# Handheld Haptic Interface for Rendering Size, Shape, and Stiffness of Virtual Objects

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## Abstract
*PaCaPa* is a handheld device that presents haptic stimuli on a user’s palm when the user interacts with virtual objects using virtual tools. It is a box-shaped device and has two wings. This device can present the contact force and contact angle by opening and closing the wings based on the angle between the direction of the virtual tool and hand. By changing these haptic sensations on the palm and fingers, it enables the users to perceive different size, shape, and stiffness of virtual objects.

## Author Keywords
Haptics, Virtual Reality, Tool-based Interaction

## ACM CCS Concepts
• Human-centered computing ~ Haptic devicea

## Introduction
Recent development in Virtual Reality (VR) enables us to immerse a realistic virtual environment using high fidelity visual and audio feedback, and interact with virtual objects in the environment. As multisensory perception is significant for more immersion, many researchers have developed various haptic technologies that render haptic properties of virtual objects. In a

virtual environment, users often held a tool in hand such as wielding a sword to kill enemies and hitting a ball with a bat in a baseball game. In these tool-based interactions, users get contact with virtual objects via a handheld tool. For tool-based interaction, VR controllers are usually used. Then haptic feedback systems are sometimes integrated into VR controllers [1-4]. In the conventional case, vibrotactile feedback is used as a method of haptic rendering. Although it can tell the collision and supports delicate manipulation [5], vibrotactile feedback is often used as notification of collision and not suitable for rendering haptics in surface interaction such as force and stiffness.

Herein, we introduce PaCaPa: a handheld VR controller device which renders size, shape, and stiffness of virtual objects by presenting contact force and contact angle on a user’s palm. This device has two wings, and dynamically presents pressure sensation to the palm and fingers by opening and closing the wings.

### Device for Presenting Contact Force and Angle on Palm

When we interact with an object by touching and hitting with various tools including stick and sword, we get haptic sensations. Say there is a hard box in front of you and you are trying to hit the box with a stick. When the stick touches the box, you will sense vibration. If you keep biting the box with the stick, then you will feel pressure on your palm since the stick cannot go the way you are intended to go. In VR application, users often have a stick shaped tool such as sword or racket in their hand. If users have the tool in their hand and interact with some objects in virtual space, the same thing should occur.

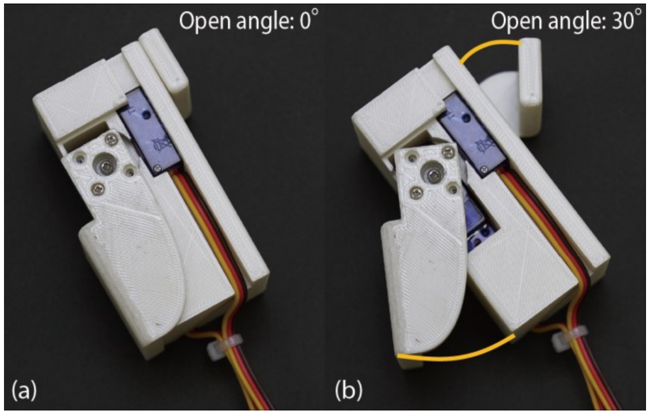


**Figure 1**: A handheld device for presenting contact force and angle via a virtual tool. (a) Wings are closed. (b) Wings are opened to give pressure sensation on palm and fingers.

To present these touching sensations of virtual surfaces in tool-based interaction, we created a box-shaped device, which represents part of the stick (Figure 1). Users will feel the stick rotates in the opposite direction users are intending to go with their hand as an axis. Therefore, we attached two wings to the device so that it opens and closes to create this pressure when people hold it in hand. We created a handheld device for ease of use so that user can just hold a device without any setup procedure.

To accomplish the mechanism that wings open and close, we used a servo motor (TowerPro 9g digital servo SG92R). We used one servo motor for each wing to create bigger torque. Two servo motors are placed in the center of the box and wings are attached to the motors. Both box and wings are 3D-printed and made of PLA. By manipulating the two motors, wings can open and close in the range of 0 to 90 degree. This hardware design imitates part of the stick so that user can hold like a stick. This design was adapted to present pressure sensation with two wings when the user waves the stick and touch some objects. This device gives pressure on three fingers, middle, ring and pinky fingers and skin between the root of the index finger and that of thumb as the wings open. These are based on the observation that we feel pressure when having a stick and hit something.

We used a microcontroller (Arduino UNO) to control two servo motors in the device through pulse-width modulation (PWM). Unity 3D game engine is used for rendering VR applications. We used USB serial communication to connect the microcontroller and PC at a baud rate of 9600. Unity 3D game engine handles the communication with the device and determines the degree wings open and close.

## Interaction in VR

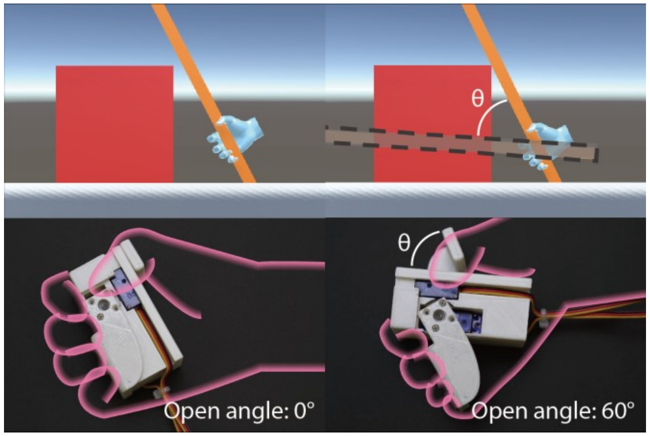


**Figure 2**: Changing the open angle of two wings to present contact sensation with a virtual object.

Since there’s a gap between the area and direction that hand can move in reality and a virtual environment, simply rendering a virtual stick according to position and rotation of the hand. We established a method to calculate the position and direction of the virtual stick using constraint-based god-object method [6]. In our method, we used an object called a god object. This is the virtual stick that does not penetrate the target object. God object is in the same location and rotation with the real stick when the real stick does not conflict with target objects. When the stick hit the object for the first time, the collision point was registered, and god object is put at the place. From next frame, we see whether the stick penetrates the target object if the stick moves to the real stick location from the god object location. If it hits anything, we put the god object at the new collision point calculated from connecting real stick and god object. God object is calculated to intersect the new collision point and hand position. If it does not hit anything, the god object starts to follow real stick. Virtual stick is always rendered at the point of god object. The degree of device’s wings from original folded-position corresponds to the angle between real stick manipulated with the controller and virtual stick shown in VR space as a result of these calculations (Figure 2). This makes a stronger sense of pressure as stick bites into the target object.

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