Second Milestone presentation Pre recorded video – Upload to ELMS Oct 31 EOD

We will move it from Oct 26 to Oct 31 (from Wed to Mon) so that you have a bit more time to work on it.

Format:

5 min presentation ~~+ 3 min Q& A~~

A brief overview of what you've been working on since the first milestone

A live demo to showcase your current progress (achievement and challenges)

Plan for improvement

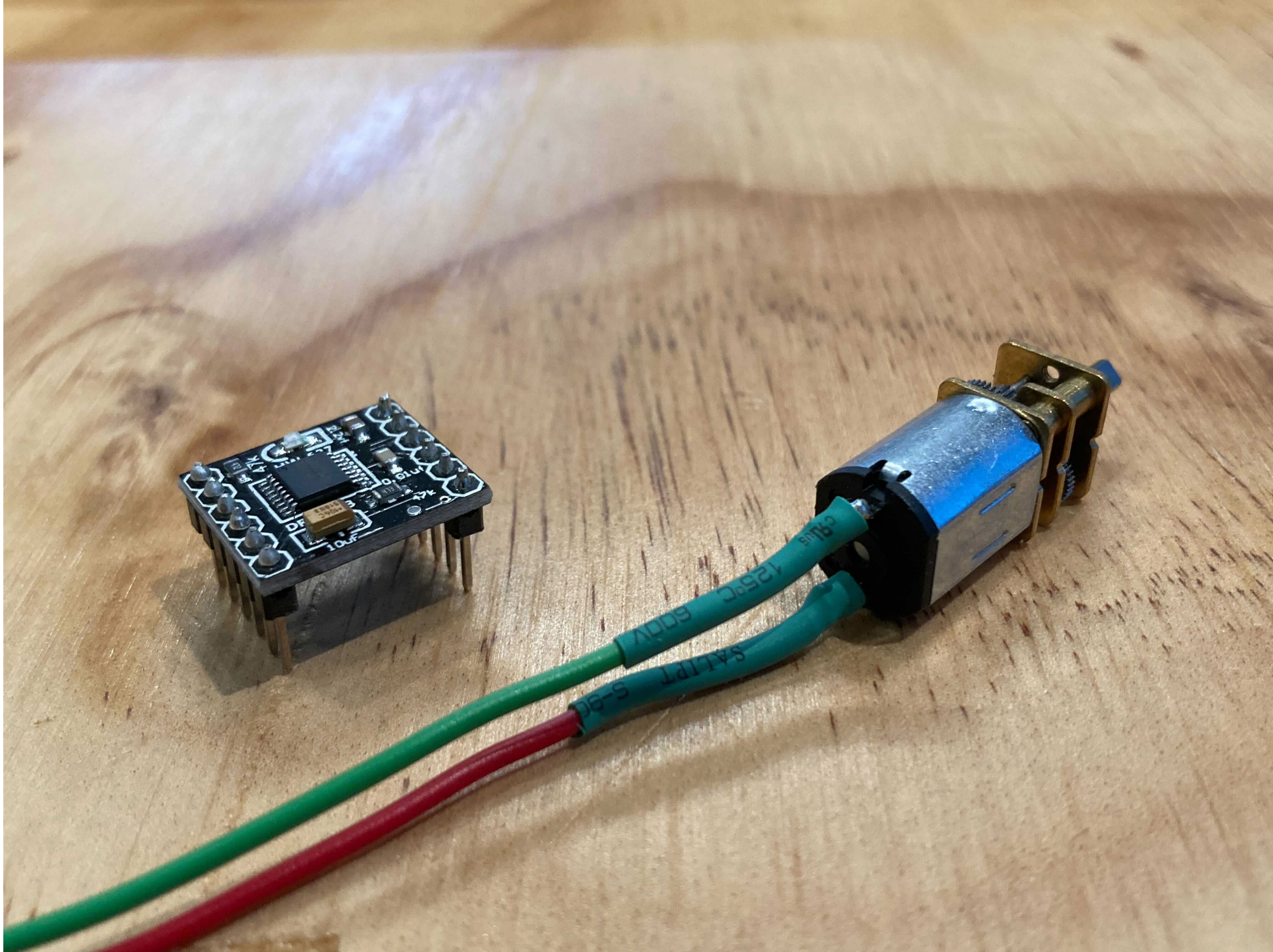
Documentation (which is due on Wed of the week of presentation)

Robot Competition

Tube

Robot Competition

Motor



Robot Competition

Logic

SMALL _ARTIFACTS LAB;

Rapid-Prototype Robot Competition

Abstract

In this project, you are going to design, build, and prototype a working bridge-crossing robot. The robot design is under given constraint and will fulfill given tasks at the competition. Please read this document **THOROUGHLY** before starting on the project!!!

Design Constraints and Requirements

The basic function of your robot is to move along a "bridge". The bridge is about 1 meter long and is wrapped with a layer of soft foam. You will try to move your robot from the start — one end of the tube to the other end, then come back. The bridge is installed in Sandbox and you are free to test your design any time before the competition day.

For this project, there is no dedicated design you should follow. In other words, as a designer and prototyper, you are free to design the bot and its climbing mechanism however you want. Although, as there is no project without limitations on resources, here are four design requirements that you should follow:

1. Only one ESP32, one motor driver, and one gear motor are allowed in your design. Figure 1 shows the motor driver and the gear motor. Alternatively, you are allowed to substitute the gear motor with the servo motor that is provided in your kit. If you decide to use the servo motor, you are not allowed to use the gear motor, hence no motor driver is needed. You are allowed to use other non-actuation components in your design, e.g. IMU. If you are not sure whether certain parts can be used for your project, consult your instructor and TA.
2. Your robot will be powered via either the usb cable provided, or a 7.4v 250-350 mah Li-Po battery. Note that there are advantages and disadvantages both ways, please read the "Hint" section for more information.
3. Your robot has to be controlled by a laptop via keyboard. There should be at least 3 commands functional: move left, move right and stop. You can choose to send the command either via Bluetooth or serial (closely related to how do you want to power your robot). You can also implement WIFI connection between your laptop and your esp32, however, since WIFI drains the battery really quickly and router won't be provided at the competition, we don't recommend WIFI as your first choice. But if you do decide on using WIFI, please make sure you can accommodate your robot with proper power source and connection at the competition.
4. You should design your robot self-contained. That is, your robot should hold all the electronics, except the usb cable if you decide to use one. Any Free hanging/moving motor, battery, breakout board, bread board, etc. will lead to points off. Any glue or tape will also lead to points off. We will provide a set of M2 bolts and nuts to work with, you are welcome to introduce any hardware you have access to into your assembly. Note that the batteries are going to be for shared use, so you should design your battery holder easy to access and easy to get battery in and out.

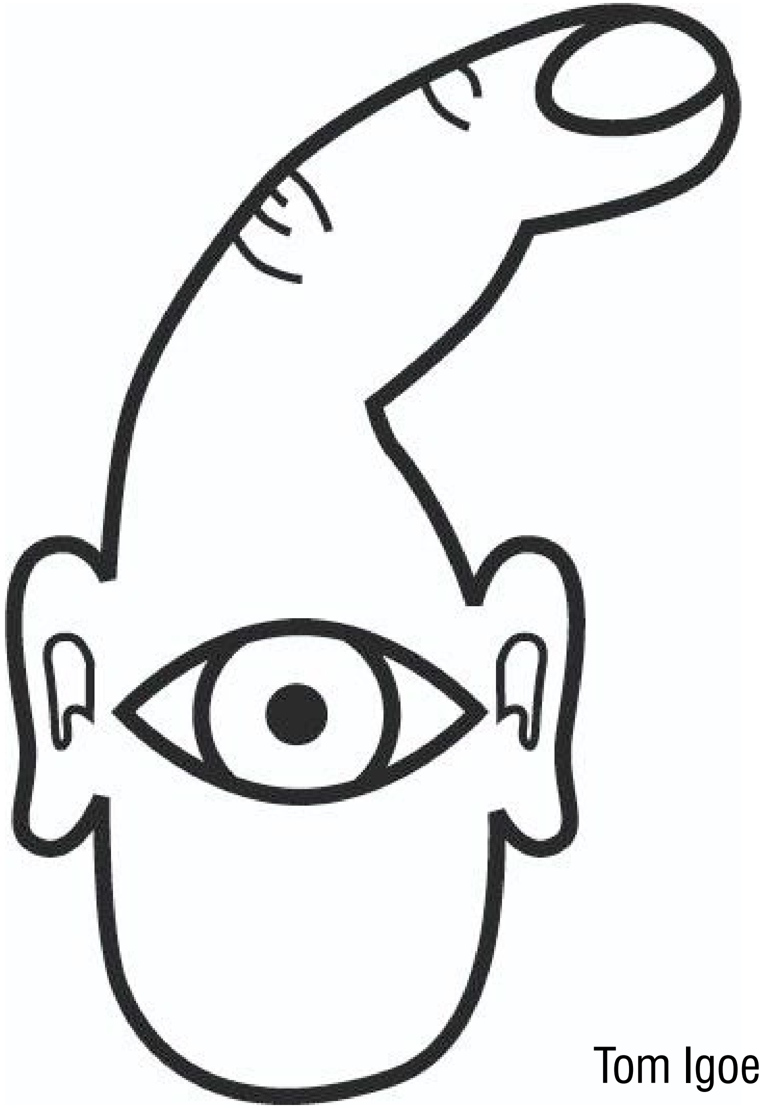
Haptics for VR

CMSC730 | Huaishu Peng | UMD CS


Small taste of VR
Haptics Research

Visual rendering is not enough to offer immersive experience

Sight vs Touch



Touch

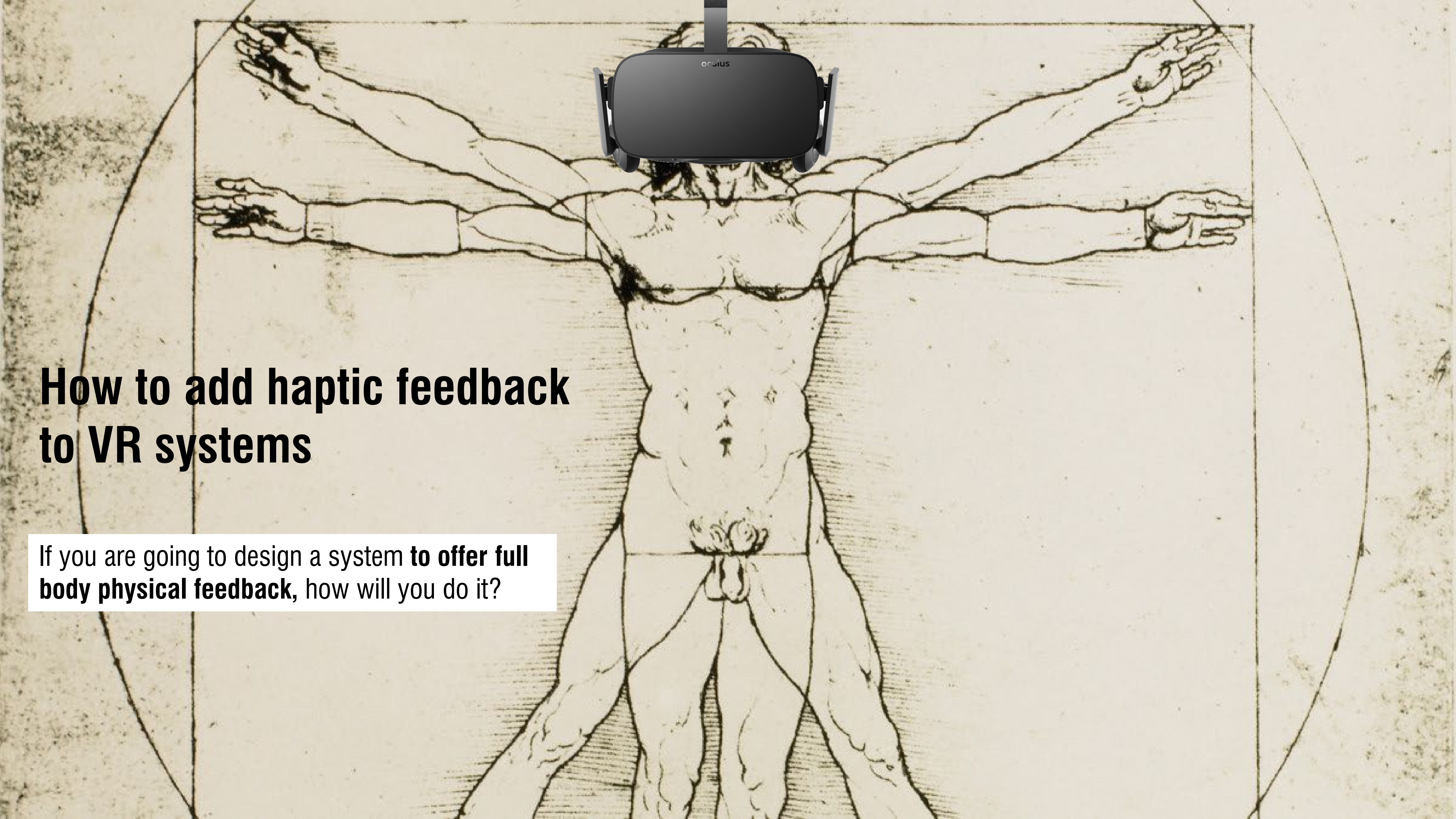
distributed
narrow
active
physical

Sight

centralized
broad
passive
cognitive

Tom Igoe


Current VR Controllers
Vibration
SONY
VIVE
SONY
VIVE
VR SOURCE



How to add haptic feedback to VR systems

If you are going to design a system **to offer full body physical feedback,** how will you do it?

Pure vibrotactile stimulation ignores the role of sustained or distributed force in conveying realism.

In the real world, very few experiences are conveyed by vibration alone.

Hardlight VR Suit

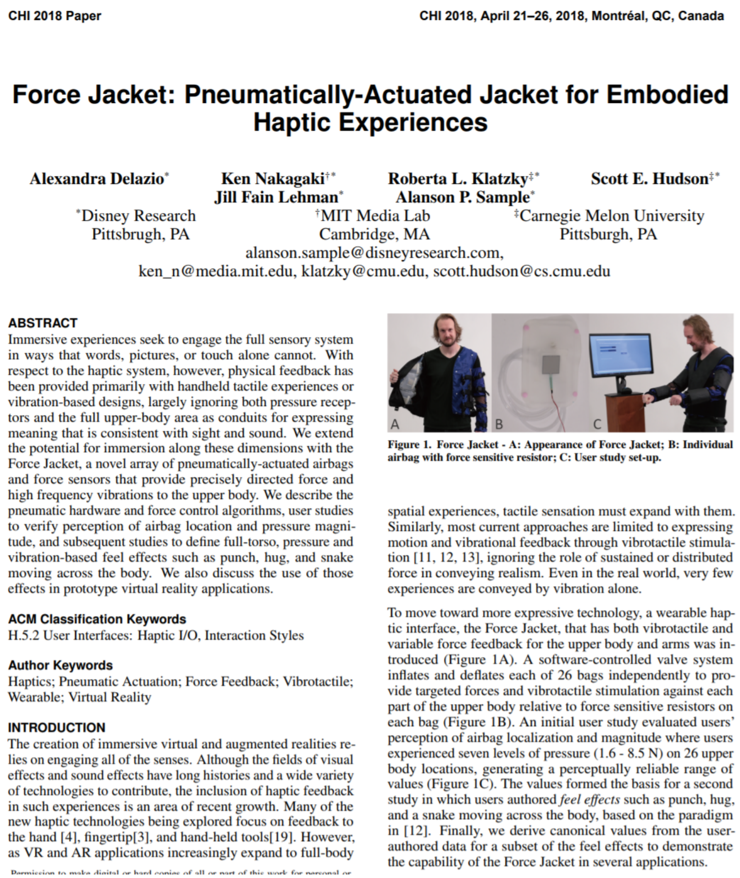
Failed Kickstarter Campaign

An alternative idea?

An alternative idea?

Offer both **vibration** and **variable force feedback** with pneumatic haptic wearable system

Force Jacket: Pneumatically-Actuated Jacket for Embodied Haptic Experiences



Force Jacket: Pneumatically-Actuated Jacket for Embodied Haptic Experiences

Alexandra Delazio* Ken Nakagaki†* Roberta L. Klatzky‡* Scott E. Hudson‡*
Jill Fain Lehman* Alanson P. Sample*
*Disney Research, Pittsbrugh, PA
†MIT Media Lab, Cambridge, MA
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ken_n@media.mit.edu, klatzky@cmu.edu, scott.hudson@cs.cmu.edu

ABSTRACT
Immersive experiences seek to engage the full sensory system in ways that words, pictures, or touch alone cannot. With respect to the haptic system, however, physical feedback has been provided primarily with handheld tactile experiences or vibration-based designs, largely ignoring both pressure receptors and the full upper-body area as conduits for expressing meaning that is consistent with sight and sound. We extend the potential for immersion along these dimensions with the Force Jacket, a novel array of pneumatically-actuated airbags and force sensors that provide precisely directed force and high frequency vibrations to the upper body. We describe the pneumatic hardware and force control algorithms, user studies to verify perception of airbag location and pressure magnitude, and subsequent studies to define full-torso, pressure and vibration-based feel effects such as punch, hug, and snake moving across the body. We also discuss the use of those effects in prototype virtual reality applications.

ACM Classification Keywords
H.5.2 User Interfaces: Haptic I/O, Interaction Styles

Author Keywords
Haptics; Pneumatic Actuation; Force Feedback; Vibrotactile; Wearable; Virtual Reality

INTRODUCTION
The creation of immersive virtual and augmented realities relies on engaging all of the senses. Although the fields of visual effects and sound effects have long histories and a wide variety of technologies to contribute, the inclusion of haptic feedback in such experiences is an area of recent growth. Many of the new haptic technologies being explored focus on feedback to the hand [4], fingertip[3], and hand-held tools[19]. However, as VR and AR applications increasingly expand to full-body spatial experiences, tactile sensation must expand with them. Similarly, most current approaches are limited to expressing motion and vibrational feedback through vibrotactile stimulation [11, 12, 13], ignoring the role of sustained or distributed force in conveying realism. Even in the real world, very few experiences are conveyed by vibration alone.

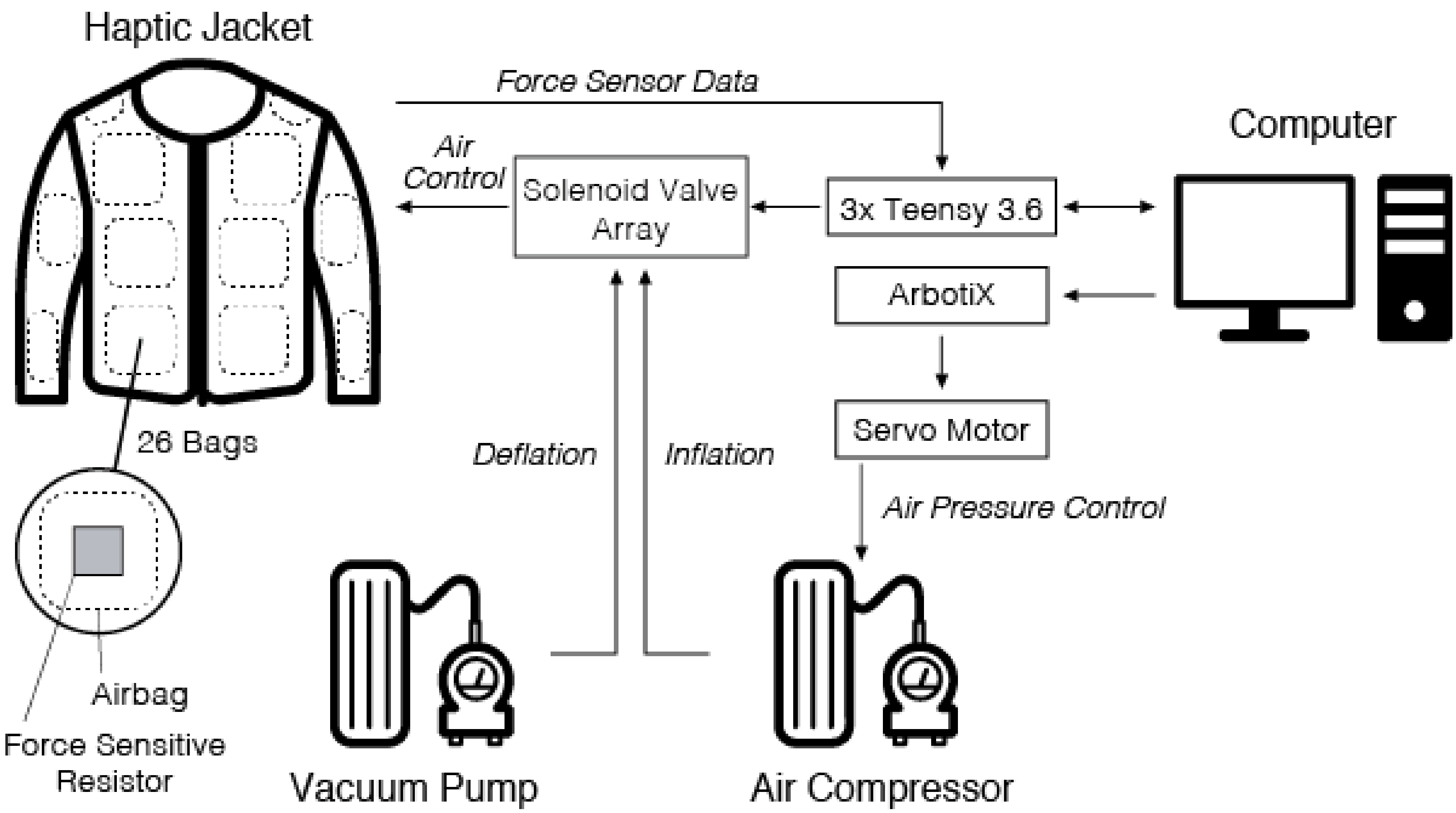
Figure 1. Force Jacket - A: Appearance of Force Jacket; B: Individual airbag with force sensitive resistor; C: User study set-up.

To move toward more expressive technology, a wearable haptic interface, the Force Jacket, that has both vibrotactile and variable force feedback for the upper body and arms was introduced (Figure 1A). A software-controlled valve system inflates and deflates each of 26 bags independently to provide targeted forces and vibrotactile stimulation against each part of the upper body relative to force sensitive resistors on each bag (Figure 1B). An initial user study evaluated users' perception of airbag localization and magnitude where users experienced seven levels of pressure (1.6 - 8.5 N) on 26 upper body locations, generating a perceptually reliable range of values (Figure 1C). The values formed the basis for a second study in which users authored *feel effects* such as punch, hug, and a snake moving across the body, based on the paradigm in [12]. Finally, we derive canonical values from the user-authored data for a subset of the feel effects to demonstrate the capability of the Force Jacket in several applications.

CHI 2018

Delazio et.al.

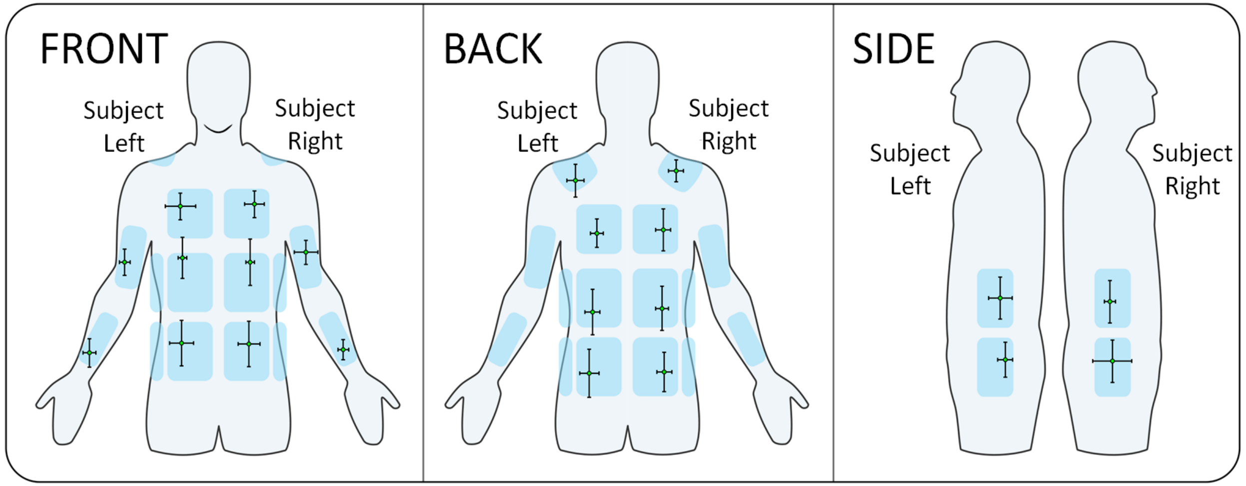
How are you going to build such system? What are the possible hardware components?


Haptic Jacket
Force Sensor Data
Computer
Air Control
Solenoid Valve Array
3x Teensy 3.6
ArbotiX
Servo Motor
26 Bags
Deflation
Inflation
Air Pressure Control
Airbag
Force Sensitive Resistor
Vacuum Pump
Air Compressor

Will it work? What would be the next step with the initial prototype?

Localization User Study

to determine users' ability to perceive the location of the various inflatable compartments in the haptic pneumatic wearable.



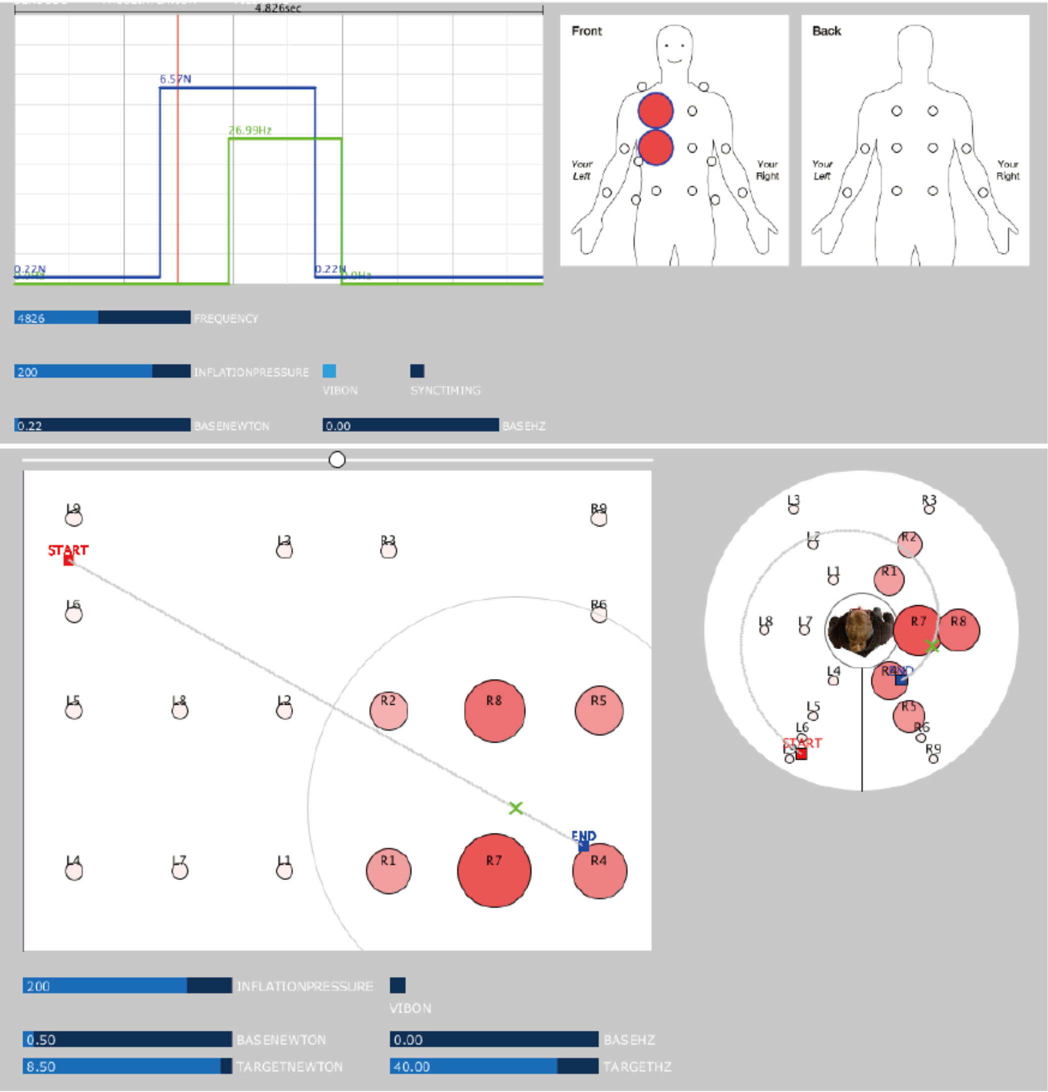
There was a tendency to feel the lower arm location toward the wrist. Shoulder locations were biased toward the upper back rather than centered on top of the shoulders.

Free Magnitude User Study

to determine how perceived pressure magnitude was related to inflation magnitude of the various air compartments in the Jacket.

Haptic Effect Editor

to easily create and control haptic feedback sequences

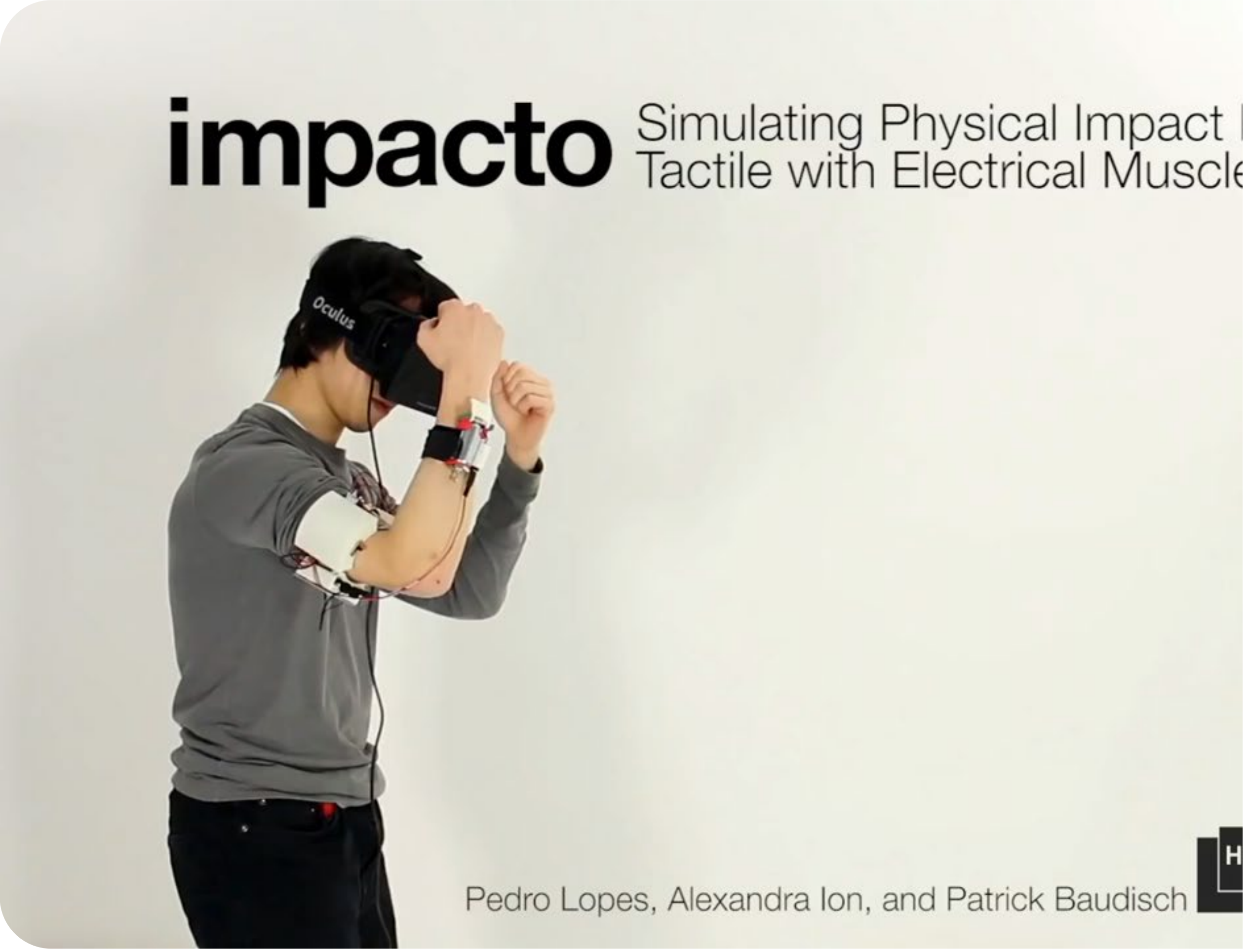


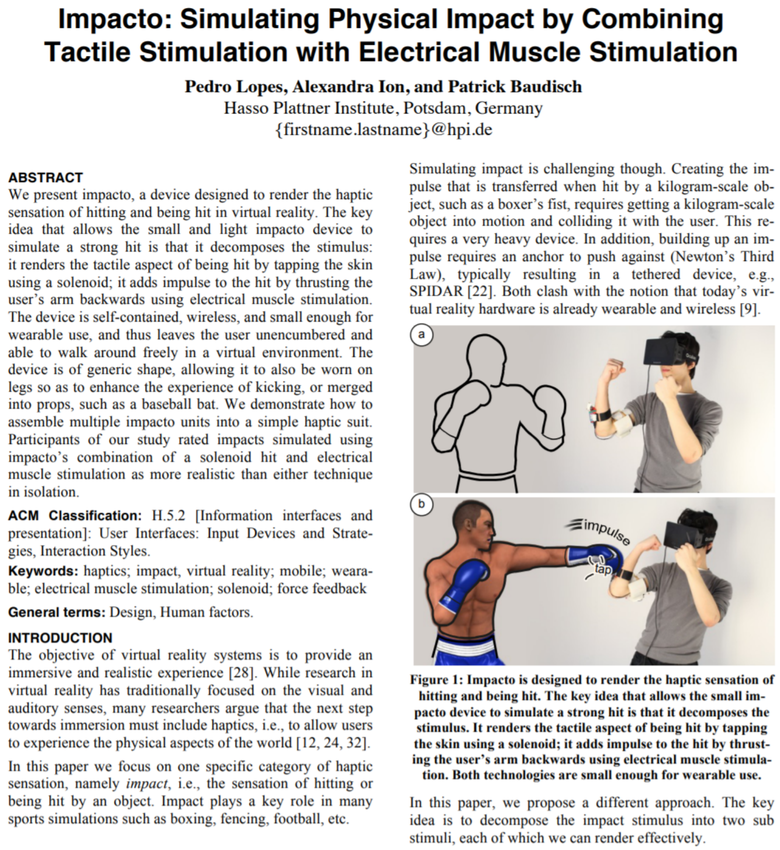
Inflation Pressure [psi]
Target Force [N]
Feedback Duration [ms]
Target Frequency [Hz]
Bags To Inflate

Applications


Oculus
Simulate **impact** in VR

Impacto: Simulating Physical Impact by Combining Tactile Stimulation with EMS





Impacto: Simulating Physical Impact by Combining Tactile Stimulation with Electrical Muscle Stimulation

Pedro Lopes, Alexandra Ion, and Patrick Baudisch
Hasso Plattner Institute, Potsdam, Germany
{firstname.lastname}@hpi.de

ABSTRACT
We present impacto, a device designed to render the haptic sensation of hitting and being hit in virtual reality. The key idea that allows the small and light impacto device to simulate a strong hit is that it decomposes the stimulus: it renders the tactile aspect of being hit by tapping the skin using a solenoid; it adds impulse to the hit by thrusting the user's arm backwards using electrical muscle stimulation. The device is self-contained, wireless, and small enough for wearable use, and thus leaves the user unencumbered and able to walk around freely in a virtual environment. The device is of generic shape, allowing it to also be worn on legs so as to enhance the experience of kicking, or merged into props, such as a baseball bat. We demonstrate how to assemble multiple impacto units into a simple haptic suit. Participants of our study rated impacts simulated using impacto's combination of a solenoid hit and electrical muscle stimulation as more realistic than either technique in isolation.

ACM Classification: H.5.2 [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies, Interaction Styles.

Keywords: haptics; impact, virtual reality; mobile; wearable; electrical muscle stimulation; solenoid; force feedback

General terms: Design, Human factors.

INTRODUCTION
The objective of virtual reality systems is to provide an immersive and realistic experience [28]. While research in virtual reality has traditionally focused on the visual and auditory senses, many researchers argue that the next step towards immersion must include haptics, i.e., to allow users to experience the physical aspects of the world [12, 24, 32].

In this paper we focus on one specific category of haptic sensation, namely *impact*, i.e., the sensation of hitting or being hit by an object. Impact plays a key role in many sports simulations such as boxing, fencing, football, etc.

Simulating impact is challenging though. Creating the impulse that is transferred when hit by a kilogram-scale object, such as a boxer's fist, requires getting a kilogram-scale object into motion and colliding it with the user. This requires a very heavy device. In addition, building up an impulse requires an anchor to push against (Newton's Third Law), typically resulting in a tethered device, e.g., SPIDAR [22]. Both clash with the notion that today's virtual reality hardware is already wearable and wireless [9].

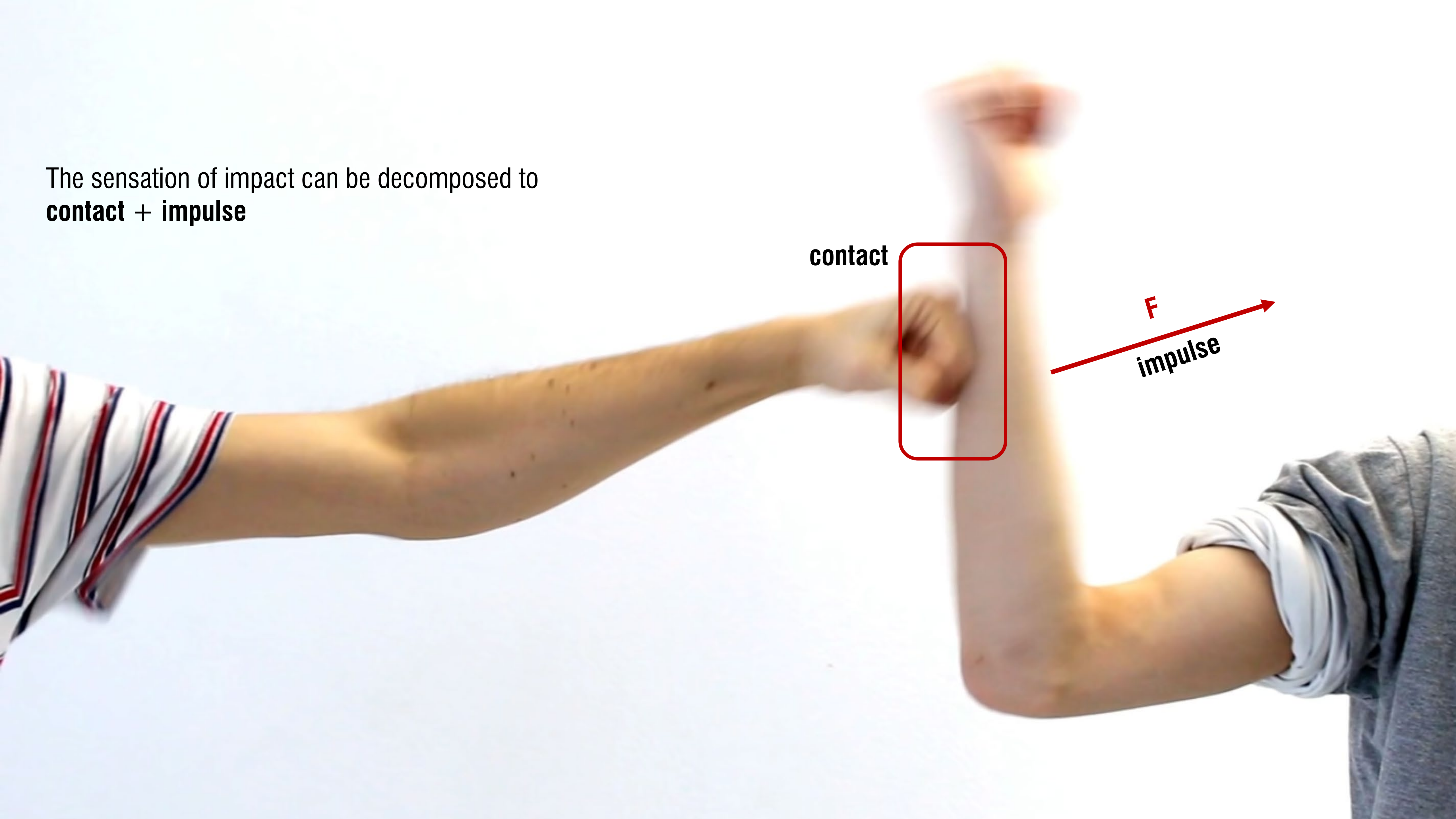
a
b
impulse
tap

Figure 1: Impacto is designed to render the haptic sensation of hitting and being hit. The key idea that allows the small impacto device to simulate a strong hit is that it decomposes the stimulus. It renders the tactile aspect of being hit by tapping the skin using a solenoid; it adds impulse to the hit by thrusting the user's arm backwards using electrical muscle stimulation. Both technologies are small enough for wearable use.

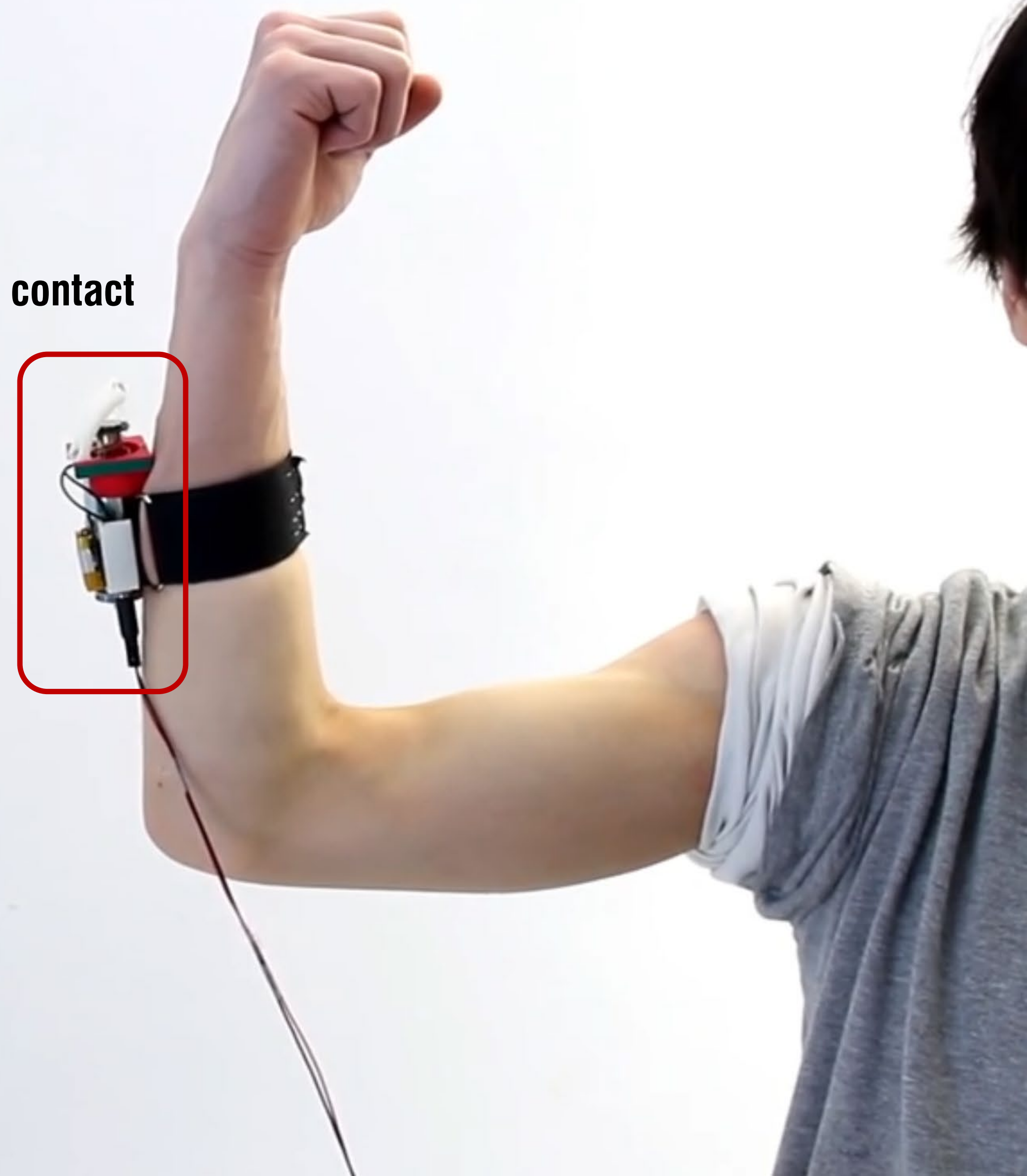
In this paper, we propose a different approach. The key idea is to decompose the impact stimulus into two sub stimuli, each of which we can render effectively.

UIST 2015

Lopes et.al.

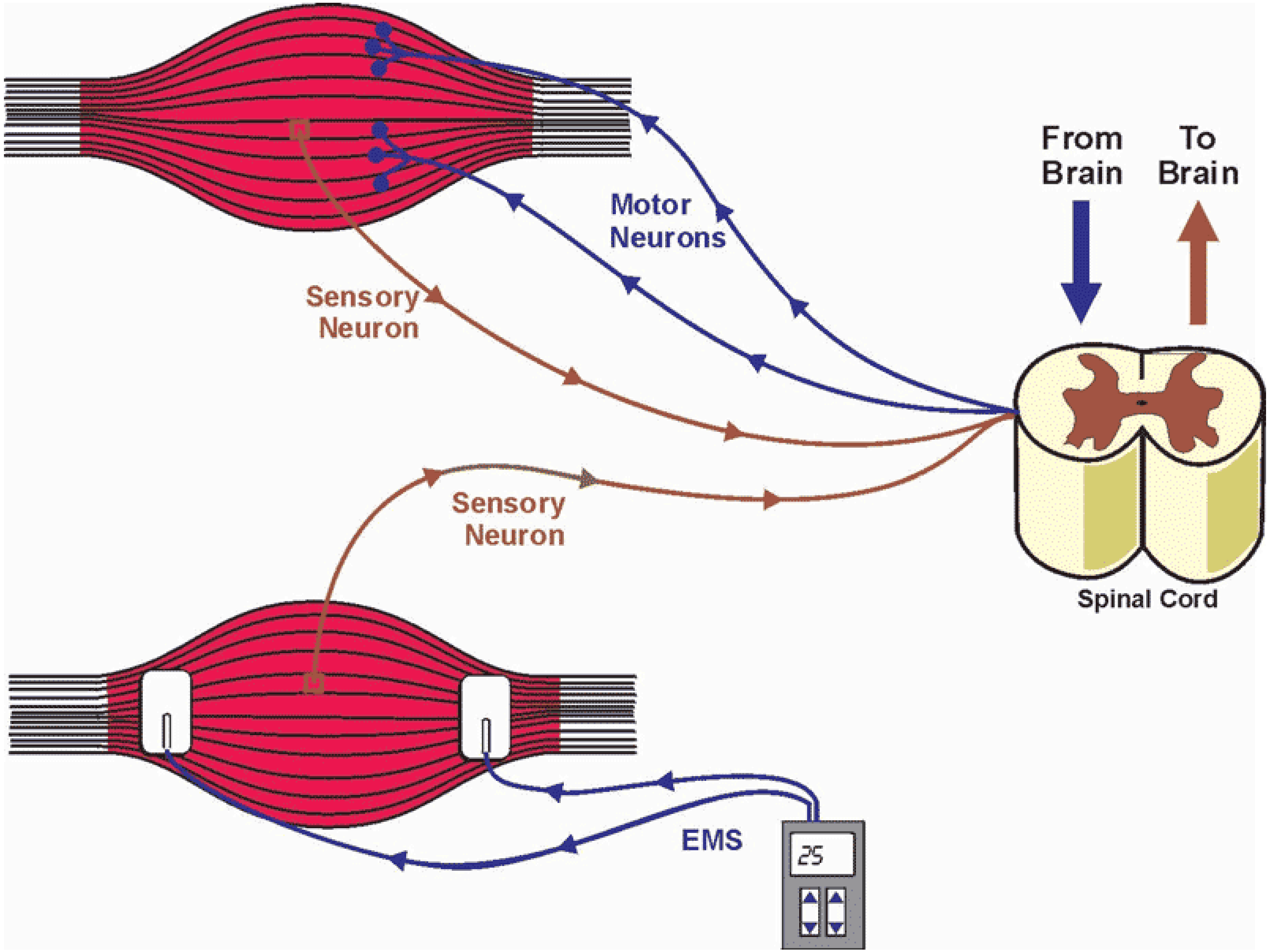

The sensation of impact can be decomposed to
contact + impulse
contact
F
impulse

The sensation of impact can be decomposed to
contact + impulse

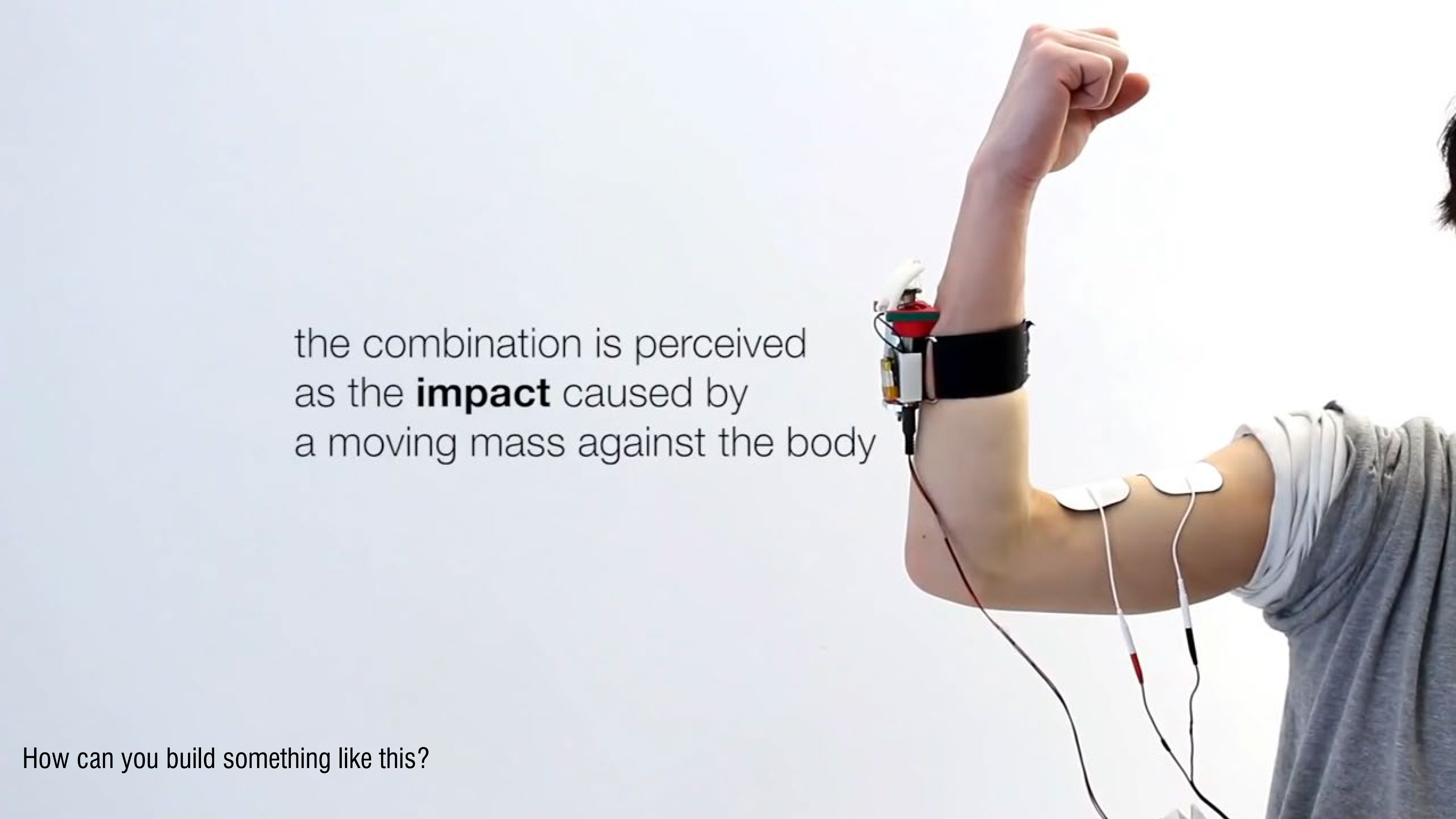


the **impulse** component
is rendered using
electrical muscle stimulation

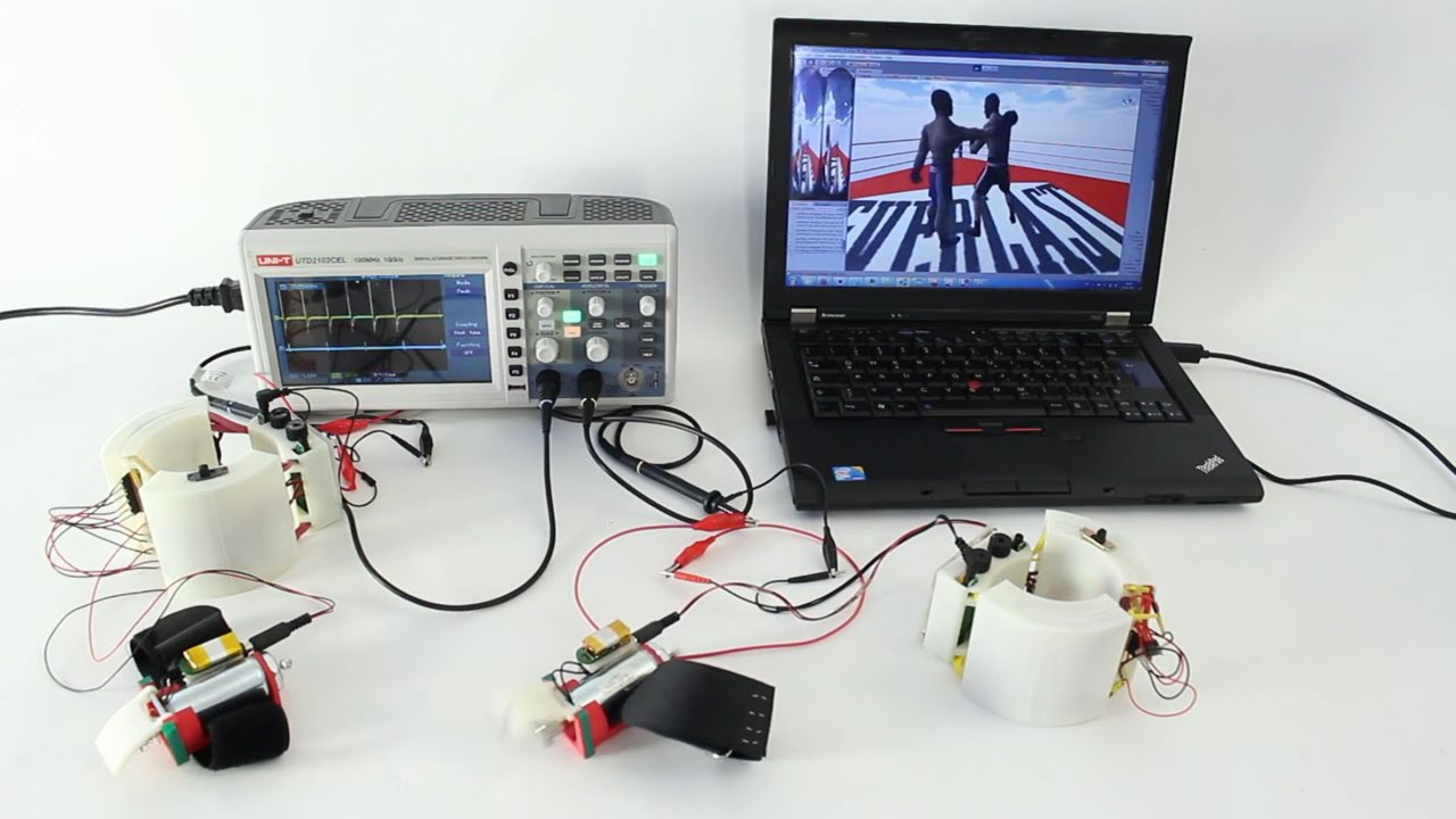
it thrusts the arm backwards

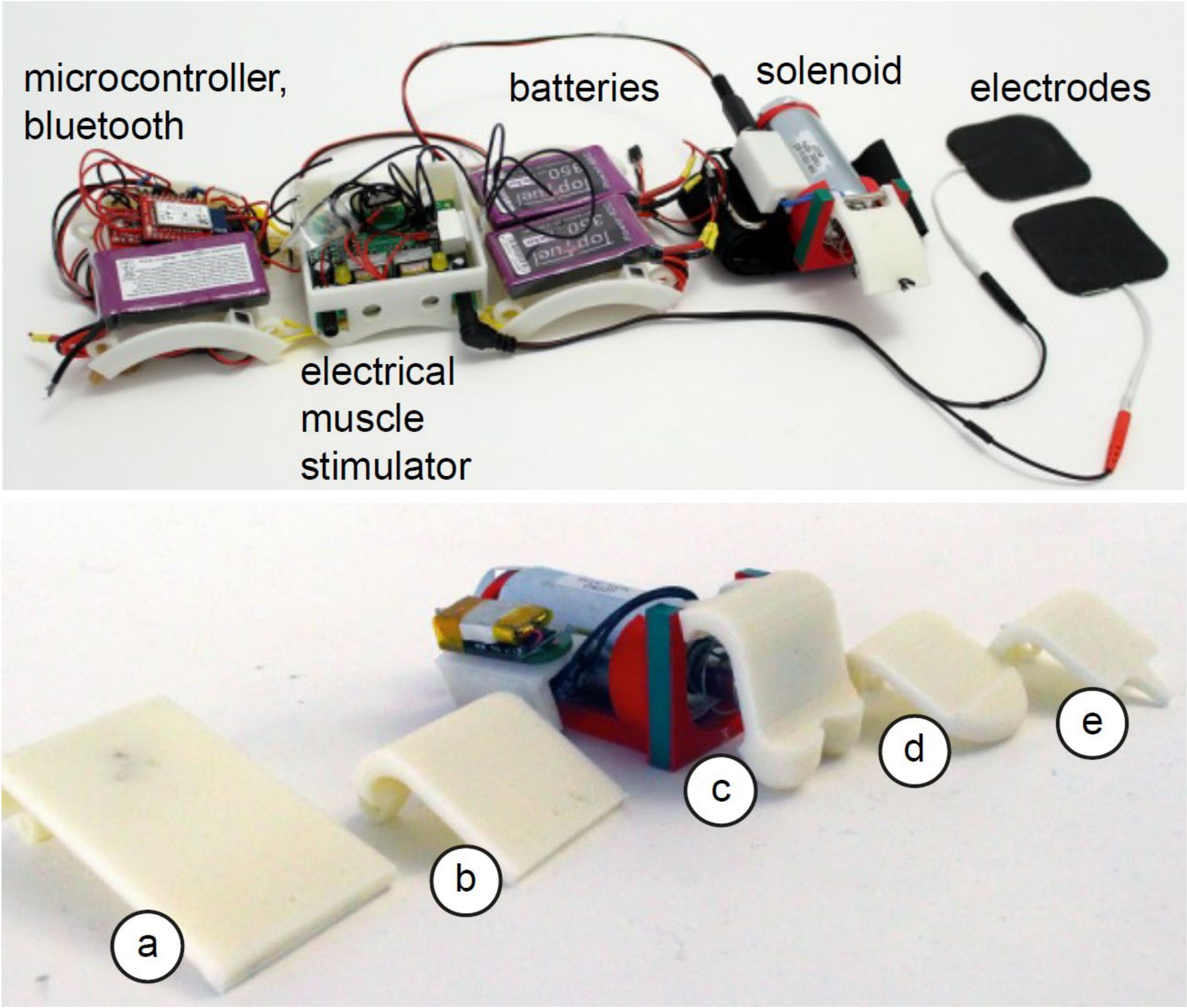


From Brain
To Brain
Motor Neurons
Sensory Neuron
Sensory Neuron
Spinal Cord
EMS
25

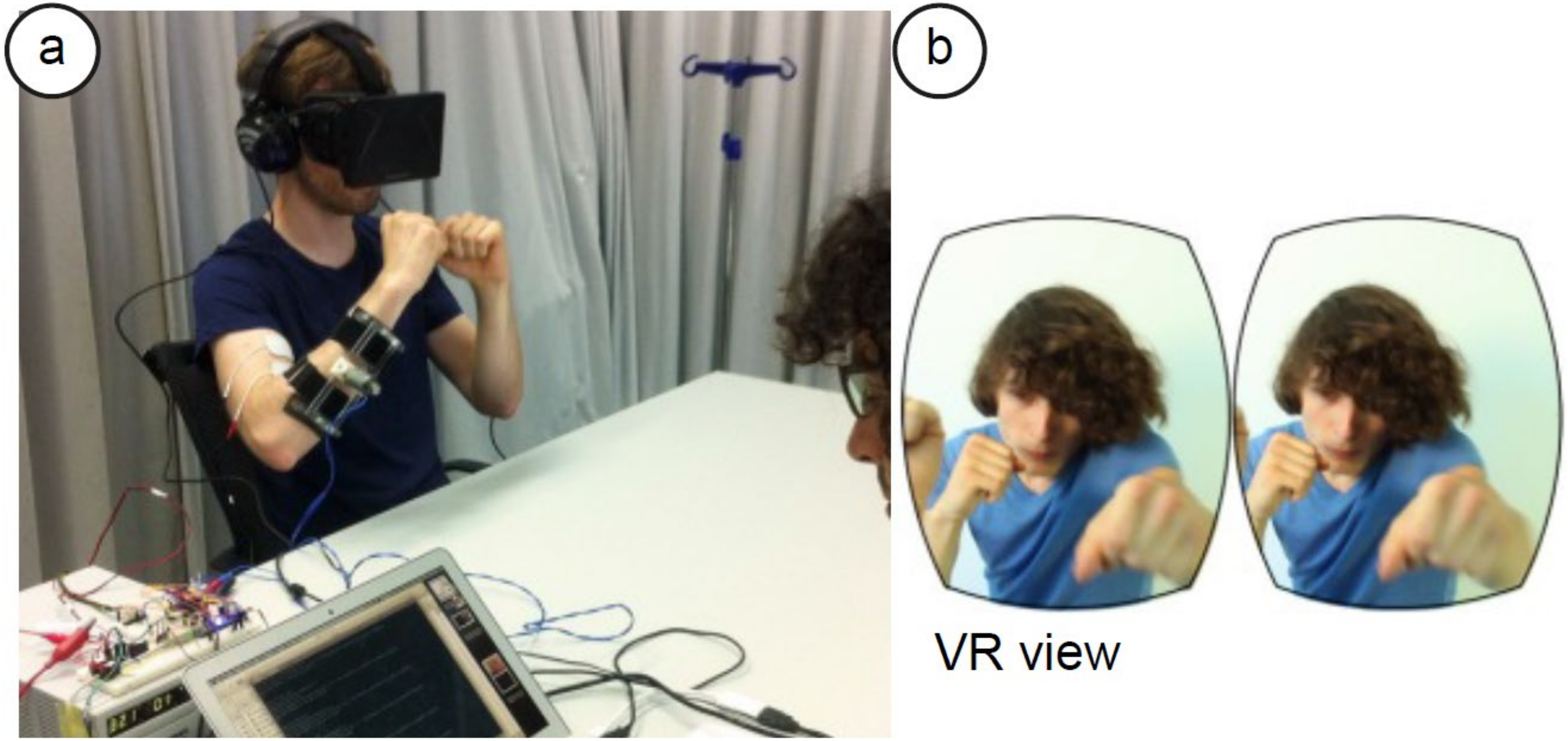


How can you build something like this?

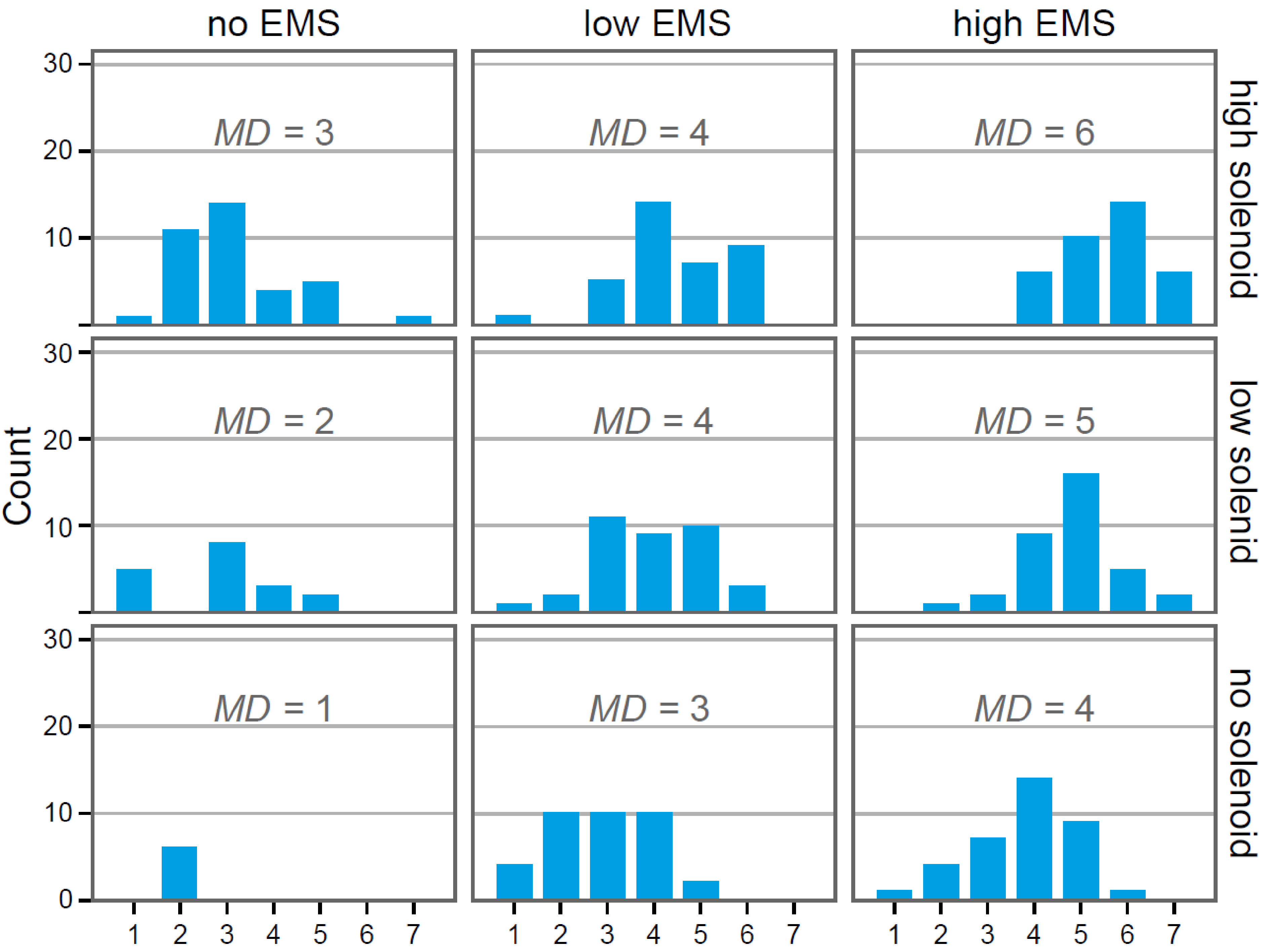

UNI-T
UTD2102CEL
100MHz 1GS/s


microcontroller,
bluetooth
batteries
solenoid
electrodes
electrical
muscle
stimulator
a
b
c
d
e

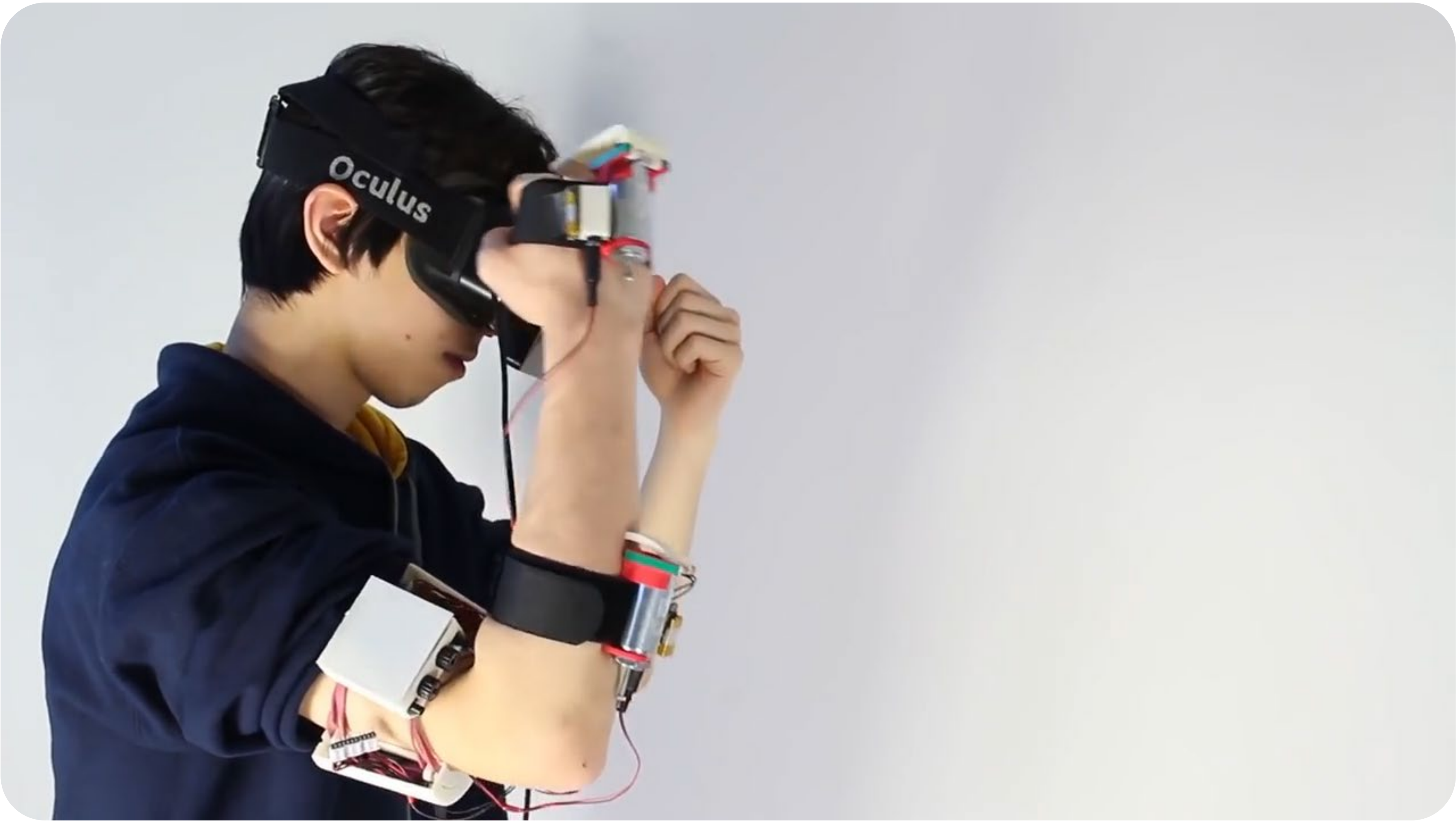
User study to evaluate the core idea ->decomposing an impact's haptic feedback into a tactile component (solenoid) and an impulse component (EMS)

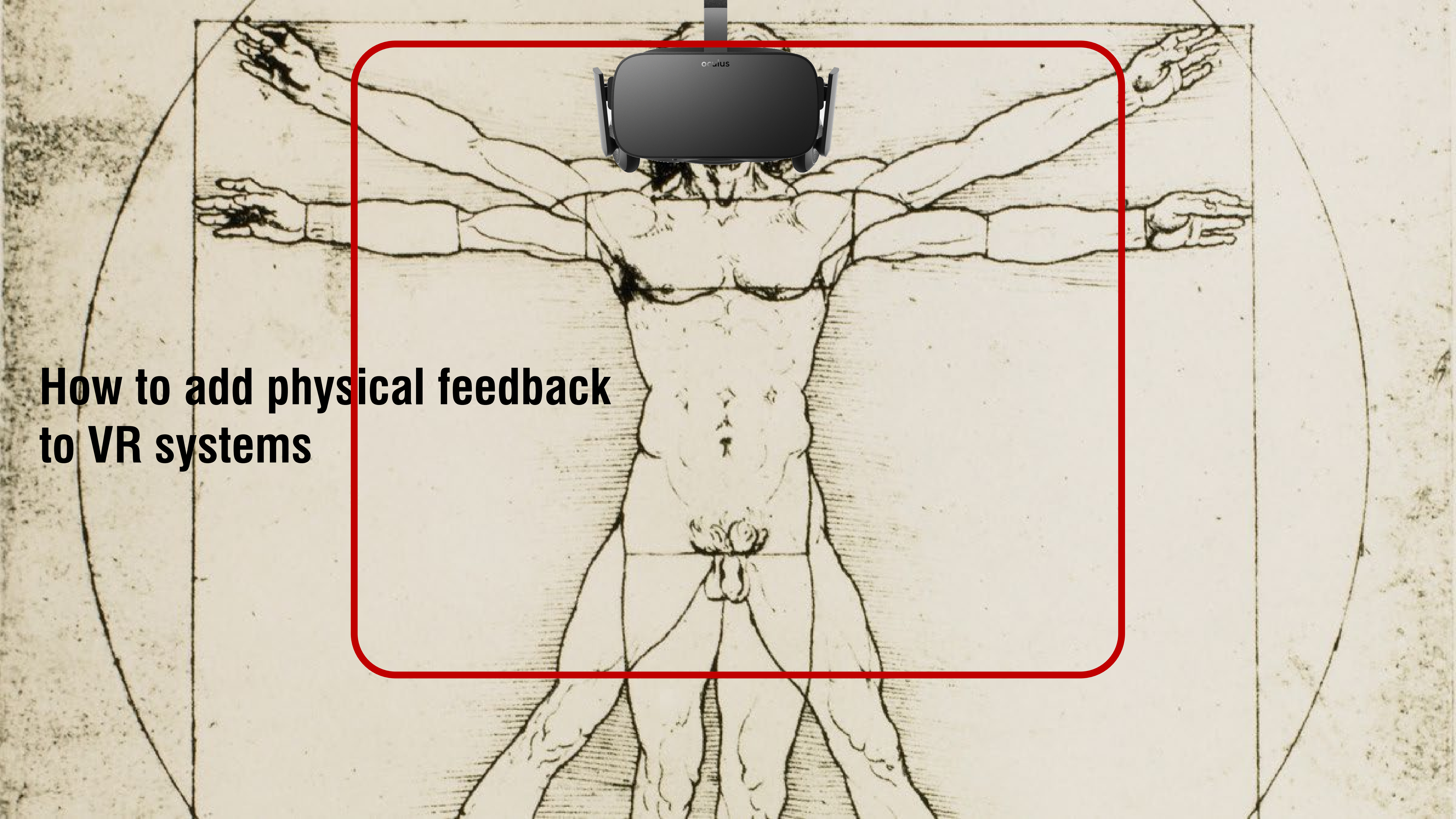


With no EMS no Solenoid
With only EMS
With only Solenoid
With both



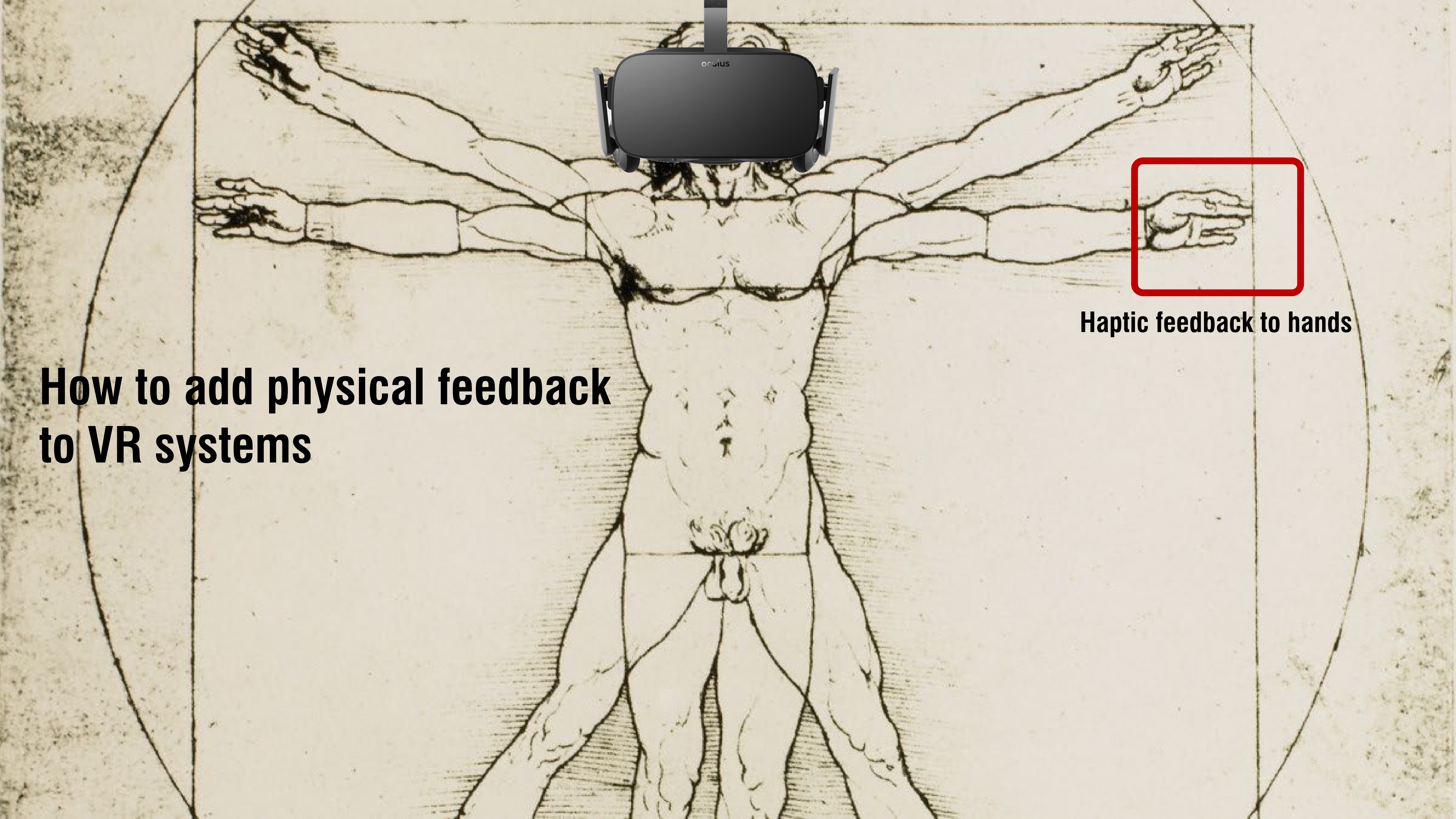
With no EMS no Solenoid
With only EMS
With only Solenoid
With both

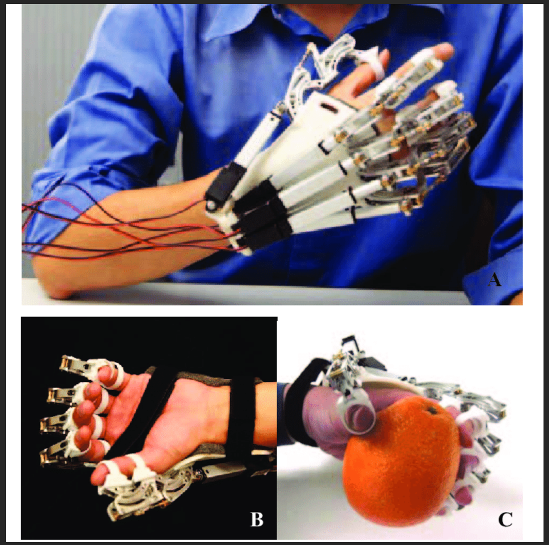

Oculus

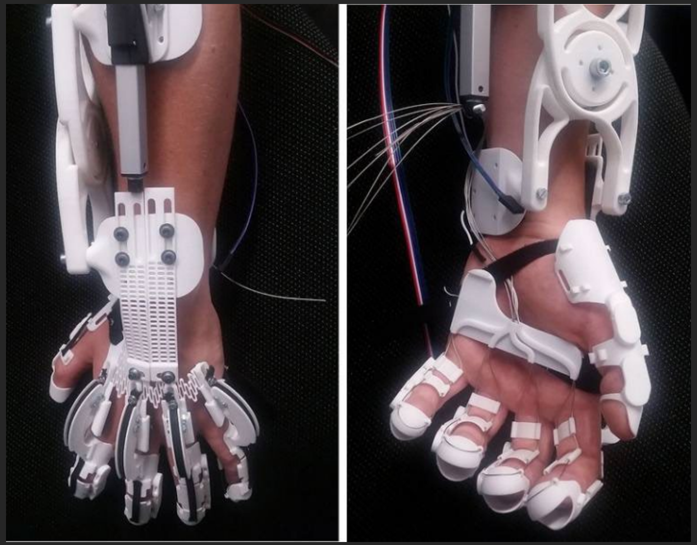


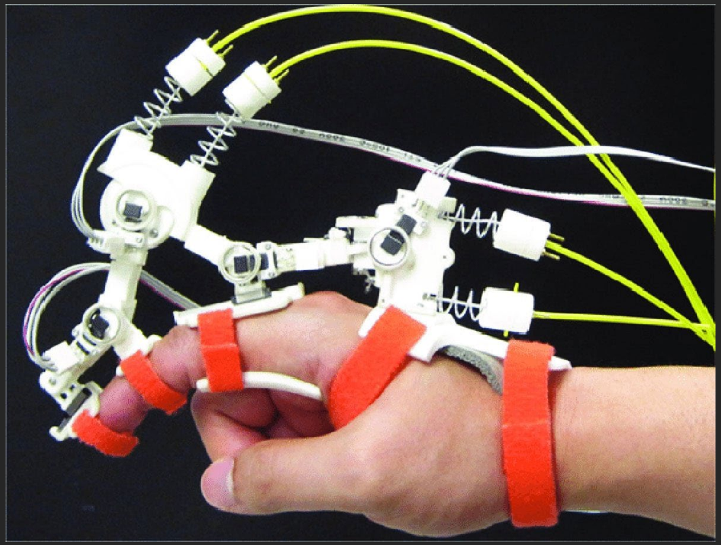
How to add physical feedback to VR systems

How to add physical feedback to VR systems









What do you see here? Any problem with exoskeleton hand solution?

DextrES: Wearable Haptic Feedback for Grasping in VR via a Thin Form-Factor Electrostatic Brake

Session 17: Haptics and VR — UIST 2018, October 14–17, 2018, Berlin, Germany

DextrES: Wearable Haptic Feedback for Grasping in VR via a Thin Form-Factor Electrostatic Brake

Ronan Hinchet[1†], Velko Vechev[2†], Herbert Shea[1], Otmar Hilliges[2]
[1]EPFL, [2]ETH Zurich
{ronan.hinchet, herbert.shea}@epfl.ch, {velko.vechev, otmar.hilliges}@inf.ethz.ch

a) Electrostatic Brake b) c) Power Pincer Laterall Parallel

Figure 1. DextrES is a flexible and thin form-factor haptic feedback mechanism for precise manipulation of virtual objects in VR and AR. a) Our approach provides kinesthetic feedback via electrostatic brakes and piezoelectric actuators for cutaneous feedback. b) We experimentally show that DextrES improves precision of virtual object manipulations in VR across c) a number of different types of grasps, each affording different hand poses.

ABSTRACT
We introduce DextrES, a flexible and wearable haptic glove which integrates both kinesthetic and cutaneous feedback in a thin and light form factor (weight is less than 8g). Our approach is based on an electrostatic clutch generating up to 20 N of holding force on each finger by modulating the electrostatic attraction between flexible elastic metal strips to generate an electrically-controlled friction force. We harness the resulting braking force to rapidly render on-demand kinesthetic feedback. The electrostatic brake is mounted onto the the index finger and thumb via modular 3D printed articulated guides which allow the metal strips to glide smoothly. Cutaneous feedback is provided via piezo actuators at the fingertips. We demonstrate that our approach can provide rich haptic feedback under dexterous articulation of the user's hands and provides effective haptic feedback across a variety of different grasps. A controlled experiment indicates that DextrES improves the grasping precision for different types of virtual objects. Finally, we report on results of a psychophysical study which identifies discrimination thresholds for different levels of holding force.

†Authors contributed equally to this work.

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DOI: https://doi.org/10.1145/3242587.3242657

Author Keywords
Haptics; VR; electrostatic brake; dexterous interaction

INTRODUCTION
The dexterity of the human hand enables us to perform a number of useful everyday tasks such as actively exploring surfaces and grasping and moving objects [20, 16]. In Virtual Reality (VR), dexterous manipulation using the hand is a popular means of interaction. It allows us to leverage learned motor skills and vice versa, to train for real-world scenarios in VR [19]. While rapid progress has been made on the input side (display and sensing technologies), haptic interfaces providing physical feedback to the hand lag behind in their fidelity. In particular, the lack of appropriate kinesthetic feedback limit our ability to precisely steer and place grasped objects in 3D space [34].

The ability to grasp objects is amongst the most useful skills we can perform in VR [8]. One challenging aspect is the wide array of possible grasps which require the fingers to be free to move into different configurations [16]. Traditionally, grasping feedback in VR has been supported via glove-based exoskeletons which create braking forces on the fingers [12, 21], render localized tactile feedback on the fingertips [13, 31], or combine aspects of both [10, 22]. These devices often employ complex mechanisms placed around the hand which may either add weight, constrain the movement of the fingers, or both. As a result, the full range of interaction capabilities of the human hand are under-utilized.

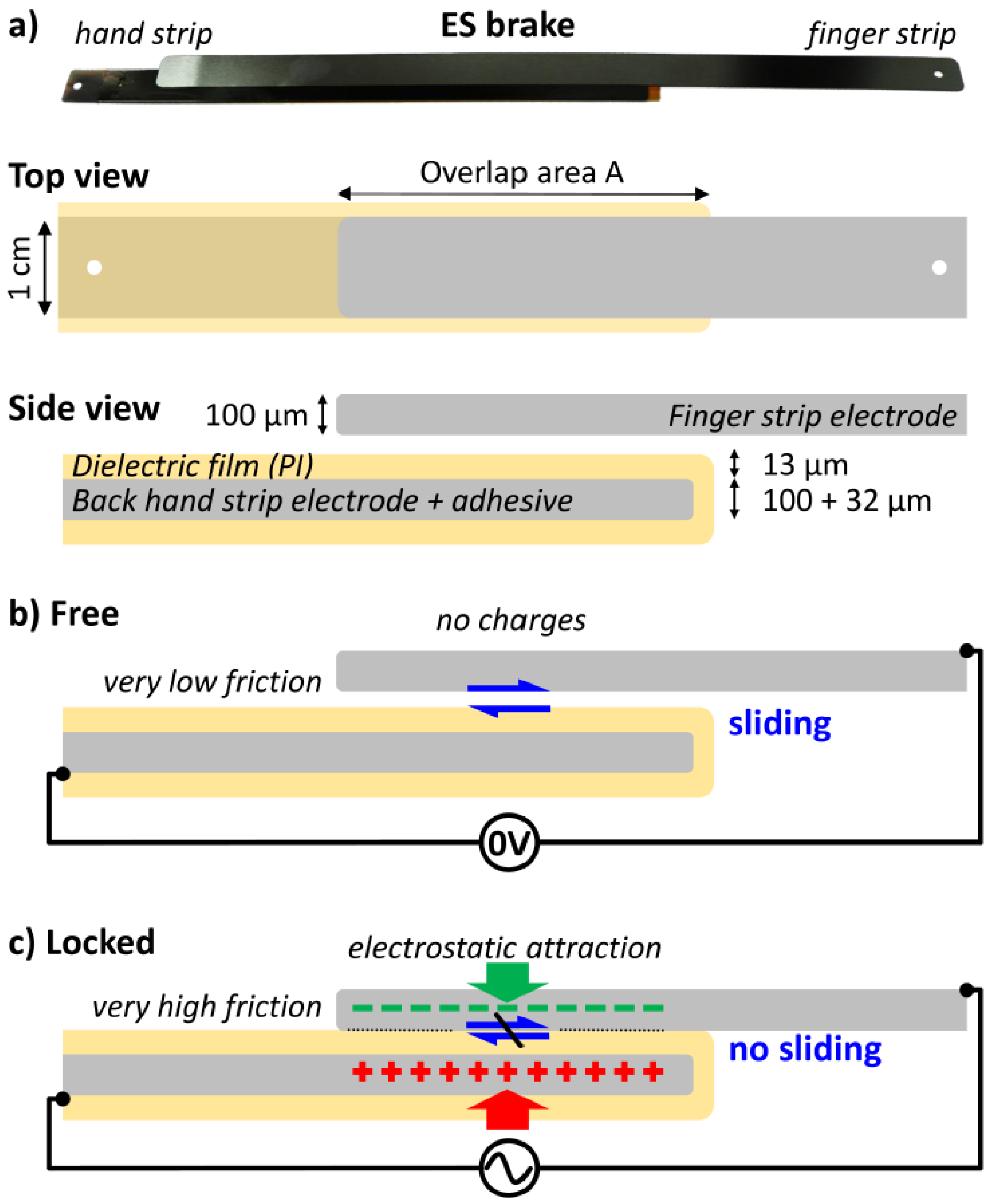
To address this challenge, we introduce DextrES, a finger-mounted haptic mechanism capable of achieving up to 20N of holding force on each finger when flexing inward. Our

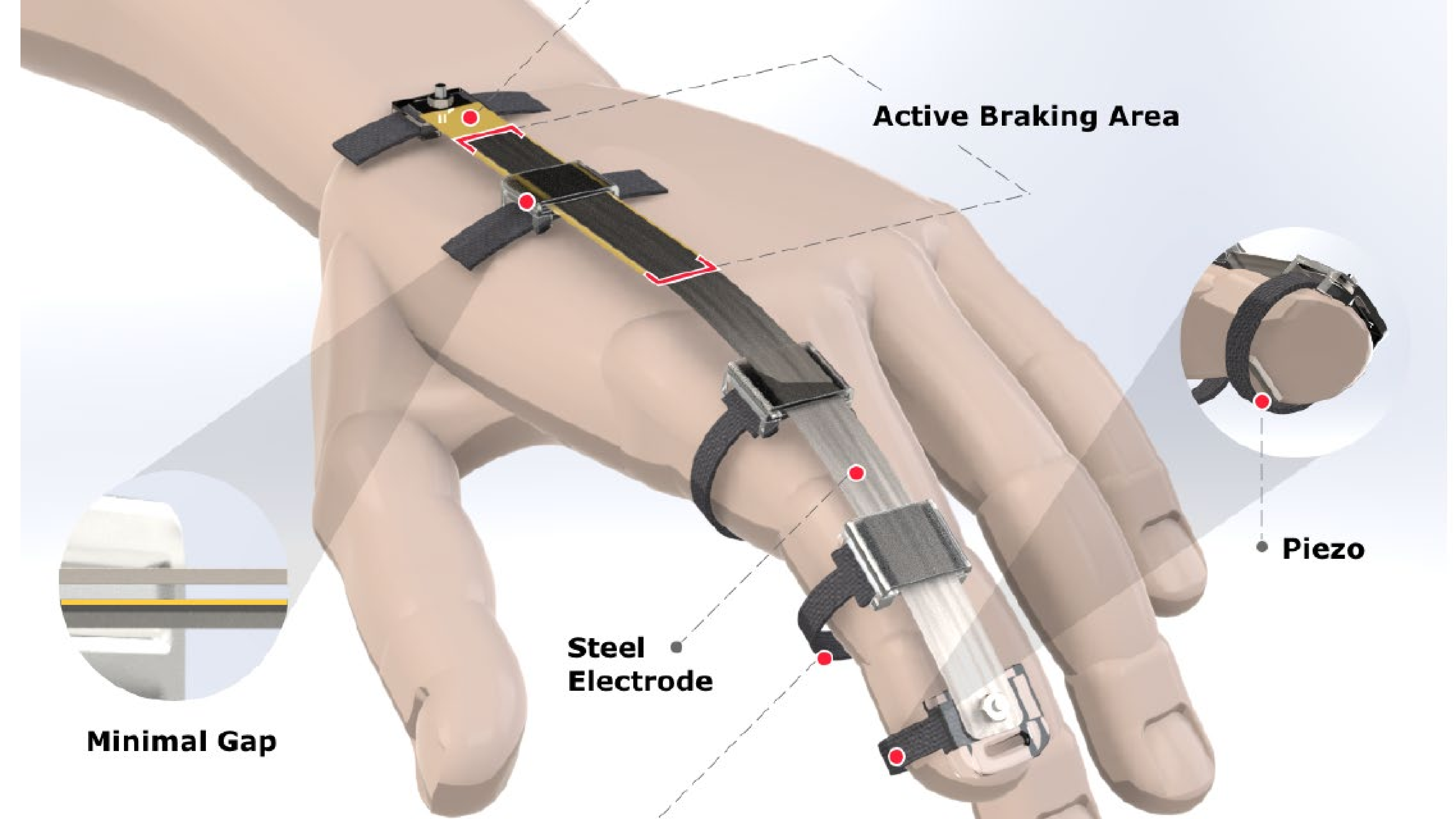
901

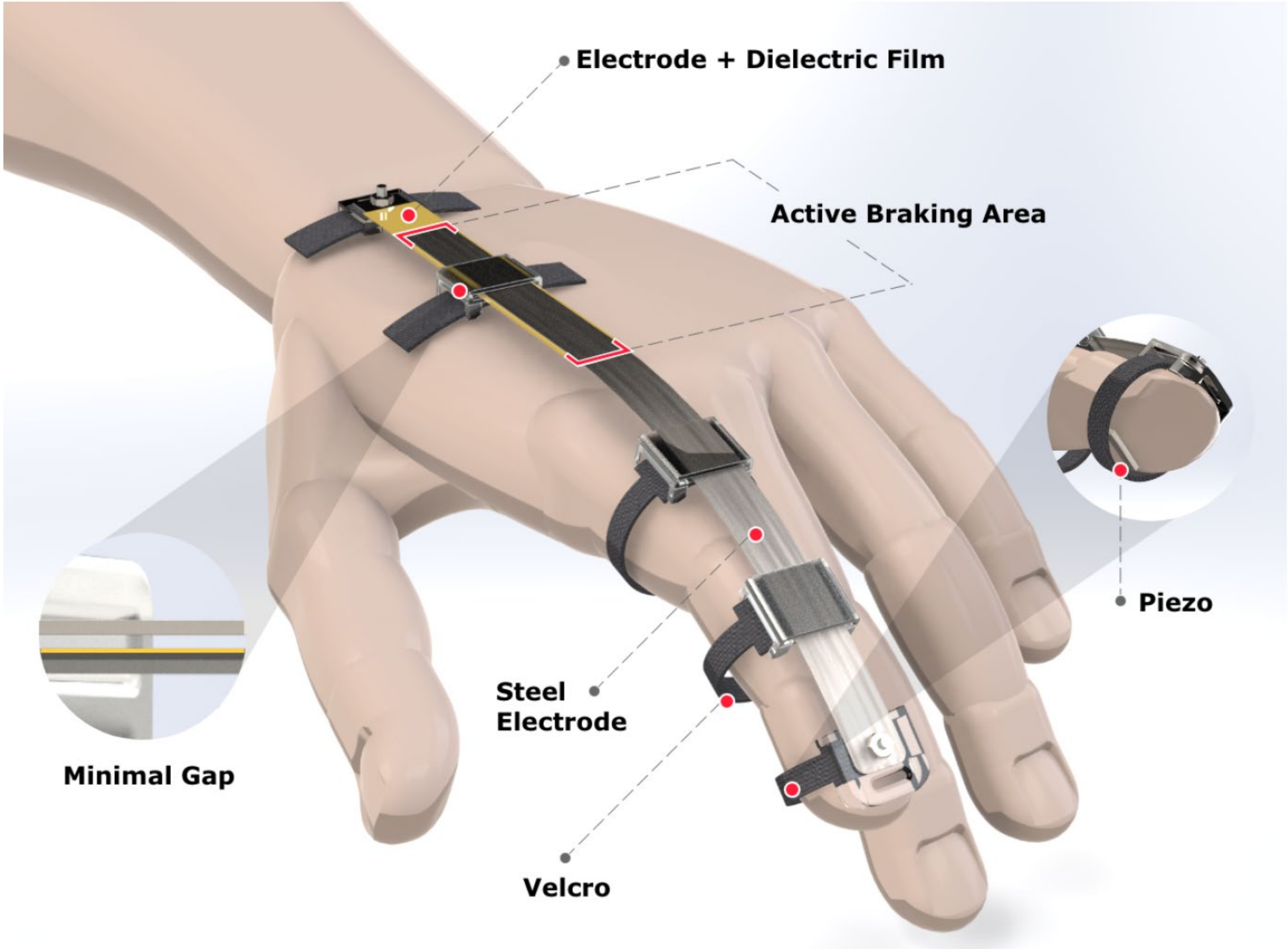
UIST 2018

Hinchet et.al.

Electrostatic braking mechanisms




Active Braking Area
Piezo
Steel
Electrode
Minimal Gap


Electrode + Dielectric Film
Active Braking Area
Piezo
Steel
Electrode
Minimal Gap
Velcro

PuPoP: Pop-up Prop on Palm for Virtual Reality

always-available physical proxies for generating grasping haptic feedback in VR.

Also pneumatic system, but hands-worn

PuPoP: Pop-up Prop on Palm for Virtual Reality

Shan-Yuan Teng Tzu-Sheng Kuo Chi Wang‡ Chi-huan Chiang
Da-Yuan Huang† Liwei Chan* Bing-Yu Chen
National Taiwan University, Taipei, Taiwan *†National Chiao Tung University, Hsinchu, Taiwan
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‡m10615047@mail.ntust.edu.tw †dayuan.huang@acm.org *liweichan@cs.nctu.edu.tw

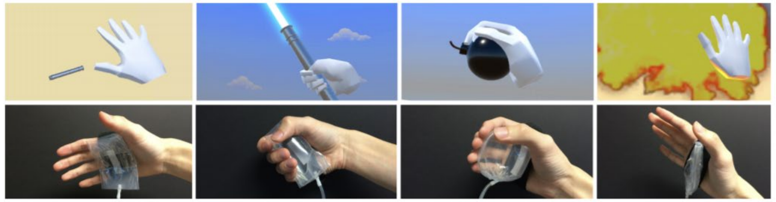


Figure 1. PuPoP is a wearable pneumatic shape-proxy interface for VR capable of popping up to primitive shapes and flattening on the palm. We demonstrate grasping emulation of picking up a virtual Lightsaber with a cylindrical PuPoP and throwing a virtual bomb with a spherical PuPoP.

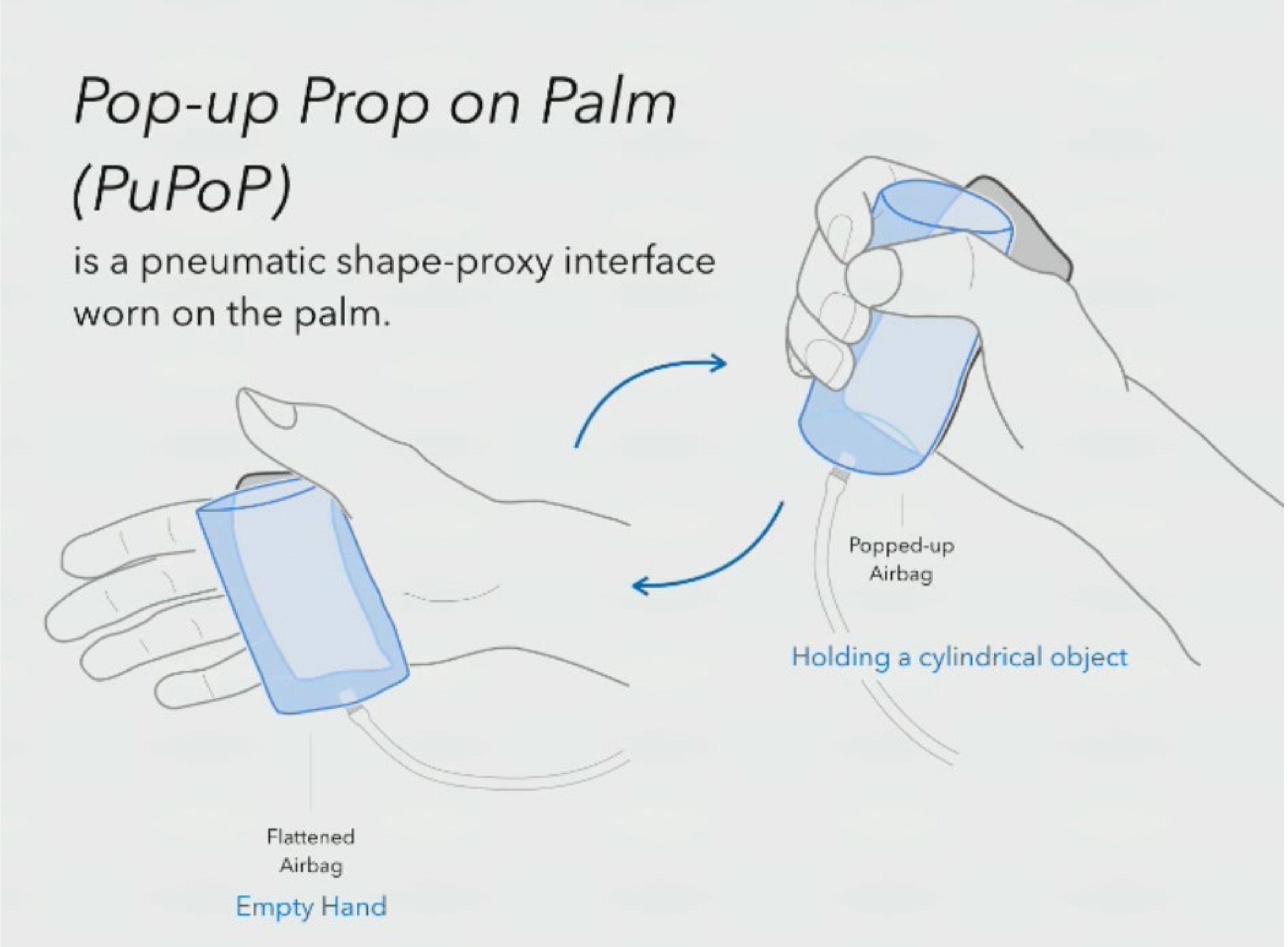
ABSTRACT
The sensation of being able to feel the shape of an object when grasping it in Virtual Reality (VR) enhances a sense of presence and the ease of object manipulation. Though most prior works focus on force feedback on fingers, the haptic emulation of grasping a 3D shape requires the sensation of touch using the entire hand. Hence, we present *Pop-up Prop on Palm (PuPoP)*, a light-weight pneumatic shape-proxy interface worn on the palm that pops several airbags up with predefined primitive shapes for grasping. When a user's hand encounters a virtual object, an airbag of appropriate shape, ready for grasping, is inflated by way of the use of air pumps; the airbag then deflates when the object is no longer in play. Since PuPoP is a physical prop, it can provide the full sensation of touch to enhance the sense of realism for VR object manipulation. For this paper, we first explored the design and implementation of PuPoP with multiple shape structures. We then conducted two user studies to further understand its applicability. The first study shows that, when in conflict, visual sensation tends to dominate over touch sensation, allowing a prop with a fixed size to represent multiple virtual objects with similar sizes. The second study compares PuPoP with controllers and free-hand manipulation in two VR applications. The results suggest that utilization of dynamically-changing PuPoP, when grasped by users in line with the shapes of virtual objects, enhances enjoyment and realism. We believe that PuPoP is a simple yet effective way to convey haptic shapes in VR.

Author Keywords
Haptics; Virtual Reality; Airbag; Shape-Proxy

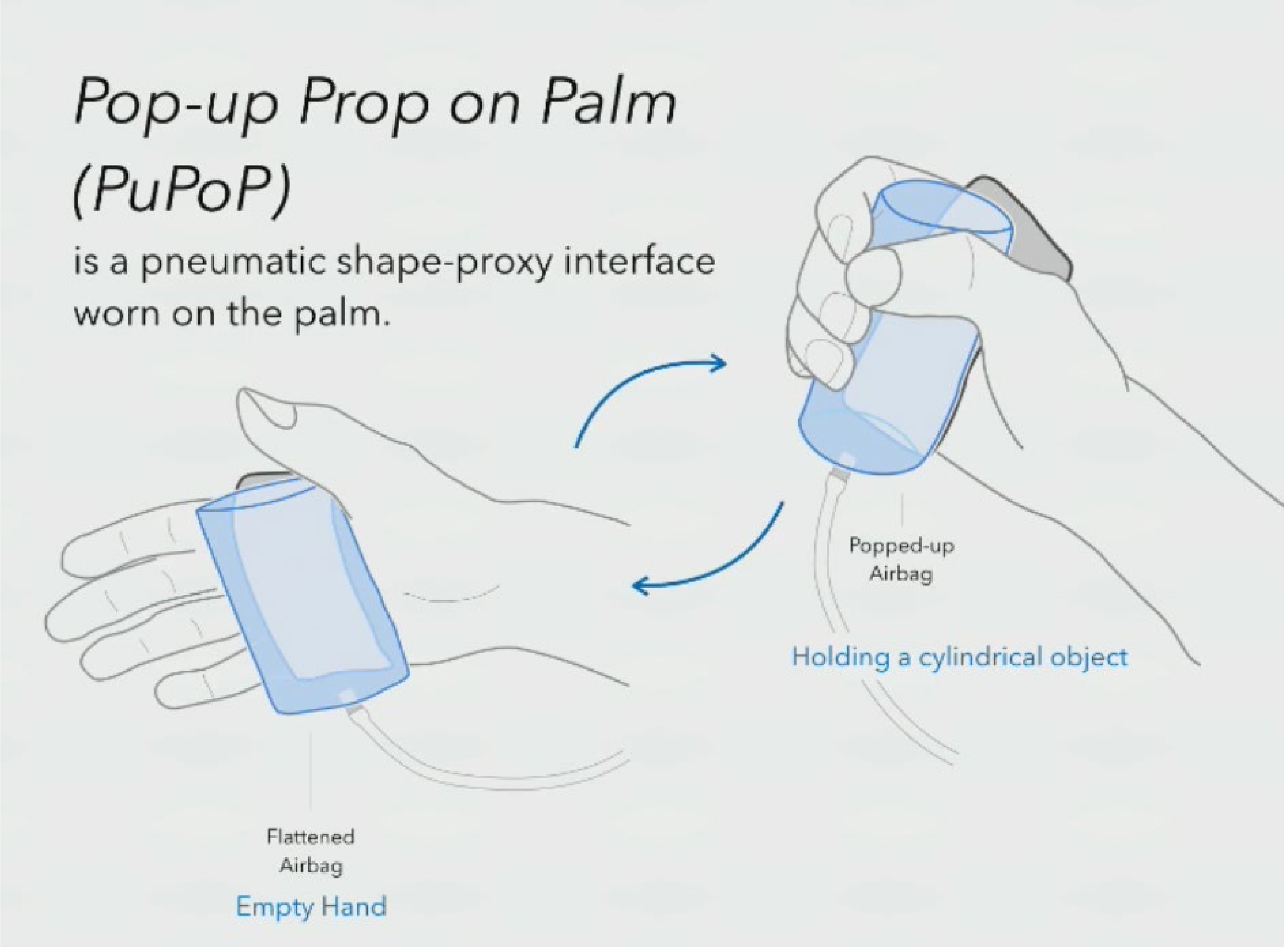
INTRODUCTION
Direct hand manipulation is how humans interact with objects in reality. We grasp objects and perceive their rich haptic feedback to manipulate them [14]. For Virtual Reality (VR), wearable haptic devices have been developed to simulate object grasping using different mechanisms [1, 6, 37, 10, 9]. Although highly mobile, they focus on force feedback on fingers to generate the feeling of firm grasping, the skin contact sensation with the surface of objects during hand manipulation is not provided.

UIST 2018

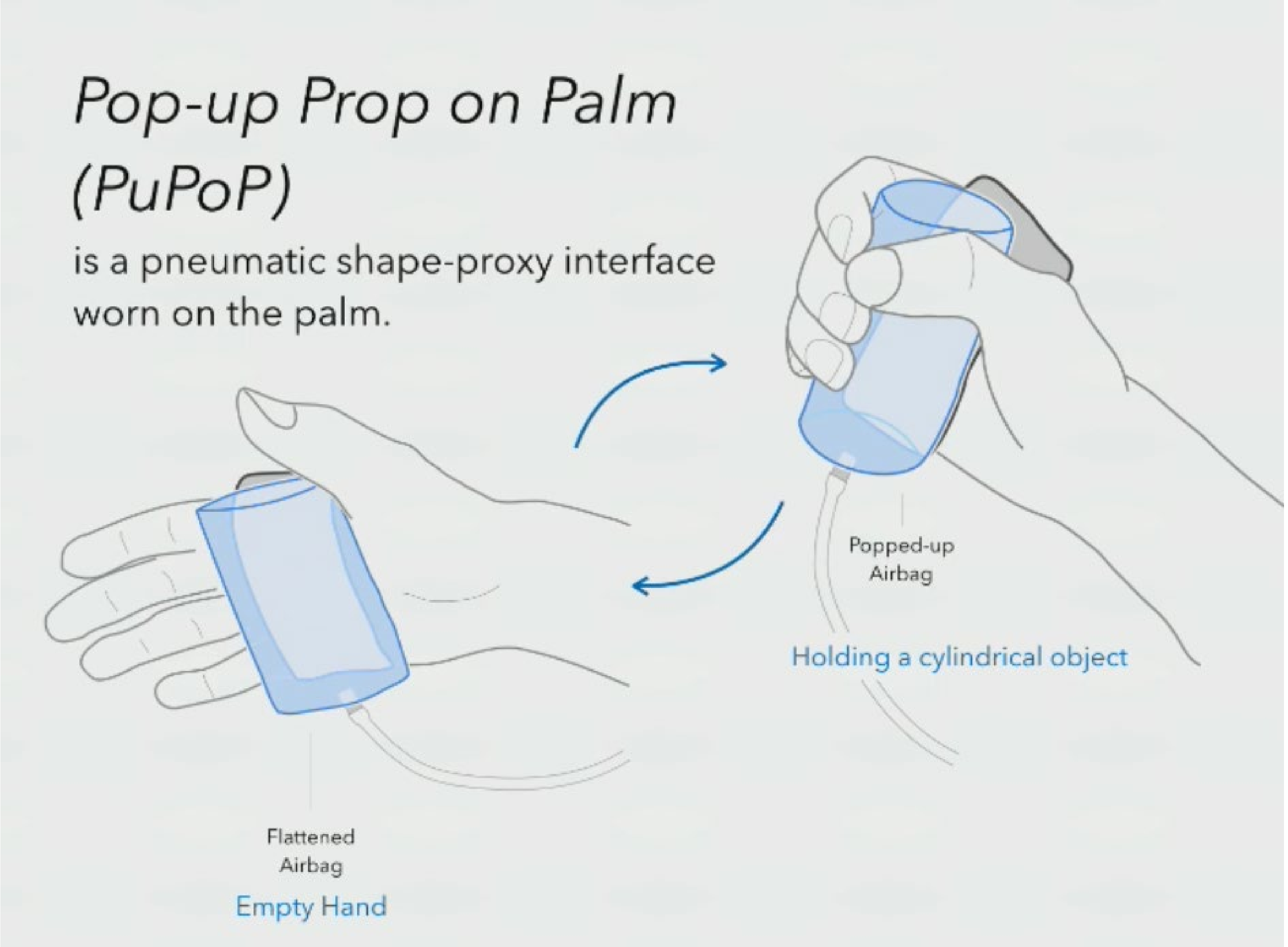
Teng et.al.



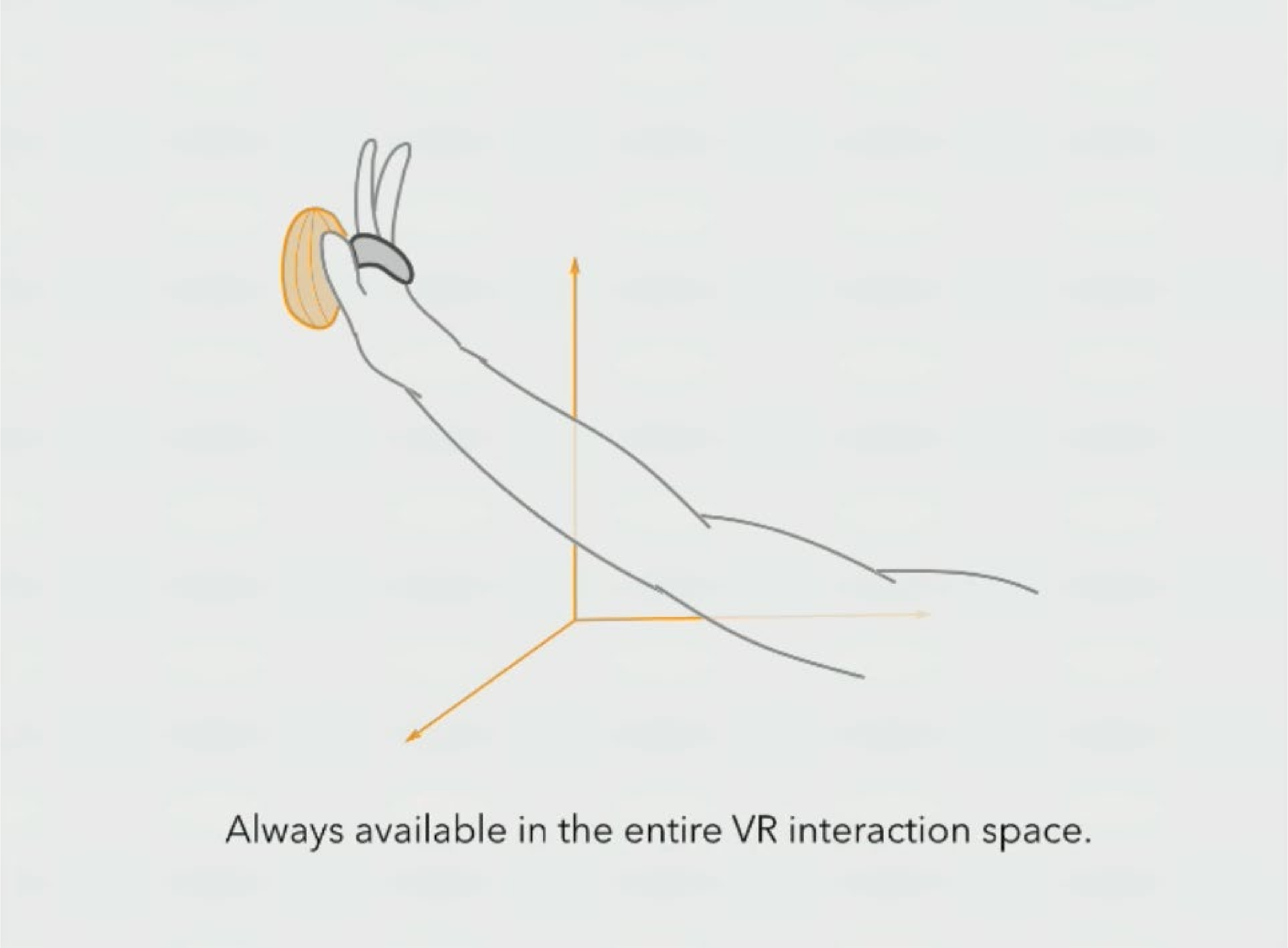
What problem does this paper trying to solve?



How does this paper solve it?



What are the potential challenges for this solution?



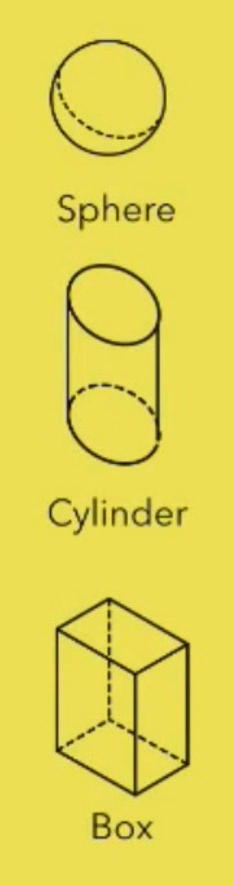
There will be limited shapes that can be rendered, how to decide what shape to generate?

Identify Primitive Shapes

VR Game Objects

111 hand-held objects found in 20 game trailers.

Sphere	balls in sports, snowballs, bombs, and grenades, etc.
Cylinder	rackets, bottles, hammers, and swords, etc.
Box	sandwiches, books, milk package, and camera, etc.
Disk	Frisbee
Cone	carrot
Hemisphere	bowl
Others	scissors, clothes, chain, fish, cat, etc.

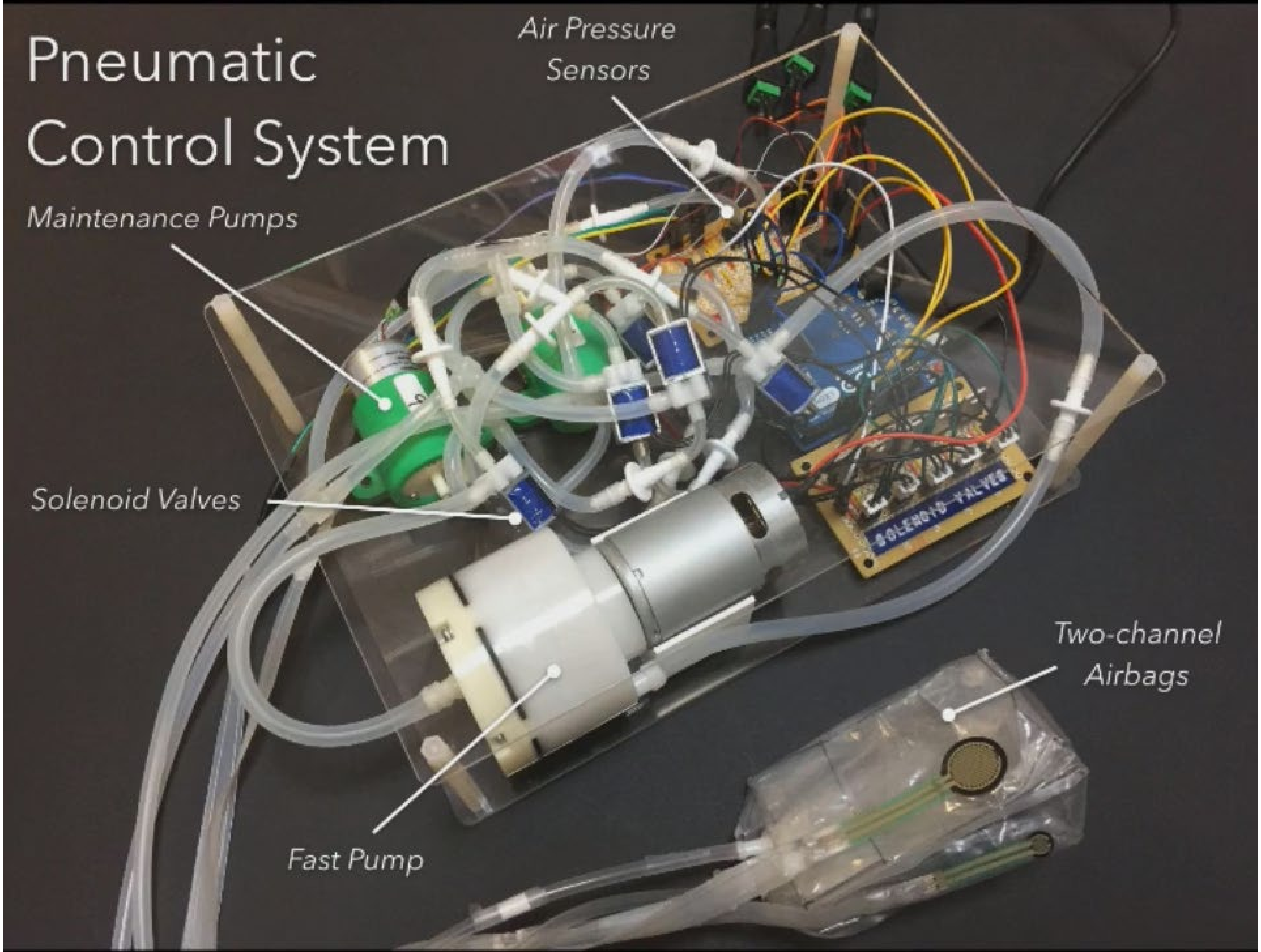


Props on Palm

Prop Stacking

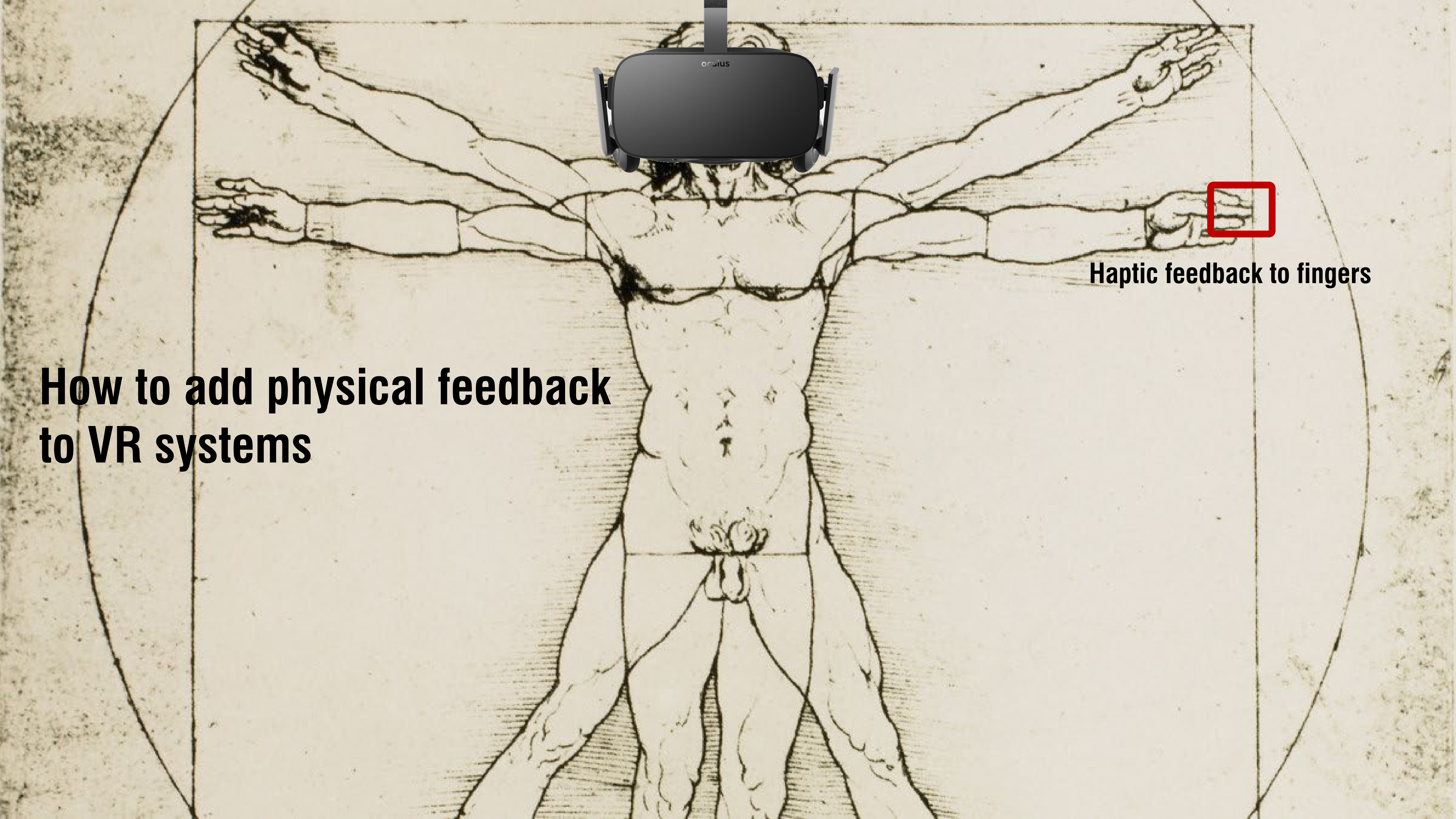
Shape Stacking

Size Stacking


Pneumatic
Control System
Air Pressure
Sensors
Maintenance Pumps
Solenoid Valves
SOLENOID VALVES
Fast Pump
Two-channel
Airbags


We demonstrate
two fantasy VR applications
using PuPoP

How to add physical feedback to VR systems



So far haptics are all from **body-worn** devices

Other approaches to offer tangible feedback for VR?

Snake Charmer: Physically Enabling Virtual Objects

Snake Charmer: Physically Enabling Virtual Objects

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Figure 1: A user wears a head-mounted display to render a virtual scene. When the user attempts to touch a virtual object, the robotic arm spatially aligns with that object's virtual representation and provides a physical surface, matching one or more of the object's shape, texture, and temperature, for the user to touch and feel.

ABSTRACT
Augmented and virtual reality have the potential of being indistinguishable from the real world. Holographic displays, including head mounted units, support this vision by creating rich stereoscopic scenes, with objects that appear to float in thin air - often within arm's reach. However, one has but to reach out and grasp nothing but air to destroy the suspension of disbelief. Snake-charmer is an attempt to provide physical form to virtual objects by revisiting the concept of *Robotic Graphics* or *Encountered-type Haptic* interfaces with current commodity hardware. By means of a robotic arm, Snake-charmer brings physicality to a virtual scene and explores what it means to truly interact with an object. We go beyond texture and position simulation and explore what it means to have a physical presence inside a virtual scene. We demonstrate how to render surface characteristics beyond texture and position, including temperature; how to physically move objects; and how objects can physically interact with the user's hand. We analyze our implementation, present the performance characteristics, and provide guidance for the construction of future physical renderers.

INTRODUCTION
Virtual reality has long been sought in both academic and corporate labs. In recent years, advances in pixel densities, display latency, tracking, and other innovations have brought forward a new generation of head-mounted displays. These displays have brought increasingly realistic virtual reality to consumer-level devices, and demonstrate the power of head-mounted displays for creating a sense of realism.

These efforts have largely focused on visual and auditory rendering; largely absent from these recent commercial offerings is rendering for the sense of touch. Of course, significant past efforts have been expended to attempt to further augment virtual reality with physicality, but each approach seen so far has distinct limitations. As an example, the popular *Phantom* device [21] is highly effective at producing the feeling of poking at an object with a handheld probe – which must remain in the user's hand throughout the experience. While past efforts have attempted to provide hands-free physical feedback, their reliance on air or electrical signals limits their range of sensation [15, 20, 27].

Another approach, known as *Robotic Graphics* or as *Encountered-type Haptic* interfaces [22, 32], utilizes robotic arms as actual physical objects to provide haptic feedback. They provide solid physical feedback, without requiring anything to be held in the hand. In this paper, we present *Snake Charmer*, shown in Figure 1, which builds on this past work of encountered-type haptic interfaces. Snake Charmer combines a head-mounted display (HMD) and, similar to past work, a robotic arm to dynamically simulate the physical

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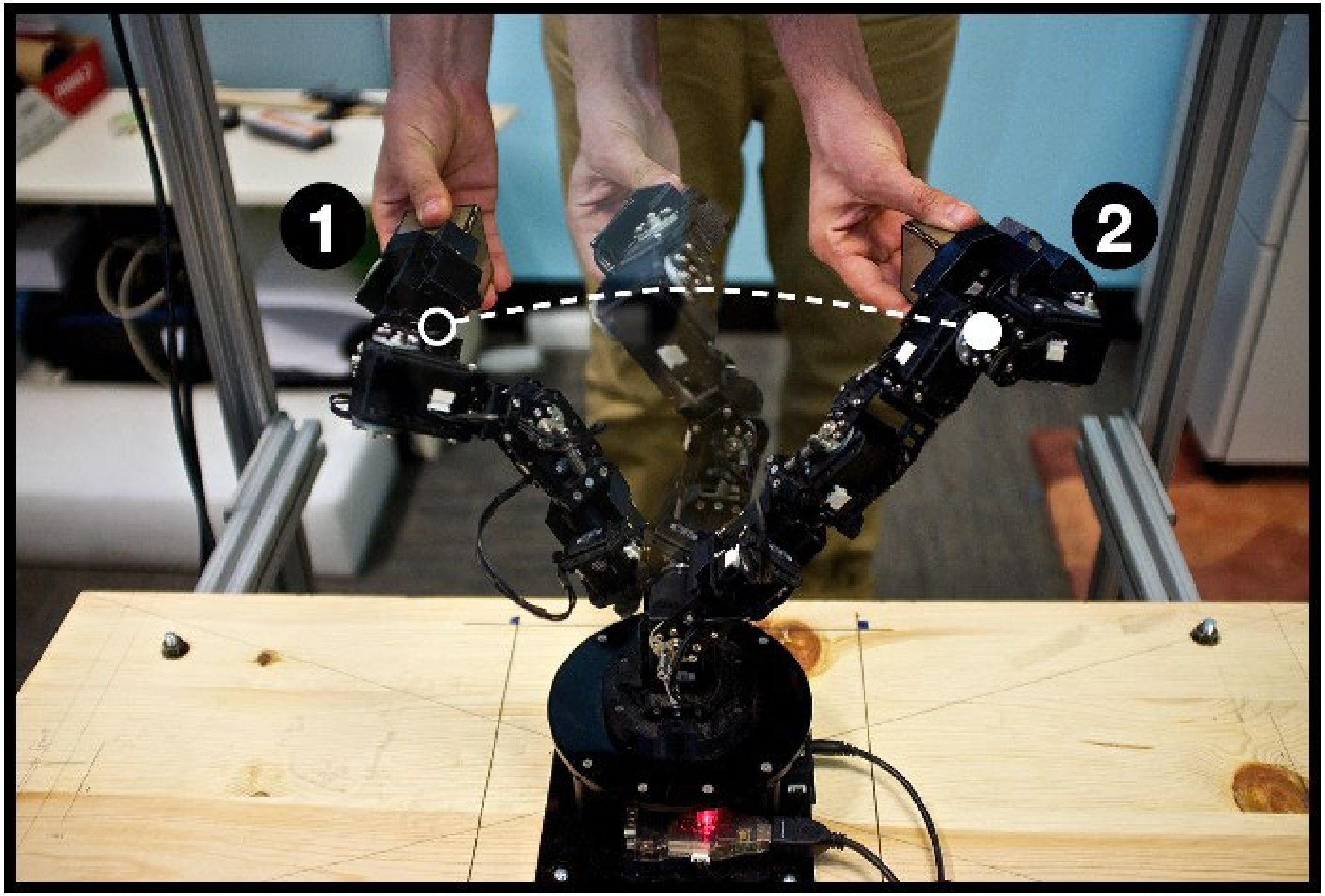
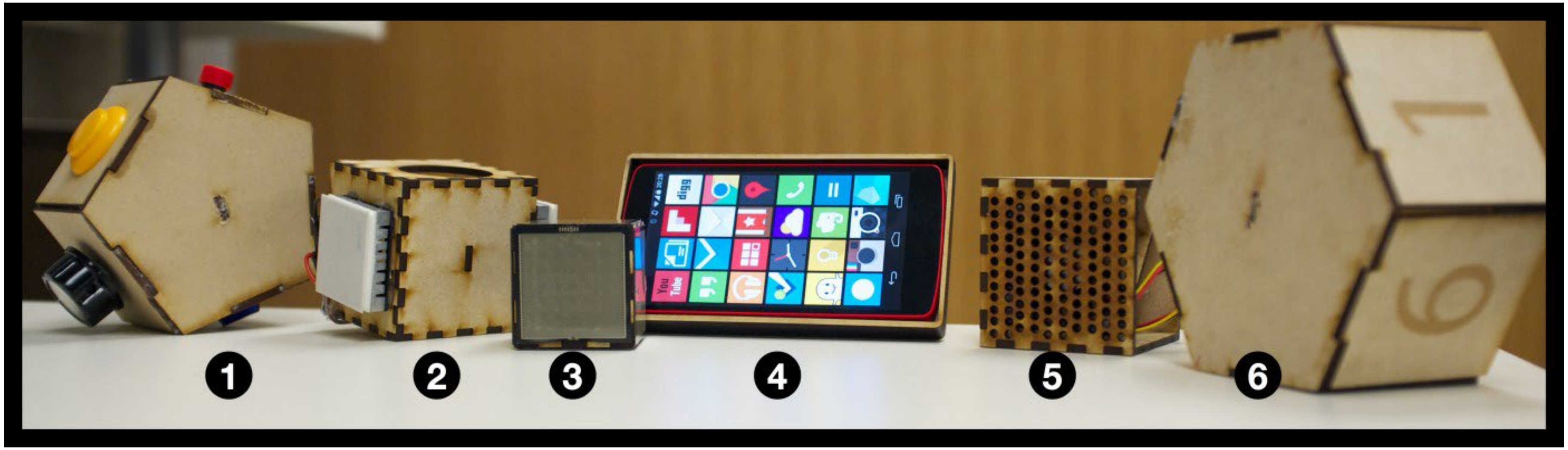
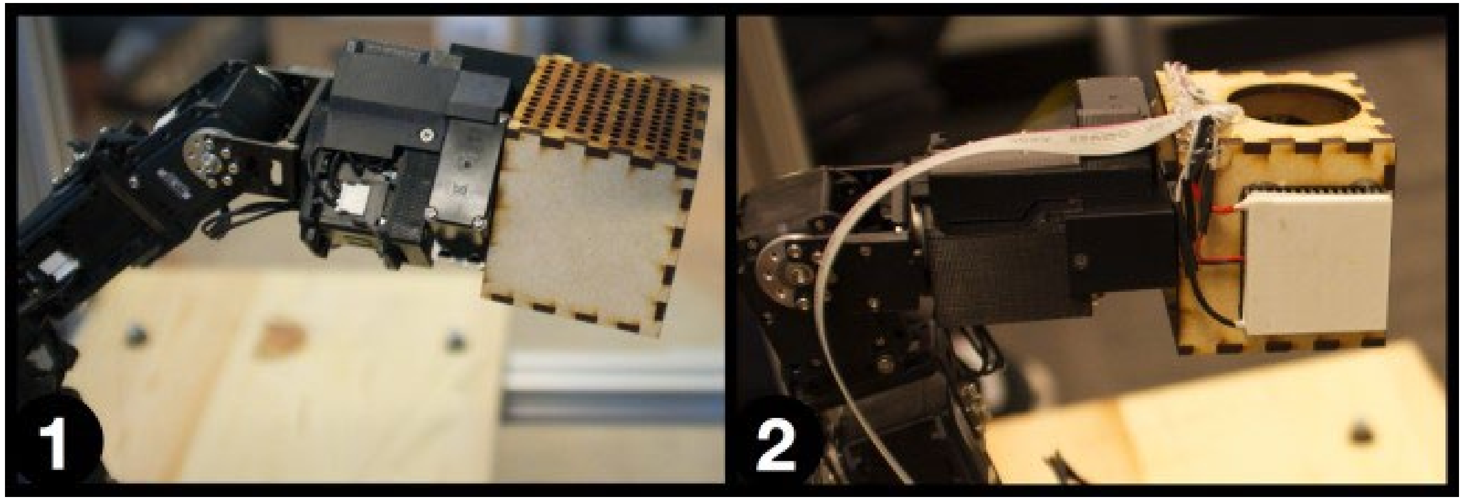
Based on hand's trajectory and VR content
Robotic arm will pose the corresponding surface at the right location



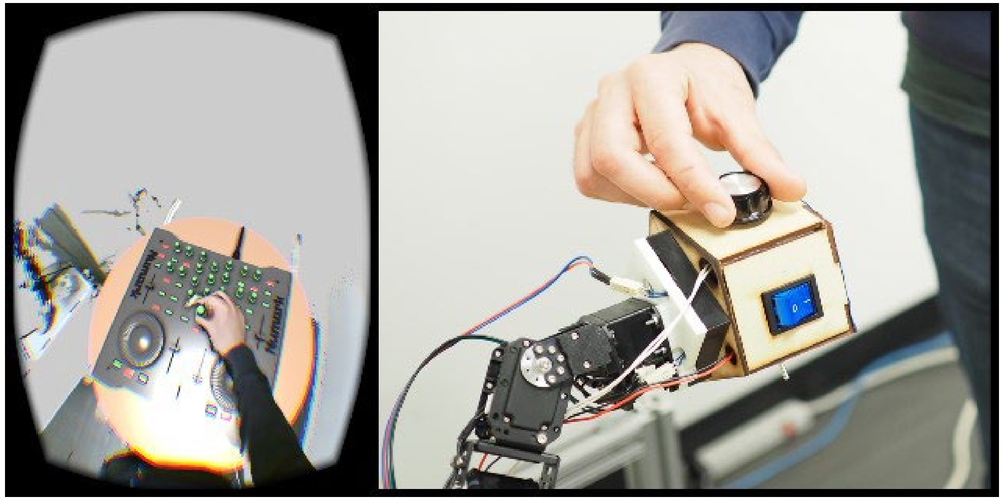
Back-driving: the user can physically move the virtual object.



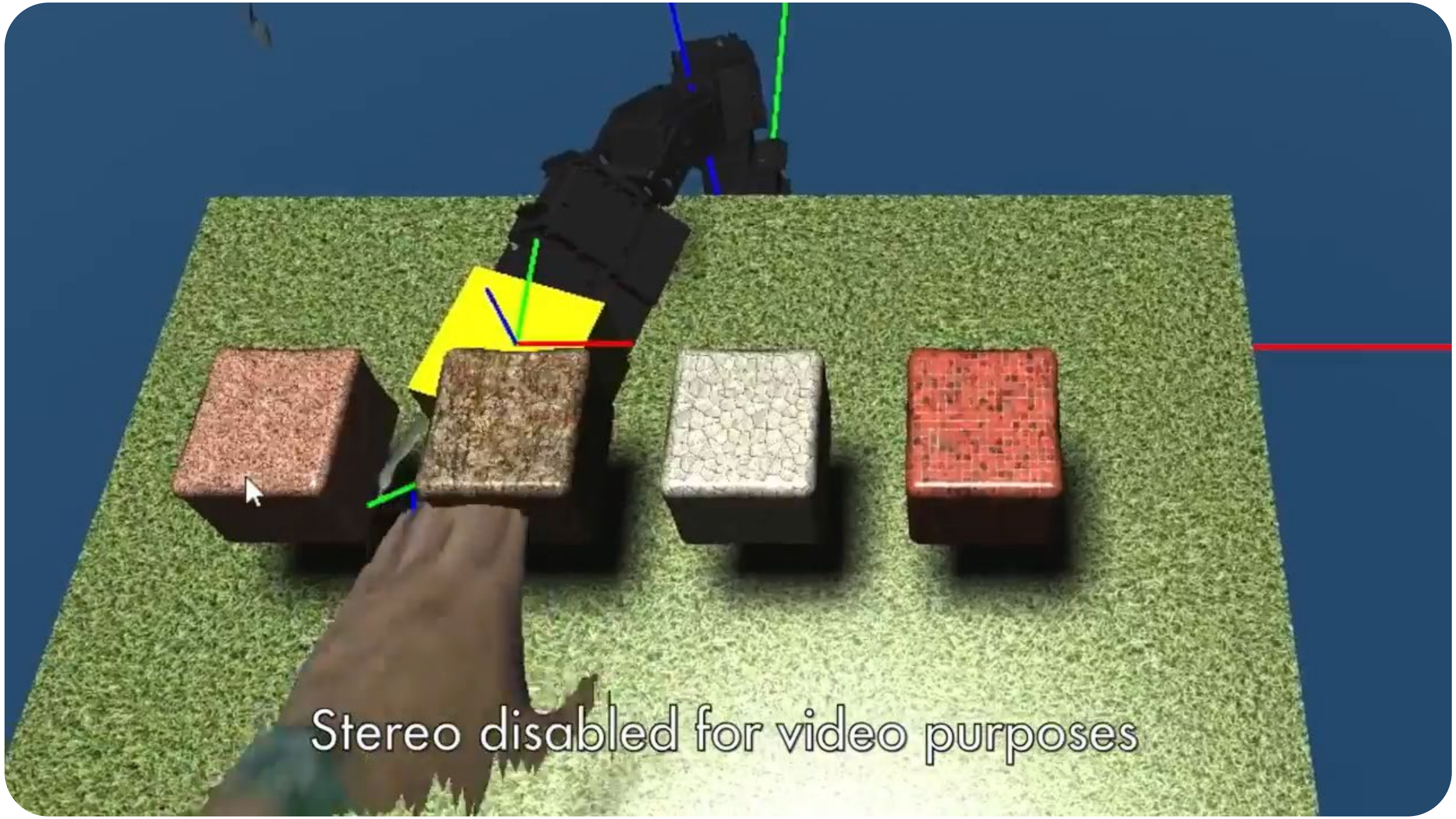
Robotic arm can change the interactive surface based on VR content
Even change to active props



Air flow; Temperature



virtual DJ mixer

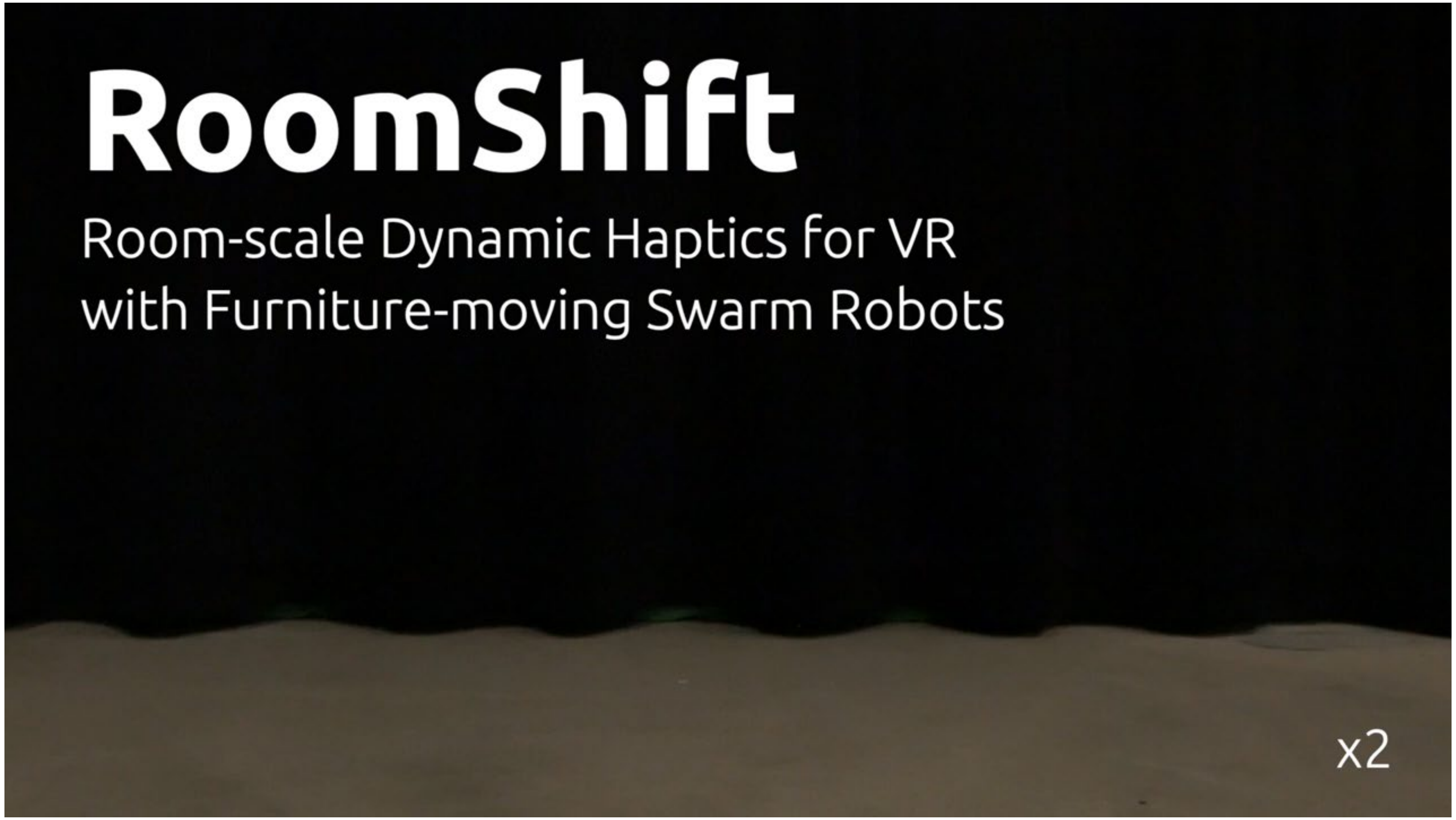


Robotic arm has its range -> which can be an limitation for the interaction area
Improvement?

Next?

Does the robotic arm have to be grounded to one location?

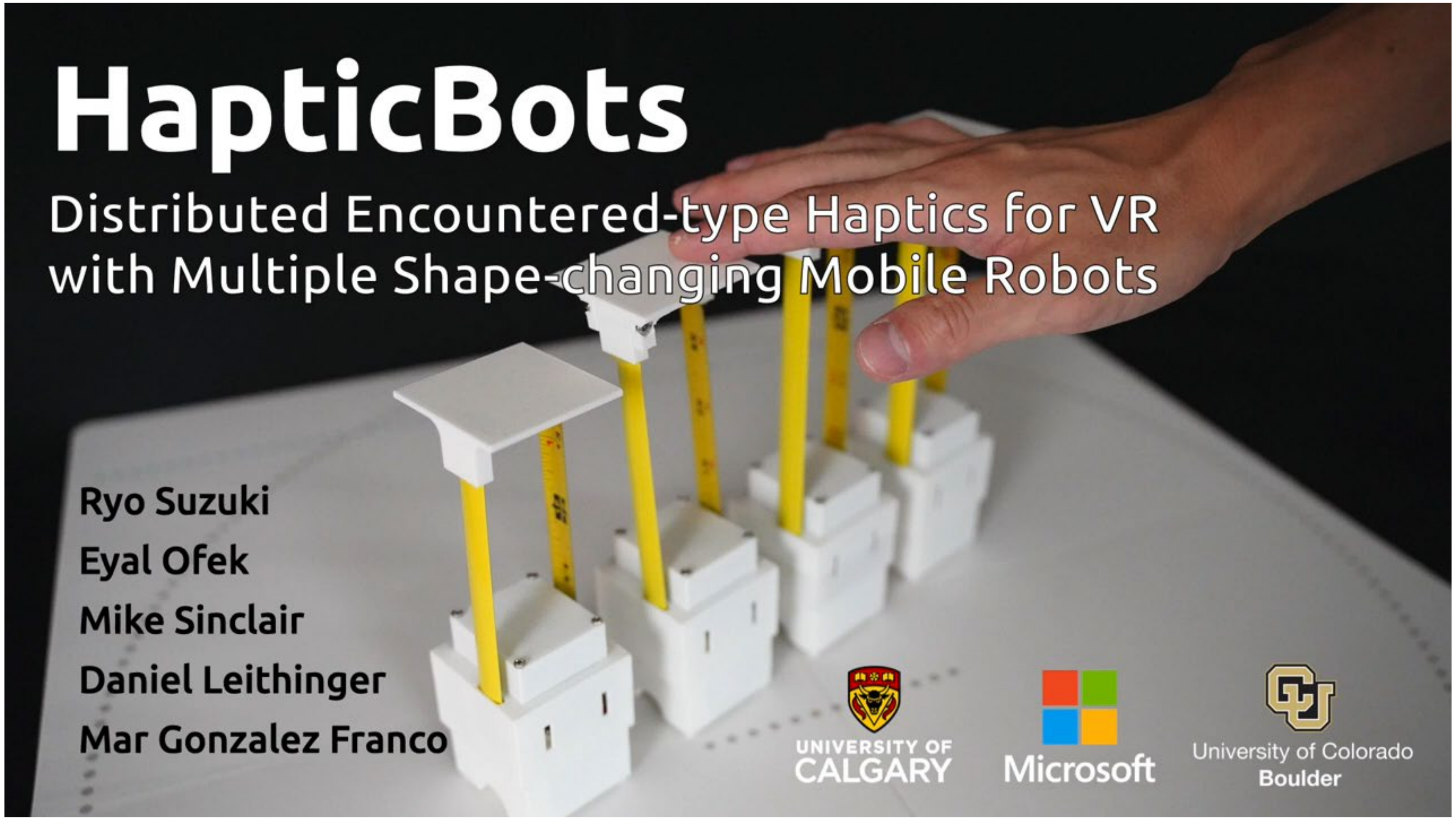
RoomShift: Room-scale Dynamic Haptics for VR with Furniture-moving Swarm Robots



Next?

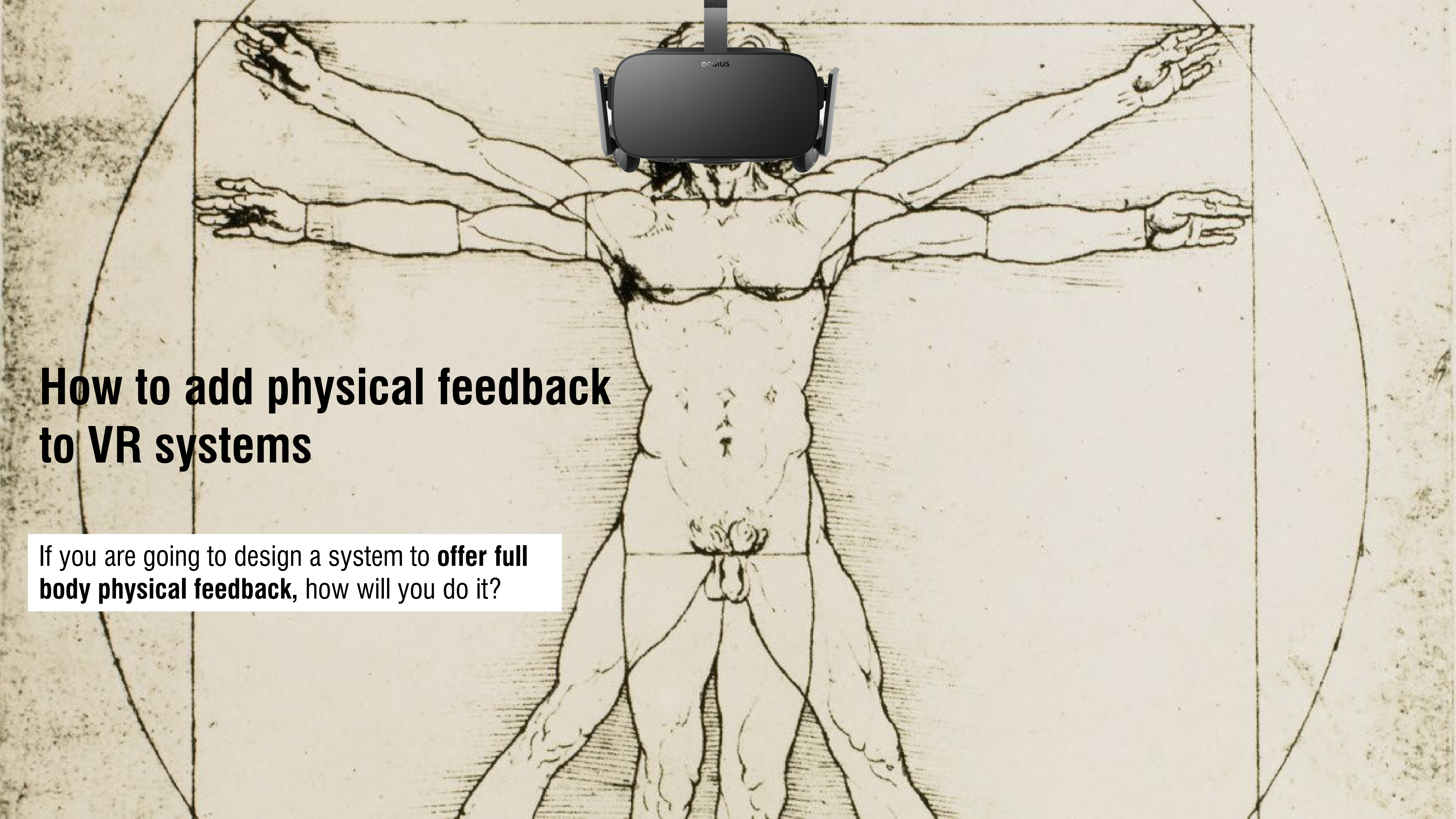
A desktop version? What problem might it solve?

HapticBots: Distributed Encountered-type Haptics for VR with Multiple Shape-changing Mobile Robots



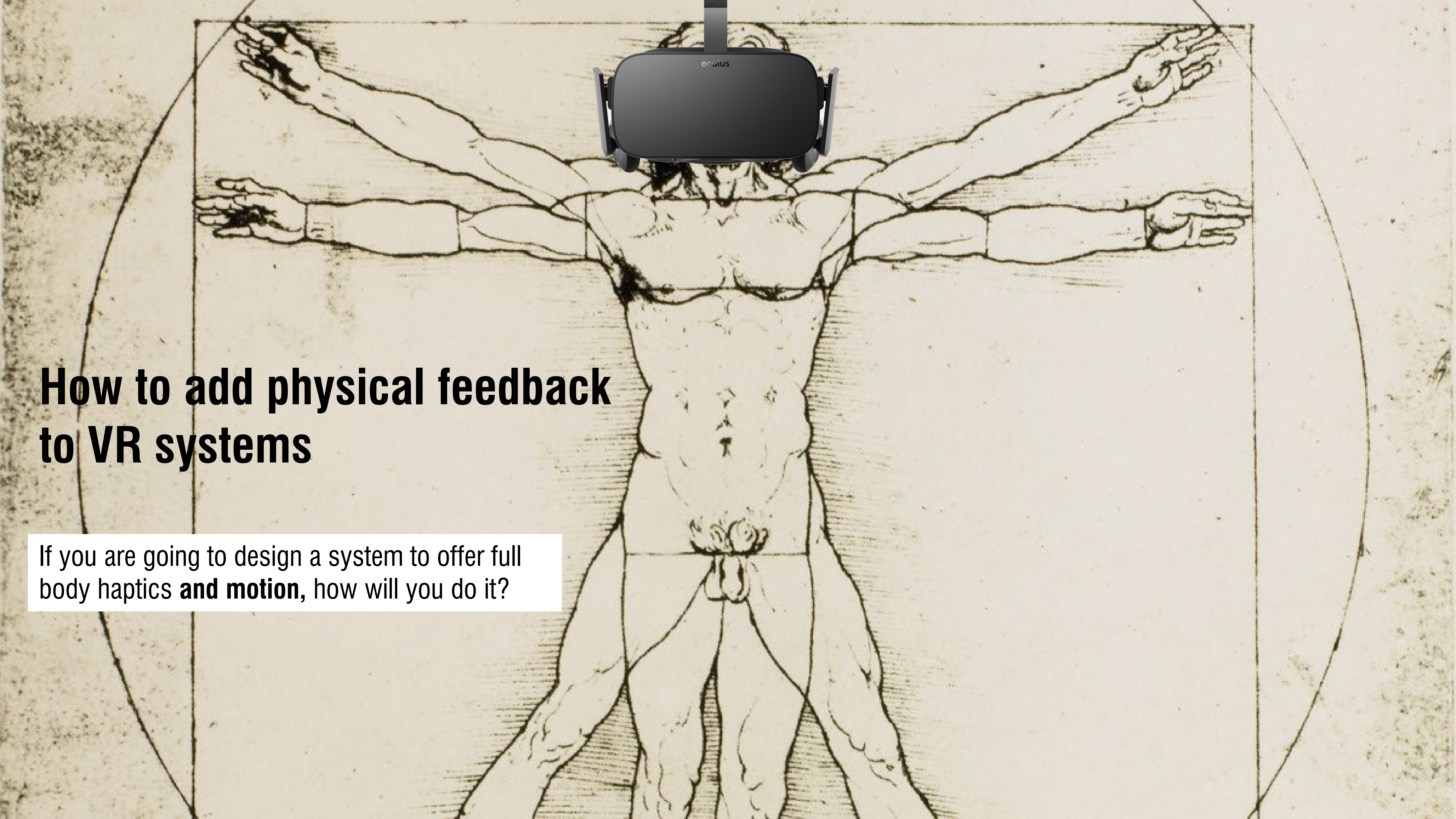
Next?

Combining with retargeting and prediction right?



How to add physical feedback to VR systems

If you are going to design a system to **offer full body physical feedback,** how will you do it?



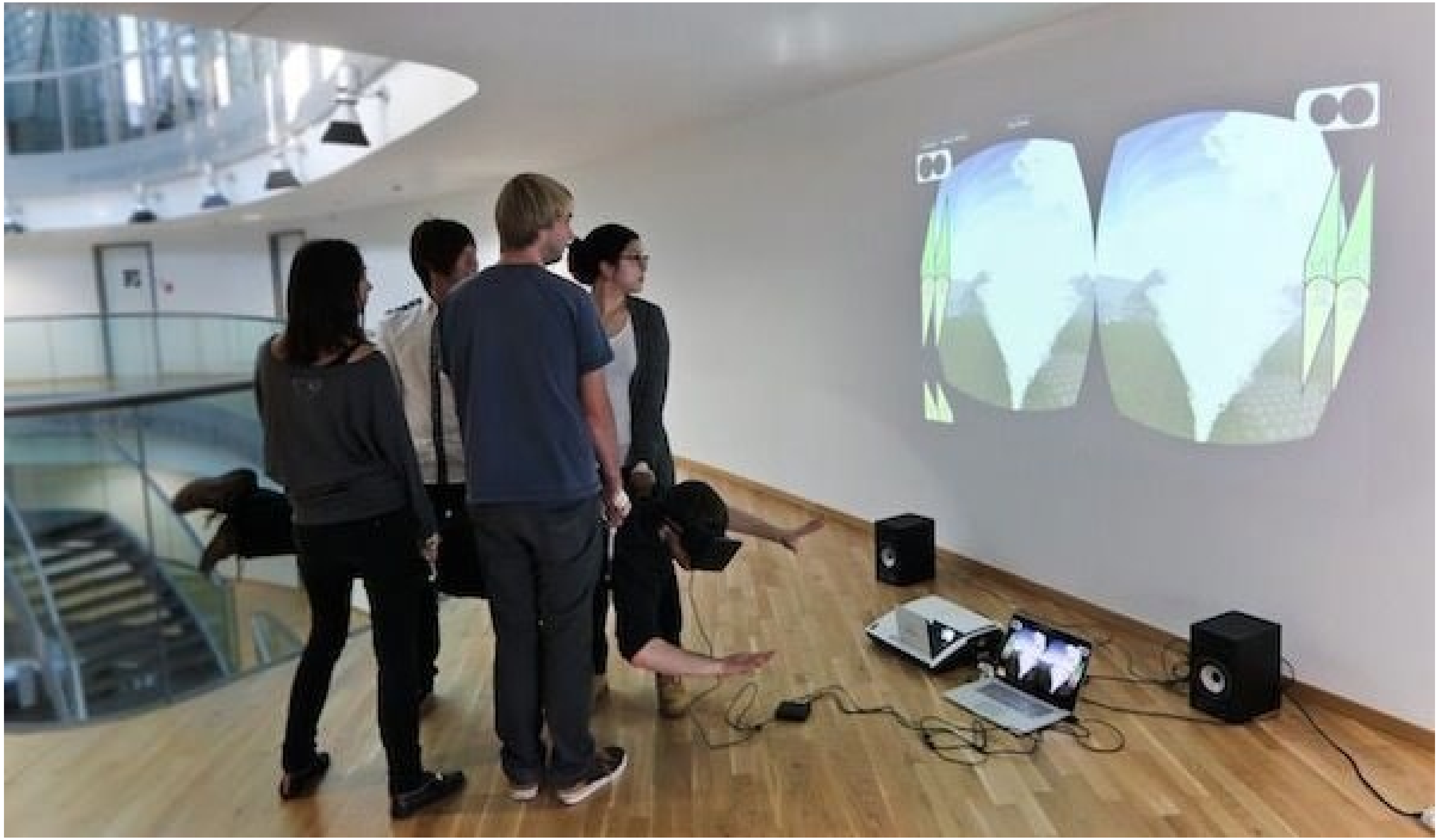
How to add physical feedback to VR systems

If you are going to design a system to offer full body haptics **and motion,** how will you do it?


VRLADER
DATENFLUG
DATENFLUG

Motion platforms are expensive, large, heavy and thus stationary – Alternative approach?

Human actuators!



Haptic Turk: a Motion Platform Based on People

How does it work?

Haptic Turk: a Motion Platform Based on People

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ABSTRACT
Motion platforms are used to increase the realism of virtual interaction. Unfortunately, their size and weight is proportional to the size of what they actuate. We present *haptic turk,* a different approach to motion platforms that is light and mobile. The key idea is to replace motors and mechanical components with humans. All haptic turk setups consist of a *player* who is supported by one or more *human-actuators*. The player enjoys an interactive experience, such as a flight simulation. The motion in the player's experience is generated by the actuators who manually lift, tilt, and push the player's limbs or torso. To get the timing and force right, timed motion instructions in a format familiar from rhythm games are displayed on actuators' mobile devices, which they attach to the player's body. We demonstrate a range of installations based on mobile phones, projectors, and head-mounted displays. In our user study, participants rated not only the experience as player as enjoyable (6.1/7), but also the experience as an actuator (4.4/7). The approach of leveraging humans allows us to deploy our approach anytime anywhere, as we demonstrate by deploying at an art festival in the Nevada desert.

Author Keywords
Haptics; force-feedback; motion platform; immersion.

ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

INTRODUCTION
For a long time, the key to immersion in interactive experience and games was sought in photorealistic graphics [8]. More recently, game makers made games more immersive by requiring players to physically enact the game such as with Wii (http://wii.com) and Kinect [26]. With graphics and user interaction now part of many games, many researchers argue that *haptics and motion* are the next step towards increasing immersion and realism, i.e., applying the forces triggered by the game onto the player's body during the experience.

While some game events can be realistically rendered using one or more vibrotactile actuators (e.g., driving over gravel in a racing game [14]), a much larger number of gaming

railing. Such events have been simulated using motion platforms [27]. Motion platforms are able to move one or more users around and have been used to add realism to flight simulators [22] and theme park rides.

Unfortunately, the size and weight of motion platforms tends to be proportional to what they actuate. As a result, motion platforms not only tend to be prohibitively expensive, but also large and heavy and thus stationary, limiting their use to arcades and lab environments.

Figure 1: Haptic turk allows producing motion experiences anywhere anytime. Here, the suspended player is enjoying an immersive hang gliding game. The four *actuators* create just the right physical motion to fill in the player's experience.

In this paper, we present *haptic turk,* a software platform that allows experiencing motion anywhere there is people. Its key idea is to substitute the motors and mechanical components of traditional motion platforms with humans.

HAPTIC TURK
Haptic turk is a motion platform based on people. The name is inspired by the 18th century chess automaton "The Turk" [20] that was powered by a human chess master.

The specific configuration shown in Figure 1 involves one *player* located in the center. The player is enjoying an immersive experience, here a first-person simulation of flying a hang-glider, running on a hand-held device (iPad). In the shown setup, the player can steer the hang-glider by tilting the iPad.

UIST 2015

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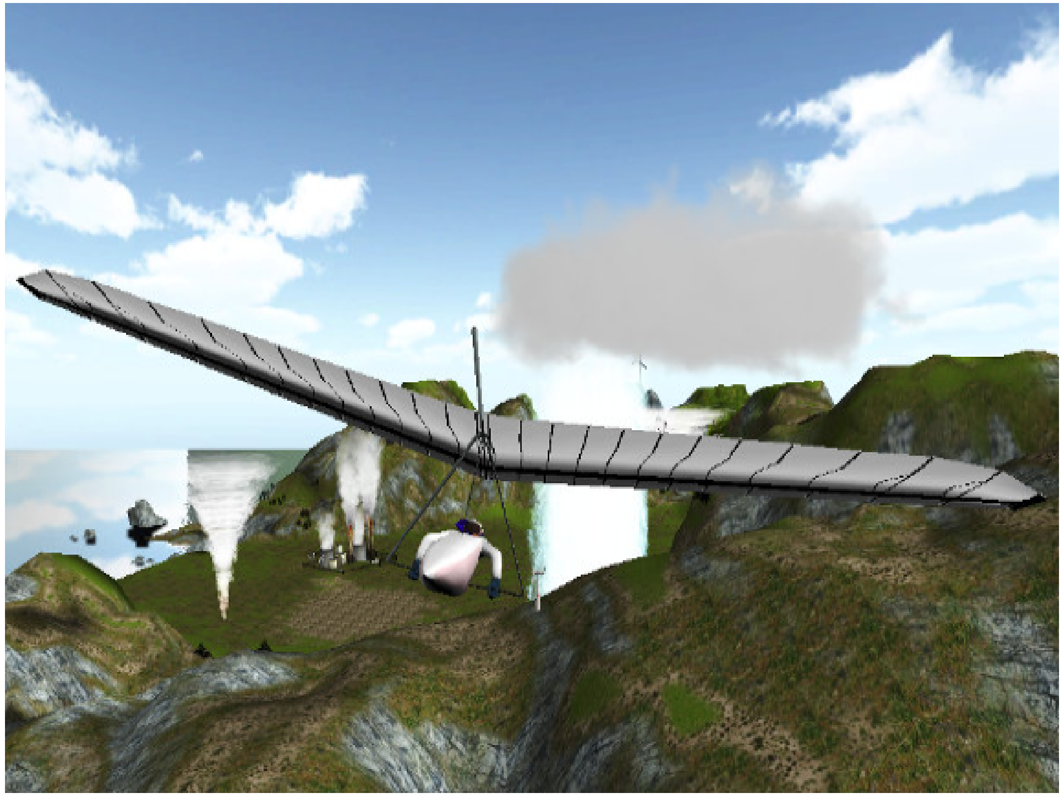
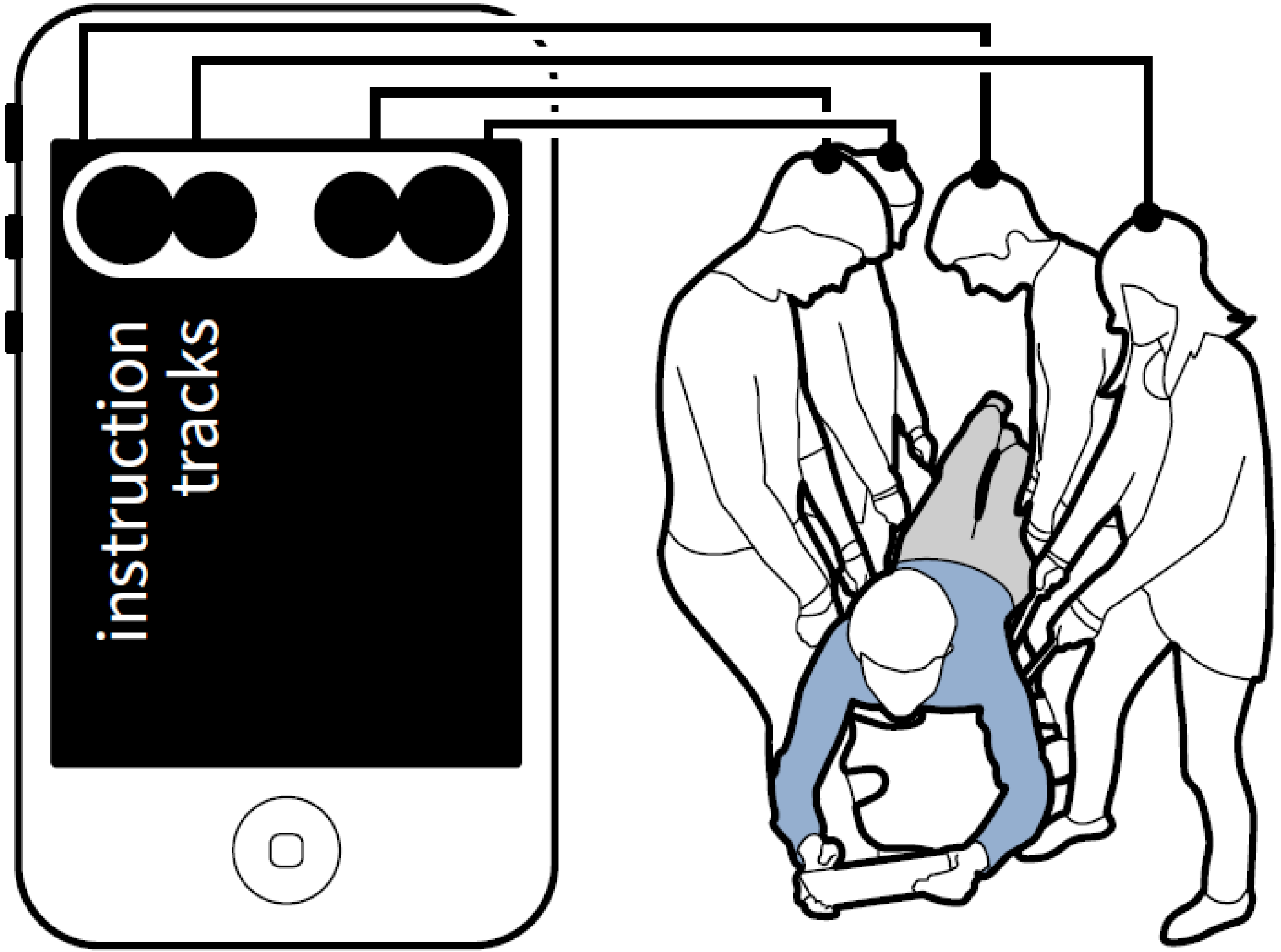
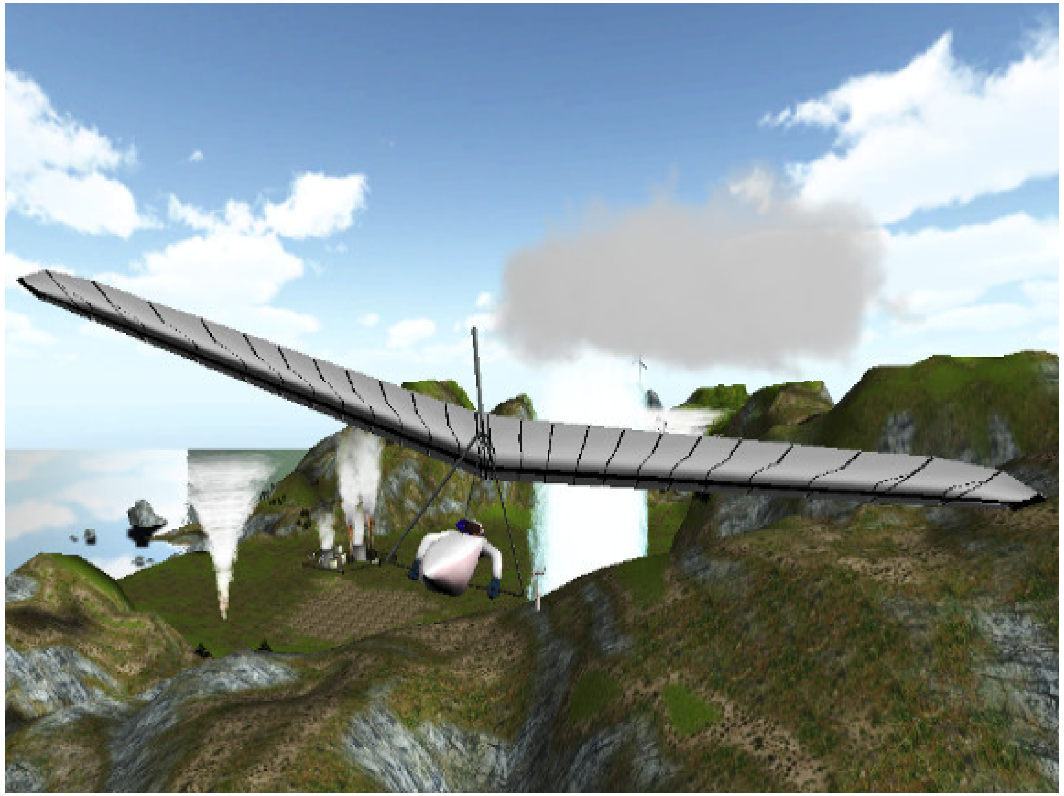
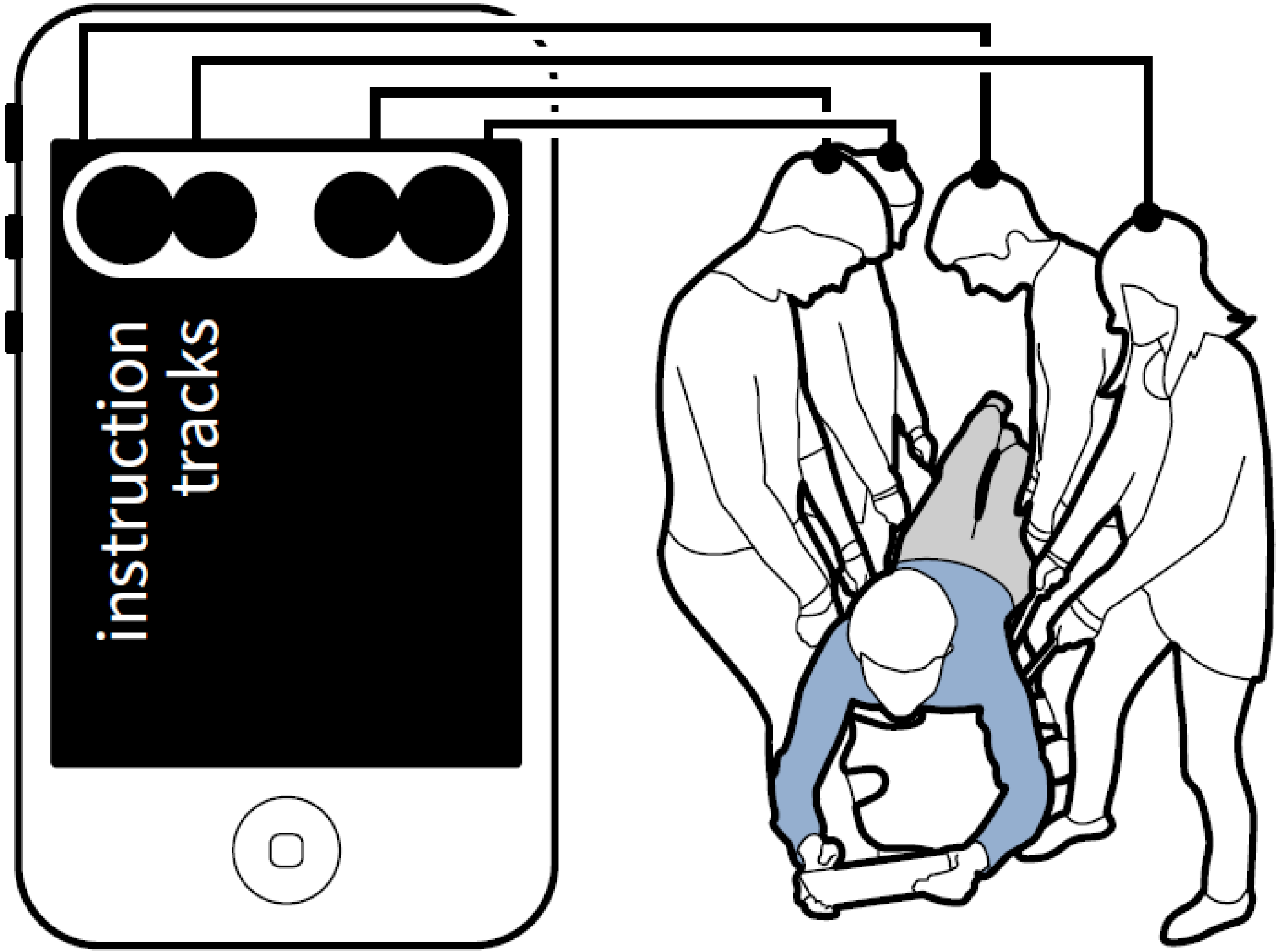




A scheduler for each of the human actuator
The instructions can generate **preemptive** warnings
Similar to Tap-Tap-Revenge

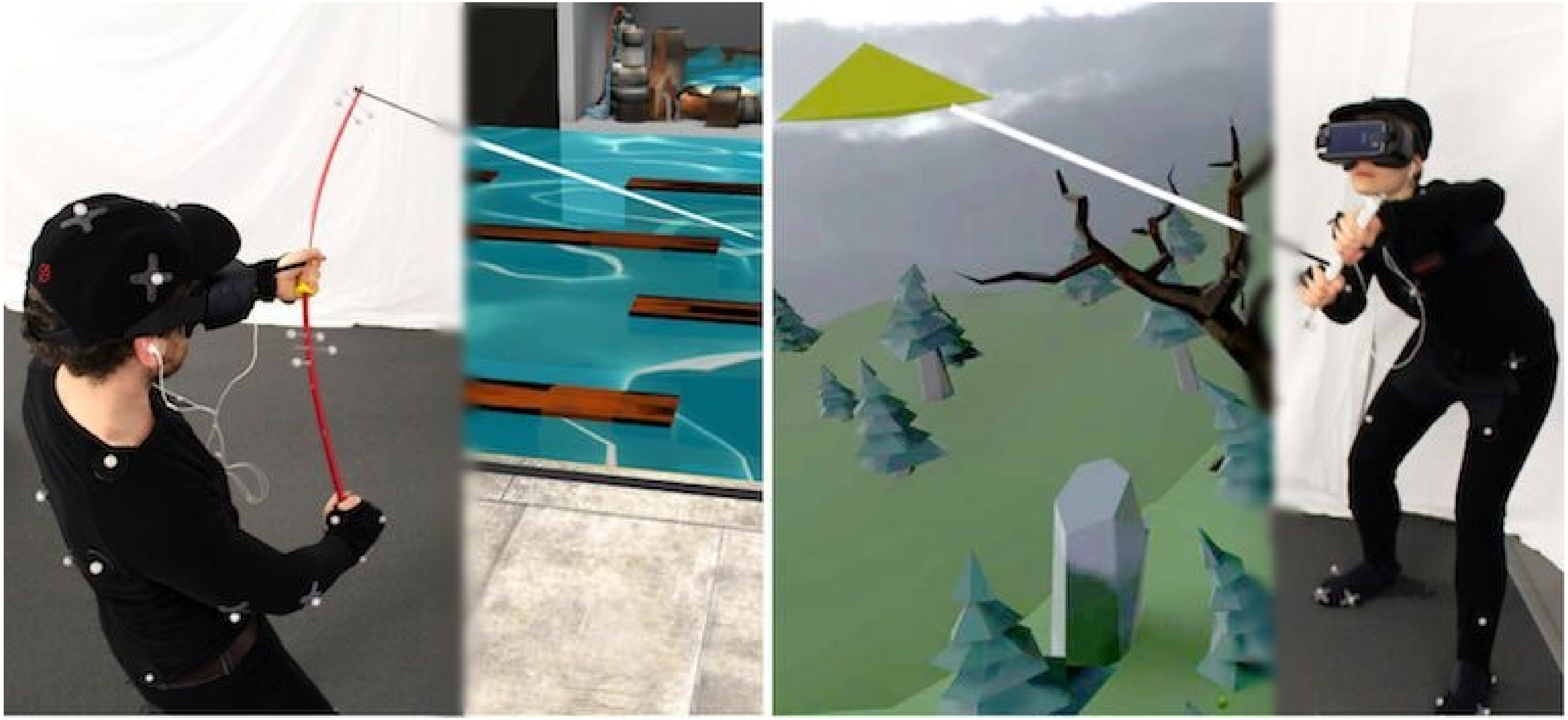




Because its mainly a software contribution,
it is scalable and flexible

Limitation?

1. We don’t always have multiple friends available
2. 4+ are supporting and only 1 is playing



Mutual Human Actuation
run pairs of users **at the same time** and have them provide human actuation to **each other**

Mutual Human Actuation

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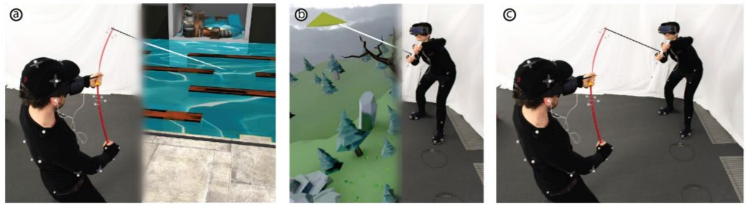

Figure 1: (a) This user, alone in his virtual world, is trying to pull a huge creature out of the water. He feels how the creature is struggling and pulling on his fishing rod. (b) At the same time, this other user, also alone in her virtual world, is struggling to control her kite during a heavy storm, which is whipping her kite through the air. (c) While users' experiences of force might suggest the presence of a force feedback machine, Mutual Turk achieves force feedback instead using *shared props* that transmit forces *between* users. The system orchestrates users so as to actuate their prop at just the right moment and with just the right force to produce the correct experience for the other user.

ABSTRACT
Human actuation is the idea of using people to provide large-scale force feedback to users. The Haptic Turk system, for example, used four human actuators to lift and push a virtual reality user; TurkDeck used ten human actuators to place and animate props for a single user. While the experience of human actuators was decent, it was still inferior to the experience these people could have had, had they participated as a user. In this paper, we address this issue by making *everyone* a user. We introduce *mutual* human actuation, a version of human actuation that works without dedicated human actuators. The key idea is to run pairs of users at the same time and have them provide human actuation to *each other*. Our system, Mutual Turk, achieves this by (1) offering shared props through which users can exchange forces while obscuring the fact that there is a human on the other side, and (2) synchronizing the two users' timelines such that their way of manipulating the shared props is consistent across both virtual worlds. We demonstrate mutual human actuation with an example experience in which users pilot kites though storms, tug fish out of ponds, are pummeled by hail, battle monsters, hop across chasms, push loaded carts, and ride in moving vehicles.

Author Keywords
Virtual reality; haptics; immersion; Haptic Turk.

ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

INTRODUCTION

Many researchers argue that the next step in virtual reality is to allow users to not only see and hear, but also *feel* virtual worlds [8]. Researchers initially explored the use of mechanical machinery for that purpose, such as exoskeletons [1] or passive [13,19], robotically actuated [11] props.

Unfortunately, the size and weight of such mechanical equipment tends to be proportional to what they actuate, often constraining such equipment to arcades and lab environments.

Researchers therefore proposed creating similar effects by replacing the mechanical actuators with *human* actuators. Haptic Turk, for example, uses four such human actuators to lift, bump, and shake a single human user [2]. TurkDeck brings human actuation to real walking [3]. It allows a single user to explore a virtual reality experience that is brought to life by ten human actuators that continuously rearrange physical props and apply forces to the user.

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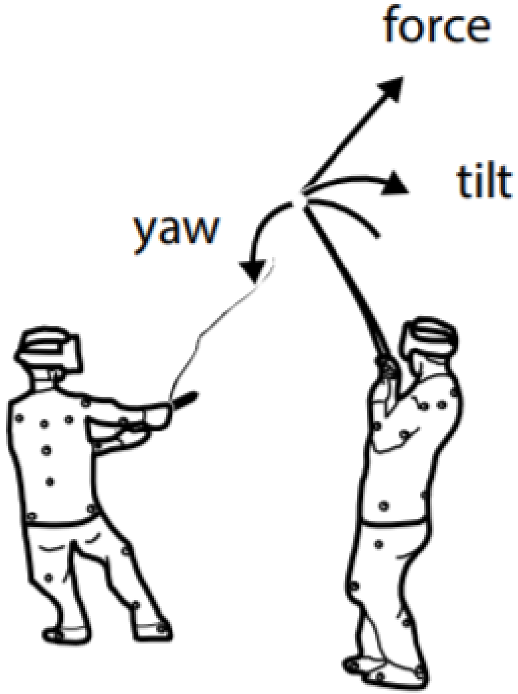
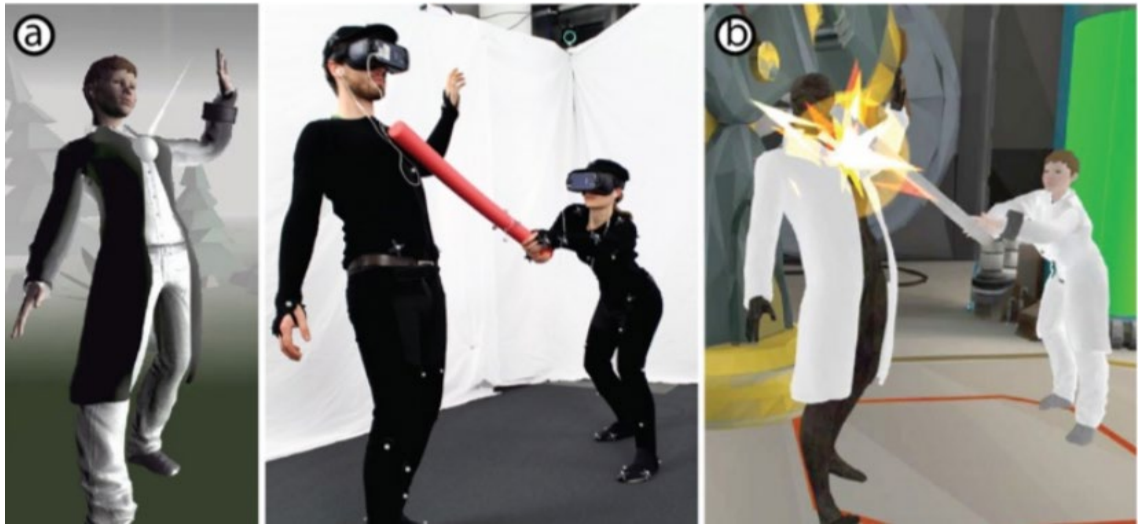
Shared Props

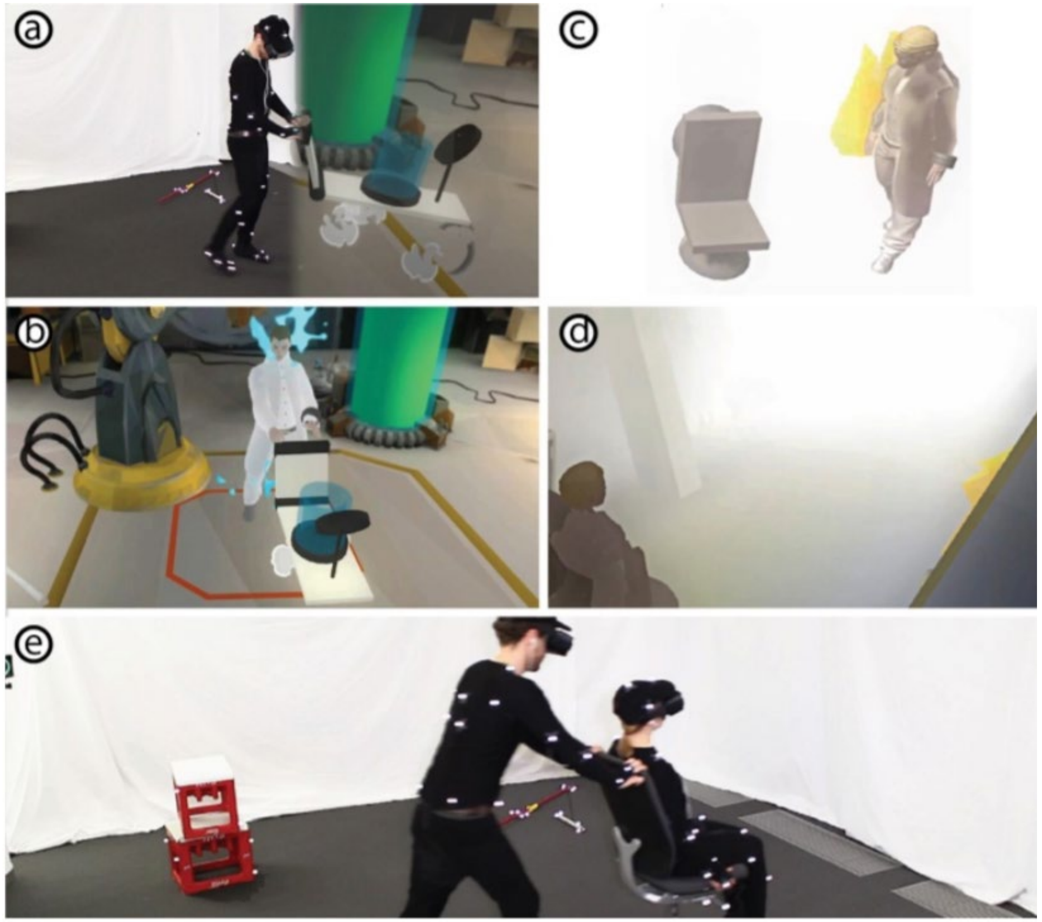


1.Continuous exchange of force between users’ hands

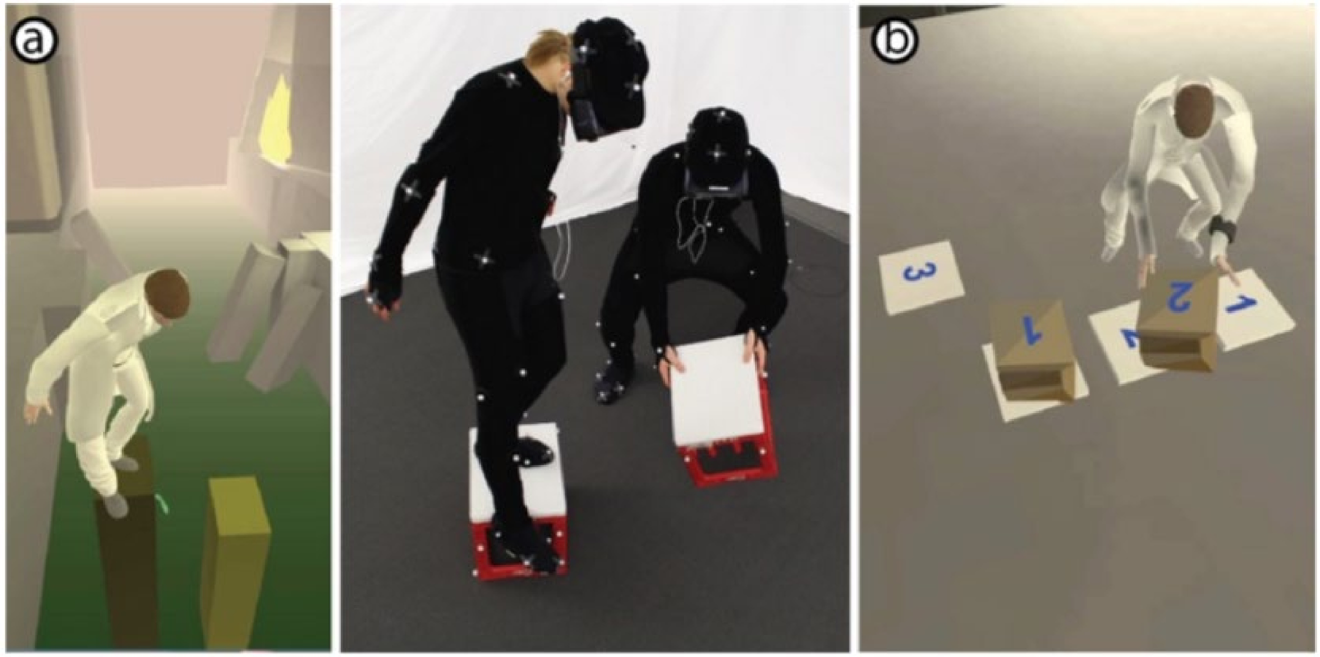


2.Impact

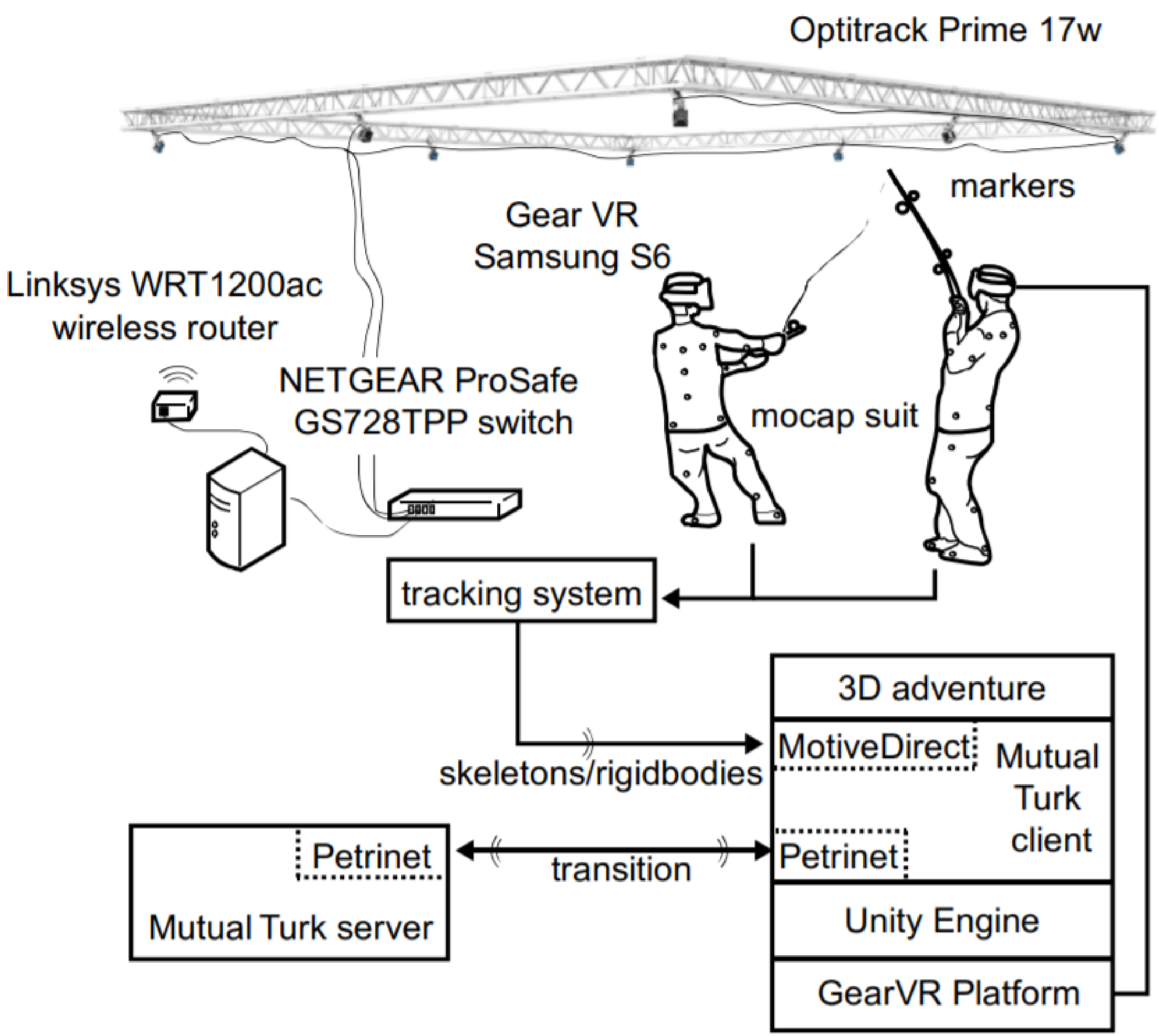
Shared Props



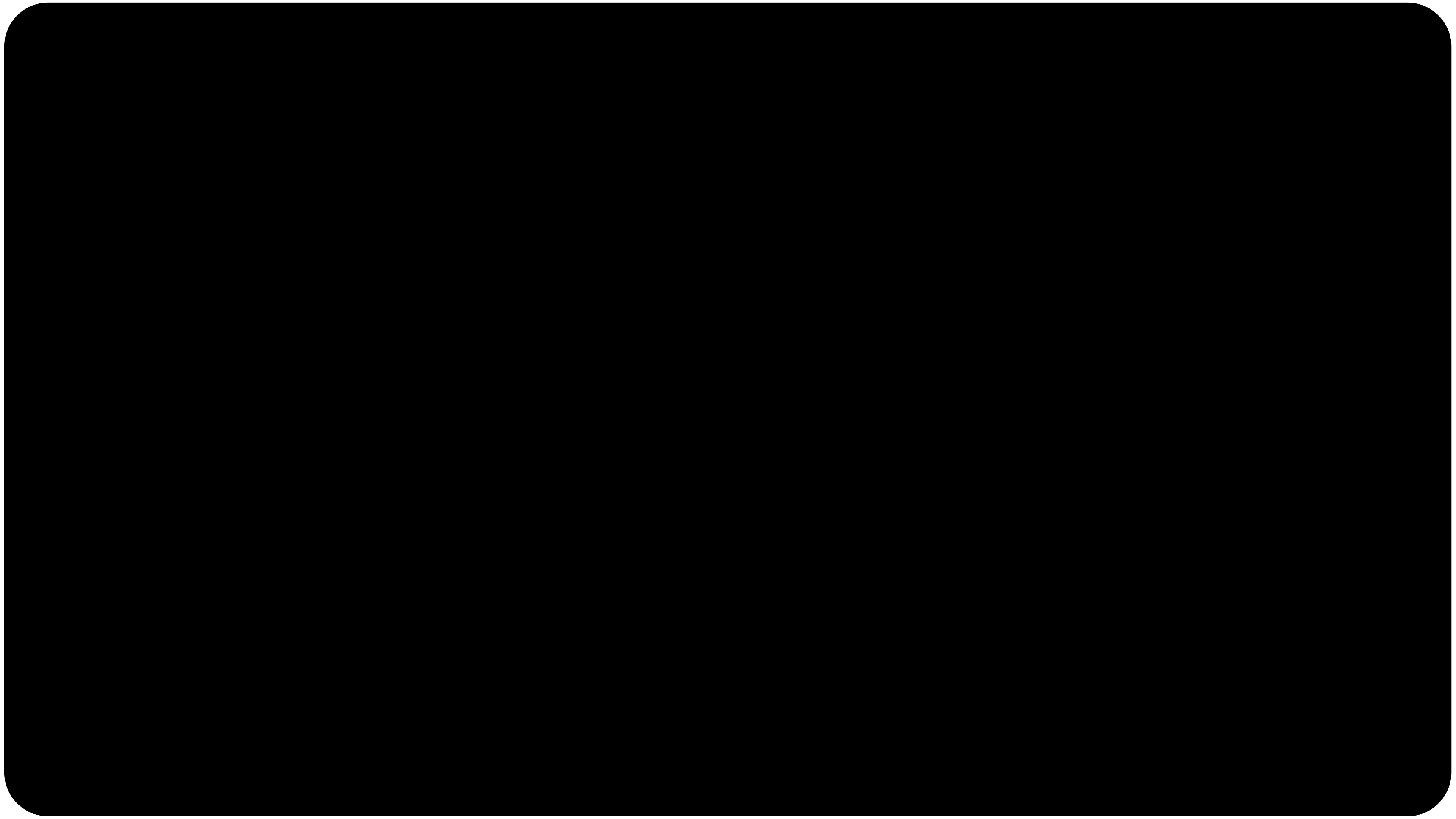
3.Continuous motion



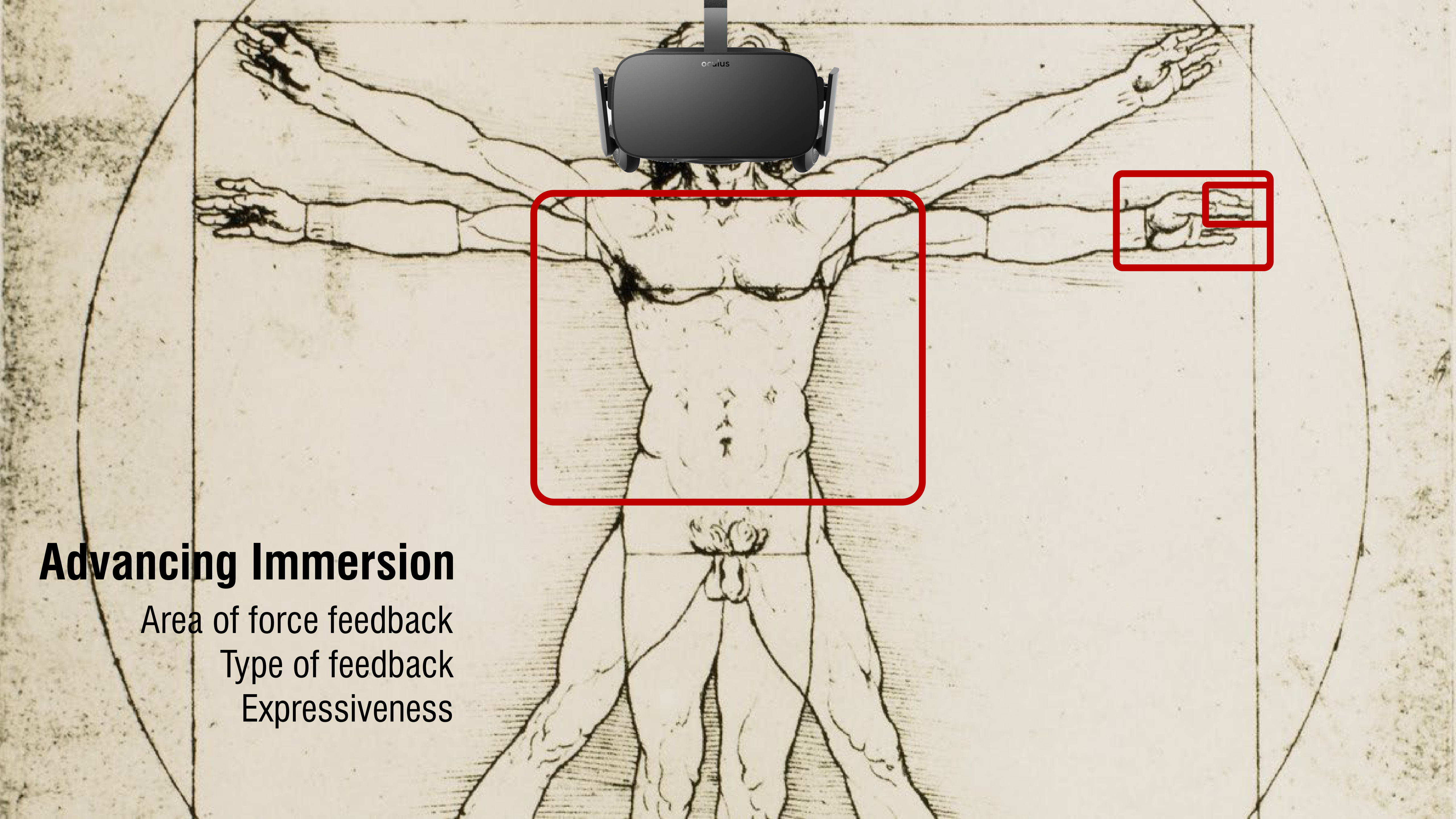
4. Rearranging props



But again, mainly a software scheduling problem



VR scenes need to be carefully designed to map the mutual motion



Advancing Immersion

Area of force feedback
Type of feedback
Expressiveness

Optional readings

Wireality: Enabling Complex Tangible Geometries in Virtual Reality with Worn Multi-String Haptics

Cathy Fang Yang Zhang Matthew Dworman Chris Harrison
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ABSTRACT
Today's virtual reality (VR) systems allow users to explore immersive new worlds and experiences through sight. Unfortunately, most VR systems lack haptic feedback, and even high-end consumer systems use only basic vibration motors. This clearly precludes realistic physical interactions with virtual objects. Larger obstacles, such as walls, railings, and furniture are not simulated at all. In response, we developed Wireality, a self-contained worn system that allows for individual joints on the hands to be accurately arrested in 3D space through the use of retractable wires that can be programmatically locked. This allows for convincing tangible interactions with complex geometries, such as wrapping fingers around a railing. Our approach is lightweight, low-cost, and low-power, criteria important for future, worn consumer uses. In our studies, we further show that our system is fast-acting, spatially-accurate, high-strength, comfortable, and immersive.

Author Keywords
Virtual Reality; Haptics; Force Feedback; String-Driven; Touch; Grasp.

CSS Concepts
Human-centered computing → Human computer interaction (HCI) → Interaction devices → Haptic devices.

INTRODUCTION
Virtual reality (VR) systems, such as the Oculus Quest [15] and HTC Vive [28], use controllers for tracking the hands, capturing buttoned input, and delivering basic vibrotactile haptic feedback. The latter is insufficient to produce immersive physical interactions with virtual objects. More critically, large obstacles like walls, railings, and furniture – key elements in most VR worlds – are not simulated at all. The current state-of-the-art in consumer VR systems is a vibration alert when a hand intersects a virtual object or obstacle – falling far short of any reality.

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DOI: https://dx.doi.org/10.1145/3313831.3376470

Figure 1. Wireality enables strong, whole-hand haptic feedback for complex objects in VR experiences.

This shortcoming has long been recognized, and researchers have looked into ways to bring rich haptics to VR experiences for many decades [36]. As we will review in greater detail, most systems have focused on hand haptics, such that virtual objects feel as though they are being held and are able to be moved in space. Less common are systems that attempt to arrest the hands *and* arms to simulate immovable objects, such as walls. To achieve this effect, systems often use mechanical exoskeletons [10, 23, 57] or fixed infrastructure in the environment [29, 40, 54], neither of which is particularly practical for consumer use.

We set out to design a new VR haptic system that was entirely self-contained and mobile. This implied a worn system, which in turn, meant our approach needed to be both lightweight and battery-powered. To simulate interactions with heavy or fixed objects, we needed a system that was both fast-acting and able to provide large arresting forces. Finally, in order to be a plausible consumer accessory, it should cost no more than $50 in volume production.

In this paper, we present our work on *Wireality*, which meets the above design criteria. Our system is comprised of modular, spring-loaded cables, which we can programmatically lock with a ratchet gear and a solenoid-driven pawl (Figure 1). This locking action takes under 30ms, provides up to 180N of arresting force, and yet only consumes 0.024mWh of energy (allowing our approach to be battery powered and mobile). Each module is responsible for limiting one degree of freedom on the hand. With many modules acting together as a unit, Wireality enables interactions with

CHI 20
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Mutual Human Actuation

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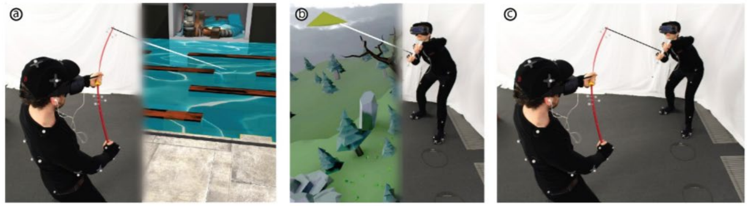

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ACM Classification Keywords
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