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Navigating in 3D space with a handheld flexible device ☆

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ABSTRACT

Prototypes for handheld, flexible devices are becoming popular in the research community. We explore opportunities in the domain of mobile gaming with flexible devices, by focusing on deformable inputs to control navigation in 3D virtual environments. We compare two sets of bend gestures to control a first person camera in a 3D maze, one inspired by console game controllers, and the other inspired by PC game controls (i.e. mouse and keyboard). Our results shows that users prefer the set inspired by the console controller: moving forward and backwards mapped to the top left corner, turning to the top right corner, and strafing to the bottom right corner. This results in lower wall collisions and an overall better user experience. We propose design recommendations to create deformable game controls in 3D spaces.

1. Introduction

Deformable user interfaces (DUI) propose the physical deformation of an object as an input technique, such as bending, twisting, folding, and stretching [1]. The thin, lightweight, and flexible nature of these devices support such novel interaction techniques. When using bend gestures on flexible devices, users leverage the tangible, kinesthetic feedback of manipulating paper documents (e.g. turning a page on a book), providing an improved experience [2,3].

To explore the potential of bend input, researchers have proposed various applications, most of them focusing on creating mobile apps: icon navigation, maps, e-book readers, contacts, and photo browsing [1,2,4]. As the next generation of smartphones emerges [1,5,6], flexible displays offer an unprecedented opportunity to expand the field of mobile entertainment, as games are the most popular and used mobile applications [7]. Deemed physically engaging [8], bend gestures offer a unique opportunity to explore new interactions and input technologies for mobile games: moving characters on a 2D plane can easily be mapped to bend gestures [9].

However, many games involve more complex actions than navigating a 2D plane: for instance, players often need to move their character in 3D space. In first person video games, this translates to commands to navigate and orient the player, or to select the viewport. Beyond using a flexible device as a smartphone, we see an opportunity to use them as a next-generation video game controller to accomplish such actions.

In this paper, we explore different input sets for bending a flexible handheld device to move a character in 3D space, from a first person perspective. We base our inputs on game console controllers, and personal computing (PC) game controls (mouse and keyboard). In our study, participants navigated a 3D maze with each input set (Fig. 1). We discuss the intuitiveness of the methods and propose design recommendations on using flexible devices as game controllers.

2. Related work

To develop a system which would enable users to navigate intuitively in 3D space with a flexible device, we considered two areas of research: how individuals use flexible devices, and how people navigate in 3D space. We present key prior works that form the basis for our current study.

2.1. Flexible displays

Schwesig et al. [10] envisioned the purpose of flexible displays in future products: the authors imagined a flexible handheld device, slightly larger than a credit card, where the entire body of the device would be used for interactions. They used bending to control zooming and transparency in the interface. With their prototype Gummi, they found that bend input was helpful for simple tasks that can be conceptually mapped to physical gestures, yet it was not useful for complex tasks such as text input. Additionally,

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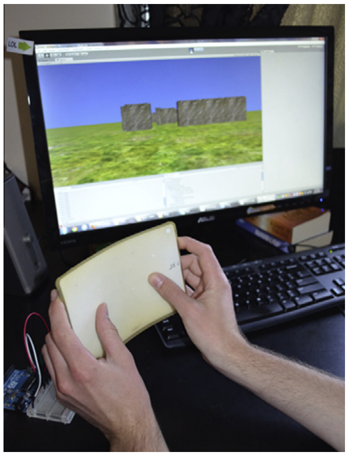

Fig. 1. Users can manipulate a flexible device to navigate a 3D maze.

they observed that people responded well to semantically opposed operations for bending.

While the Gummi prototype used a rigid display with flexible handles, other researchers decided on using projection to better evaluate the possible flexible interactions while commercial flexible displays are still unavailable. Konieczny et al. [11] projected an image on a bendable device using a fisheye camera, allowing the user to simulate the interaction with a flexible display. The device was piece of laminated paper with solid edges on each side. Two corner markers tracked the deformations of the device. The authors explored medical 3D volume visualization, a magic window (where you see the volume before you slice into it), and a shader lamp.

Recently, Steimle et al. [12] presented Flexpad, a real-time tracking system for flexible materials that does not use markers. This system used a Kinect sensor, a projector, and sheets of flexible materials. Flexpad enabled bending the device for a variety of tasks, including manipulating character animations. Overall, Flexpad can detect detailed deformation and offer a complex and board interaction language.

PaperPhone [2] used a functional flexible display to create the first flexible smartphone. With PaperPhone, Lahey et al. studied what bend gestures users were comfortable producing, and how they preferred the bend gestures to match software actions. They found a link between the polarity of the action and the direction of the movement: users selected to bend up to go left, and down to go right in their prototype, which contained a rigid bezel on the left.

With the Kinetic Device [1], Kildal et al.'s primary goal was to develop design guidelines for mobile flexible devices. The prototype, which uses the smartphone form-factor, featured an image browser and a music player. The Kinetic was designed to be used with two hands and to provide "good use of spatial mapping of actions" [1]. They observed that individuals preferred lower-resistance flexible devices to higher resistance flexible devices due to fatigue [13]. The Nokia researchers expressed the importance of identifying interactions that would benefit intrinsically from a deformable device.

Only one set of researchers have approached the problem of games on a flexible device. Ye and Khalid developed Cobra, a flexible device for mobile gaming [8]. Cobra used a projector and a flexible mobile device, like Konieczky's system, though in this case, the whole system was portable as the projector was shoulder-mounted. They developed a few small 3D demos, though the nature and breadth of their demos were not described in their short paper. The Cobra system took advantage of the analog nature of flexible device input to create physical metaphors, such as deforming the device to control a digital car's speed. Ye and Khalid argued that these hands-on metaphors, combined with the passive haptic feedback of the flexible device, could be used to make physically engaging games.

2.2. 3D games

Navigation in 3D games can be presented in either the first or third person perspective. In the former, the player moves around the environment similarly to a tourist that explores a new city: by walking around. In the latter, the player has a bird-eye-view, or a map view of the scene. Each perspective offers different types of information and levels of immersion [14], and an impact the player's navigational abilities [15].

For 3D navigation, the two most common inputs use either the two joysticks located on a gamepad, for console games, or a combination of mouse and keyboard, for PC games [16]. In comparing the use of the mouse, the keyboard, a joystick and a gamepad, Lapointe et al. [16] found the mouse to outperform the other three inputs, although it only offers two degrees of freedom (one translation and one rotation). They also note that the main advantage of the gamepad is its portability, as it does not require a desktop surface to be operated.

El-Nasr et al. [17] explored which areas of the screen users look at the most when playing different genres of 3D video games. The considered both first-person shooters (FPS) and third person action-adventure games, as well as three levels of expertises. In the FPS scenario, users focused solely on the center of the screen. In the third person action-adventure game, users still focused predominantly on the center of the screen but their eyes wandered to different areas of the screen. When using handheld flexible displays, parts of the screen are sometimes obstructed from view by the deformation of the device or occluded by the hold. This research suggest that first person game formats may be more suitable for flexible displays, because the center of the device is seldom obscured during input deformations.

3. Navigating 3D space with bend gestures

In a first person perspective video game, users can typically perform the 3D navigation movements of moving forward, back, left, right, as well as turn left, turn right. "Moving" refers to the character movement translating to the left or right (often called "strafing", or "side-stepping"), while "turning" rotates the body on itself in relation to the camera movement [16].

We are interested in investigating how to implement bend gestures to navigate in 3D space on a mobile flexible device. We propose two different sets of input deformations based on the two primary traditional input methods for video games: console controllers, and mice and keyboards. In a traditional PC game, the camera movements are typically controlled by the mouse, while moving movements are controlled with the keyboard. The movements are discrete, controlled by buttons. Console controllers use two analog joysticks - one to control the character's movement, and the other to control the camera's orientation.

The first set of inputs, set A (Fig. 2), is inspired by the console approach to movement. The left joystick on a console controller normally controls character movement and the right joystick controls camera movement (turning). We designated the top left location (using both directions) to control movements forward and backwards in 3D space, respectively. The player can turn the camera left and right by bending the top right corner backwards and forward, respectively. The strafing movements are located on the bottom right corner of the flexible device. As this movement is deemed less important for gameplay in console controllers, we