HapticBots

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

Ryo Suzuki

Eyal Ofek

Mike Sinclair

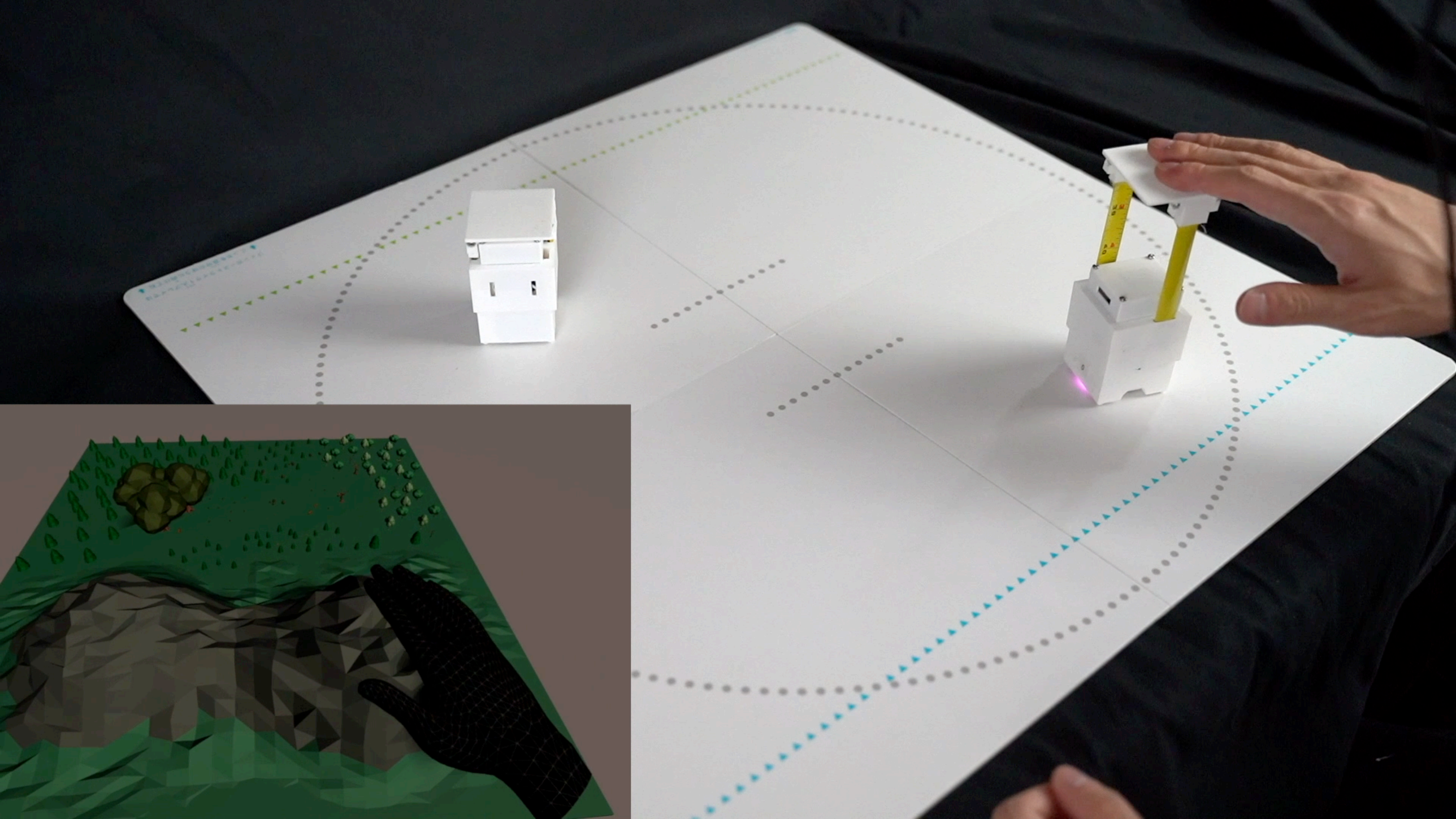
Daniel Leithinger

Mar Gonzalez Franco

UNIVERSITY OF CALGARY

Microsoft

University of Colorado Boulder

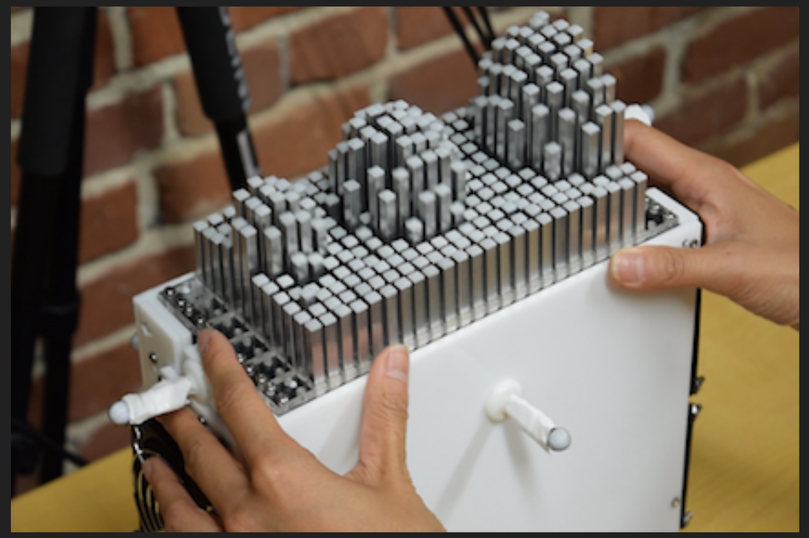


Contributions

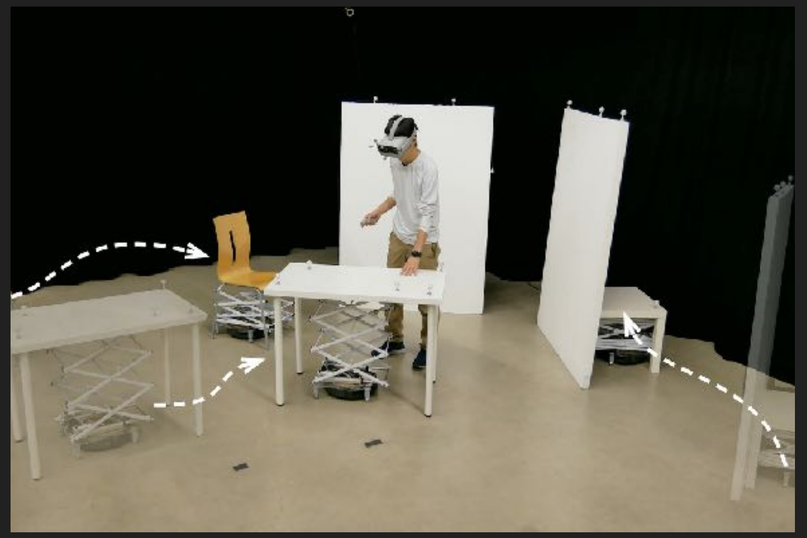
1. A novel concept of **distributed encountered-type haptics** for VR, enabled by swarm robots.
2. A hardware and software implementation of **HapticBots**, including a highly robust extendable mechanical structure.
3. **Applications** and **user evaluation** to demonstrate the effective continuous haptic illusions.

Related Work

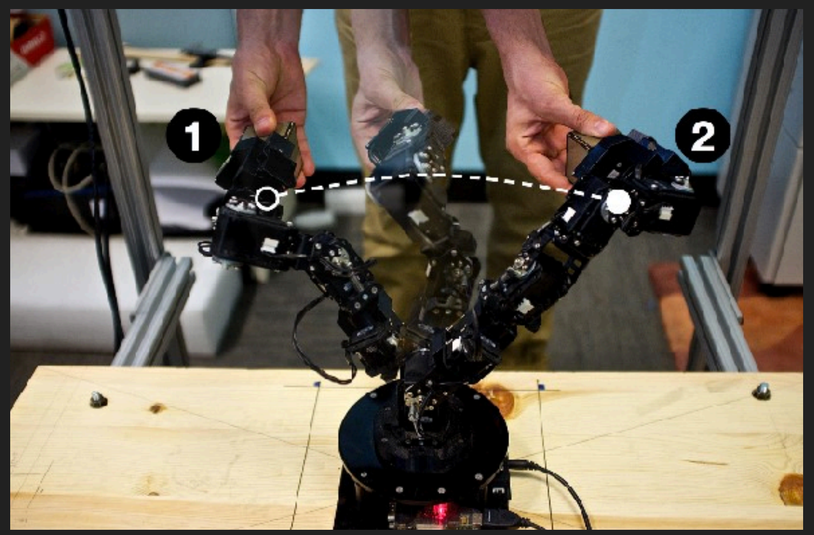
Encountered-type Haptics



shapeShift [CHI 2018]



RoomShift [CHI 2020]



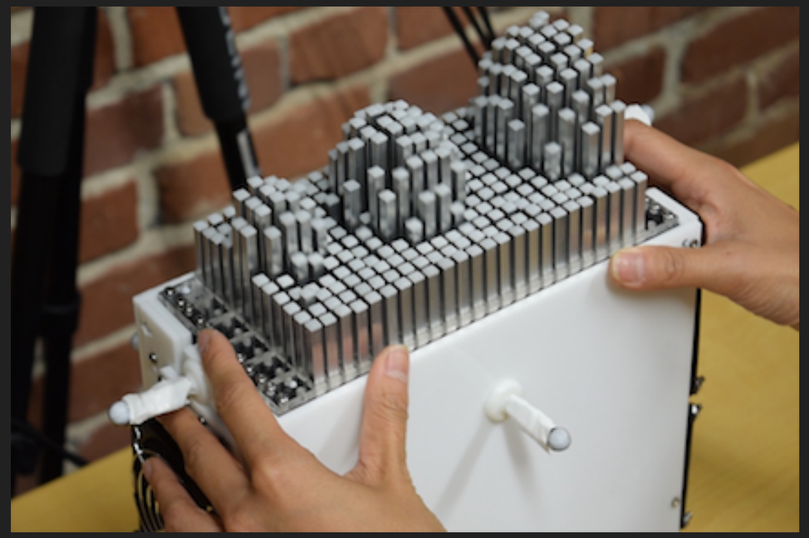
Snake Charmer [TEI 2016]

providing haptic sensation by reconfiguring physical environments

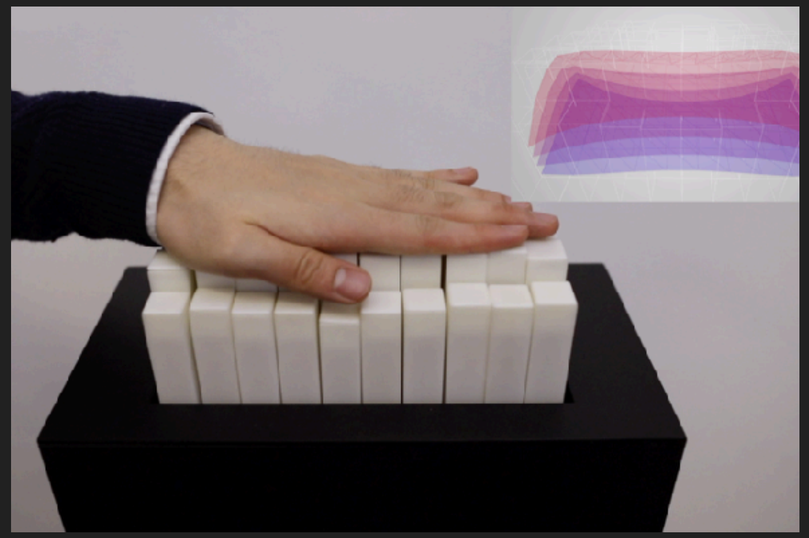
Encountered-type Haptics - Shape Display

inFORM [UIST 2013]

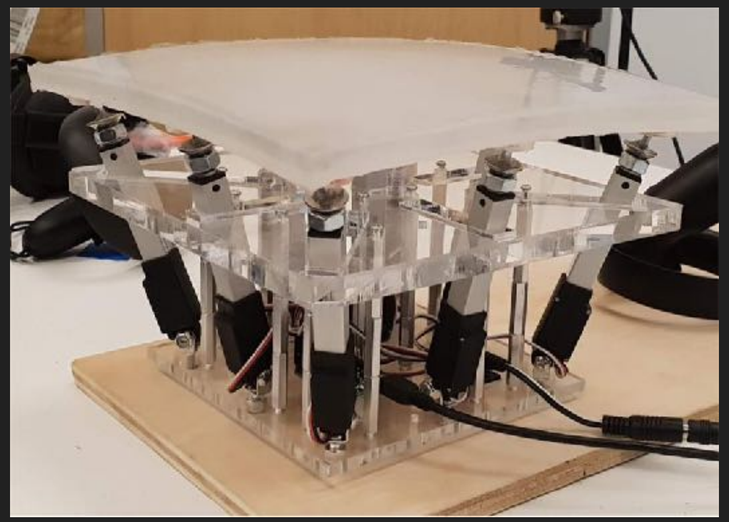
Encountered-type Haptics - Shape Display



shapeShift [CHI 2018]

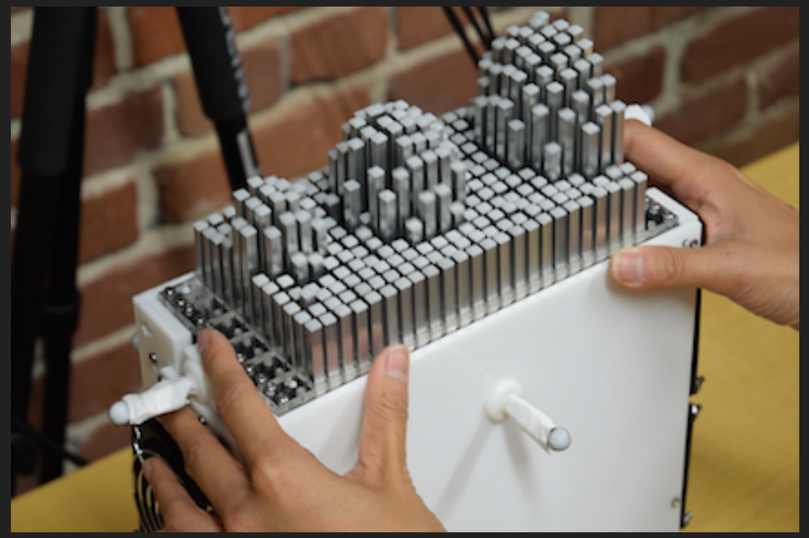


inFORCE [TEI 2019]

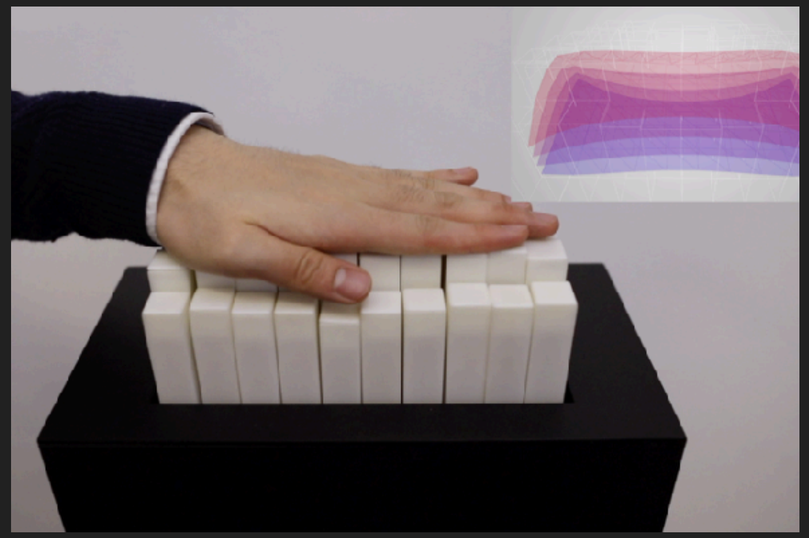


Auxetic Display [Nature 2021]

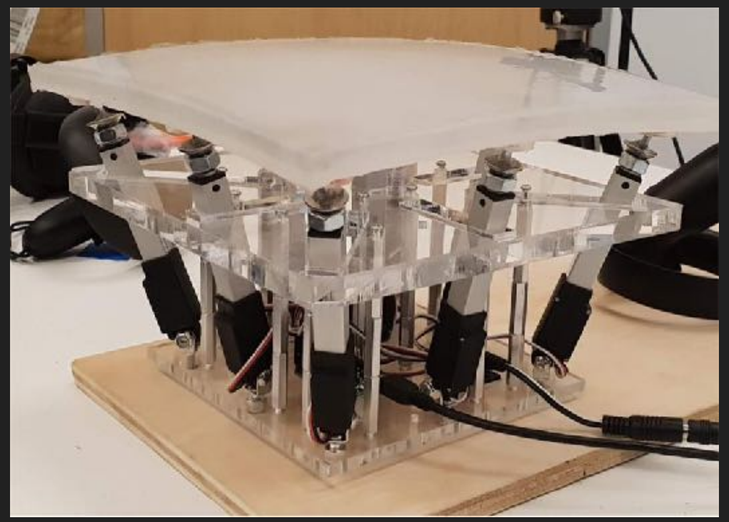
Encountered-type Haptics - Shape Display



shapeShift [CHI 2018]



inFORCE [TEI 2019]

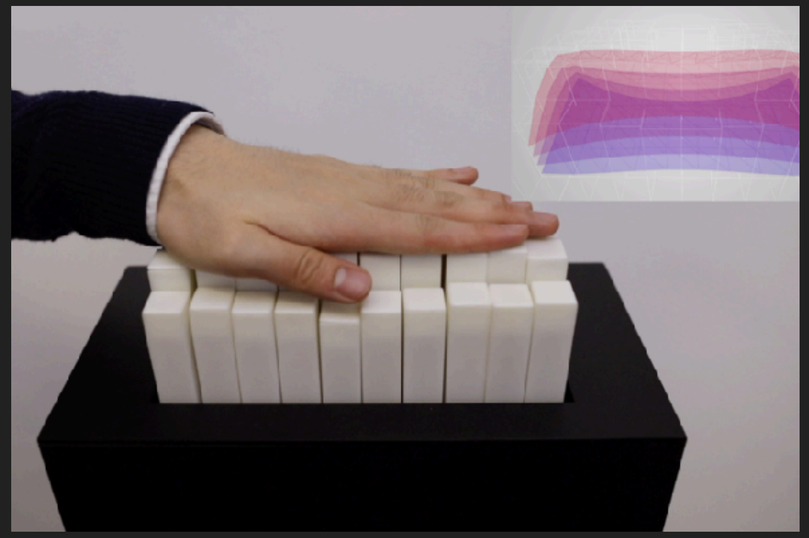


Auxetic Display [Nature 2021]

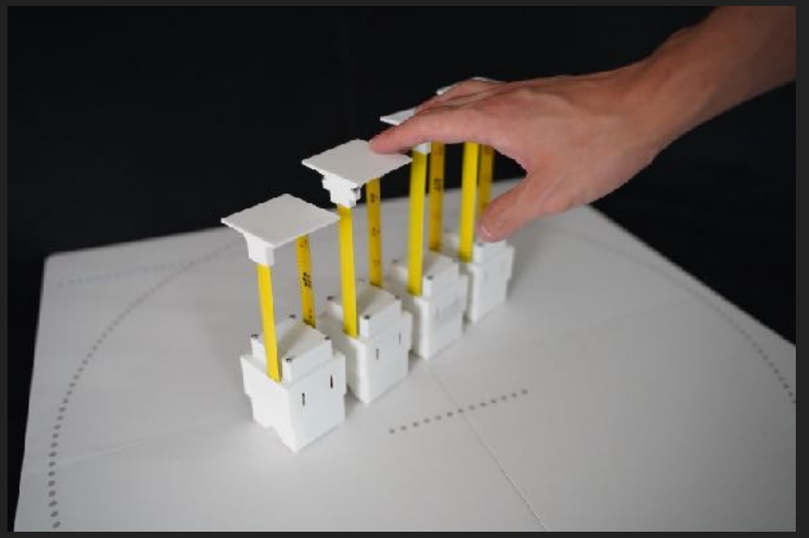
Limitation:

1. **Fixed interaction area**: significantly increase costs if making it large
2. **Not graspable**: pins are fixed on the base, which also limits lateral movement
3. **Not deployable**: requires heavy, large, and complex mechanical systems

Encountered-type Haptics - Swarm Robots



Shape Display based Haptics



Swarm Robotic based Haptics

Limitations of Shape Display

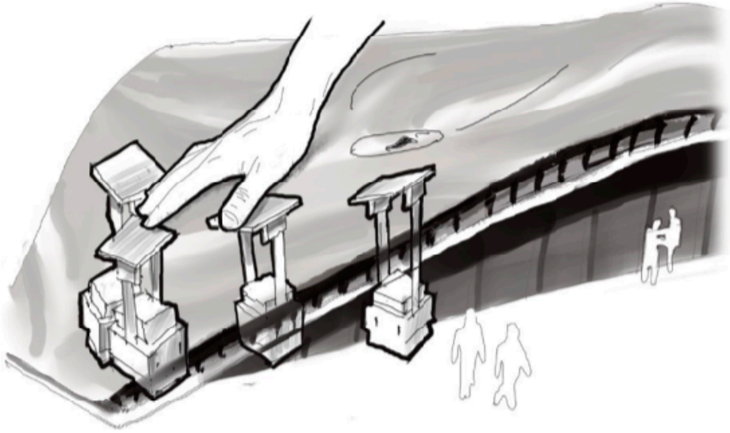
1. Fixed interaction area →
2. Not graspable →
3. Not deployable →

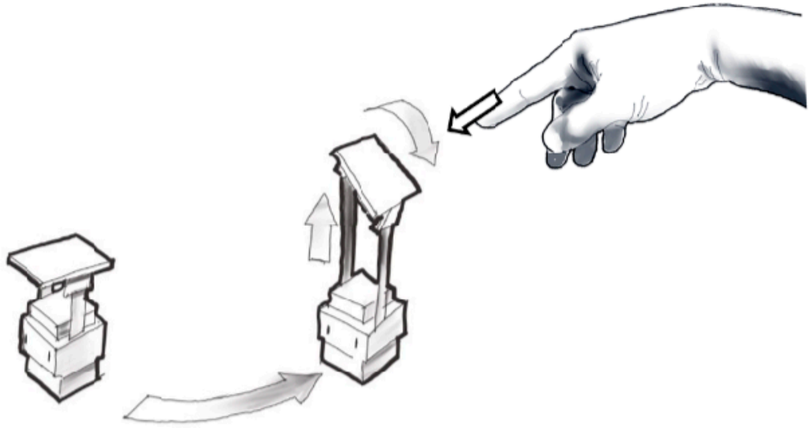
Our Approach:

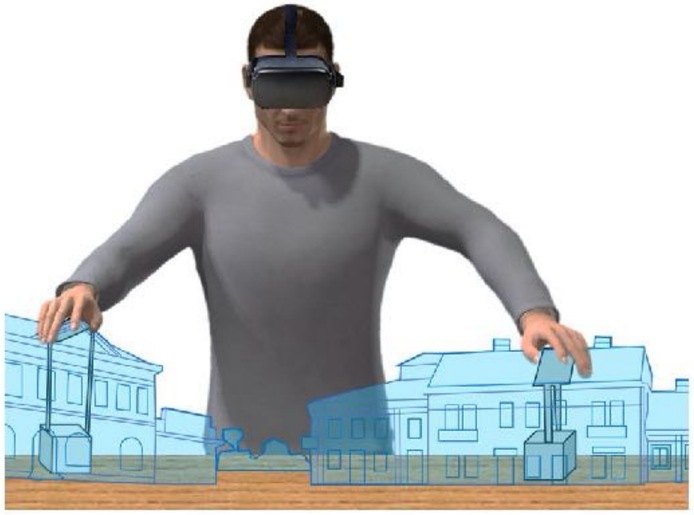
1. **Large** and **flexible**
2. **Graspable** and **portable**
3. Easily **deployable**

HapticBots

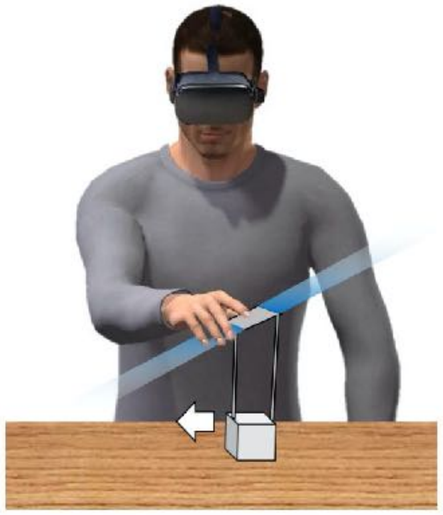
Distributed Encountered-type Haptics
with Shape-changing Swarm Robots





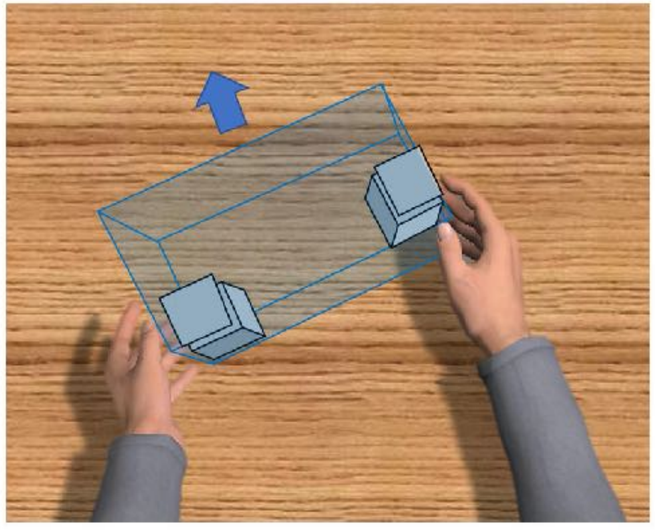


Large and flexible interaction area



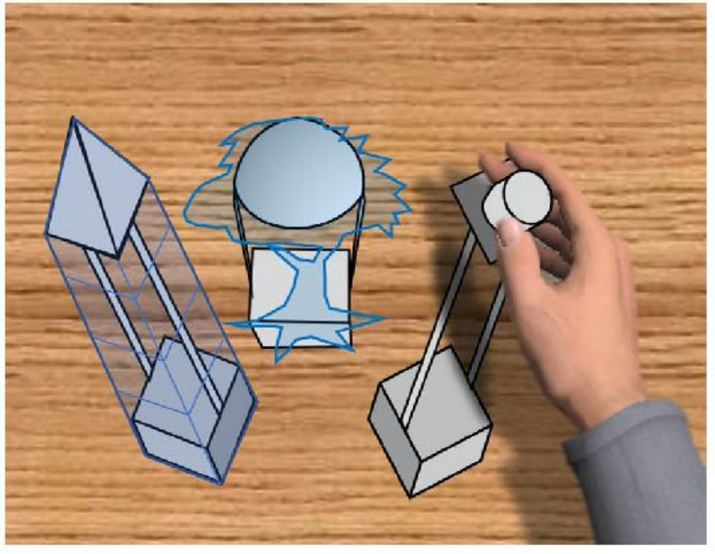
Lateral and Continuous motion

Graspable, portable and easy deployable

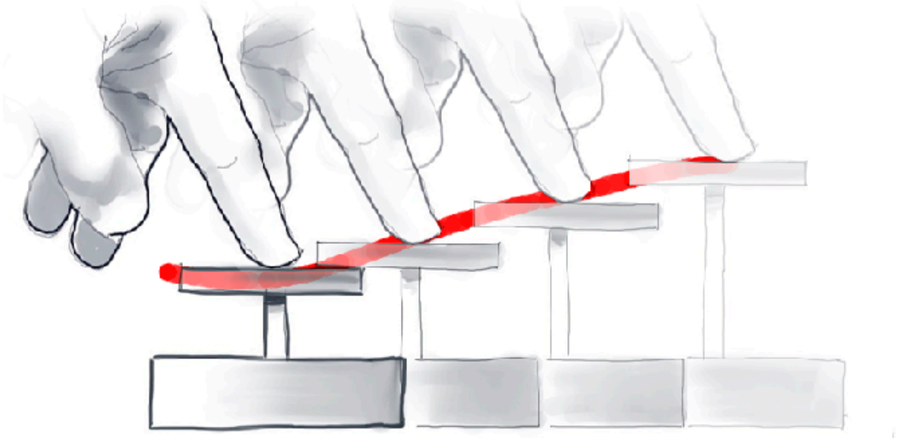


Multi Point interaction with virtual objects

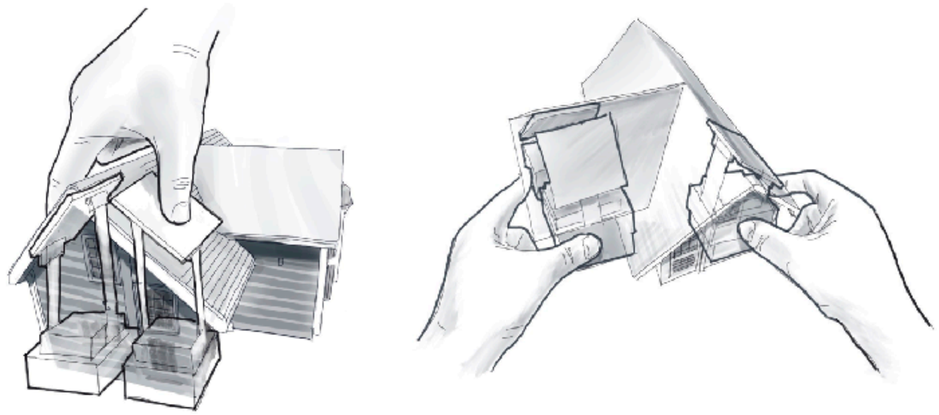
Swarm behavior



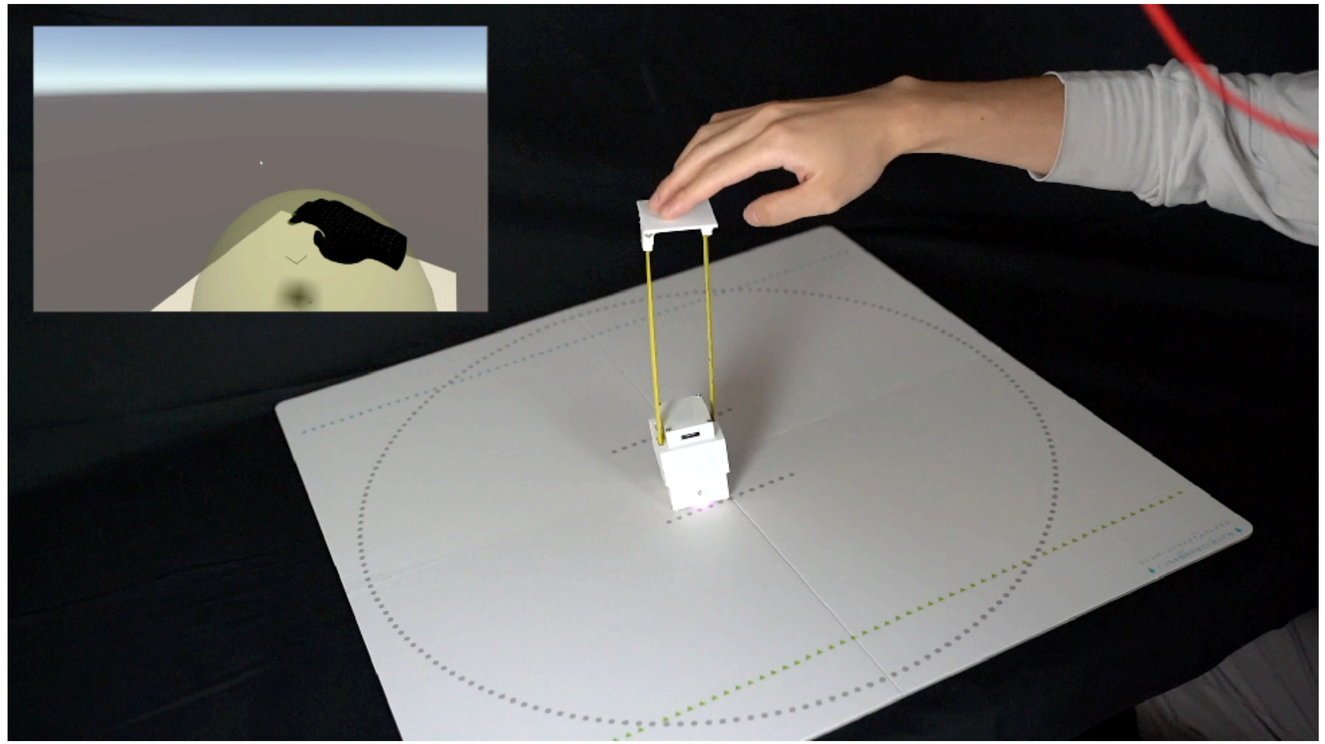
Customizable haptic props



Lateral Movements

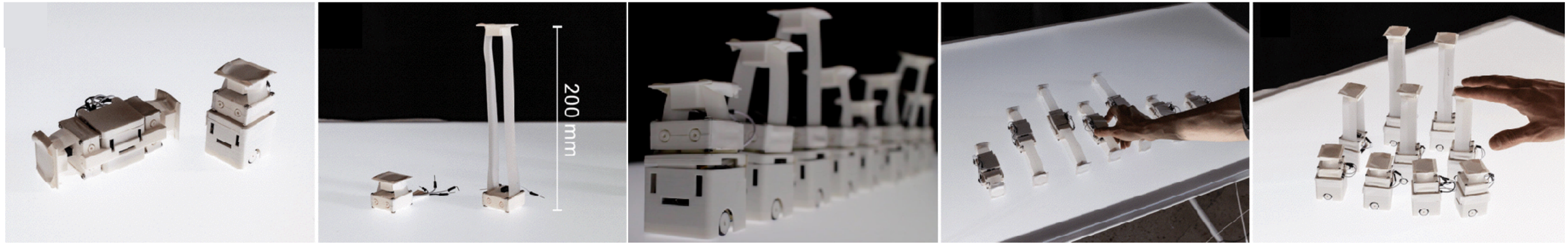


Coordinated Behaviors



Implementation

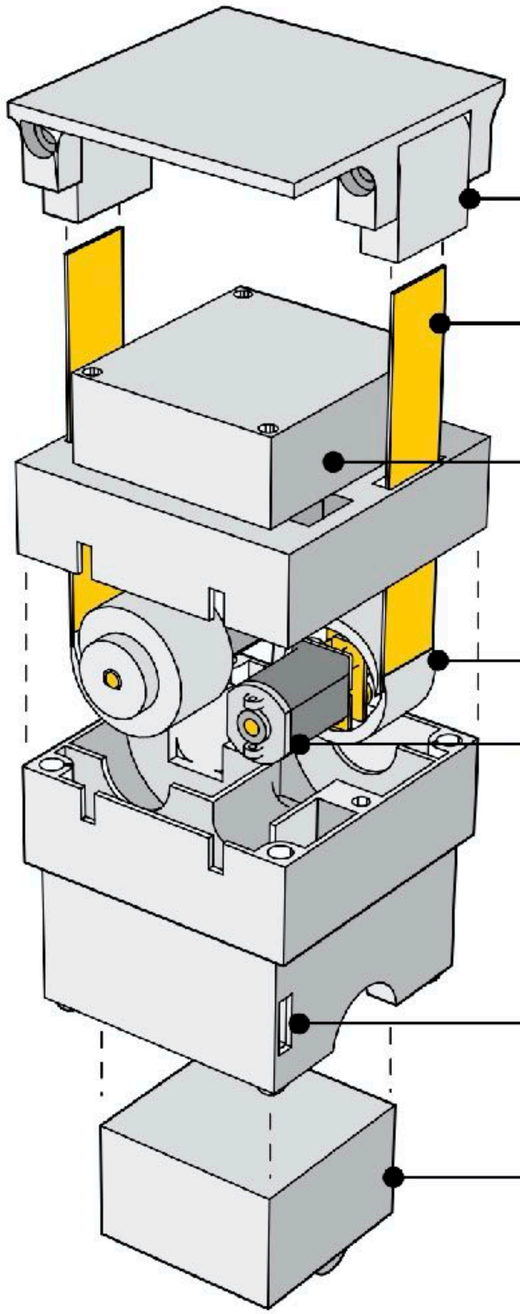
Inspiration



[UIST 2019] *ShapeBots: Shape-changing Swarm Robots*

→ ***Limitations and Challenges*:**

1) ***Weak*** *Actuator Robustness*
2) ***Imprecise*** *Open-loop Control*
3) ***Non-tilt*** *Support*
4) ***Non-VR*** *Integration*



Tiltable Cap

Exetendable Reel
Lufkin CS8506 Metal Tape Measure

Microcontroller
ESP 8266 + DRV8833 Motor Driver

3D Printed Shaft

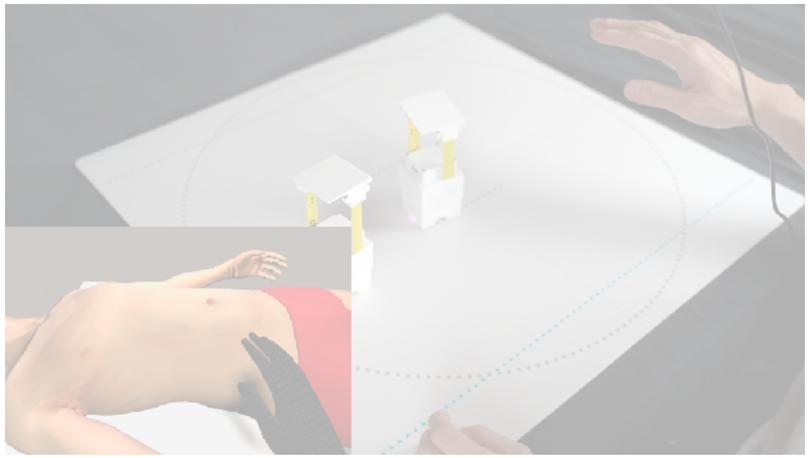
DC Motor
Pololu 1000 : 1 HP 6V Geared Motor
12 CPR Magnetic Rotary Encoder

Battery
3.7V 350mAh LiPo Battery + TP4056

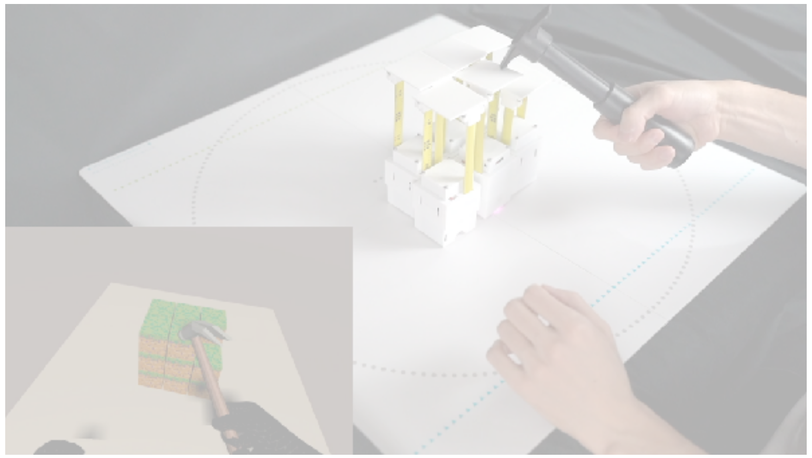
Mobile Robot
Sony TOIO™

x4

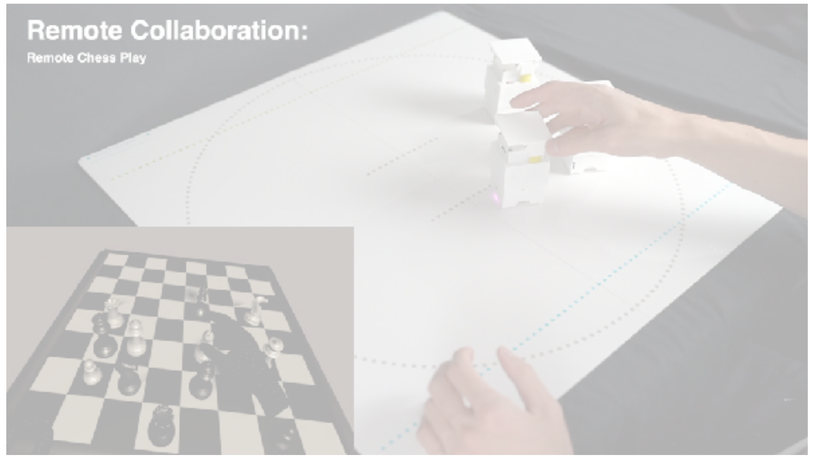
Flight Training



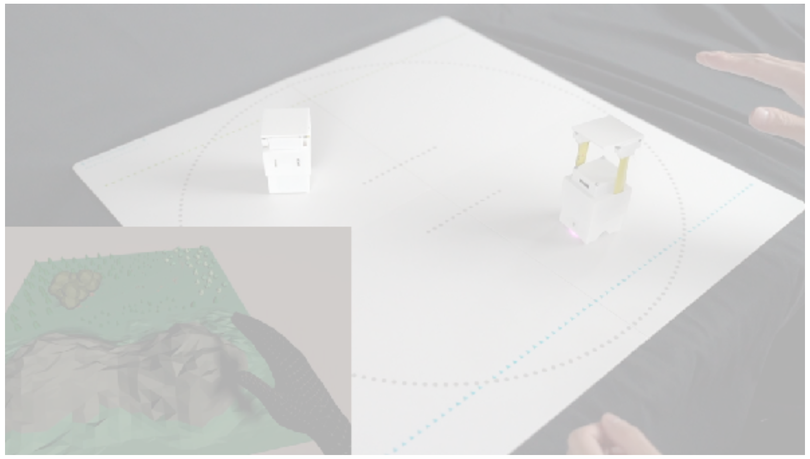
Medical Education



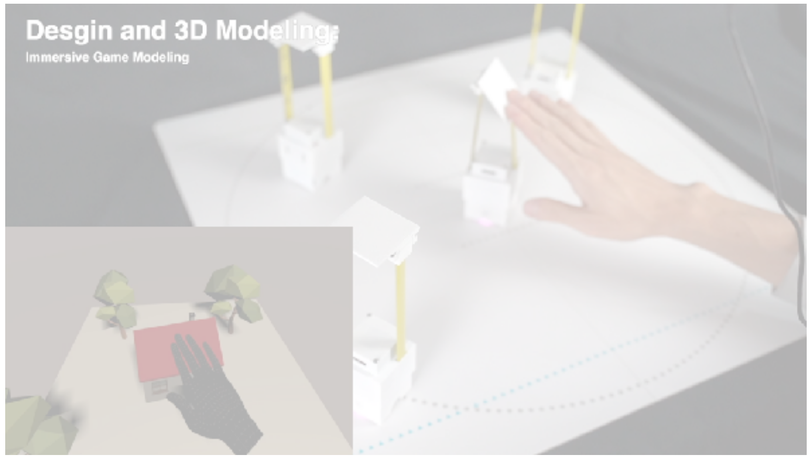
Games and Entertainment



Remote Collaboration



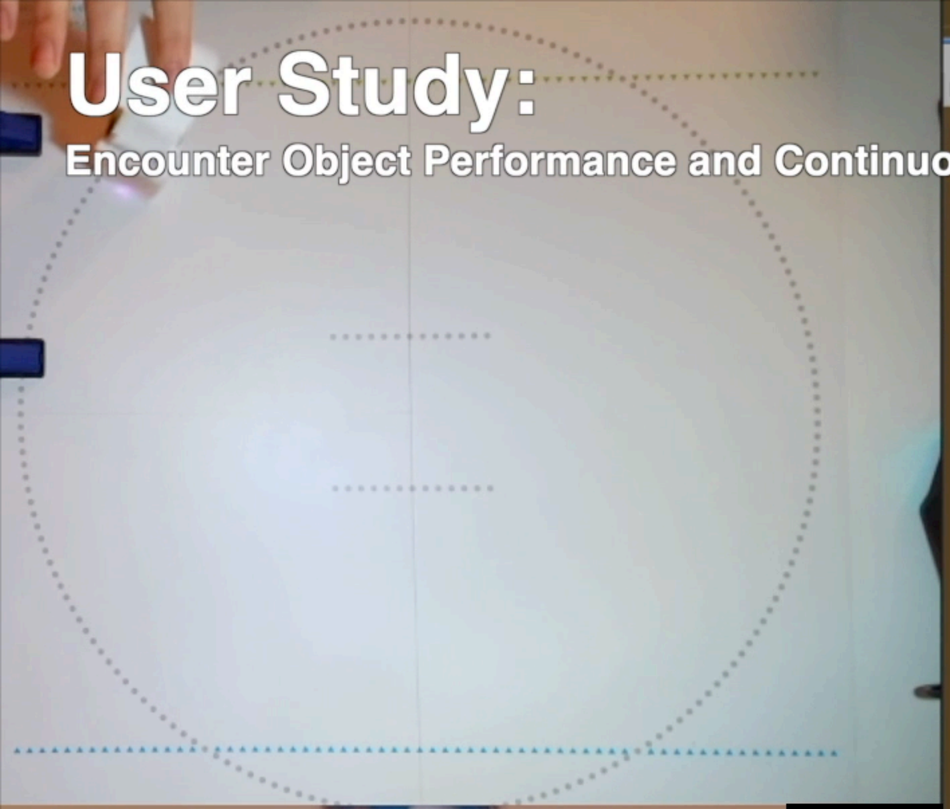
Map and Scene Rendering

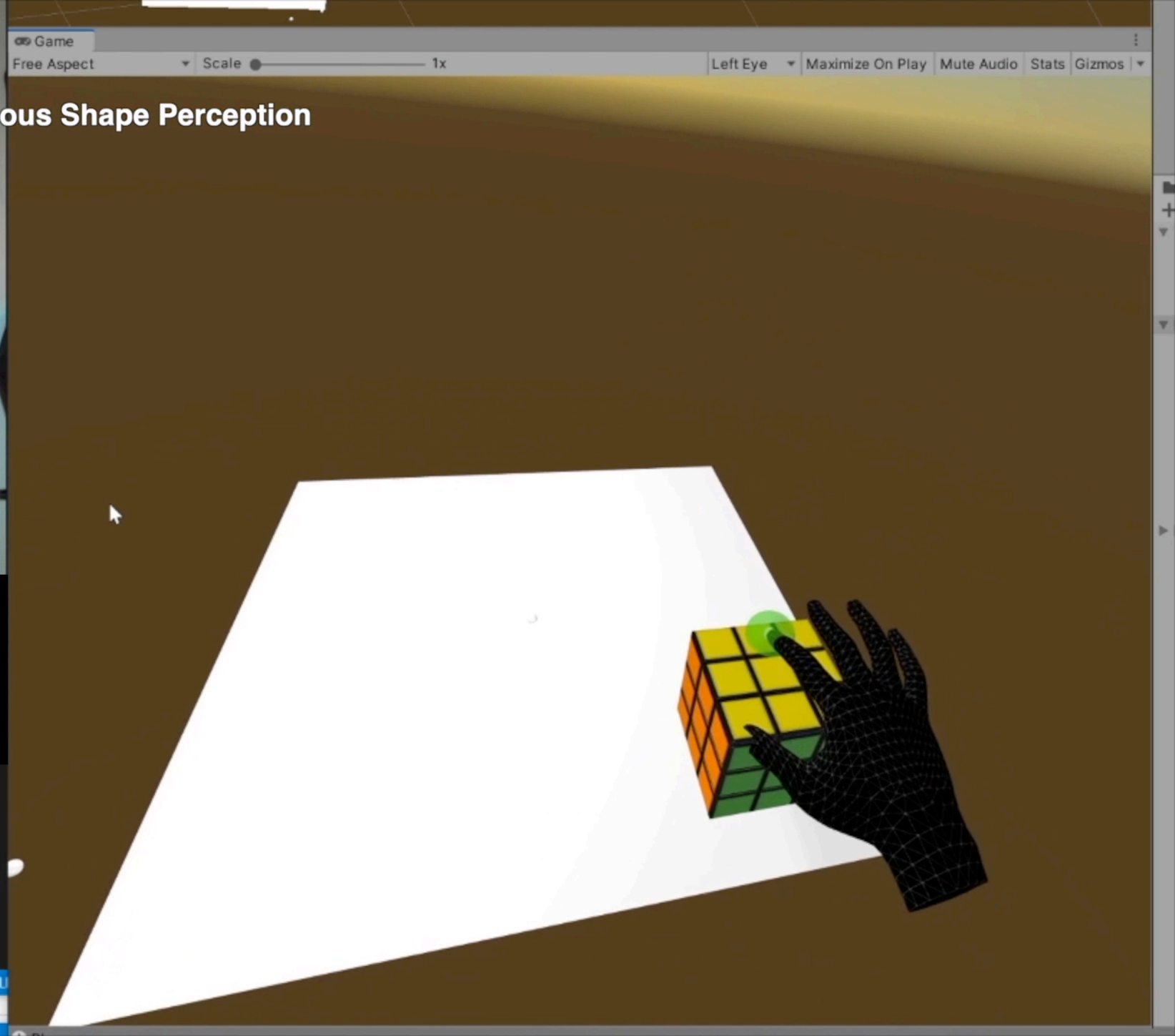


Design and 3D Modeling

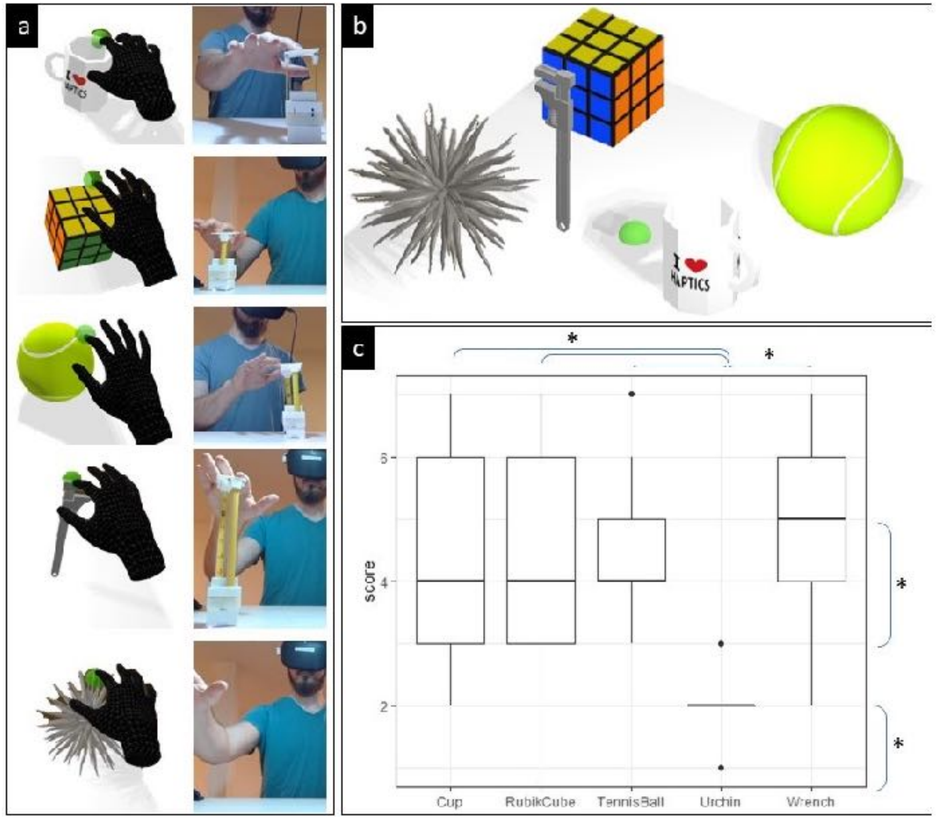
User Study:

Encounter Object Performance and Continuous Shape Perception

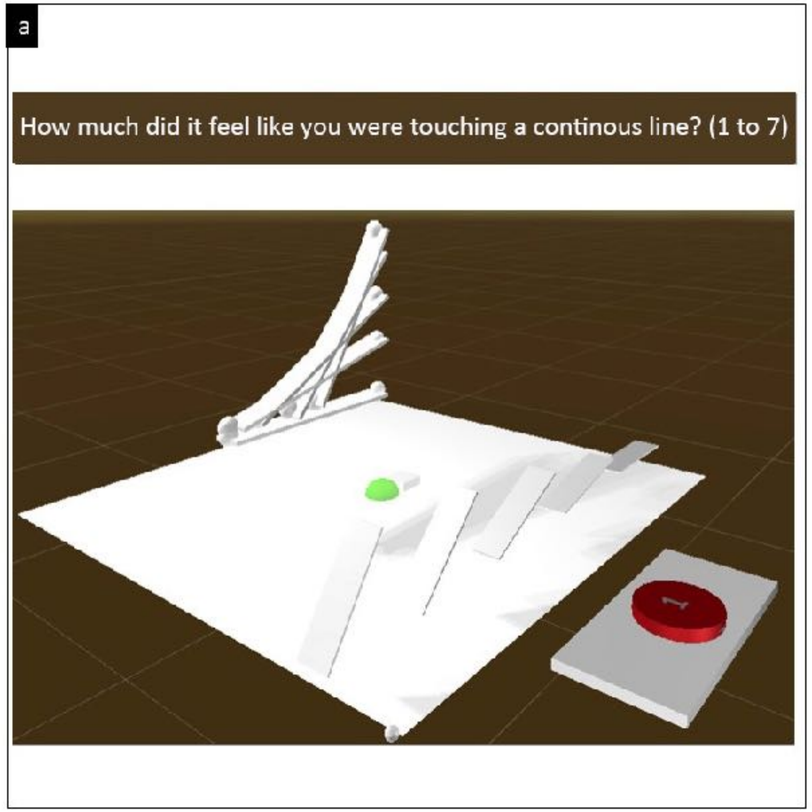


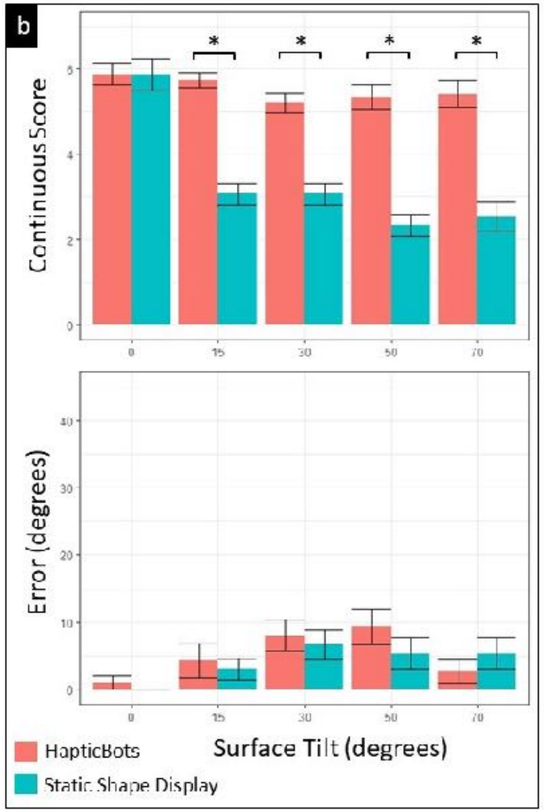


Study 1 - Results



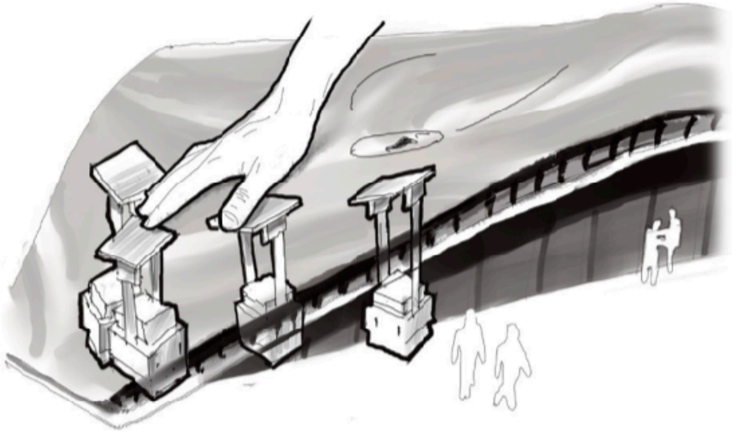
Study 2 - Results

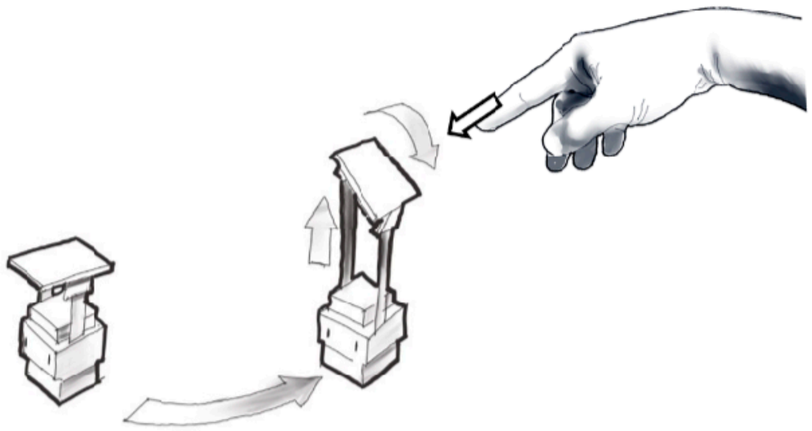




HapticBots

Distributed Encountered-type Haptics

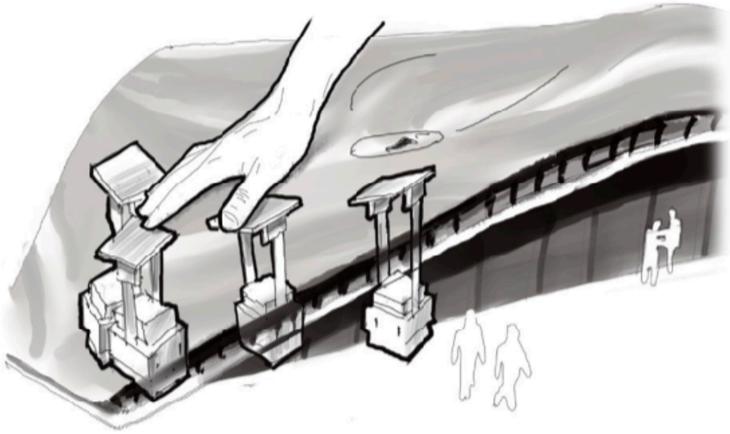


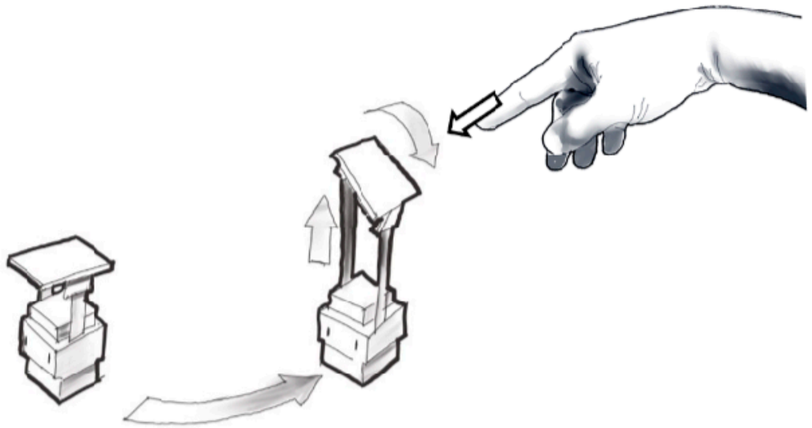


1. A novel concept of **distributed encountered-type haptics** for VR, enabled by shape-changing swarm robots.
2. A hardware and software implementation of **HapticBots**, including a highly robust extendable mechanical structure.
3. **Applications** and **user evaluation** to demonstrate the effective continuous haptic illusions.

HapticBots

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





Ryo Suzuki, Eyal Ofek, Mike Sinclair
Daniel Leithinger, Mar Gonzalez Franco

UNIVERSITY OF CALGARY

Microsoft

University of Colorado Boulder