Transcalibur : Dynamic 2D Haptic Shape Illusion of Virtual Object by Weight Moving VR Controller

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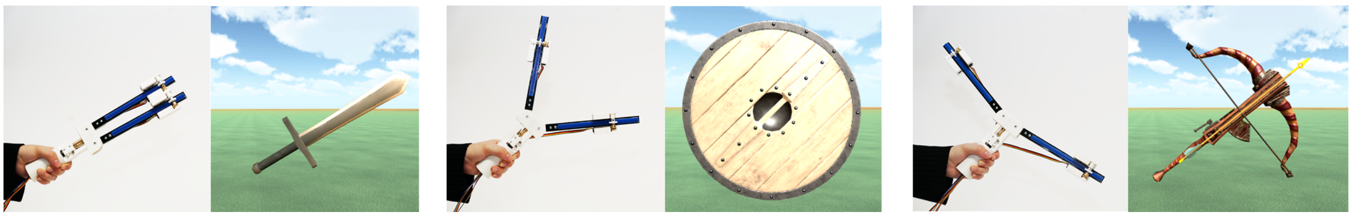

Figure 1: Transcalibur can dynamically present size of various object in VR, actuating weight and angle mechanisms. Although the actual contoroller's appearance differs from its appearance in VR, a user feels as if s/he is wielding sword(left), shield(center) and crossbow(right) with the same VR controller.

ABSTRACT

We introduce a dynamic weight moving VR controller for 2d haptic shape rendering using a haptic shape illusion. This allows users to perceive the feeling of various shapes in virtual space with a single controller. In this paper, we describe the mechanical design of prototype device that drives weight on a 2d planar area to alter mass properties of the hand-held controller. Based on the experiment, our system succeeded in providing shape perception over a wide range. We discuss limitation and further capability of our device.

CCS CONCEPTS

• **Human-centered computing** → **Haptic devices**; • **Computing methodologies** → *Virtual reality*; *Perception*;

KEYWORDS

Virtual Reality, Haptic Shape Illusion, Perception, VR Device

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1 INTRODUCTION

Recent development in Virtual Reality allows for immersive user experiences using high fidelity visual and audio feedback. As multisensory perception is significant for more immersive experiences, many researchers and companies delivered various haptic technologies which provide a physical reality of virtual objects in contact[Kajimoto et al. 1999; Minamizawa et al. 2012]. Conventional VR controllers focus on providing functionality to manipulate various virtual objects. However, the shape of such objects can vary depending on the VR context. Even if we ignored the cost for having various size and weight VR controller optimized for each specific experience, it still requires users' time and effort to switch these controllers. Herein, we introduce *Transcalibur* : weight moving VR controller for 2d haptic shape rendering. Figure 1 shows a transforming sequence of Transcalibur. In this paper, we explore the hardware design and evaluation of our prototype.

2 RELATED WORK

There is a substantial number of proposals for haptic rendering technique based on tactile sensation, such as vibrotactile, ultrasonic, electric stimulation[Kajimoto et al. 1999; Minamizawa et al. 2012]. Although, rendering various shape of a wielded object in VR is not yet well studied. Shifty[Zenner and Krüger 2017] proposed the 1d-weight shifting technique to render a change in length and thickness, but still not able to present a shape of a virtual object over a wide range. Fujinawa et al. presented a system aimed to generate the optimized shape of the laser-cutted object targeted to render desired width and height in VR object using *haptic shape illusion* [Fujinawa et al. 2017]. Exploiting human shape perception, generated props can render various width/length in virtual space, even larger object than actual wielded props. However, the fabricated controller can only render a single static shape.

3 HARDWARE PROTOTYPE

We designed a 3D-printed prototype which consists of mechanisms to move weighted objects on a 2d planar space. Our prototype consists of two main mechanisms, *angular mechanism* and *weight shifting mechanism* as shown in Figure 2.

The *angular mechanism* enables to open/close two arms by rotating a worm gear drive connected to two worm wheels. These gears are fixed and connected to a PLA casing and are actuated by Pololu 150:1 HPCB 12V Micro Metal Gearmotor with a magnetic encoder. The mechanism is designed to be *non back-drivable*, so even if some torque were applied to the worm wheels by shaking, these arms can maintain their angle. This setup is capable of moving the arm 90[deg] in 2.3[sec]. Each *weight shifting mechanism* also consists of a worm gear and worm wheel, connected to spur gear through a metal shaft then to a rack gear. This allows shifting on an acrylic arm by actuating the Pololu 30:1 HPCB 12V Micro Metal Gearmotor. The motor is mounted on a PLA casing, then counterweighted by mounting another same motor on the other side, and weighing 60 grams. This mechanism is also *non back-drivable*, so no centrifugal force or gravity affects the position of the weight mechanism. The weight is capable of moving 100[mm] in 2.2[sec].

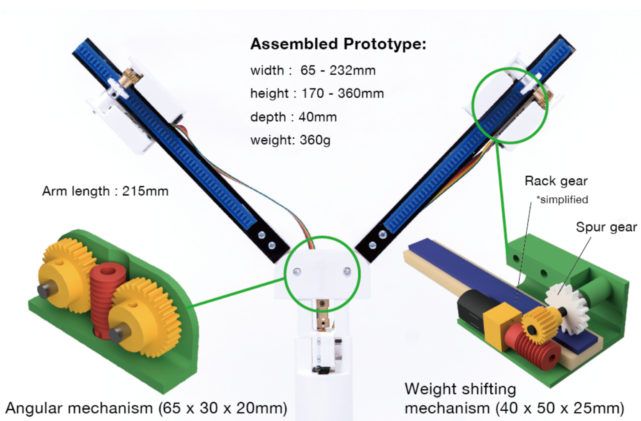

Figure 2: Mechanical design of the proposed device in detail. Both Angular Mechanism(left) and Weight Shifting Mechanism(right) are actuated by motor through worm gears.

4 EVALUATION

To evaluate how our designed controller can render various shape perception of wielded VR objects, we conducted a user study. We used tuning methods to evaluate the size of the virtual object at given angle and position of weights. 5 participants (4 males, 1 female, average 22 years old) participated in the user study. Initial size of 100[mm] × 100[mm] × 5[mm] square plane attached to the handle was presented to the participants in a virtual environment. Then participants were asked to adjust the width and height of the plane in VR using a gamepad until feeling suitable to the perceived size of the wielded object. After clicking confirm button, the weight of the controller moves to another position then the participants repeated the procedure. 5 angles steps 0[deg] to 90[deg], and 5 distance steps from 40[mm] to 125[mm] from the center of rotating arm are presented. We also presented same hardware with acrylic square plane identical to the initial size of VR object, to control assumptions for material displayed in VR which may differ among participants. It was attached to the Angular Mechanism instead of weight and arms. Figure 3 shows the result of perceived width and height of wielded object fitted by linear regression. The participants reported as follows: *'I felt the object shape has significantly changed'*, *'I felt a strong change in width direction'* Another user stated: *'I felt comfortable when the shape of visual object matched to perceived object'*. These comments suggested that the proposed VR controller successfully renders a wide range of shape perception.

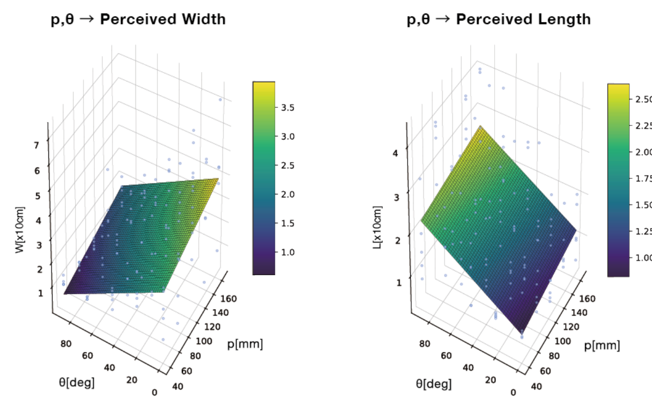

Figure 3: Evaluation result. p[mm] is the distance from the rotation axis of each arm, and θ[deg] is the angle of arm from the horizontal line. Blue points are observed data and plane is fitted to the data using linear regression.

5 DISCUSSION

The VR controller needs to be powered to actuate motors and the weight is only capable of moving a 2D planar area of the limited range. On the other hand, it is suggested that the perceived object can be biased by visual cue based on user's comment. We will further investigate the relationship between weight configurations and visual cues to render more various shape with a simple hardware design.

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