Physical Computing-Flexible and Shape-Changing Interfaces

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Guest Editors' Introduction

Physical Computing—Flexible and Shape-Changing Interfaces

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In his 1965 article "The Ultimate Display,"[1] Ivan Sutherland envisioned a "computer [that] can control the existence of matter." With recent advances in science and engineering, researchers in human-computer interaction (HCI) have begun to explore this vision. The resulting flexible and shape-changing interfaces aim to leverage malleability as the primary means for interaction. The users can physically deform the interface to provide input, or the interface can self-actuate to provide an additional output channel.

From Vision to Reality

The vision of flexible and shape-changing computers is a promising approach toward Mark Weiser's 1991 vision of ubiquitous computing.[2] By embedding computational capabilities into the physical objects we see, manipulate, and feel, computational systems can "take into account the [physical] human world."[2] Flexibility and shape changes leverage our rich manipulation capabilities and haptic sensations. They directly couple the digital and physical worlds by making the shape of physical objects as dynamic as the shape of their digital counterparts.

This domain of flexible and shape-changing interfaces is still in its early years, and there are many questions yet to be answered. The field requires prototypes that go beyond fragile mechanical implementations. These currently don't exist, as the required materials and construction techniques are still being established, and because HCI labs typically lack the resources to construct such high-resolution, robust devices. This fragility of prototypes means that field studies are few and far between, leaving large gaps in the knowledge of how users would behave and interact with these devices in longitudinal settings. Without this long-term understanding, researchers will struggle to build fundamental theories and models of users' experiences and interaction with shape-changing interfaces. Furthermore, vast arrays of user application areas exist, but the "killer apps" that will drive these interfaces to market are still unknown.

Continued developments in flexible and shape-changing interfaces also rely on the progress of adjacent research fields, such as material science, electrical engineering, and mechanical engineering. HCI researchers will look to these fields to provide knowledge,

tools, and materials for future shape-changing interfaces and interactions. The relative immaturity of this field opens an array of exciting opportunities for research and development, but true innovation will only occur through cross-disciplinary collaboration.

In This Issue

This special issue explores the definition and the origin of the field of flexible and shape-changing interfaces. It further explores the balance between physical and virtual user interfaces, the long-term vision for flexible and shape-changing interfaces, and the biggest challenges in the field. It also addresses potential applications and their diffusion to the general public.

The first submitted article, "Designing Line-Based Shape-Changing Interfaces," comes from Ken Nakagaki at the MIT Media Lab and his collaborators, Sean Follmer, Artem Dementyev, Joseph A. Paradiso, and Hiroshi Ishii. The article illustrates the main challenges around the design, implementation, and potential applications of a line-based shape-changing user interface. LineFORM and ChainFORM, the devices that look like serpentine robots, were composed with linearly connected motors and modules with I/O functionalities. The devices could be used for physical display, tangible interaction, physical constraints (such as on-body constraints), and the customization of physical objects. The article discusses design spaces and potential applications of the new material-like interfaces that will support seamless interactions with the digital world, empowering our physical activity and stimulating our creativity.

The second article, "Typhlex: Exploring Deformable Input for Blind Users Controlling a Mobile Screen Reader," comes from Matthew Ernst, Travis Swan, Victor Cheung, and Audrey Girouard at Carleton University, Canada. The article addresses, in particular, the promising application of a shape-changing gesture input device for blind users. Typhlex is a soft-bodied gesture input device that could be easily held and used with one hand. The authors designed it to perform multiple bend gestures, allowing basic site navigation and browsing for mobile devices. A user study with blind participants suggests that deformable input could greatly improve the accessibility of mobile interaction, which relies heavily on touch interactions.

The emergence of new additive and subtractive fabrication technologies, such as 3D printers and laser cutters, are indispensable for the fabrication of shape-changing interfaces. In addition to the established digital fabrication tools, researchers have been proposing new tools to manufacture various kinds of functional prototypes, such as hydraulic[3] and pneumatic[4] actuators, electrical circuits, and sensors.[5] This issue's Spotlight department documents student experiences at this year's SIGCHI Summer School for Computational Fabrication and Smart Matter, co-located with the Symposium on Computational Fabrication, held in June 2017. These students learned many of the techniques crucial to the realization of flexible and shape-changing interfaces.

To share perspectives on visions for the future of shape-changing interfaces, we also include an interview with Anne Roudaut (University of Bristol, UK), Kasper Hornbæk (University of Copenhagen, Denmark), and Hiroshi Ishii (MIT Media Lab, US). Questions included how they define shape-changing interfaces and how such interfaces relate to the vision of "tangible bits," "radical atoms," and wearable computers. Through these dialogues, we explore the challenges and applications of this new concept as well as

a migration path for the long-term deployment in the real world.

This special issue takes a step back to reflect on this very novel domain and its tools, illustrating the field through the deeper exploration of two examples of flexible and shape-changing interfaces. The future of the devices is now in the researchers' hands, who must address significant challenges before such devices can reach the general public. We hope the issue will inspire many of you to take up these challenges and further explore flexible and shape-changing interfaces to provide users with dynamic, hybrid physical-digital systems, leveraging human capabilities for physical manipulation and observation.

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Abstract: This special issue on physical computing explores flexible and shape-changing interfaces and how, by embedding computational capabilities into physical objects, we can bridge the divide between the digital and physical worlds. Shape-changing interfaces leverage users' rich manipulation capabilities and haptic sensations and directly couple the

digital and physical worlds by making the shape of physical objects as dynamic as their digital counterparts. The articles and related departments in this issue consider the challenges and deployment opportunities of this evolving field of research.

Keywords: physical computing, shape-changing interface, flexible interface, pervasive computing, Internet of Things, mobile, deformable interface, reconfigurable interface