Body-Centric Interaction with Mobile Devices

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ABSTRACT
Most current mobile technologies require on-screen operations for interacting with devices' visual contents. However, as a trade-off for mobility, screens usually provide limited space for interactions. To address this problem, I explore *Body-Centric Interaction (BCI)* – a design theme that extends a mobile device's interaction space from *screen space* to *body space*. My research methodology follows several steps. First, I use a generative bottom-up method – sketches and proof of concept implementations – to frame the *breadth* of the design space. Second, I populate the space with related work, which also unifies what has been done. Third – which is work in progress – I explore the *depth* of promising BCI methods, with the goal of developing, refining and testing particular mobile interaction techniques.

Author Keywords
Body-centric interaction, mobile interaction, design space.

ACM Classification Keywords
H.5.2 [User Interfaces]: Input devices and strategies, Interaction styles.

General Terms
Design, Experimentation, Human Factors

BACKGROUND AND PROBLEM
Current mobile devices rely almost entirely on direct on-screen touch input. However, to ensure portability, devices' screens are fairly small, with only a very restrictive window into one's information space. Such screen size largely restricts both users and designers to a limited interaction palette. The problem is that some actions require long sequences of on-screen operations. This problem worsens as the functionality of on-device applications increase.

EXISTING WORK TO SOLVE THE PROBLEM
Existing research, mostly implemented as point systems, has sought to provide alternate interaction modalities beyond devices' screen space. For example, advances in wearable technology make computing readily available from one's body or clothing (e.g., [9]). Similarly, some systems allow users to directly place and access digital information onto different body parts [1,4,12]. Others create virtual workspaces around a user's body, where one orients the device to "peek into" and navigate the information space [8,13]. Researchers also envision screen-less devices that allow people to point and gesture in mid-air [5,10], or towards their own bodies [6] to interact with information.

This prior work shares an important theme – they have extended mobile interaction from *screen space* to *body space*. When that work is considered collectively, it represents *Body-Centric Interactions (BCI)*—a type of interaction that allows people to perform operations on and around the body, that goes beyond the small viewport or input area of a device's screen.

GOAL OF THESIS RESEARCH
The goal of my thesis research is to construct a design space of BCI. In particular, this design space 1) clarifies the role and uniqueness of existing work in BCI; and 2) suggests new opportunities for design that eventually lead to the creation of new mobile interaction techniques that address the aforementioned research problem.

RESEARCH TO DATE
To achieve the research goal, I took a grounded approach: *theory* supports and elicits a *design* space that is further illustrated with enabling *technology*.

Theory draws on research from neuropsychology and cognitive psychology, where it relates to our innate understanding of the physical space on and around our body. First, Holmes and Spence proposed three cognitive spatial representations organized around the physical body: *personal* (immediately-on), *peripersonal* (close-to) and *extrapersonal* (far-from) spaces [7]. Next, people use *spatial memory* [2] and sometimes *knowledge-in-the-world* [11] to associate spatial and sensorimotor information with digital information in these spaces. Specifically, this thesis focuses on BCI in *personal* and *peripersonal* spaces where interactions are designed towards utilizing people's spatial memory and other associative meanings of the body.

Design is an iterative process between bottom-up prototyping and using these prototypes to compose a design space. Through a mix of sketches and implementations, I developed fundamental concepts of BCI. As these concepts flesh out the design space, they generate new thoughts which in turn stimulate the prototyping process, leading to various systems (Figure 1, left). Next, I refined the design space by using it to unify related work on BCI. Through

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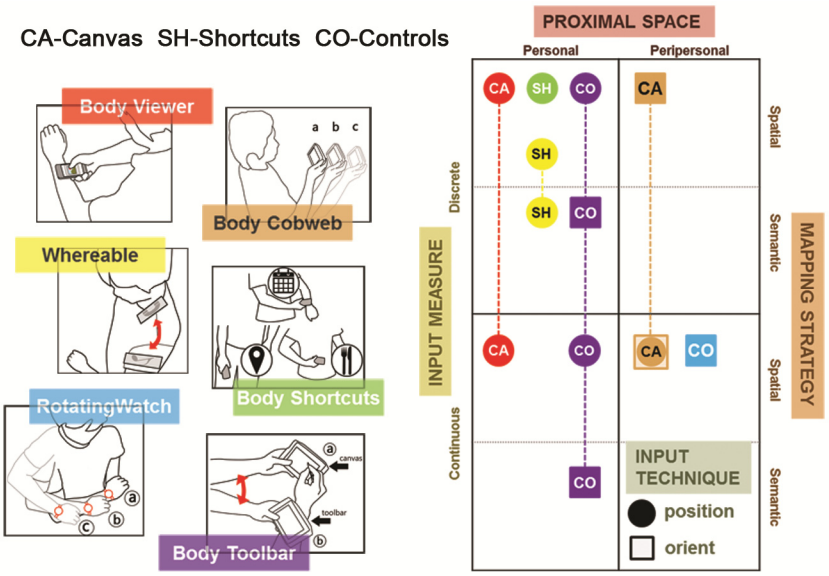

Figure 1. Situating proof-of-concept prototypes in the design space. Each set of prototypes (Canvas, Shortcuts, Controls) spans across two proximal spaces and most prototypes (listed on the left) span across different mapping strategies, input techniques and measures.

such iterations, I found three important dimensions in designing BCI (Figure 1, right):

1. *Proximal spaces* around the body (immediately-on, close-to, far-from) provide different affordances and interaction possibilities;
2. *Spatial or semantic mapping strategies* establish connections between the body's proximal space and the target interaction scenarios; and
3. To perform such interactions, people use different *input techniques* (position or orientation) where the *measurement* of this input is either discrete or continuous.

To explore design diversity, I designed and built three sets of prototypes (Figure 1 left; see also video figure; link provided at end of this paper). First, *Body Viewer* and *Body Cobweb* appropriate, respectively, *personal* and *peripersonal* spaces as a *canvas* where people can place or retrieve digital objects. *Body Shortcuts* and *Whereable* represent using different body locations as *shortcuts* to trigger applications. Further, *RotatingWatch* and *Body Toolbar* demonstrate using body parts as *controls* specific to a given application context. While these prototypes are deliberately simple, they show how ideas can span across the design space. For example, as shown in Figure 1, *Body Toolbar* situates application controls on/around the body where discrete pointing spatially maps to individual widgets and continuous orientation quantifies a control parameter, similar to our experience of turning a knob.

Finally, *Technology* concerns the implementation of BCIs. In particular, I develop methods to track the spatial relationships between different interaction entities (body parts, mobile devices, etc.). Knowing their locations and directions, I can calculate the distance, orientation, motion and other attributes that lead to modeling and realizing corresponding BCIs.

FUTURE RESEARCH

While my work to date has focused on exploring the *breadth* of BCI, my next steps emphasize delving into its *depth*. In particular, I will first identify promising opportunities from the design space. The goal is to develop these opportunities in-depth as solid mobile interaction techniques. This will further refine the design space as well as demonstrate its usefulness and expressiveness.

EXPECTED CONTRIBUTIONS

This work will make two contributions particular to solving mobile devices' limited interaction space problem. First, I articulate the *Body-Centric Interaction* design space to summarize existing work, and to help guide ongoing research into a new trend of mobile interaction. Second, I contribute a set of proof-of-concept prototypes to illustrate less-explored dimensions in this design space.

ACCOMPANYING VIDEO

Please see http:// grouplab.cpsc.ucalgary.ca/papers/ [3].

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