Space Boards:
Combining Tangible Interfaces with the Surrounding Space via RGB-D Cameras

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ABSTRACT
This paper introduces a novel take on a well-known user interface that combines the advantages of a number of new technologies. In particular, it presents a new tangible interface with an interactive surrounding space. It demonstrates the technology in an exciting user case as a printed keyboard and hand-gesture based mouse that provides one with an easy-to-use text and virtual mouse input for situations where such a medium is difficult to use (e.g. virtual keyboards for tablets and smartphones) or non-existent (e.g. gaming consoles such as the Microsoft Kinect). It also examines other applications and design questions that arise from such an interface.

KEYWORDS
Depth Sensor, Finger Tracking, Printed Keyboard, Tangible Interface, Virtual Mouse

INTRODUCTION
In the last ten years there has been significant interest in tangible interfaces, (Signer & Norrie, 2010). Tangible interfaces are part of an important objective to allow users to interact with computers and their surroundings in a natural and intuitive fashion. This has been the goal of many research endeavors beginning with the original vision of ubiquitous computing by Mark Weiser, (Weiser, 1991). In particular, one field which has received much attention is the digital augmentation of paper and other surfaces, (Signer & Norrie, 2010). Paper and similar surfaces have always interested researchers due the cheap, natural and multifaceted user interface that paper affords, (Holman, Vertegaal, Altosaar, Troje, & Johns, 2005). This research is extended here by providing a novel combination of an interactive surface with the space surrounding it.

The presented interface exploits advances in consumer hardware and software. In particular, the focus is on using technology that is cheap and easily available to the average consumer to provide an interface that will be accessible to as many people as possible. The technology used here is based on the recent wave of cheap hardware that combine a depth and video camera in one device such as the Microsoft Kinect (Microsoft Kinect, 2014), Asus Xtion (Asus Xtion, 2014), Intel RealSense camera (Intel RealSense Camera, 2014), etc. These cameras are not only cheap but also provide the software developer with simpler code development due to the ease with which the two types of cameras can communicate with each other. These advantages are exploited here to provide a system that is able to track a tangible interface with the video camera but also track the user’s gestures and other objects with the depth camera. This setup grants us the ability to create novel and intuitive applications that have the potential to be easily understood and interacted with by the average consumer.

The interface presented here combines existing technologies in a novel way to also grant the user unprecedented levels of flexibility and customization. Again, following on the idea of creating
an interactive surface that uses easily accessible technologies, one of the major virtues of the design is that the interface can be customized by the user and then printed out with a standard ink printer. This allows the user to have multiple interfaces for different languages, different use scenarios (work, gaming, etc) and different interaction paradigms (mouse touch pad, DJ deck, joystick, etc.). Due to the technology used, it is also possible for multiple users to interact simultaneously with the interface but still have their own personalized version of the technology.

In light of the previous discussion, the academic contributions of this paper are:

- Presenting a novel, movable tangible interface utilizing commodity RGB-D cameras which can be used by multiple users with a single camera,
- Extending previous work by using a RGB-D camera allowing one to move the tangible interface with a simple and easily printed marker which can be extended to pictures or simply the interactive elements themselves,
- Solving the problem of image finger segmentation for tangible interfaces and thereby allowing a more natural usage of the device without requiring gloves or putting restrictions on the design of the interface,
- Allowing user interaction with the space above the interface as well as on it by exploiting depth information.

Apart from these contributions, more novel uses of the results presented here can be found in the “Use Case Example” Section. In addition to these contributions, the code developed for this paper has been publicly published online under the MIT license so it can be used by other researchers to test and build on the code. The code repository can be found at (Shellshear, 2015).

The presentation starts with an overview of previous research on related interfaces. In the following section the technologies and methods used to develop the new interface are discussed. In the section after that, the major use case is discussed, that of a printable keyboard and virtual mouse. After that a discussion and evaluation of the chosen design is presented, where drawbacks and issues when designing the interface are analyzed. The final section presents the conclusions and future work.

RELATED WORK

The topic of natural interactions with a fixed, or tangible, surface is a well investigated area of natural user interface research. For a comprehensive overview of tangible interfaces see (Shaer & Hornecker, 2010). When considering tangible interfaces with similar applications to the one presented here, there exist numerous similar interfaces that merely use a single RGB camera, (Do-Lenh, Kaplan, Sharma, & Dillenbourg, 2009; Edwin & Supriana, 2011). Although such a system has the advantage that it only requires a single camera it has a number of disadvantages. Such systems typically rely on the ability to segment fingers from the background image and to do so they often require backgrounds that change very little or backgrounds that have colors that are significantly different from the finger colors.

For example, in (Z. Zhang, Wu, Shan, & Shafer, 2001) a camera is used for both virtual mouse and keyboard interaction. However, in (Z. Zhang et al., 2001) it is required that the finger or pointing device be easily segmented from the background in addition to ambiguities created when using a virtual mouse and keyboard together arising from using one camera. By using an additional depth camera, this limitation, and others, can be overcome. In addition, by using a depth camera the interface is not as sensitive to poor lighting, which is a problem in (Z. Zhang et al., 2001).