Adaptic: A Shape Changing Prop with Haptic Retargeting

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***Abstract*— We present Adaptic, a deformable haptic device that can reconfigure itself as a physical proxy for a range of objects in virtual reality (VR) applications. Adaptic relies on visual dominance to serve as a semi-general purpose prop. We employ haptic retargeting so users are redirected to pick up Adaptic, which reconfigures itself to match a virtual object the user thinks they are picking up. We describe our hardware implementation, and applications supported with the device.**

I. INTRODUCTION

Haptics improve interaction in virtual reality (VR) by providing a physical reference for virtual objects, enhancing immersion [8], presence [1] and user performance [3]. Approaches to VR haptics can be roughly divided into passive haptic feedback (PHF) and active haptic feedback (AHF). PHF approaches employ physical objects or "props" that correspond in shape and/or location to virtual objects [4]. PHF approaches are comparatively simple, inexpensive, and support realistic forces. However, they do not generalize well; a scene involving many unique virtual objects requires a separate prop for each object, and necessitates the complexity of switching between props.

In contrast, AHF devices, such as the Phantom [5], are motorized and thus generalize better, since they can limit joint movement and provide force feedback to match the shape of a specified virtual object. However, AHF devices tend to be expensive, complex, and potentially intrusive. Many cannot produce physically robust feedback (i.e., haptic forces feel "squishy"), and most support only a single contact point, such as a stylus, or a handheld controller.

To leverage some benefits of both approaches, we developed Adaptic (Figure 1), a new shape-changing haptic device for VR applications. Adaptic can change shape in real-time to present several different haptic shapes. The device supports both manual deformation by the user, as well as self-actuating to change to specific shapes. Like PHF props, Adaptic supports multiple contact points and robust haptic feedback through its simple and inexpensive design. Like AHF devices, its shape-changing ability allows Adaptic to map onto a range of shapes, requiring only a single prop rather than many. This combination of features creates a potentially more realistic experience for VR users.

To further generalize the application of the device, we employ haptic retargeting, a technique which shifts the user's virtual hand to make them touch the same real-world position, while thinking they are touching different virtual positions [2]. By combining haptic retargeting with Adaptic, users can be made to repeatedly pick up Adaptic, which changes shape between uses. The user thus thinks they are picking up a different virtual object each time, and get corresponding haptic cues.

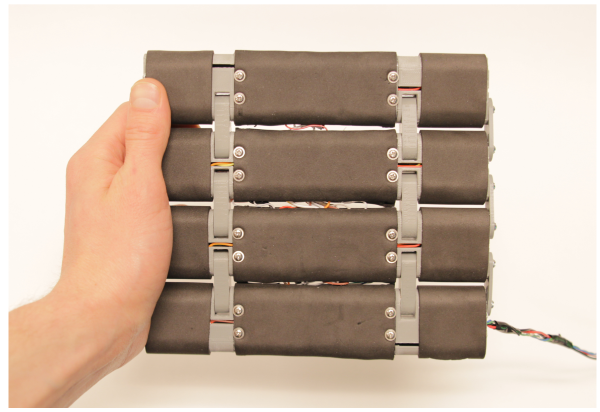

Fig. 1. Adaptic, in Flat Configuration

II. RELATED WORK

Past work on visual dominance in VR suggests that haptic approximations are generally sufficient to fool the user into thinking they are touching a perceived virtual object [7]. Based on this idea, HaptoBend [6] was a deformable prop consisting of four hinged panels, but without shape-changing ability. HaptoBend's simple design allows users to manipulate it into a several VR objects. In a user study, the authors found that the device provided a "close-enough" approximation for a variety of shapes. Adaptic takes the idea a step farther by employing self-actuated shape change.

Haptic retargeting is another benefit of visual dominance that enables the use of one haptic device to represent multiple virtual objects [2]. The technique requires either redirecting the users hand, or warping the perceived location of virtual objects relative to the haptic device. Each time the user reaches for a distinct virtual object, we retarget their hand to reach for Adaptic. The device simultaneously changes shape to provide a proxy for the desired virtual object.

III. DESIGN OF ADAPTIC

A. Form Factor

To simplify the design, we used a form factor similar HaptoBend [6] with four foam-covered elliptic flattened cylinders (Figure 1). We used double hinged connections to allow full 360 rotation. Enabling this range of rotation means

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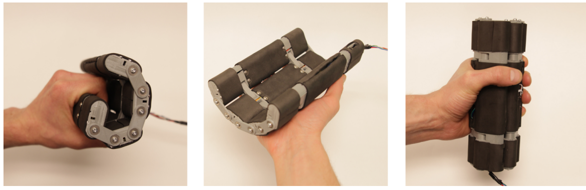

Fig. 2. Adaptic in several shapes showing the affordances of its hinged connections.

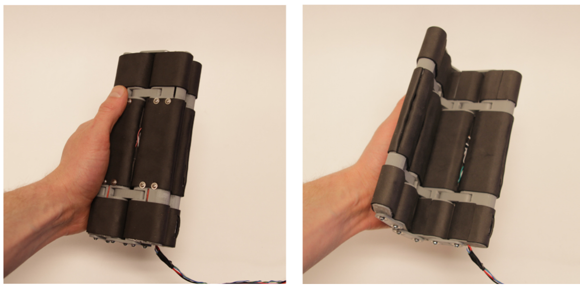

Fig. 3. The device can lock the side hinges while maintaining free motion of the middle hinge to mimic a virtual book.

that each section can fold perfectly flat on top of its neighbor, resulting in more complex shapes compared to Haptobend, which did not allow fully flat bends between sections [6]. We designed the panels to be modular and 3D printed them for assembly with metal screws. Our design offers the following features:

- Deformable: allows the user to freely manipulate the devices shape.
- Shape-locking: prevents bending specified hinges to mimic the physical attributes of a virtual object.
- Shape-changing: bends to specified shape with animated haptic feedback. Actuating from flat to a compact wand-like shape takes approximately 2 seconds.

B. Hardware and Software

A Teensy 3.5 handles data collection from each sensor and communicates with each servo. The Teensy communicates with a PC running Unity via a custom C# script utilizing the SerialPorts Class to import sensor data and control the servos. Other C# scripts translate sensor data into a real-time digital representation of Adaptic and control each servo individually. We can also map sensor data to other virtual objects allowing users to manipulate them in 3D space with Adaptic as haptic feedback.

C. Tracking

Adaptic tracks its orientation and each hinge angle. This allows for a real time digital model of the devices current shape users can interact with in VR. To measure the bend angle of each hinge we integrated a potentiometer into each servo. We also incorporated a Razer Hydra magnetic tracker module, to provide 6DOF position and orientation of the device. We can also collect overall rotation of the device with a BNO055 IMU integrated into one of the panels.

D. Applications

Adaptics primary application is providing haptic feedback for multiple VR objects by changing shape. However, it's deformation and shape-change capabilities support other haptic applications. For instance, some joints can be locked and others left loose, to simulate user-bendable objects with rigid components. For example, Figure 3 depicts Adaptic representing a book.

Adaptic offers more expressive input through bending, compared to button based input of most VR controllers. Through bending Adaptic into predefined shapes, users could quickly switch between different virtual objects, such as shield triggered by a completely flat shape and a sword activated by rolling the device up into a cylinder.

By selectively setting hinges to the deformable and shape-locking modes Adaptic can create richer representations of an objects physical characteristics. For example, a user could open and close a virtual book by locking some hinges to mimic the hardcover and allowing the middle hinges to move freely to mimic the spine. See Figure 3.

IV. CONCLUSION

To our knowledge, Adaptic is the first device to apply deformability and shape-change to VR passive haptics. By combining these added affordances with visual dominance in VR, it makes progress toward addressing the issues of complexity, limited interactions in VR, and inadequate haptic feedback. Future work will focus on more flexible prototypes, for example, supporting multi-axis deformation, to better match 3-dimensional objects.

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