A Capacitive-sensing Physical Keyboard for VR Text Entry

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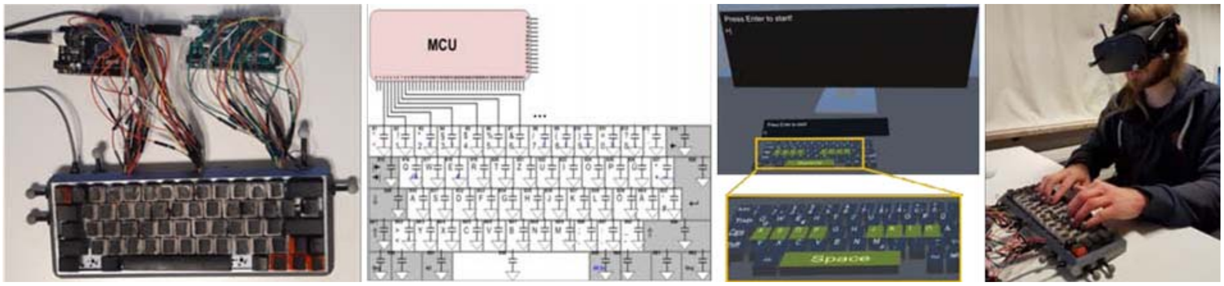

Figure 1: From left to right: The capacitive-sensing physical keyboard. The circuit diagram of the keyboard. View on the virtual office environment with inlay of the virtual keyboard with touched keys highlighted in green. User typing on the keyboard.

ABSTRACT

In the context of immersive VR Head-Mounted Displays, physical keyboards have been proven to be an efficient typing interface. However, text entry using physical keyboards typically requires external camera-based tracking systems.

Touch-sensitive physical keyboards allow for on-surface interaction, with sensing integrated into the keyboard itself, but have not been utilized for VR. We propose to utilize touch-sensitive physical keyboards for text entry as an alternative sensing mechanism for tracking user's fingertips and present a first prototype for VR.

Keywords: text entry, touch, physical keyboards, virtual reality, capacitive sensing

Index Terms: H.5.2: [User Interfaces - Input devices and strategies.]

1 INTRODUCTION

Realizing efficient and usable text entry systems is deemed crucial for creating future virtual office environments [4]. Existing consumer-grade immersive head-mounted display (HMD) VR systems, often rely on indirect control of a virtual pointer using hand-held controllers or head or gaze direction. However, these methods are limited in performance and consequently mostly used to enter short texts, such as passwords or names. Further, they require some degree of training due to their unfamiliarity to some users, compared to standard desktop and touchscreen keyboards that users are already familiar and proficient with.

Text entry has been extensively researched (see [11] for surveys and overviews). However, until recently, relatively few text entry methods have been proposed for VR. Recently, several groups investigated the feasibility of utilizing standard keyboards for text entry in immersive HMD-based VR focusing on different hand representations, including no hand representations [15], minimalistic fingertip rendering [5, 6], video see-through [12] to full inverse kinematic hand models [10]. In 2017, Logitech made a toolkit available which utilizes a blended camera view [2]. However, apart from using no hand model (which results in unacceptable high error rates without auto-decoders [15]), all proposed techniques rely on the availability of external tracking systems integrated into the environment (e.g., using infrared-based outside-in tracking systems) or in the HMD (e.g., using cameras). As cameras or external hand tracking systems are not widely integrated into the majority of HMDs, this can potentially hinder the widespread use of text entry on physical keyboards.

Our work extends these previous works proposing to use touch-sensitive keyboards through capacitive sensing, which allow to visualize a fingertip on a physical key before a character has been entered. In fact, there is a large body of work on touch-sensitive keyboards using capacitive sensing that has been investigated outside of VR (e.g, [1, 8, 14]). It has been demonstrated that touch-sensitive keyboards have the potential to be commercialized (e.g., [3]).

The closest work to ours is from Grubert et al. [5,6]. In 2018, they investigated the performance of physical and touch keyboards and physical/virtual co-location for VR text entry. They proposed to use minimalistic fingertip rendering as hand representation and indicated that this representation is as efficient as a video-see through of the user's physical hands [5].

Recent work has also investigated the feasibility of using multi-touch screens for text entry in VR, e.g., using a smartphone [9], a face-mounted display [7] or a multi-touch tablet [6]. Specifically, Grubert et al. [6] indicated a relatively low text entry performance using multi-touch tablets, Guggenheimer et al. [7] and Kim et al. [9] did not report standard text entry metrics. Within this work, we are focusing on physical keyboards, as research has shown that typing on those physical keyboards substantially outperforms text entry on multi-touch screens, which could be considered an alternative text entry method [6].

We focus on touch-sensitive physical keyboards for efficient text entry in VR as a tool for enabling portable virtual work environments [4]. We envision that future office workers only need access to a laptop with integrated touch-sensing keyboard and trackpad as well as a untethered VR Head-Mounted Display (HMD) for working productively on the go. Specifically, we do not assume any tracking capability of the mobile HMD beyond 3 degrees of freedom rotation

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sensing. As a first step towards realizing this vision it is crucial to understand if future mass-manufactured touch-sensitive physical keyboards lend themselves for efficient text entry in VR.

As a first step into this direction, we built a physical keyboard with capacitive sensing, which allows to sense and visualize the user's finger tip before a key has been pressed and integrated it into a virtual office environment. This could prove useful for future virtual office work on the go.

2 Touch-sensitive Keyboard for Typing in VR

We developed a custom-built keyboard which can detect user touches on individual keys through capacitive sensing. A diagram portraying the basic principle of the keyboard is shown in Figure 1. Each key is coated with conductive electric paint that is connected to a specific digital pin on an external microcontroller via a copper wire on the underside of the keyboard. The conductive surface of each key together with the environment around the surface functions as a capacitor whose physical properties change when the environment around the key changes, for example when the user touches the key with a finger. In software, when the pin that is connected to a key is set to high via the internal pull up mechanism of the microcontroller, the time until the signal on the pin physically reaches high differs depending on the physical properties of the capacitive system between the key and its environment. Once at application startup, we measure a baseline time delay for the signal to reach high for each key when the capacitive system consists of the key and an empty air environment, by setting the pin to high and then continuously reading its value until it returns high as well. At runtime, we then continuously measure the time delay for the signal to reach a high value for each key, which changes when the user touches a key as an effect of the physical properties of the capacitor changing. If the relative difference of this time delay to the measured baseline delay reaches an empirically determined threshold of 50%, the key is assumed to be touched by the user.

The microcontroller is connected to an external PC via a standard USB serial connection that is used for communication between the client application running the experiment software and the microcontroller that detects key touches. Each physical key on the keyboard is connected to a separate pin on the microcontroller, and when a key touch is recognized on each respective pin, a serial message is sent to the client application containing information about which key was touched.

The keyboard uses two Arduino Mega 2560 Rev3 microcontrollers, due to the number of separate keys surpassing the number of pins available on a single microcontroller. They keyboard itself consists of a GK64 hot swappable PCB using a custom 60% keyboard layout, using Kailh BOX Pale Blue as mechanical switches for each key, Tai-Hao Carbon Keycap Set ISO-DE keycaps and a 5 KBDFans 60% case as a casing for the entire keyboard. Overall, the keyboard has 62 keys, with each alphanumeric key having dimensions of 12 x 14 mm (width x height). In VR, the respective key of a virtual keyboard is highlighted as the user touches the key (see Figure 1).

We have integrated the physical keyboard into a VR enironment using the Unity game engine. The virtual environment was specifically built for conducting text entry studies. To this end, a virtual monitor presents sentences that users are asked to replicate.

3 Discussion and Conclusion

Touch-sensitive physical keyboards allow for on-surface interaction, with sensing integrated into the keyboard itself.

Our work is a first step in making touch-sensitive keyboards available for VR text entry. If touch-sensitive keyboards will become commercially widely available they could become an efficient tool for VR text entry. While a preliminary evaulation was conducted [13], in future work, we want to thoroughly investigate the performance envelope of touch-sensitive physical keyboards.

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