

Transcalibur : Weight Moving VR Controller for Dynamic Rendering of 2D Shape using Haptic Shape Illusion

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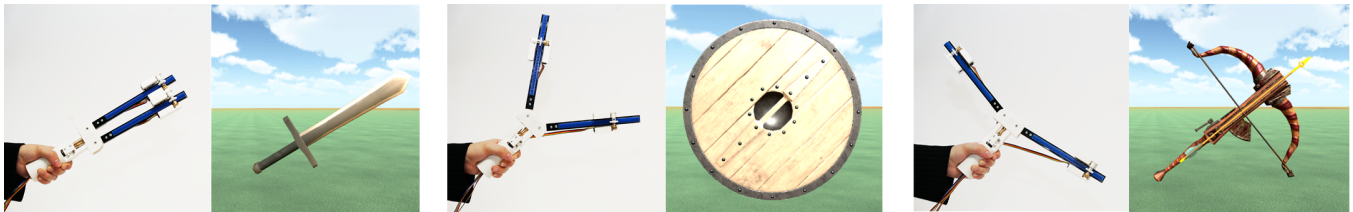


Figure 1: Transcalibur can dynamically present size of various object in VR, actuating weight and angle mechanisms. Although the actual controller's appearance differs from its appearance in VR, a user feels as if s/he is wielding sword(left), shield(center) and crossbow(right) with the same VR controller.

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. We designed a device that drives weight on a 2d planar area to alter mass properties of the hand-held controller. Our user study showed that the system succeeded in providing shape perception over a wide range.

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 immersion, many researchers and companies delivered various haptic technologies which provide a physical reality of virtual objects. 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. This device enables to change its inertia moment by moving weights on a 2d planar area to illusorily represent a haptic equivalent of visual shape in VR. In this paper, we explore the hardware design and evaluation of our prototype.

2 RELATED WORK

Many researchers have proposed haptic rendering technique based on tactile sensation, such as vibrotactile, ultrasonic, electric stimulation[Inoue et al. 2015; Kajimoto et al. 1999; Minamizawa et al. 2012]. However, rendering various shapes in VR is not yet well studied. Shifty[Zenner and Krüger 2017] proposed the 1d-weight shifting technique to render changes in length and thickness, but still not able to present the shape of a virtual object over a wide range. Previously, we presented computational fabrication method for VR controller. The system aimed to generate an optimized shape of laser-cutted object targeted to render desired width and height in VR object using *haptic shape illusion*. 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 built a hardware prototype which consists of mechanisms to move weighted objects on a 2d planar space. This consists of two main mechanisms, angular mechanism and weight shifting mechanism. Figure 2 shows mechanism models and specification of the device.

3.1 Angular Mechanism

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 fabricated by a 3D printer, then both worm wheels are connected to arms. The worm gear is 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].

3.2 Weight Shifting Mechanism

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 to shift 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 mechanisms. The weight is capable of moving 100[mm] in 2.2[sec].

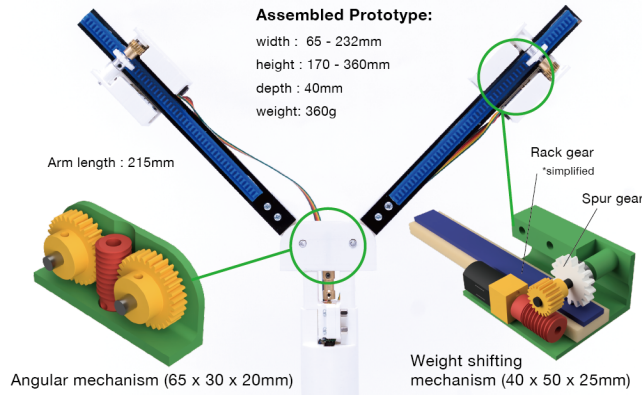


Figure 2: Mechanical design of the proposed device in detail. Both Angular Mechanism(left) and Weight Shifting Mechanism(right) are actuated by motor through worm gears.

4 EVALUATION

In order to evaluate how our prototype can alter shape perception of welded VR objects, we conducted a user study. We used tuning methods to evaluate the size of a virtual object at given angle and position of weights. Five 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 a cylinder handle is

presented to users in a virtual environment. Then users are asked to adjust the width and height of the plane in VR using a gamepad until feeling suitable to the perceived size of the welded object. After clicking confirm button, the weight of the controller moves to another position then users 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 welded object fitted by linear regression. Users reported as follows: *'I felt the object shape has significantly changed'*, *'I felt a strong change in width direction'*. These comments suggested that the proposed VR controller successfully renders a wide range of shape perception.

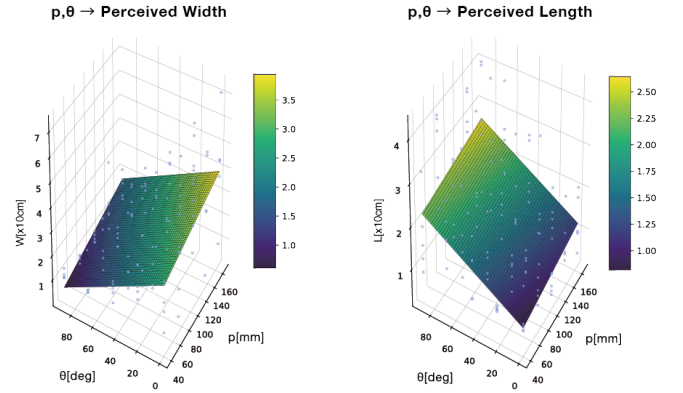


Figure 3: Evaluation result. p is the distance from the rotation axis of each arm, and θ [deg] is the angle of the arm from the horizontal line. Blue points are observed data and plane is fitted to the data using linear regression.

5 DEMONSTRATION AT SIGGRAPH2018

In SIGGRAPH2018, we are presenting demo VR applications using our VR controller (e.g. users can experience fighting against monster using various weapons with a single controller). We are also presenting an improved device based on our hardware which is lightweight and attachable to conventional VR controllers.

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