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Concepting Personal Input Devices for Micro-Gravity

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Fig. 1. Astronauts Anne McClain, Christina Koch and Kate Rubins working on International Space Station. An emphasis (vivid colors) has been put to the users, the computers and the anchoring system to lock them. Photos from NASA, 2019, 2020

In this position paper, we discuss the problem space and related design challenges of using input devices in the intravehicular micro-gravity environment. First, using typing experience as an example, we present a concept of adapting the shape of current devices to give them more freedom by removing the need of anchoring. Consequently, we then address the unwanted floating devices from the perspective of connectors and elastic interactions as input.

CCS Concepts: • **Human-centered computing** → *Interaction devices*; *Interaction paradigms*; *Interaction techniques.*

Additional Key Words and Phrases: micro-gravity, space, connectors, elastic interaction, cubic shape, text entry

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1 INTRODUCTION

The possibility of space travel has always excited the modern times humans, and the possibilities are now getting closer at hand. After a few decades of a more quiet era in human space travel, there are now new players, more investment, and visible progress in the area, creating buzz both in the sphere of space and astronautics professionals as well as with

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the public. With private sector, the scenarios of space tourism are seriously emerging, which will allow more people to work and travel in micro-gravity environments.

This development also fuels the development for human-computer interaction in micro-gravity. These environments, e.g. space station and crew vehicles, include numerous ICT systems and technologies, and people still need to interact with them for similar tasks as on Earth. Operating the control and measurement devices, documentation, and other tasks require input mechanisms. These are currently much the same as in normal gravity environments, although the use context is significantly different, as highlighted in figure 1. For instance, on the International Space Station (ISS), the keyboard is already (virtually) everywhere, but typing in micro-gravity environment requires the user and the device to be anchored (fixed or locked) together, usually through the structure of the ISS itself.

In this paper, we address the challenges with input devices when operated in intravehicular micro-gravity environments. We first address the design requirements in general, and then present ideas of selected concepts that could be applied in micro-gravity.

2 INPUT CHALLENGES

Interaction with computing devices in micro-gravity requires new aspects to be taken account, as many factors taken for granted in the set-up are different compared to the conventional situation. Whereas gravity normally stabilizes the physical set-up, in micro-gravity, the bodies and objects float around. Figure 1 highlights some of the challenges in the micro-gravity environments, where the computing devices float around, the user's body orientation is challenging to achieve, and support bars are needed for anchoring. For instance, laptops are attached to the surfaces, and handle or foot bars are provided to keep one's own posture stable.

Moreover, in the interaction event, the Newton's law of force and counter-force need to be considered. Pushing an object does not create the same effect without gravity and friction, which normally keeps it in its place. When twisting a handle, one's own body moves. To manage the counter-force, one needs either to anchor one's body to the surroundings, or to provide it within one's own body movements. Handle and foot bars at the walls, floor, and ceiling offer the needed backing, against which the body can push. Another solution is to use one's own body to create the needed symmetry for the forces, e.g., squeezing the object in the hand, or between two hands, or generally pushing or pulling the object against one's own body parts.

In addition, it should be noted that any movement becomes slower, and body moves such as turning or going from one place to another take more time than we have used to. Also, the physical space of micro-gravity environments is typically quite limited, and the setup does not allow much extra room for bulky equipment or physical activities. The confined environments also limit the design and placement of ICT tools and interaction interfaces.

3 EXAMPLE CONCEPTS

In the following, we present some concepts that we find potential for HCI in micro-gravity environments.

3.1 Cubic controller

The general idea behind this concept is to the change the structural shape of current devices to better suit their environment, in our case, by removing their need of support, thus the anchoring requirement. We took the typing experience as an example. Changing the overall size of a device usually comes with a different usability, for instance, a reduced keyboard placed on the user's arm and envisioned for micro-gravity environment was usable with one hand only [5], or the well-known mini-keyboard, usable only with the thumbs. The *keycube* (Figure 2) has 80 keys covering 5

faces with 4x4 matrices. The number of keys, their spacing, size and layout is similar to the traditional keyboard. The device has shown promising text-entry performance [1] while being held without support. A wireless module allows the cubic controller to be connected with any device, such as head-mounted displays. Moreover, it includes a touchscreen, an inertial measurement unit and a vibrating motor allowing different interactions convenient for spatial computing in micro-gravity [4]. In that regard, the cubic shape might be used well beyond text-entry activity as it has already been widely explored for three-dimensional manipulations [2] and database or menu browsing [6]. In fact, we think that the perceptual representation of this platonic shape might be more appropriate for a micro-gravity environment which fully allows three-dimensional movements of the user in contrast to flat (board-like) surfaces well associated with the relatively two-dimensional earthbound movements of humans. However, the discussion should not be limited to the cube and other shapes (sphere, pyramid, organic, etc.) must be considered. Moreover, bringing more mobility freedom to personal devices might have a side effect, increasing the number of floating objects and accidental interactions.

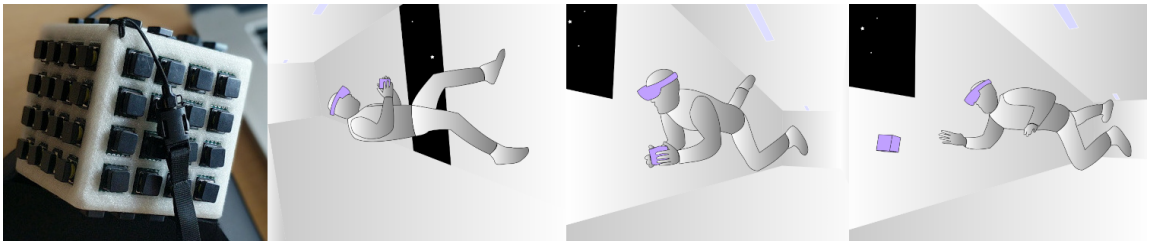

Fig. 2. An astronaut floating in micro-gravity while using an augmented reality headset coupled with a tangible cubic controller.

3.2 Using Connectors for Input

To address the issue of unwanted floating devices, connectors and anchoring pieces are needed, and there exist a number of different solutions for easily attaching and detaching parts from each other (Figure 3). The connector solutions could employ smart functions, which e.g., activate certain screen views or applications. For instance, picking up or placing an attached object, could function as a shortcut to an application (Figure 4, left), both touch fastener or tethered connector input could be considered. These solutions should, however, be carefully thought through in order to avoid false positive input events. As the floating device problem needs to be addressed, there may be potential input solutions that could be added on to the set-up.

Fig. 3. Possible connectors to tangible devices in micro-gravity: hook-and-loop fasteners, curly cord, retractable reel, magnetic attach.

3.3 Elastic Interaction Devices

Going further, elastic interaction devices, which can be manipulated, and which return to their original form when released, have potential for micro-gravity. Elastic bands or self-winding strings attached to one's body can be easily located for interaction, an example device illustrated in Figure 3 (the second from right). When attached to one's body, they provide both body-centered coordinates and a good set-up to achieve the required counter-force for the interaction (Figure 4, right). In the area of casual mobile interaction, Klamka and Dachselt have presented solutions with retractable string and a set of exchangeable traction knobs [3], which could be easily applied to this use context.

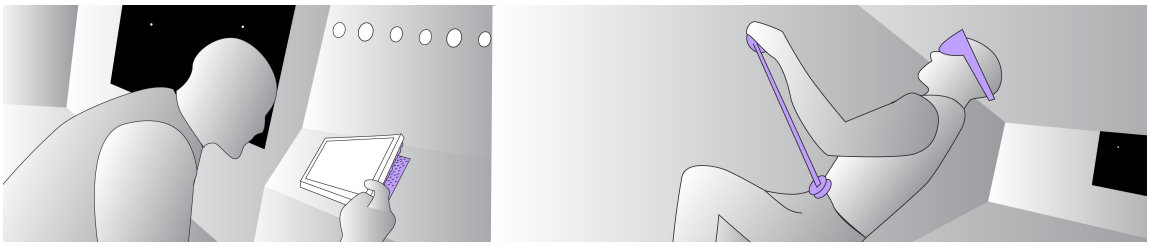

Fig. 4. Input possibilities around connectors and elastic interactions. Left: An astronaut places a velcro-attached tablet, activating an application related to experiment nearby. Right: Controlling an augmented reality headset by manipulating an elastic interface attached to the body.

4 DISCUSSION

In this paper, we have wished to contribute to the discussion of challenges when designing input devices and techniques for micro-gravity conditions. Although seemingly a minor challenge, there is certainly need for usable interfaces in the ICT intensive environments of space stations and crew vehicles. The design challenges are different than in the conventional design context on the surface of the Earth. The presented concept ideas are merely an opening of a discussion, with which we wish to stimulate the conversation around this rather novel and extremely interesting design challenge. As the next step, it would be valuable to evaluate different solutions in a simulated environment, as well as to discuss with experts working in micro-gravity conditions, to gain more understanding of the feasibility and applicability of the different input solution concepts.

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