *Data-centered view*: [8, 14, 28] define 'tangible user interfaces' as utilizing physical representation and manipulation of digital data, offering interactive couplings of physical artifacts with "computationally mediated digital information" [14]. This characterization of TUIs is dominant in HCI publications. Conceptual research from HCI and computer science tends to explores types of coupling and representations [13, 28].
- *Expressive-Movement-centered view:* An emerging 'school' in product/industrial design aims to go beyond form and appearance and to design *interaction*. This view emphasizes bodily interaction with objects, exploiting the "sensory richness and action potential of physical objects", so that "meaning is created in the interaction" [7]. Design takes account of embodied skills, focuses on expressive movement and 'rich' interaction with 'strong specific' products tailored to a domain [5, 18]. The design community prefers the term 'tangible interaction'.

- *Space-centered view:* Interactive arts and architecture increasingly talk about 'interactive spaces'. These rely on embedding systems physically in real spaces, combining real space and real objects with digital displays or sound installations, [4, 6, 24], integrating tangible devices to "trigger display of digital content or reactive behaviors" [6]. Full-body interaction and use of the body as interaction device or display are typical for this approach.

Tangible interaction, as we understand it, encompasses a broad scope of systems, building upon and synthesizing these approaches from different disciplinary backgrounds. This approach includes tangible appliances or remote control of the real world [18]. It focuses on designing the interaction itself (instead of the interface) and exploiting the richness of bodily movement [5]. Interaction with 'interactive spaces' by walking on sensorized floors or moving in space [4, 24] further extends our perspective, the body itself being used as input 'device'. Taking this broad view, we can address this larger design space, interpreting these views as emphasizing different facets.

A FRAMEWORK ON TANGIBLE INTERACTION

Theme: Tangible Manipulation

Tangible Manipulation refers to the reliance on material representations with distinct tactile qualities that is typical for tangible interaction. Tangible Manipulation is bodily interaction with physical objects. These objects are coupled with computational resources [28] to control computation. The main concepts, colloquially phrased, are:

Haptic Direct Manipulation: Can users grab, feel and move 'the important elements'?

Lightweight Interaction: Can users proceed in small, experimental steps? Is there rapid feedback during interacting?

Isomorph Effects: How easy is it to understand the relation between actions and their effects? Does the system provide powerful representations that transform the problem?

Theme: Spatial Interaction

Spatial Interaction refers to the fact that tangible interaction is embedded in real space and interaction therefore occurring by movement in space. The interfaces take up space and they are situated in places. Interaction with spatial installations or interactive spaces can be interpreted as a form of tangible interaction that is not restricted to moving objects in space, but relies on moving one's body. The main concepts for Spatial Interaction are:

Inhabited Space: Do people and objects meet? Is it a meaningful place?

Configurable Materials: Does shifting stuff (or your own body) around have meaning? Can we configure the space at all and appropriate it by doing so?

Non-fragmented Visibility: Can everybody see what's happening and follow the visual references?

Full-Body Interaction: Can you use your whole body?

Performative Action: Can you communicate something through your body movement while doing what you do?

Theme: Embodied Facilitation

Embodied Facilitation highlights how the configuration of material objects and space affects and directs emerging group behavior. We literally move in physical space and metaphorically in software space. Tangible interaction embodies structure and thereby styles, methods and means of facilitation. We can learn from facilitation methods how to shape physical and procedural structure so as to support and subtly direct group processes (for details see [16]). The main concepts are:

Embodied Constraints: Does the physical set-up lead users to collaborate by subtly constraining their behavior?

Multiple Access Points: Can all users see what's going on and get their hands on the central objects of interest?

Tailored Representation: Does the representation build on users' experience? Does it connect with their experience and skills and invite them into interaction?

Theme: Expressive Representation

Expressive Representation focuses on the material and digital representations employed by tangible interaction systems, their expressiveness and legibility. Often hybrid representations combine material and digital elements, each with distinct representational qualities, In interaction we 'read' and interpret representations, act on and modify them. Here the main concepts are:

Representational significance: Are representations meaningful and have long-lasting importance? Are physcial and digital representations of the same strength and salience?

Externalization: Can users think and talk with or through objects, using them as props to act with? Do they give discussions a focus and provide a record of decisions?

Perceived Coupling: Is there a clear link between what you do and what happens? Are physical and digital representations seemingly naturally coupled?

On the Framework

The themes and concepts summarize our experiences from system assessments and reflections on design, in combination with a literature review on the use of material artifacts in social situations, distilling a set of social affordances [15], synthesizing previous works of other researchers and concepts developed by us.

Tangible Manipulation is the most specific theme, relying on the use of material objects. It applies best to systems usually referred to as tangible interfaces [28] and tangible appliances. *Spatial Interaction* and *Embodied Facilitation* provide insights relevant for the broader research area of

'embodied interaction' [8], where movement in space and physical configuration of computing resources are central characteristic, e.g. mobile interaction and ubiquitous computing. *Expressive representation*, insofar as it concerns tangible representations, is specific to tangible interaction, but can be generalized to mixed reality representations.

FINDING PHYSICALITY

Physicality turns up in all four themes, and usually concerns the interrelation of physical bodies (users) and objects respectively the physical world in general.

In *Tangible Manipulation* physical interaction is central. Our tactile sense is in fact multimodal, as on touching something a whole battery of sensors and nerves fires, feeling resistance, temperature, surface quality, softness, weight and more. The word tangibility itself refers to the specific double-side characteristic of the sense of touch, that one cannot touch something without being touched oneself, being active and passive at once [2, 19]. Touch is our only active sense, which is not purely receptive. The tendency of western philosophy to take vision as our primary or highest sense, has led to looking down at touch (similarly on smell) as a lower sense, claiming that it does not allow for abstraction and detachment. Yet perhaps: "Hands are underrated because they are poorly understood" [20] (see also the grandiose voyage into the anthropology, psychology, and mechanics of human hands from Wilson [30]).

From an anthropological viewpoint (or phenomenological) [2, 11, 19], the sense of touch reminds us that we are embodied beings and forms the permeable border between outside and inside, enabling our primary experience of the world. Touch reassures us of our existence – e.g. people who have lost their sense of touch feel like dissolving, and mental-cognitive development and health of children depends on human touch. But, because touching something always brings us in close (and potentially dangerous) encounter, it is deeply emotional – the aesthetics of touching something have immediate emotional responses.

With the theme of *Expressive Representation*, physicality is the least salient. Still, physicality can be considered as one means of expressiveness – materiality provides an endless array of properties for an object [25], such that e.g. the weight of a tangible object being used suddenly influences how it is used and interpreted (something very surprising for system developers 'grown up' with computers, who are used to think of objects as only referentially representational). The physical properties of external representations are read and reacted upon just like their symbolic ones.

How does *Spatial Interaction* relate to physicality? We may think of space as abstract and non-physical. Yet lived space in fact is physical. We cannot escape spatiality - we are spatial beings; we live and meet each other in space. The graspable objects of TUIs exist in this "real" space that we live in. "People and physical space are made of the same stuff, but people and virtual space are not", as Toni Roberson notes [23, p.308]. Physical objects are experienced as part of real space, which is not abstract, geometrical space, but a habitat filled with life [29]. Phenomenology talks of situated space, which receives orientation from an embodied HERE [21, 29]. Because we are spatial beings, our body is the central reference point for perception (defining e.g. what is HERE). Movement and perception are tightly coupled and we interpret spatial qualities (or e.g. the positioning of other objects) in relation to our own body. Spatial relations therefore have psychological meaning and effect our perception of a setting. Real space is always *inhabited* and situated, becoming *place* [6, 12]. By inhabiting space, we appropriate it, interpret it and give it meaning.

Physical company of people and objects makes their presence noticeable and vivid. We *encounter* objects and people in space. They have material/physical presence (demanding our attention) - we meet them face to face, feel their (potential) resistance to our actions. Some philosophers, in particularly those in phenomenology, talk of people emitting an atmosphere like an aura, making us resonate [3, 29]. Social effects of *sharing space* are intimacy, social nearness and a higher tendency to cooperate. When sharing physical space we enter a *reciprocal situation* where seeing implies being seen [22, 23]. This creates both vulnerability and trust [29]. Visibility furthermore contributes to account-ability [22], because it implicitly requires vindication of public action.

One of the concepts explicating spatial interaction is performative action. In the foreground of performativity is the users' body as the means with which one represents oneself. Movement expressiveness [18] and unescapable individuality are relevant here. Our body is the thing we cannot escape from (or only partly, with avatars and face lifts). The physical world takes part in this performance, as the stage acted upon, in form of props that take a role in the performance, in setting the constraints for acting.

In *Embodied Facilitation*, again, physicality implicitly is central, by moderating the interaction of physical bodies in physical configurations of space and objects. With tangible interaction we act (or move) in physical space and in system space (software). Software defines virtual structure, determining interaction flow. Physical space prescribes physical structure. Both types of structure facilitate, prohibit and hinder some actions, allow, direct, and limit behavior, determining usage options and behavior patterns. E.g. the size of a table in combination with our bodily size moderate how much of the table we can reach and touch. The number of pens provided to a group determines whether these need to be shared for an activity, and even the size of pens may make a difference in terms of how easily they can be shared or hidden for private use. If we could easily overcome the constraints proposed by these

physical configurations, they would be powerless and not perform the role of embodied facilitation. We even react to such signs in virtual worlds (e.g. people trying to avoid running into other avatars or walking around the virtual gap in the floor instead of across it) as we still tend to interpret them in relation to our physical body.

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