Demonstration of Transcalibur: A VR Controller that Presents Various Shapes of Handheld Objects

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ABSTRACT

We demonstrate Transcalibur, which is a hand-held VR controller that can render a 2D shape by changing its mass properties on a 2D planar area. We built a computational perception model using a data-driven approach from the collected data pairs of mass properties and perceived shapes. This

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enables Transcalibur to easily and effectively provide convincing shape perception based on complex illusory effects. Our user study showed that the system succeeded in providing the perception of various desired shapes in a virtual environment. In the demonstration, users can explore VR application that can feel the sensation of wielding sword, shield and crossbow and with these fight with a dragon.

CCS CONCEPTS

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

KEYWORDS

Computational interaction; Haptic display; Virtual reality; Shape perception

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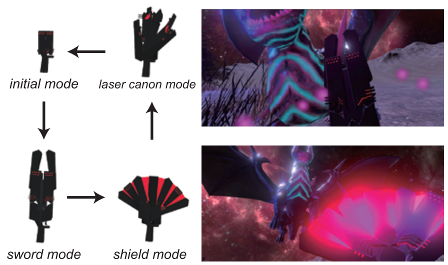

Figure 1: Application footage. The left image shows the transition between different weapons in VE. The right image shows the game footage of players fighting the dragon with a sword and a shield.

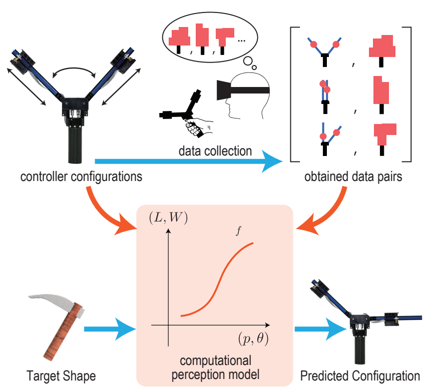

Figure 2: System diagram. Transcalibur renders shape using the computational perception model obtained by data collection.

TRANSCALIBUR

Transcalibur is a hand-held VR controller that dynamically and illusorily changes the perceived shape of a 2D object. Figure 3 shows the hardware overview of the Transcalibur. The weight moving mechanisms on the controller changes its 2D mass properties, which provides various shape perceptions for the user in VR. The perceived shape can be rendered based on a perception model which is built by precollected perception data through the experiment (Figure 2).

When we grab and wiggle an object, we feel the object through haptic sensation: the skin on the hand in contact will be stretched and the muscles and tendons of the arm will contract. This means that humans can guess what s/he is holding even when their *eyes are closed*. Researchers in psychology have revealed that the mass properties of an object, such as rotational inertia and center of gravity, affect the perception of what shape of the object people are wielding [2–5]. This occurs even when the actual shape differs from the perceived shape. That being said, we can *illusorily* present various sensations of wielded objects through changes in the mass properties of the object. We call this *Haptic Shape Illusion*. By utilizing this effect: namely *Haptic shape illusion*, we can simulate the shape of a wielded object without using the actual shape of a targeted object.

Haptic shape illusion involves utilizing the perceptual illusion existing between the mass properties of a wielding object and shape perception. However, in most cases, this relation makes it difficult to predict how or how much of the illusion effect could occur, especially for a VR experience designer, owing to the nonlinearity of human perception, which means that what one perceives is not always

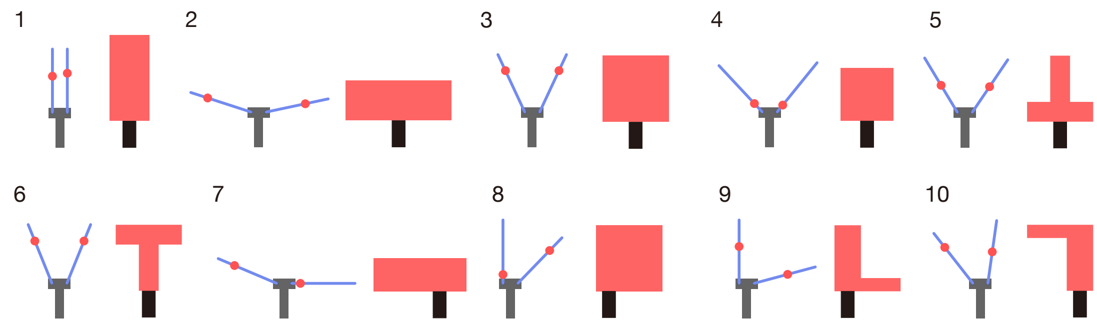

Figure 5: Ten pairs of physical properties of Transcalibur and their corresponding virtual shapes provided in the experiment. Each configuration of Transcalibur is predicted from the linear regression model.

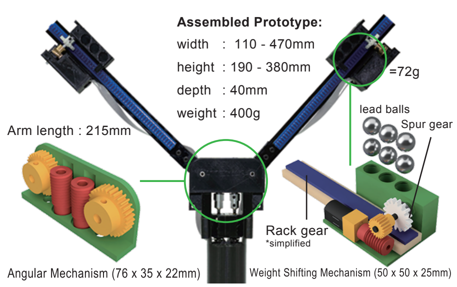

Figure 3: Mechanical design of the proposed device.

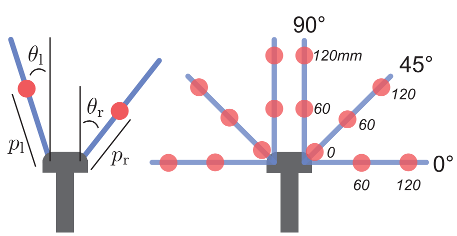

Figure 4: Illustrated configuration variables of Transcalibur ($p_r, \theta_r, p_l, \theta_l$).

consistent with what one is actually exposed to. Even if the type of sensory input and perceptual phenomenon are clarified through previous psychology studies, their mapping must be restudied and reoptimized when a device or an environment that we assume is different from the one observed in previous studies. To overcome this problem, we apply the *Computational Perception Model* to this device. This approach allows providing haptic feedback based on actual human perception data. We collect data pairs of physical configurations of Transcalibur (positions of weight modules on the controller) and the shapes displayed in VR for users and fit to the machine learning model. Then, from the desired shape that we want to display in VR, we derive Transcalibur configurations from the trained model. In this manner, we can easily and efficiently design and provide haptic shape experiences for various users.

PERCEPTION MODEL DESIGN

Mapping from Controller to Virtual Shape

As a previous work on computational fabrication of hand-held controller [1] proposed, we assumed a perception model f that maps the physical configuration of the controller ϕ to the perceived shape of the wielded object in VR ψ. That said: $f : \phi \mapsto \psi$

Regression Model

Using the obtained data pairs, we performed regression analysis to build a map f from the configurations of the controller onto the perceived shapes. For each parameter in ϕ, we used a linear

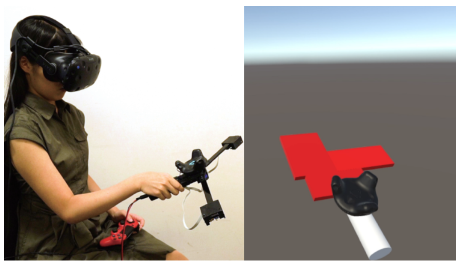

Figure 6: In the data collection experiment, a participant grabs and wiggles the Transcalibur with him/her dominant hand and uses joypad with him/her non dominant hand. In VE (right) the participants can see the adjustable shape.

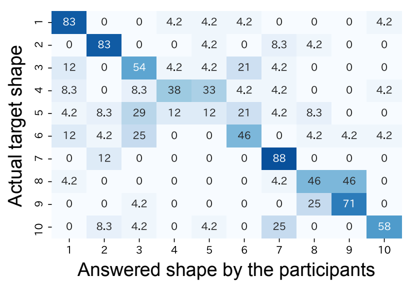

Figure 7: Confusion matrix derived from the results of the experiment. To measure the validity of the perception model, we conducted validation experiments. We prepared ten shapes to present in the VE, which can be described using the same parameter format d_i as that of the data collection experiment (Figure 5). Each row shows ratio [%] of the actual target shape answered as the test shape in VR.

regression model and trained model $\psi = f(\phi; \boldsymbol{A}, \boldsymbol{b})$ to describe the perceived shape $\psi = \phi \boldsymbol{A} + \boldsymbol{b}$, where $\boldsymbol{A} \in \boldsymbol{R}^{4\times4}, \boldsymbol{b} \in \boldsymbol{R}^{1\times4}$ as parameter and $\phi, \psi \in \boldsymbol{R}^{1\times4}$ as an input and output data.

Collecting Perceived Shape Data

Data Collection Experiment. In the data collection experiment, we provided the participants with various shapes of the controller and asked them to report the perceived shapes in VE. This generates matched pairs of (ϕ_i, ψ_i), which are used to build a regression model for the training data. The mass properties of the controller presented and the exact values used for configurations are shown in Figure 4, and 28 different configurations are used in the data collection experiment. As shown in Figure 6, participants are provided adjustable virtual shape with four rectangular area in VE, and are asked to provide the shape that best fits to the perceived sensation through a Transcalibur. A joypad is used for the input device for the experiment. The input variables are converted into four variables representing a rectangular bounding box the shape and a Center of Gravity (CoG) coordinates (H, W, G_x, G_y). Overall, our perception model succeeded in providing various target shapes in VR.

CONCLUSION

In this paper, we introduced Transcalibur: the weight moving VR controller for 2D haptic shape illusion. We implemented a hardware prototype, which can change its mass property in 2D planar space, and applied data-driven methods to obtain maps between mass property and perceived shape. Based on the demonstration and experiment, we succeeded in rendering various shape perceptions through the controller based on pre-computed perception model. In the demonstration, we present a VR application that users can fight against dragon using a sword, shield and guns and feel different sensation of shape through the proposed device.

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