Pull'n Retract: Experimenting with a String-based Wearable Input Device

Erik Koch and Hendrik Witt
TZI-Wearable Computing Lab. - University of Bremen - Germany

Abstract
In this paper we describe a novel wearable interaction device that is based on the principle of a badge reel often found in corporate environments. Our prototype device is composed of hardware components from an ordinary off-the-shelf game pad. Preliminary results of a user study show that the device allows for a more accurate and intuitive interaction than an ordinary game pad when performing a navigation task in a three-dimensional information space. Furthermore, the study suggests that device operation requires minimal attention demands due to the provided tactile feedback cues when maneuvering the retractable string in various directions in front of the body.

1. Introduction

Wearable computers should support their users during a primary task while the interaction with the wearable computer is only secondary. Such dual task situations call for interaction designs that require minimum effort to control the computer. Therefore, the design of interaction devices for the wearable computing paradigm is a challenging task that usually requires the device to be unobtrusive, robust, and easy to use in a dual task scenario without imposing significant attention demands.

Badge reels, attached to the belt, are very popular because they provide a small and intuitive to use mechanism to access frequently needed cards to pass security checks. The retractable string of a badge reel provides an approach to move an object in a three dimensional (3D) but restricted space in front of the body.

Inspired by these badge reels we designed a wearable input device that makes use of a retractable string to control an application. The device is meant to be chest-worn on the users' body. The string can be pulled out of the device and moved in various directions in a spherical coordinate frame. Our first proof of concept prototype presented in this paper is composed of different hardware components from an off-the-shelf USB game pad and a badge reel.

2. Related Work

Quite a lot work for managing user input in wearable computing with gesture input has been documented so far (e.g., [3,6]). Here, distinct gestures are usually needed to execute application commands. In [8] an approach was shown that combined different gestures by using the chording principle to provide an approach for gesture-based text input. Similar approaches for wearable keyboards are known, too (e.g. [4]).

Little work has been documented on string-based interaction. Vickers [7] and Vectorix [2] both use strings to mechanically track objects. The *Yo-Yo* interface created by Rantanan et al. [5] also gives the capability to interact within the 3D space. Against all other devices these interface is integrated in some arctic cloth and cannot fixed to other clothes. Blasko et al. [1] presented a string-based interaction technique for dual-display mobile devices. Their device was wrist-worn and occupied the activity of both hands during interaction. Their prototype used optical 3D tracking technology, external to the spool enclosure, to track the string in a polar coordinate frame. Our functional prototype neither requires sophisticated optical tracking techniques nor does it occupy both hands. However, it can still track the string position in a spherical coordinate frame.

3. Device Concept

Using the principle of a badge reel with its retractable string one can pull and move the string arbitrarily in space as long as the limit of the string length has not been reached. Once pulling force on the string is released the string is automatically retracted. However, two limitations have to be taken into account. First, there is a limit that belongs to the mechanical concept of a badge reel, i.e. the length of the string, which is limited to approximately 25 cm. Second, there is a certain limit for the mobility of the human arm and how it can be moved in front of the body when controlling a chest-mounted device. These two limitations as well as the envisioned mounting position on the chest were the major constraints for our input device design. Given the mounting position, a retractable string of an input device would span a kind of cone-shaped space for interaction once being pulled out of the device in front of the body (Figure 1). Since the cone-shaped space is basically due to the retractable string pulled away from the body, this space could be fragmented into different polar coordinate frame assigned to a certain length the string is pulled out of the device. E.g. every 10 cm the string is pulled, a new virtual polar coordinate frame is defined. The advantage of this fragmentation is that one could map, e.g., a cursor to a certain area within the two dimensional polar space. Considering usability and ease of use of the new input method, nine different areas on each polar coordinate frame are likely the maximum to handle for a user. Otherwise, to much attention demands in terms of motor skills would be imposed by the interaction technique, which would make it difficult to use.

Although in theory there is almost no limit to the number of polar coordinate frames assigned to a certain distance the string is pulled out of the device, we decided to use three different coordinate frames only. In one of our pre-studies subjects mentioned that with a given maximum length of 25 cm for the string they could easily manage to use three different coordinate frame but each additional was very difficult to use. For this reason, we designed our device so that every 8 cm the string is pulled out of the device a next level with a virtual polar coordinate frame is reached.

In summary, our interaction approach includes three levels. On each level we defined nine different areas, which we deemed to be easy to separate from each other by users. Hence, our interaction design allows for 27 (3 x 9) different actions to be triggered with the device.

To match these needs we designed a prototype. Our prototype consists out of an off-the-shelf Saitek P880[1] game pad and a badge reel. We use one potentiometer to match the needs on the polar coordinate system. The second potentiometer where used to create the cone-shaped three dimensional space. By attaching the string from the badge reel to the second potentiometer we can determine, how far the ring is pulled out of the device.

4. User Study

The user study compared our novel string-based input device with an ordinary game pad. We assume that by using the novel string-based device the subjects will accomplish given navigation

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1 http://www.saitek.com/

tasks with higher accuracy compared to our baseline game pad, which was a Logitech[2] Wingman Rumblepad.

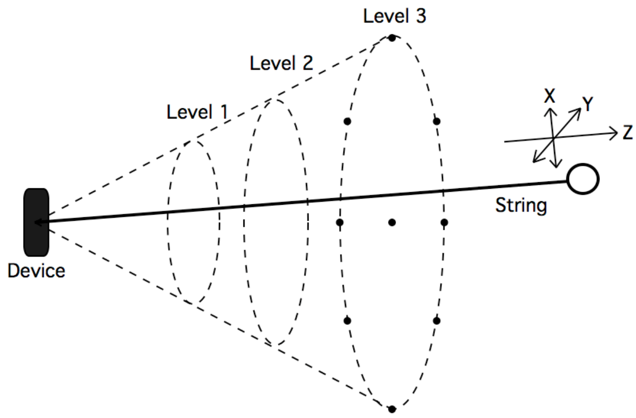

Figure 1. Cone-shaped interaction space with a string.

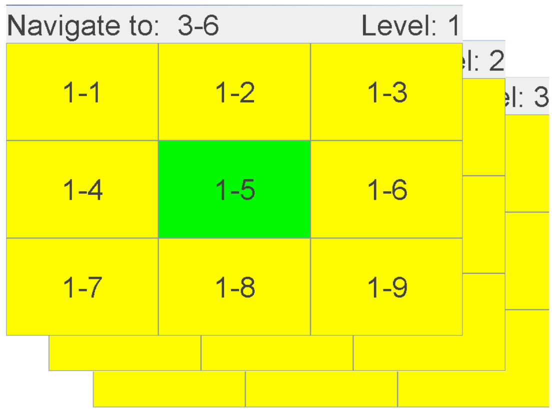

Figure 2. User interface representing the navigation task

4.1 User Study Setup

We tested ten users recruited from students of the local university and university unrelated people with an average age of 30.8 years. All subjects were screened not to be colorblind. The study uses a within-subject design with the input devices as the single independent variable. Users were divided into counterbalanced groups where the order of devices differed. Five subjects first used our base line game pad before the performed the studies navigation task with our string-based input device. Subjects of the second group started the test with the string-based device and continued with the game pad. Before running the actual experiment, subjects could experience both devices as well as how they are supposed to handle given navigation tasks for about 30 seconds. After this period we continued with the experiment where the number of given tasks users had to perform as well as their achieved error rate were recorded. The time for each device was limited to 5 minutes in which subjects were requested to do as much as possible tasks without neglecting accuracy. To include the mobility aspect of wearable applications, subjects were requested to stand in front of a TFT-Monitor that shows the navigation task.

4.2 Visual Interface

For the study we created a graphical user interface representing our navigation tasks. The interface was designed to allow interaction in our envisioned 3D information space. The user interface consisted of three different panels. Each panel, which represents a certain level of our interaction approach, has nine buttons aligned in a grid similar to a mobile phone keypad. Each button features a unique label consisting of the level number (1-3) where the button is located on, followed by the number of the button itself (1-9).

Figure 2 shows the graphical user interface. An indicator in the right top corner of the interface shows the current level the user is at. Also on top, but aligned to the left, the navigation tasks subjects are requested to navigate to are presented.

A green color was chosen to visualize the current position of the cursor. Pressing the button located on the ring of our string-based device selects the current button as the answer for the task. To answer a task with our game pad the right fire button was used. Once a button has been selected the system generates a new navigation task. A new task is a randomized button label that has to be found on one of the three levels of the interface. For the string-based device changing the current

2 http://www.logitech.com/

level is done by pulling or releasing the string. For the game pad this is done with the right analog joystick.

5. Preliminary Results

Although the conducted experiment was rather small in terms of time and number of subjects, the preliminary results confirm our hypothesis that subjects answered navigation tasks with higher accuracy than with the game pad.
The average number of accomplished tasks with a game pad was about 22% higher than with our string-based device. An ANOVA showed that this difference was significant (F= 10,61; p<0.004). From our post-hoc interviews we learned that all subjects mentioned that they felt more familiar with the game pad than with the new device, providing one possible reason why they accomplish more tasks with the game pad then with the novel device.
To verify our hypothesis that subjected answered navigation tasks more accurate we calculate a single factor ANOVA for our average error rate metric. It showed a strong significant (F=19,16; p<0,001) difference between both input devices. Subjects did two times more errors with the joy pad (11,31%) than with the string-based device (5,42%), supporting our hypothesis.

6. Conclusion and Future Work

We presented a novel string-based input device for 3D space navigation. Our prototype was composed from an off-the-shelf game pad. Our preliminary study showed that users could achieve higher interaction accuracy with the string-based input device than with the baseline standard game pad for our tested 3D navigation tasks. Navigation was more accurate and intuitive compared to a conventional game pad.
Future work includes the enhancement of prototype device as well as an in-depth users study with a larger number of participants. For device enhancements we will primarily focus on integrating a force feedback generator, because our study observations suggest that many erroneous answers were given due to subjects loosing orientation when changing to another interaction level in the navigation task.

7. References

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