Let's Get Physical
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The boundaries between "the digital" and our everyday physical world are dissolving as we develop more physical ways of interacting with computing. This forum presents some of the topics discussed in the colorful multidisciplinary field of tangible and embodied interaction.
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The Role of Physicality in Tangible and Embodied Interactions
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Olivia Newton John's popular single "Let's Get Physical" came out in the early 1980s, at about the same time that HCI researchers were bringing the physical world back into computing by inventing new interfaces that let you talk, move, touch, and gesture with them [1]. Within HCI, Hiroshi Ishii and his tangible media group were among the first to explore the merging of form and computation in the late 1990s. They were looking for ways to bring the richness of physical interaction into the sterile world of digital information. Technological advancements and a better understanding of the psychological and social aspects of HCI have led to a recent explosion of post-WIMP interaction styles, in which many novel input devices draw on user skills in interacting with the real world. Artists and interaction designers are embracing these possibilities, especially since the availability of rapid prototyping toolkits like Arduino. Physical computing has emerged as a culture of tinkering and making interactive things, which involves fast prototyping with electronics, reusing and scavenging existing technology. At the same time, "intelligent" devices have spread into all fields of life and work. This has required product designers to design complex, digitally controlled behavior, which has no inherent relationship to product form, and to explore intelligent, adaptive form [2]. In reverse the notion of a tangible user interface [3] required HCI researchers to consider physical form factors, choice of materials, and so on.

Tangible and embodied interaction (TEI) is now an established field of research and design practice that focuses on the implications and new possibilities for interacting with computational objects within the physical world. It constitutes a deliberately broad view that encompasses a wide scope of systems relying on embodied interaction, body movement, 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, the physical computing tinkering tradition, robotics, and the interactive arts. By providing a shared concern for designers, artists, social scientists, and technologists alike, TEI has become a meeting place of disciplines seeking inspiration and insight, trying to understand what the other might have to offer.

When I started my Ph.D., people would stop in when our lab door was open and ask in disbelief, sometimes mockery, why we were playing with wooden blocks. Our work seemed even more obscure when we explained that we were wearing data gloves to track how we moved blocks and other pieces around. From this tracking data we simultaneously generated an executable digital model, which could then be projected back into the physical space, showing us the outcomes of our design decisions in simulations. Much has changed, fortunately. Whereas in the late 1990s, specialized hardware and expertise were required to build a prototype with comparatively simple functionality and abominable usability, building tangible interfaces is now a standard project assignment in many industrial and interaction design courses. It has become significantly easier to build systems, and with the ACM-sponsored TEI conference, this kind of work has turned into an established field. Yet we still encounter this peculiar mix of envy (*you're allowed to play?*),

skepticism (*is this really research?*) and fascination (*cool stuff!*). The irony is that as a research area, TEI is still young and smallish, yet augmented objects permeate our lives.

TEI investigates an augmented physicality that takes us away from the desktop and searches for other ways of interacting. As we start to embed computing in the everyday environment, this requires designing the digital and physical together. It also requires us to design new types of interaction that enable the user to directly interface with the computer in ways that require fewer intermediaries and that fit better with our innate abilities. In a way, tangible and embodied interaction implements the vision of media-artist and technologist Myron Kruger, who advocated increased physical engagement and direct interaction. While Kruger's 1970s and 1980s installations mostly relied on the recognition of users' silhouettes from video, using these for shadow-play interactions, we now employ a broad spectrum of mechanisms.

Whereas Kruger had to pay for the use of computing resources by the hour, we can now buy an XBox Kinect for around $150. The new genres of computer games supported by Kinect or the Wii fundamentally change the social dynamics of play, reaching new user groups, creating new kinds of computer games (could you imagine doing yoga with a keyboard?), and implicitly change the ways we define and see computing. Numerous open questions relate to how these computerized artifacts (not just those that are games) affect us.

Can they improve learning? How do they change play behavior? Might they help disabled children learn new skills? If we embed computing in the environment, should it be visible or invisible? Can interaction with physical objects support tasks with abstract content and scale to complex problem-solving tasks, or does it prevent us from reflecting? How do we perceive responsive artifacts—will they appear to be alive, and is this good or bad? Is interaction through bodily movement more effective than keyboard and mouse interaction, or do we just trade one kind of repetitive strain syndrome for another? Will the Wii-arm be the next medical condition? What might constitute aesthetics in movement interaction?

So far the field is characterized by exploration, building of design examples, and playful investigation of new technologies. As it matures, so has interest in theory grown. When we started our research in this field in the late 1990s, we began to wonder why the prospect of tangible interfaces enthralled us so much. What was so satisfying about being able to touch and physically manipulate computing by handling some wooden blocks on a table [4]? What had been missing before? Might these blocks be helping us to externalize our thoughts, as embodied and distributed cognition theorists suggest? How do physical affordances help? This in turn led us to more philosophical questions surrounding the notion of embodiment. What does it mean to have a body? And if we can't escape our body, can there be ever be something like non-embodied interaction? Should we base all post-WIMP interfaces on the model of reality-based interaction [5]?

Objects, Bodies, and the World
"Tangible and embodied interaction" provides a broad umbrella description for a research field united through an interest in the role of physicality. There is the physicality of our own bodies, the materiality of objects, the physical world in general, and the physicality of space. We touch and feel objects. Our bodies are living, experiencing, and feeling bodies. Tangible objects and our bodies are embedded in a physical space that we experience and interact in and with.

These physicalities intersect in interaction. Tangible interaction merges physical form and computation, resulting in interactive and responsive form [2]. Through tangible manipulation of objects we experience these [physicalities – *this word was added in the printed version but the phrase was to refer to 'these objects'*] through our senses. The tactile sense is multimodal: Touching something fires a whole battery of sensors and nerves; we feel resistance, temperature, surface quality, softness, weight, and more. The word "tangibility" refers to the peculiar double-side characteristic of the sense of touch—that one cannot touch something without being touched oneself, being at once active and passive [6]. The tendency of Western philosophy to take vision

as our primary or highest sense has led to the demotion of touch (as well as smell) as a lower sense, claiming it does not allow for abstraction and detachment [7]. But from an anthropological and phenomenological viewpoint, the sense of touch reminds us that we are embodied beings [6]. Touch forms the permeable border between outside and inside, enabling primary experience of the world, and reassures us of our existence [8]. But because touching something always means a close (and potentially dangerous) encounter, touch is responsive and dialogic and can be deeply emotional; the aesthetics of touch have immediate emotional responses. Material properties can influence the interaction experience—weight or heft increasing importance, or softness making something more likable—and can be read and interpreted along with visual characteristics, contributing to the meaning of objects. Besides active touch, our body has a wide range of kinaesthetic, tactile, and proprioceptive senses, which until recently have been relatively ignored in discussions of sensory perception but influence our wellbeing. Focusing on lived body experience, we may ask: What is the sensory experience of moving when interacting with this system?

We may think of space as abstract and non-physical, yet lived space is physical. We cannot escape spatiality; we are spatial beings. We live and meet each other in space. The tangible objects in an interface exist in this "real" space that we live in and become part of this space. Big objects may contribute to structuring the space, changing how it is interpreted. Movement and perception are tightly coupled. Since we interpret spatial qualities in relation to our own body, spatial relations attain psychological meaning. A room that we encounter for the first time and know nothing about may have a specific atmosphere and invite a particular kind of usage. Architects and interior designers are experts in designing space to do this. This does not imply that we are physically determined (this rather is like a field of intersecting forces) [9]. Real space is always inhabited and situated, becoming place. Over time, by inhabiting space, we appropriate it, interpret it, and give it further meaning. The relation is bidirectional. People might identify existing physical affordances for new uses of a given place (think of skateboarding and parcours), which then changes its meaning through the new (socially and culturally defined) use.

Ten years ago, Dourish published his seminal book on embodied interaction, which greatly influenced thinking in HCI [10]. Seeing another Ph.D. student carrying this book or displaying it prominently on their bookshelves was like a secret Freemasons sign that triggered discussions ("Did you understand this bit here?"). Dourish highlights how embodied interaction is grounded and situated in everyday practice, constituting a direct and engaged participation in a world that we interact with. Through this engaged interaction, meaning is created, discovered, and shared. Embodied interaction is thus socially and culturally situated. But phenomenologists and ecological psychologists would argue that being situated also means being situated in a body: Your body affects your experience of the world, changing your viewpoint quite literally as well as your experience of the world in terms of what it allows you to do (Husserl's "I can's"). In this sense the physicality of our bodies is tightly linked with our experience of the physicality of our surroundings. Physicality is a central aspect of embodied interaction. We are incarnate, physical beings that live in a physical world. Humans are not abstract cognitive entities (the Cartesian view of cognition); our bodies and active bodily experiences inevitably shape how we perceive, feel, and think. As McCarthy and Wright remind us, user experience is on many levels [11]. Extending their emphasis of felt life, our understanding of embodiment includes the "user experience" of the felt body. This may include both the ergonomics and the experienced aesthetics of movement [12, 13]. In embodied interaction we have to consider the experience of the living human body, as well as the materiality of the world we interact with and live in. This can call us to explicitly design for bodily experience, for the moving and feeling body, and to exploit our bodily intelligence.

A Meeting Place for Disciplines and Approaches
We enjoy breaking away from the screen, devising and experimenting with more physical ways of interacting with computing. The division between computation and traditional materials has become fluid, especially considering electronic paper and fabrics. Tangible interaction design transgresses disciplinary boundaries, requiring "a mashup of skills and methods," as Baskinger and Gross argue [2]. The approaches are diverse, making this a lively, intrinsically

interdisciplinary field where designers and artists tackle engineering challenges and engineers learn about interaction and form design. This makes for a stimulating and dynamic meeting place of disciplines. Artists and designers are looking for engaging means of expression and interaction. For many product designers, TEI may already be a given: Integrated appliances permeate everyday life, and physical interaction has been their daily bread for decades. In a way it is a return to the roots of product design, using complex physical interaction mechanisms instead of merely sticking screens and buttons on devices. We are just rediscovering that physical interaction may increase both usability and enjoyment.

When we think of tangibles beyond small blocks on a table and change scale, we discover architects thinking about reconfigurable spaces and interactive furniture. Hardware tinkerers build new toolkits and solve mechatronic and engineering challenges to overcome the static nature of physical objects. Research on actuated tangibles has us talk to robotics, mechatronics, and material sciences. HCI and ethnographic fieldwork research investigates how these old and new devices and products are being used. In these analyses, the material aspects of interaction become more prevalent as objects can be handled off-screen, moved about, shared, and passed on to collaborators. This extends CSCW research (i.e., workplace studies) to think more of physical-digital resources and objects instead of on-screen digital versus traditional (i.e., paper-based) resources. Maybe at some point the physical-digital distinction stops making sense altogether.

On a more conceptual level the notion of embodiment has become a strong motivation for research. This rediscovery of the body has happened across several disciplines, including philosophy, cognitive science, anthropology, and in product design, which investigates the aesthetics of movement in bodily interaction with products. TEI allows us to explore questions of embodiment through practical experiments.

Interactions, Not Interfaces
When we were setting up the TEI conference, we initially had long discussions about which title to choose. At the time, one of the main questions was whether to use "interface" or "interaction, both indicating a somewhat different perspective and intellectual tradition. While Tangible User Interfaces had become an MIT trademark, designers had begun to use the term "tangible interaction." I had also argued in one of my own papers that the emphasis should be on the design of the interaction not the interface, putting interaction dynamics and qualities into the foreground of attention [14]. Using the word "interaction" further encourages thinking of the tangible system as part of a larger ecology and located in a specific context. We felt that "tangible interaction" would bring together both perspectives and provide more openness, allowing for evolution of the field. The adoption of this umbrella term has supported the development of a larger interdisciplinary research community (the TEI conference series), but as a downside, results in some ambivalence as to where to draw the line between tangible interaction and other areas.

Meanwhile the conference has added "embodied" to the "tangible and embedded" title, reflecting the growing role of movement-based interaction and psychological or philosophical aspects of embodiment. Whole-body interaction is a new trend in HCI and ubiquitous computing as new technologies like the Wii, wireless motion tracking, and image-processing software have greatly increased our capabilities for using body movement as input.

A focus on physical manipulation and movement-based interaction takes Ishii's early credo serious of bringing some of the richness of interaction we have with physical devices back into our interaction with digital content, exploring the many facets of human sensory experience. An interesting development is while tangible interfaces are often portrayed as intuitive and easy to use, the advocates of movement-based interaction stress aesthetics and skill. We are most happy when we feel we perform an activity skillfully and gracefully even if it took us a painfully long time to get to this point. Tangible and embodied interaction can thus be a mindful activity that builds upon the innate intelligence of human bodies.

Epilogue

This forum aims to provide a glimpse of the discussions and approaches in TEI, reflecting the diversity of the field and the field's interest in the role of physicality in interaction. I hope you are looking forward as much as I am to the articles to follow, exploring this rich and diverse field.

Additional historical and introductory literature of note

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D. O'Sullivan and T. Igoe, Physical Computing: Sensing and Controlling the Physical World with Computers. Boston: Muska and Lipman, 2004.

Endnotes

[1] P. Wellner, W. Mackay and R. Gold. Computer-Augmented Environments. Back to the Real World. Communications of the ACM 36 (7), 1993 24–26.

[2] M. Baskinger, and M. Gross. Tangible Interaction = Form + Computing. Interactions 17,1, 2010

[3] H. Ishii and B. Ullmer, "Tangible bits: Towards seamless Interfaces between people, bits and atoms," in Proceedings of CHI97, pp. 234–241, ACM, 1997.

[4] One of my favorite books that starts to answer these questions is F.R. Wilson's The Hand — How Its Use Shapes the Brain, Language, and Human Culture. This starts to construct an argument about the human urge to be active and creative with one's hands.

[5] R. J. K. Jacob, A. Girouard, L. M. Hirshfield, M. S. Horn, O. Shaer, E. T. Solovey, and J. Zigelbaum. Reality-based interaction: A framework for post-WIMP interfaces. Proc. of ACM CHI 2008, pp. 201–210, ACM, 2008.

[6] H. Böhme. Playdoyer für das Niedrige. Der Tastsinn im Gefüge der Sinne. G. Gebauer (ed). Anthropologie. Reclam: Leipzig, germany 1998

[7] Modern day psychology has started to question the assumption that most of our senses are receptive, and begun to study the perception-action relation (enactive perception defines that perception is always active) as well as interrelations between the senses, uncovering e.g. how visual information can override auditory perception (the McGurk effect) and the plasticity of our perceptual system (the rubberhand illusion,) which even allows for sensory substitution or new senses (such as feeling magnetic north via a vibrating belt).

[8] B. Becker. Marking and crossing borders: bodies, touch and contact in cyberspace. Body, Space & Technology. Vol. 03 02 (2003)

[9] In many science areas we find a dispute about determinism, whether it is technological versus social determinism (on the development of technology) or social versus genetic/biologic determination of intelligence and gender roles ("nature or nurture").

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