The Future of Tangible User Interfaces

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ABSTRACT

Tangible user interfaces have a rich history in HCI research ever since their introduction two decades ago. But what are the practical implications, the commercial potential, and the future of this influential paradigm? This panel starts by looking into the importance of tangible interaction and its current role. It will then draw on the expertise of both the panelists and the audience to speculate about its future and new opportunities for the field. The panelists represent a variety of perspectives from both industry and academia, and includes some of the most well-known innovators in the field. The format builds on the CHI 2006 panel *The state of tangible interfaces: projects, studies, and open issues,* which shared some of the same organizers.

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KEYWORDS

Tangible user interfaces; tangible interaction; embodied and embedded interaction; ubiquitous computing

1 INTRODUCTION

The desire to make computers more natural and easy to use lies at the heart of the HCI field. Over its history, we have seen computing move from specialized and hard-to-use mainframes, over desktop workstations, to everyday devices like phones, video games and smart homes. Weiser's notion of *ubiquitous computing* has been realized in many ways; computers are now weaving themselves into the fabric of everyday life. [2]

As computers have become more ubiquitous, the way we interact with computing has developed in different directions. For personal computers, the dominant paradigm remains the GUI (Graphical User Interface), which still is in many ways the same as the WIMP (windows, icons, mice and pointers) developed by researchers at Xerox PARC in the 1970s. For mobile devices, touchscreens have become the dominant form for on-the-go interaction, and are also making inroads to the productivity domain, in particular on ultralight laptops and tablets. For the home, voice interaction has taken great strides recently, especially due to advances in artificial intelligence and data collection, with a number of "smart speakers" available from various manufacturers. In entertainment and training, interest in virtual and augmented reality is seeing a resurgence, although usage still remains largely limited to specialists and enthusiasts.

But even with all these interaction paradigms existing side by side, many in the HCI community would agree that the way we interact with computers is still not ideal. While research has had a great influence on the interaction styles mentioned above, other alternatives have been proposed in addition to those already in the mainstream. In particular, the notion of *tangible user interfaces* (TUI) or *tangible interaction* was introduced by Ishii and Ullmer in 1997. [1] It proposes to allow users to "grasp & manipulate bits in the center of users' attention by coupling the bits with everyday physical objects and architectural surfaces." This notion has been highly influential in the research community, and the 1997 paper alone has to date been cited over 4,700 times. Special issues of prominent journals have been devoted to tangibles, and there is a dedicated annual ACM conference, *Tangible, Embedded and Embodied Interaction* (TEI).

While the academic legacy is obvious, the commercial influence is less clear. In 2010, Gartner's *Emerging Technologies Hype Cycle* listed Tangible User Interfaces at the Technology Trigger stage, with mainstream adoption expected in "more than 10 years", but it has not appeared on the chart since. Several products and interfaces have been launched that incorporate tangible interaction, although industry adoption is not as prominent as the research volume would indicate. One striking example in recent years is Microsoft's *Surface Dial,* which was introduced in 2017. Billed as a "completely new way to interact with technology and create in the most natural, immersive way", the Dial is a re-purposable tangible interface that can be adapted for a variety of functions.

However, compared to other forms of interaction such as touchscreens, the amount of successful tangible interfaces is comparatively small. This could have multiple reasons, including the relatively high cost of producing bespoke tangible devices; the lack of general-purpose interaction paradigms; or even simply not enough marketing to the consumer market.

Does the Dial and other new tangible controller point the way to a new wave of interfaces? Or will the ideas remain mainly in the academic world for the foreseeable future? To answer these questions – and pose entirely new ones – this panel will discuss the present state, future development, and far-reaching implications of tangible user interfaces.

2 CURRENT TRENDS AND PANEL COMPOSITION

In the recent decade, TUI research has been evolving from the Tangible domain into two direction: the Material domain (HMI: Human Material Interaction) and the Mixed Reality domain (XR: Extended Reality). HMI research including programmable and interactive materials, shape-change interfaces, and convergence of biology and chemistry with interaction design. XR research include VR and AR experiences that involve physical interaction with smart objects and smart environments.

The panel composition reflects some of the major research strands in tangible interaction, wearable interaction, human-material interaction, human-biology interaction, blended reality, XR, and advanced 3D printing. Panel members research the future of tangible interaction from a technology innovation perspective, material science perspective, design and human values perspective, and commercial viability.

3 PANEL FORMAT

The panel includes 5 panelists and one moderator, and builds on a previous CHI panel on the topic. [3] The panel will have a minimal time devoted to prepared presentations and strive for a maximum amount of interaction between panelists and audience. Careful moderation will ensure that all views are equally represented.

At the start, the panelists will each be given 2 minutes to introduce themselves and their view on the TUI field, supported by a single slide. After that, the format will be that of discussion between panelists and audience, facilitated by the moderator.

First, in order to set the scene we will briefly discuss what led up to the notion of tangible interfaces, what its role was, and how it impacted the research at the time. Then, we will talk about the current state of TUI, what has been realized of the vision, and what is still to be developed. Following this, the panel will speculate about the future applications and directions of tangible user interfaces – what role it may play and what other paradigms are. This discussion of the future will take up the major portion of the allotted time.

While the panelists represent a wide range of perspectives, we are sure there will be many other experts in attendance in the audience, and we will be keen to encourage their creative participation in ways beyond the standard question-and-answer format. Therefore, to ensure that the audience is kept engaged, throughout the panel, questions will also be asked *directly to the audience.* This is a somewhat experimental feature, where rather having the audience ask us questions, we reverse the roles and ask questions to the them!

4 PERSONAL STATEMENTS (ALPHABETICALLY BY SURNAME)

Rafael "Tico" Ballagas, Senior Research Manager of the Immersive Experiences Lab at HP Labs:

The past has demonstrated the promise of tangible interaction, and the benefits of externalizing cognition into the physical world. In the present tangible interaction is still an active and relevant research topic, but to date has had limited commercial impact. Current notable commercial examples of tangible interaction include the toy industry leveraging physical objects to interact with digital content (e.g. Osmo, Skylanders), and the rise of computer vision and augmented reality interactions with printed materials including photos, documents, and product packaging.

In the future, tangible interaction will become more widespread through the advancement of 3D print technology and smart materials, allowing tangible interactions to scale by simplifying fabrication and reducing the cost of intelligent custom physical interfaces. One emergent capability of these 3D printers is the ability to modulate material properties at the voxel-level; essentially by precisely applying chemical agents to a base material, material properties like elasticity, translucency, color, and even conductivity can be controlled voxel-by-voxel. This capability is potentially transformative, but at the same time disruptive to our current design and engineering practices. We need new approaches and tools to facilitate interactions and "backtalk" around these novel materials with varied and potentially dynamic material properties.

Lars Erik Holmquist, Professor of Innovation at Northumbria University, School of Design:

I believe that rather than just talk about *interfaces,* or even interaction, researchers and practitioners need to consider digital artefacts more holistically. Already, the boundaries between hardware and software are starting to disappear, leading to a new class of *hybrid digital-physical products*. When information is no longer confined to computer screens, it will be meaningless to talk about a division between "system" and "interface", as they are both aspects of the same entity.

This revolution in digital products is already manifest in areas such as the Internet of Things. One way of saying this is that every physical product will have a corresponding "shadow" in the digital world, and this will provide much of its functionality. What the user interacts with is literally only a minute part of the whole picture, the very tip of the iceberg. Yet, a designer will have to pay attention to the whole iceberg, not just the tip that the consumer can see! For instance, a smart thermostat will need to provide obvious hands-on interfaces to control the temperature in a home, while at the same time collect and process sensor data from millions of users to continuously improve and adapt its behaviour. Cars have to be easy to steer with ergonomic controls, while under the hood, software will monitor and optimise their road handling and functions, constantly evolving with new conditions. Even children's toys have to provide a diverting shape to grab onto and play with, while connecting with complex game mechanics and other users that might reside in the same room – or on the other side of the world. The challenge is to design products that reflect the underlying functions based in artificial intelligence and big data, while simultaneously providing a rich and sensual user experience in the here and now.

Hiroshi Ishii, Jerome B. Wiesner Professor of Media Arts and Sciences at the MIT Media Lab:

Tangible User Interfaces (TUI) are moving toward the vision of "Human-Material Interactions" (HMI) to go beyond the current HCI paradigm, by integrating computations with the Programmable Materials. We call those new physical/digital materials "Radical Atoms." In this panel at CHI 2019, I would like to address the challenges waiting for us to break the boundary between physical and virtual worlds, and bring the kinesthesia back to the equation.

Kimikio Ryokai, Associate Professor at the UC Berkeley School of Information and Berkeley Center for New Media: TUI has the potential to connect people in uniquely personal and social ways. Yet, the benefit of TUI has remained, for the most part, within the context of the privileged. I argue that TUI has not reached far enough into our marginalized populations, e.g., homeless people, women and girls, people with disabilities or mental health needs, etc. Today, more than ever, TUI research needs to go beyond the familiar and privileged, and learn from vulnerable populations in order to be inclusive and to make real impact in both technologies and design that can honor even more inherently human qualities.

Haiyan Zhang, Innovation Director at Microsoft Research Cambridge:

Where the industrial revolution introduced standardized education and eventually more opportunities and prosperity for society as a whole, we now see an acceleration of STEM learning to be vital for the long-term future of work. For kids, ever younger, there is more varied knowledge to absorb in the curriculum, more ways to incorporate rational and computational thinking into their everyday play. Here we have the opportunity to revolutionise learning through multi-modal tools, of which Tangible User Interfaces will play an enormous part to bring together visual, tactile, auditory elements into a seamless and natural interface. This physical and digital seamlessly will also create a more inclusive learning environment, where kids of all abilities, whether they might be lacking in sight or hearing, can still tap into learning opportunities and not be left behind in such as a society.

We are on the cusp of a new revolution in the form of Artificial Intelligence, where algorithms and computers will be defined through data and experience. Here we understand the impact of computation decision making will be all-encompassing across our environments, and the opportunities for TUIs abound in realising a world of seamless interactions across our physical objects and world, both in terms of sensing and display.

Oren Zuckerman, Founder and Co-director of the Media Innovation Lab at the Interdisciplinary Center (IDC) Herzliya:

Direct interaction with physical material is key to human development. However, the efficiency and versatility of multi-touch screen-based technologies provide interaction designers with great freedom in design using colors, layouts, and shapes. The fields of Tangible User Interfaces and Material User Interfaces are in great need for new types of materials that can enable similar freedom of design, including shape transformation, control of physical movement, and manipulation of material properties such as stiffness, flexibility, density, conductivity, and temperature. New collaborations are needed between Biologists and Chemists with Designers and HCI researchers to form the design vocabulary for Human Material Interaction.

5 CONCLUSIONS

With a host of competing interaction paradigms continuing to struggle for domination of the digital product world, tangible user interfaces still have a unique potential to offer novel and intuitive interaction, perhaps in particular to non-typical computer users. Yet many challenges remain in making tangible interaction truly useful and commercially viable. With this panel, we will both crystalize the current state of the field and its outlook, and point towards new research and development directions for the future.

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