Tracking User Interaction

6.S063 Engineering Interaction Technologies

Prof. Stefanie Mueller | HCI Engineering Group

you want to track a user's body motion
(e.g. as input for a game).

how would you do it?
list all the different methods (at least 5)

<1 min brainstorming>

optical tracking:

structured light

structured light:

- project a **known pattern** onto the scene
- infer depth from the **deformation of that pattern**

Zhang et al, 3DPVT (2002)

- typically IR light and IR cameras are used (invisible)
- the first Kinect used this approach

Kinect only ‘sees’ a pattern of stretched ellipses

here’s what the algorithms compute from this:

so can we use more
than 1 Kinect at the same time?

<30s brainstorming>

so can we use more than 1 Kinect at the same time?

no, the different projected patterns overlap and can no longer be clearly recognized

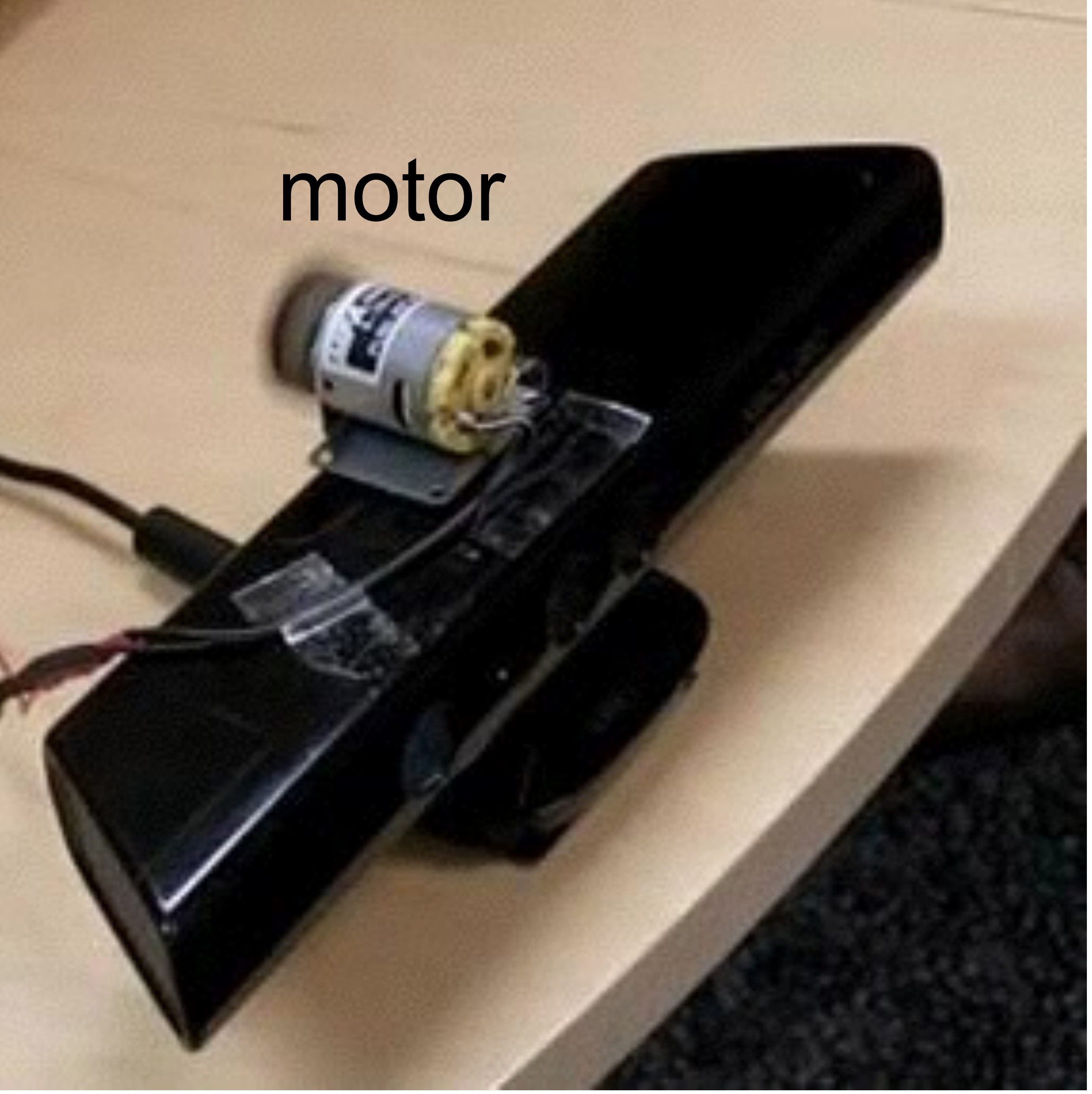
-> very noisy tracking

so can we use more than 1 Kinect at the same time?

no, the different projected patterns overlap and can no longer be clearly recognized

or maybe we can?
can you **invent** sth that fixes the problem?
(while still using the same IR emit/sense approach)

<30s brainstorming>



solution for multiple structured light sensors:

- vibrate each Kinect at a predefined frequency
- since both emitter and sensor vibrate at the same frequency, the IR pattern is still sharp
- however, for other Kinects the pattern will be motion blurred

[Shake’n’Sense 2012]

[Shake'n'Sense 2012]

Shake'n'Sense: Reducing Interference for Overlapping Structured Light Depth Cameras

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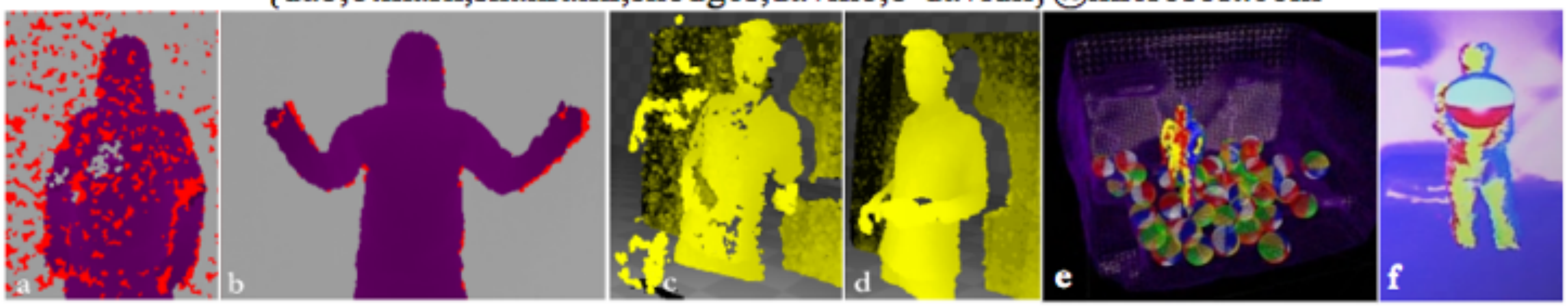

Figure 1: We present a novel yet simple mechanical technique for mitigating the interference when two or more Kinect cameras point at the same part of a physical scene. (a) Interference between overlapping structured light patterns from two regular Kinect cameras pointing at a person produces invalid and noisy depth pixels marked red. (b) Our method reduces noise and invalid pixels in the depth map. (c) The resulting point-cloud shows significant artifacts without our technique. (d) Point-cloud with our technique applied. (e) Our technique can be used to create an entire instrumented room with multiple overlapping Kinect cameras. (f) Meshed output accumulated from multiple Kinects shows reduced interference between cameras (color-coding indicates data from different cameras).

ABSTRACT

We present a novel yet simple technique that mitigates the interference caused when multiple structured light depth cameras point at the same part of a scene. The technique is particularly useful for Kinect, where the structured light source is not modulated. Our technique requires only mechanical augmentation of the Kinect, without any need to modify the internal electronics, firmware or associated host software. It is therefore simple to replicate. We show qualitative and quantitative results highlighting the improvements made to interfering Kinect depth signals. The camera frame rate is not compromised, which is a problem in approaches that modulate the structured light

community and computer science research [4,5,7]. Whilst there has been a great deal of research on depth sensing cameras, Kinect has now made such sensors cheap, commodity devices and dramatically broadened accessibility.

Kinect's depth sensing is based on a structured light source positioned at a known baseline from an infrared (IR) camera. IR laser light passes through a diffractive optical element (DOE) to project a pseudo-random pattern of dots into the scene. The disparity between the illumination pattern and the observed dots is used to calculate depth. An on-board ASIC performs this calculation, generating a 640x480 depth map at 30 frames per second.

The simultaneous use of multiple depth cameras can ex-

optical tracking:

time-of-flight

time-of-flight:

- emit light
- **light bounces of nearby objects** and reflects back
- **measure time** until the light hits the sensor

- closer objects = less time until the light reaches them
- far away objects = more time until the light reaches them

Kinect 2

- again IR light and camera
- but measures bounce time and not how the pattern looks

Computational Imaging with Multi-Camera Time-of-Flight Systems

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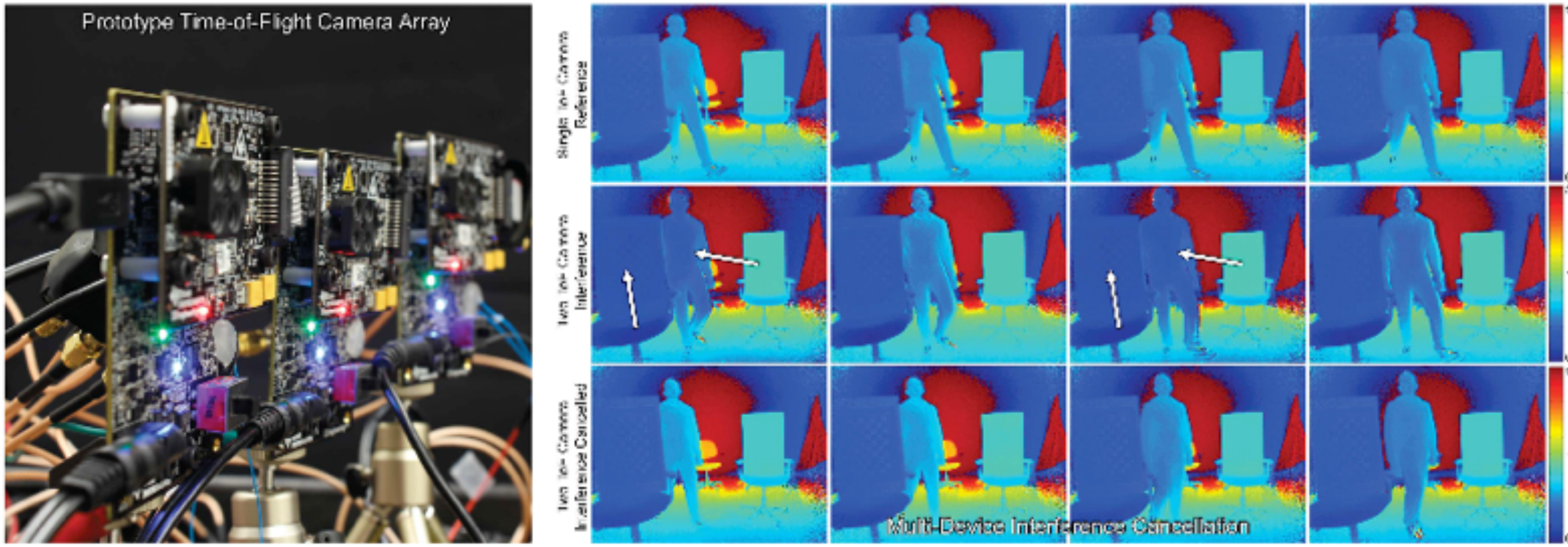


Figure 1: *We explore computational imaging with multi-camera time-of-flight systems. Our prototype (left) uses commercially-available sensors, but we design and build external signal generation and control electronics to synchronize the exposures of up to three sensors and drive them with programmable waveforms. One of many applications is multi-device interference cancellation (right). When two time-of-flight cameras are used simultaneously (right), their temporally-modulated illumination codes interfere with one another, which creates periodic artifacts in the estimated depth maps. Operating each light source-camera pair at a different modulation frequency solves this problem. We explore this and other applications of computational multi-camera time-of-flight systems.*

Abstract

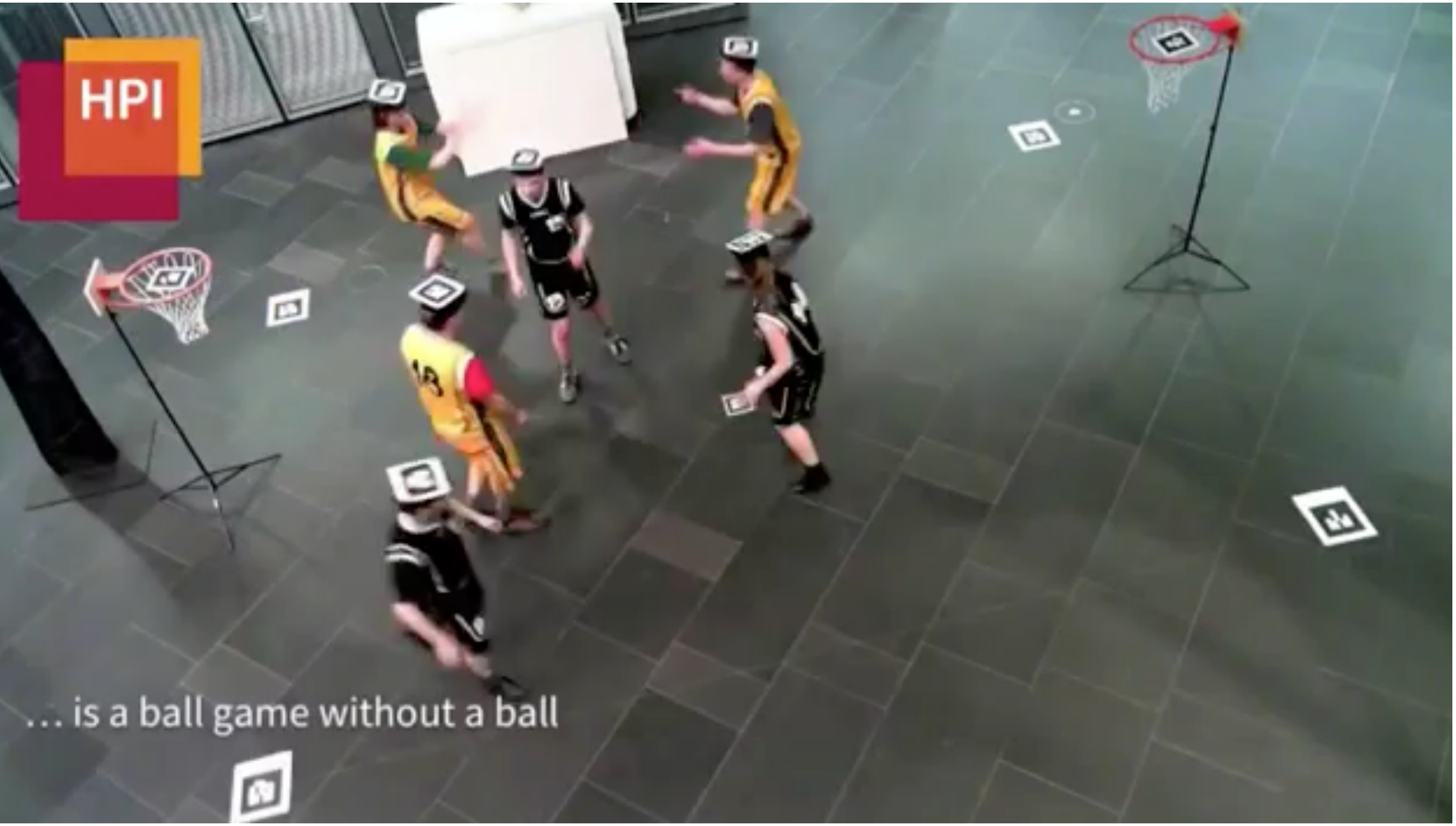
Depth cameras are a ubiquitous technology used in a wide range of applications, including robotic and machine vision, human-computer interaction, autonomous vehicles as well as augmented and virtual reality. In this paper, we explore the design and applications of phased multi-camera time-of-flight (ToF) systems. We develop a reproducible hardware system that allows for the exposure times and waveforms of up to three cameras to be synchronized. Using this system, we analyze waveform interference between multiple light sources in ToF applications and propose simple solutions to this problem. Building on the concept of orthogonal frequency design, we demonstrate state-of-the-art results for instantaneous ra-

computer graphics researchers, with applications such as scene reconstruction and understanding, pose estimation, action recognition, localization and mapping, navigation, tracking, segmentation, recognition, feature extraction, and reconstruction of geometry, material properties, or lighting conditions (see [Gall et al. 2014] for an overview). Beyond computer vision applications, range imaging is useful for human-computer interaction [Shotton et al. 2011], biometrics, autonomous vehicle and drone navigation, and also for positional tracking of immersive visual computing platforms (augmented and virtual reality, AR/VR). Today, range imaging technology is largely dominated by time-of-flight (ToF) cameras due to their small device form factors, good resolution, robustness in the presence of ambient light, low power, and fast on-chip pro-


HPI
imaginary reality basketball

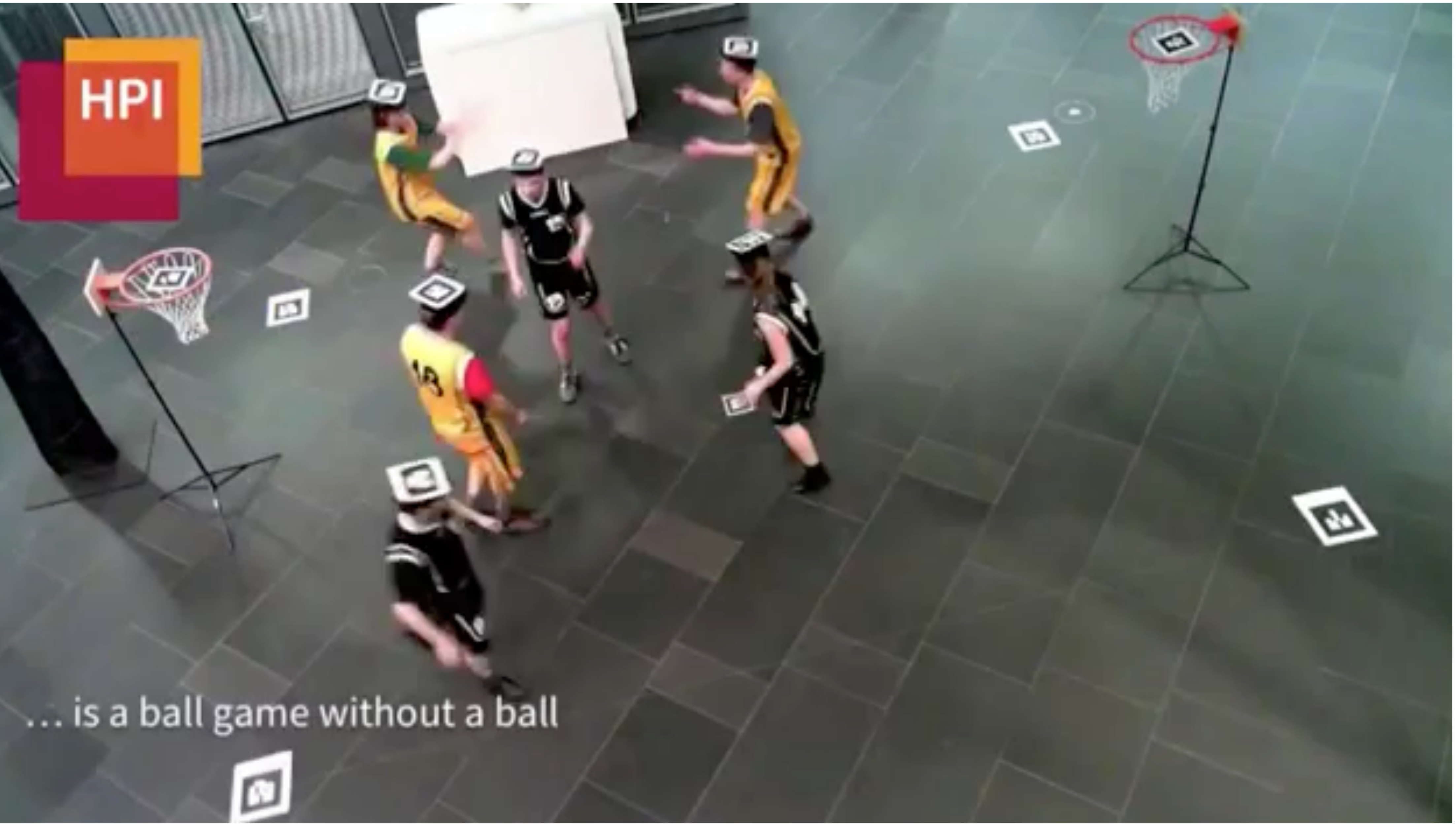
how would you have to **mount a set of Kinect cameras** to track all players while minimizing occlusion?

<30s brainstorming>



how would you have to mount a set of Kinect cameras to track all players while minimizing occlusion?

- let players wear the kinects on their chest
- let them track each other (hard)



Imaginary Reality Gaming: Ball Games Without a Ball

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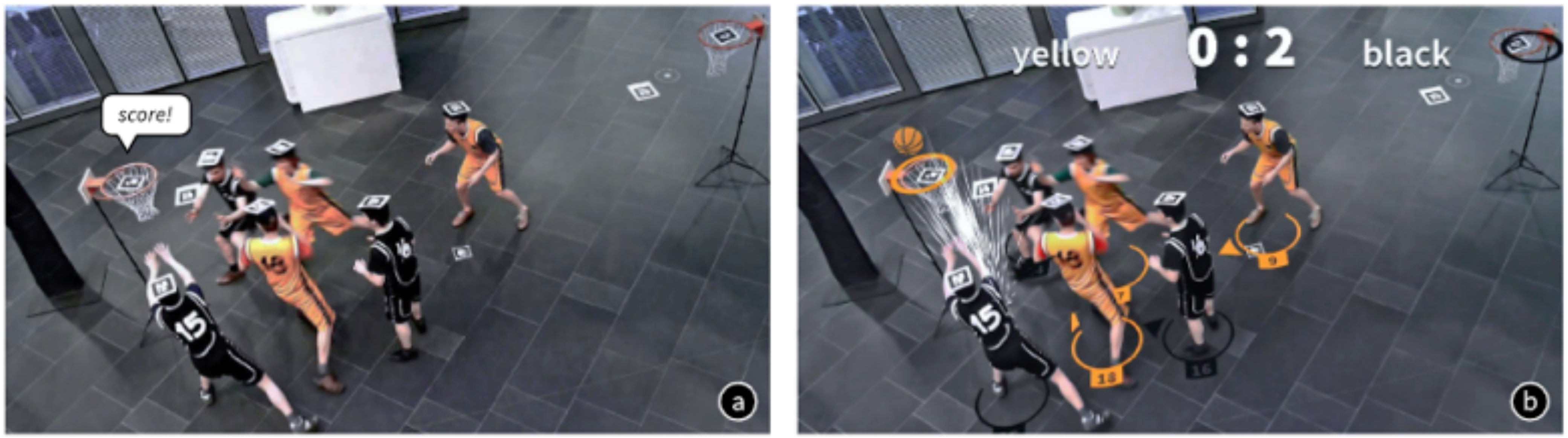


Figure 1: (a) Six players in a game of *Imaginary Reality Basketball*. Player 15 on the Black team has thrown the *imaginary ball* at the basket and scored. There is no visible ball; players get all information from watching each other act and a small amount of auditory feedback. (b) Under the hood & invisible to the players, the system represents the imaginary ball as a large number of *ball particles,* each of which represents one plausible ball trajectory. Players are tracked using accelerometers and an overhead camera.

ABSTRACT

We present *imaginary reality games,* i.e., games that mimic the respective real world sport, such as basketball or soccer, except that there is *no visible ball*. The ball is virtual and players learn about its position only from watching each other act and a small amount of occasional auditory feedback, e.g., when a person is receiving the ball.

Imaginary reality games maintain many of the properties of physical sports, such as unencumbered play, physical exertion, and immediate social interaction between players. At the same time, they allow introducing game elements from video games, such as power-ups, non-realistic physics, and player balancing. Most importantly, they create a new game dynamic around the notion of the invisible ball.

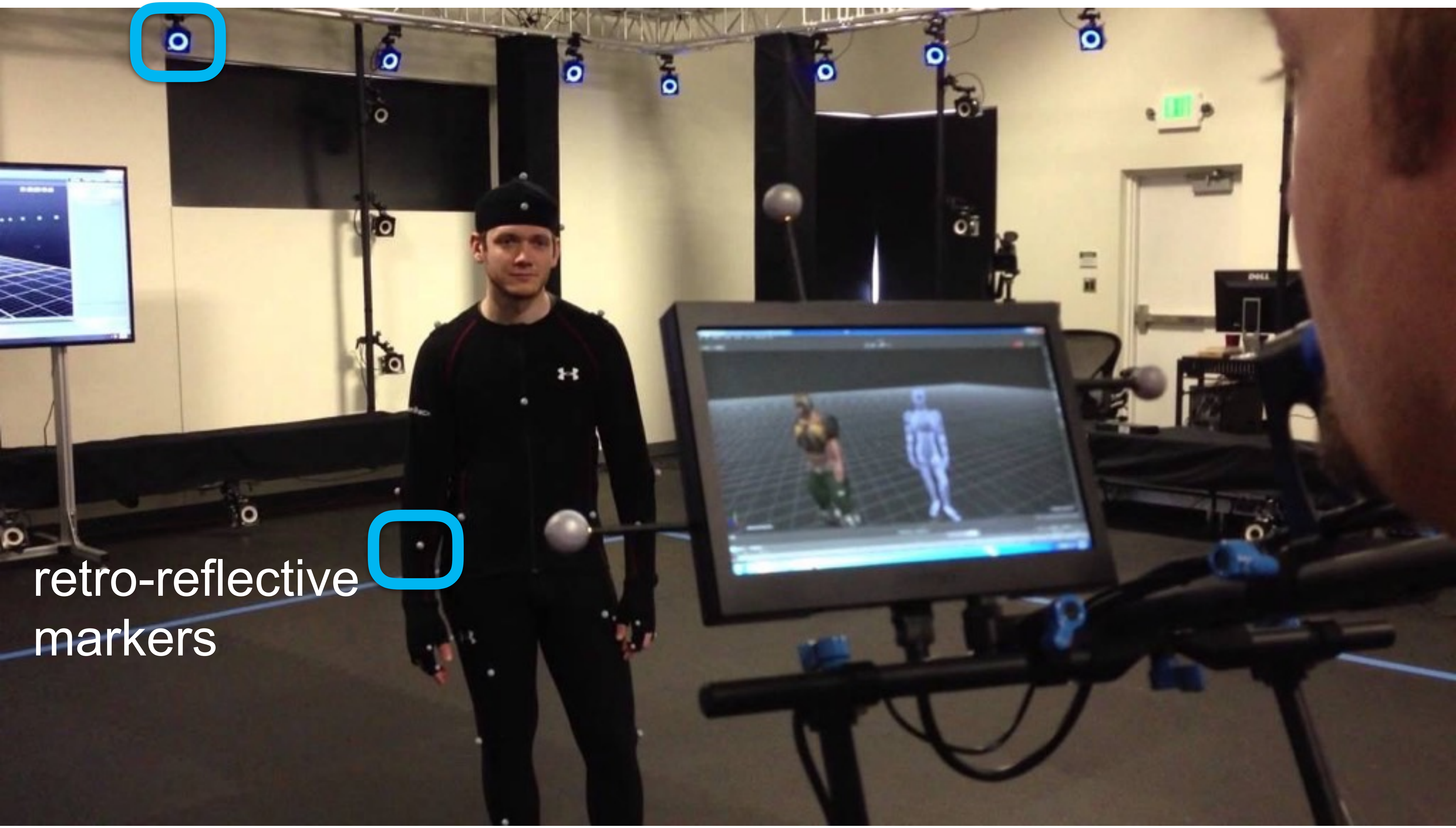
tion, and create immediate social interaction between players. Unfortunately, physical games are limited by the constraints of the real world, restricting their game mechanics to what is physically possible.

Researchers have tried to merge physical and virtual play in display-based augmented reality games such as Human Pacman [5] or AR Quake [16]. These games overlay a virtual world onto the physical world using hand-held or head-mounted see-through displays. This allows these games to introduce virtual game elements, such as power-ups (e.g. [22]) or creating virtual game elements that are not limited by the rules of physics (e.g. [20]).

Unfortunately, the use of displays takes away many of the qualities of physical sports, as players now perceive the optical tracking:

passive markers

infra-red cameras

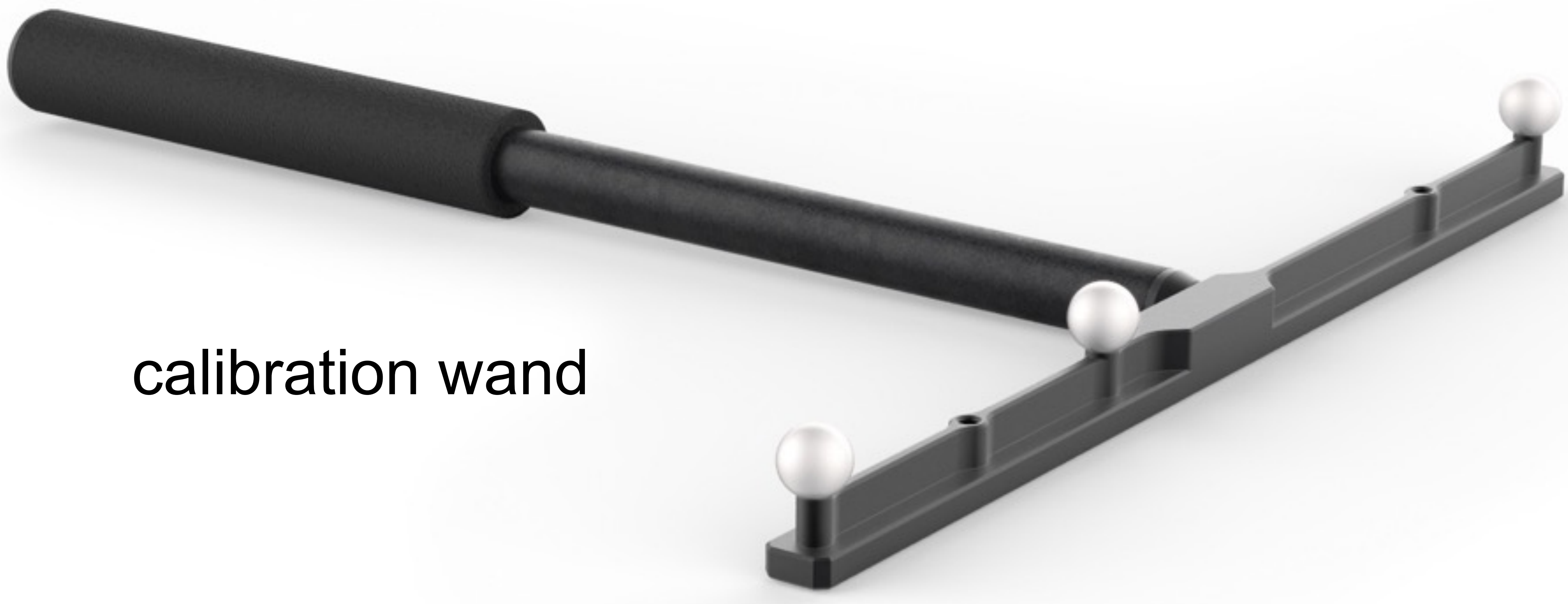


IR light + retro-reflective markers:

- cameras emit infrared light
- bounces of the retroreflective marker
- camera sees the marker as a **bright dot** in the IR image

extracting marker position:

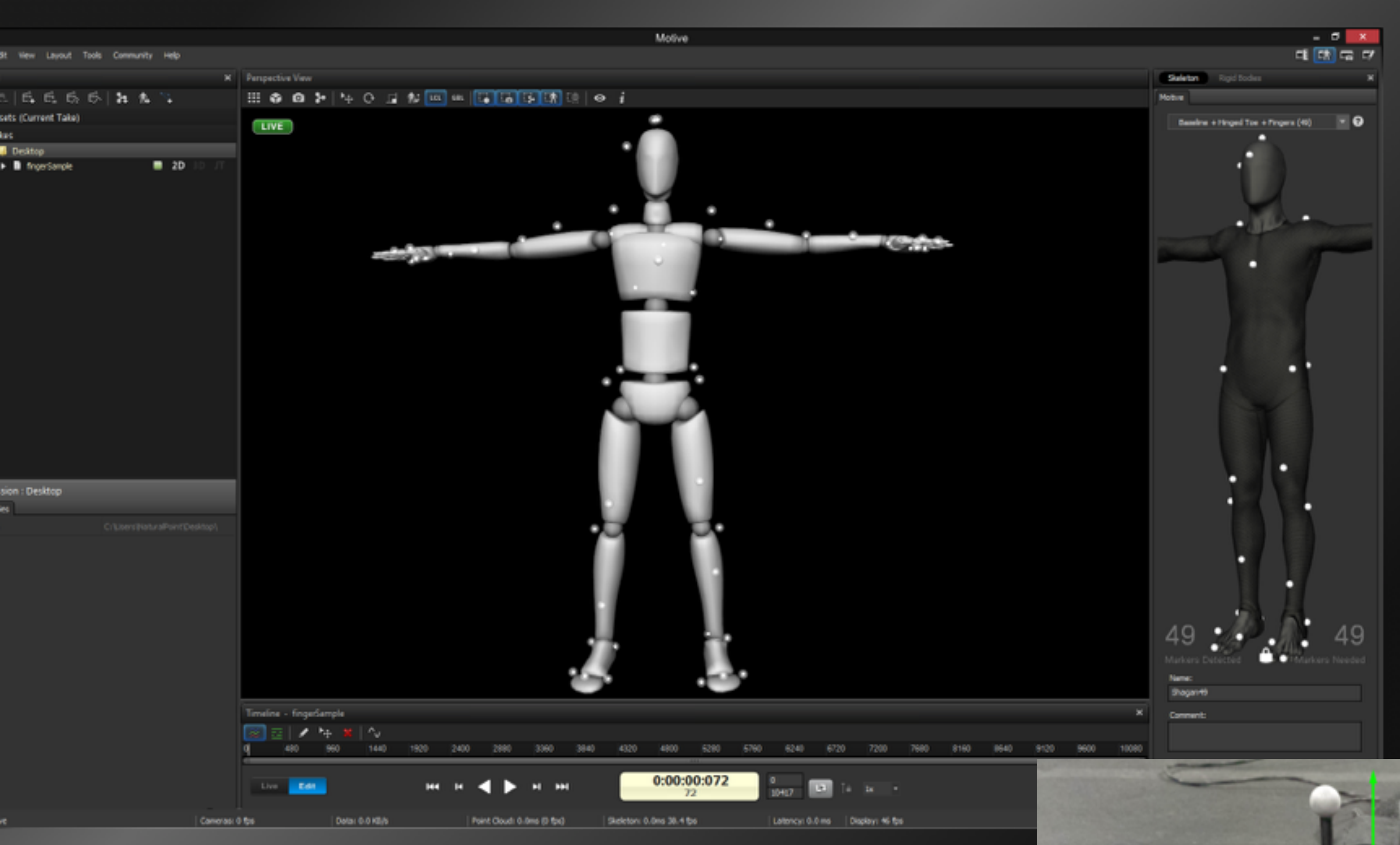
- track marker from **two or more cameras** at the same time
- cameras are **calibrated** to each other
- **triangulate** the marker position to get the 3D coordinate

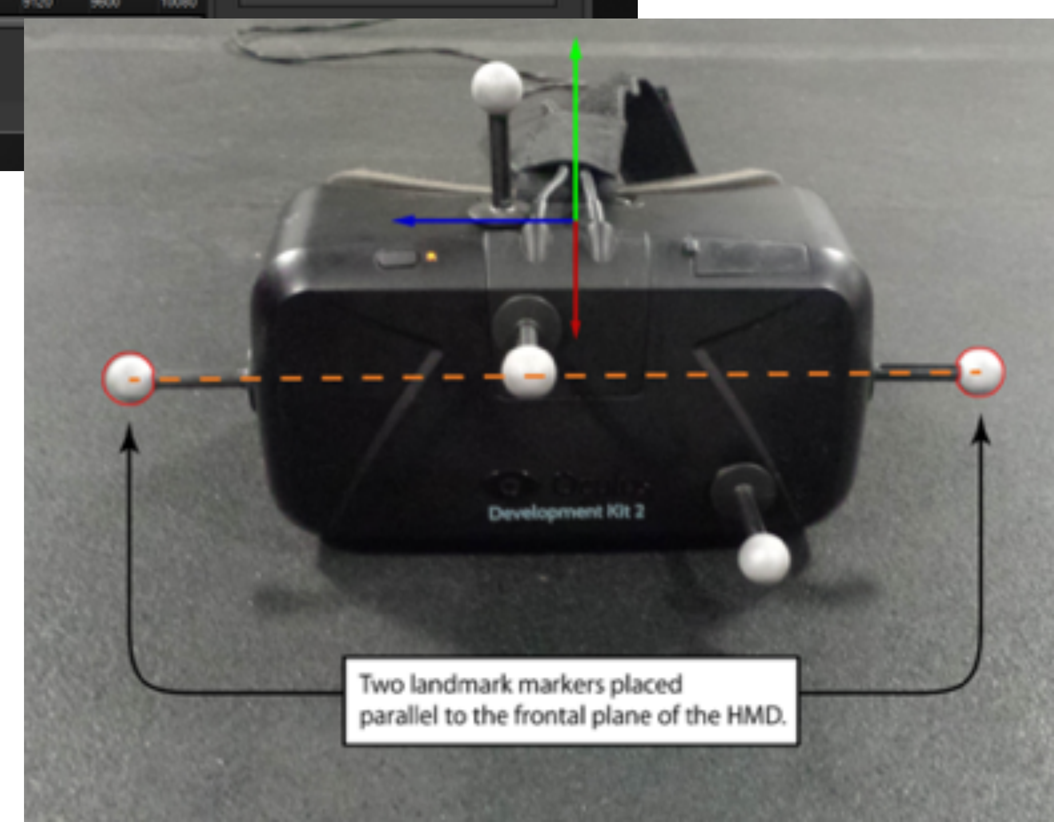


calibration wand

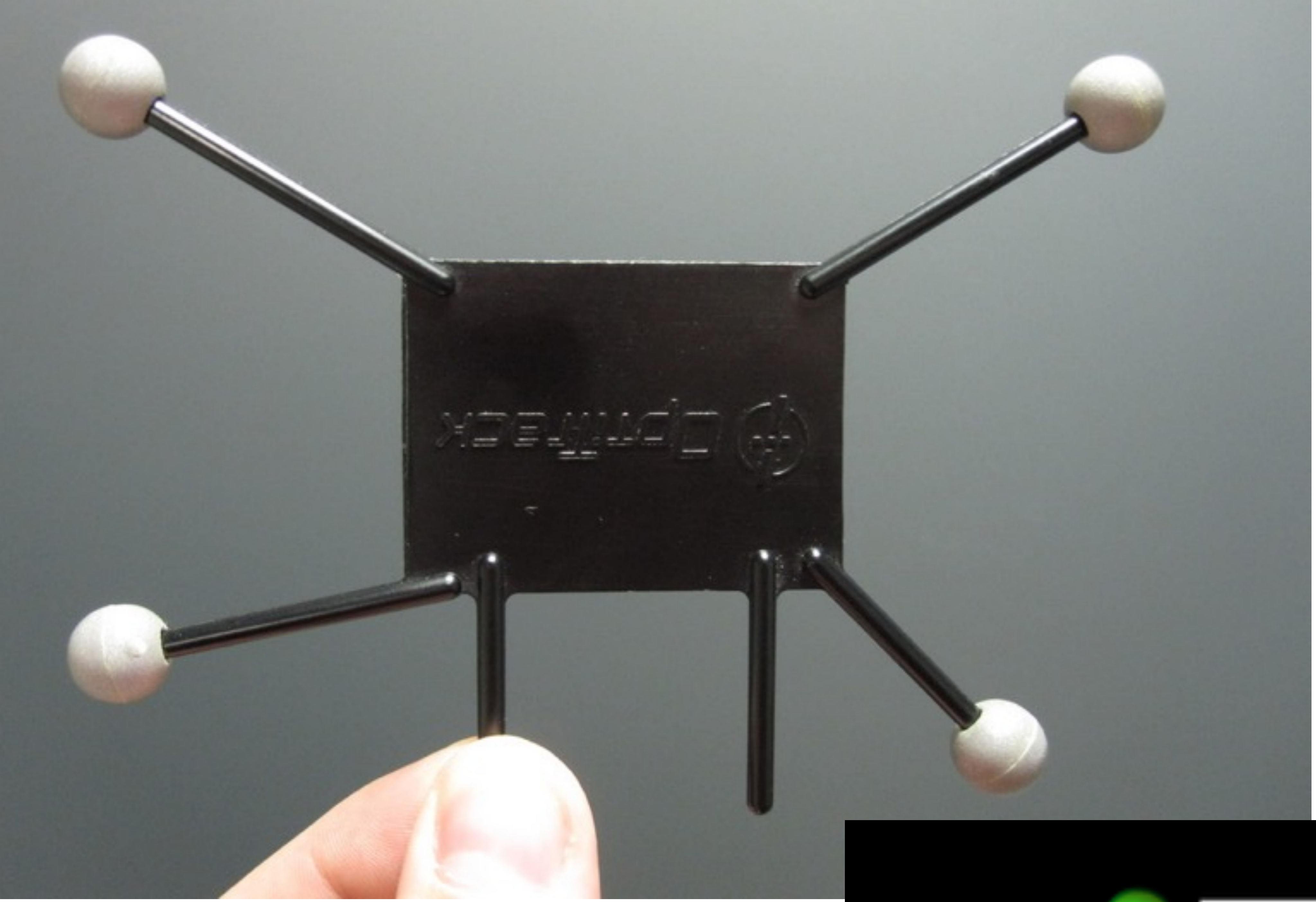
mh, but this is only a point, so it only gives me location.
how do I get the **rotation?**

<30s brainstorming>

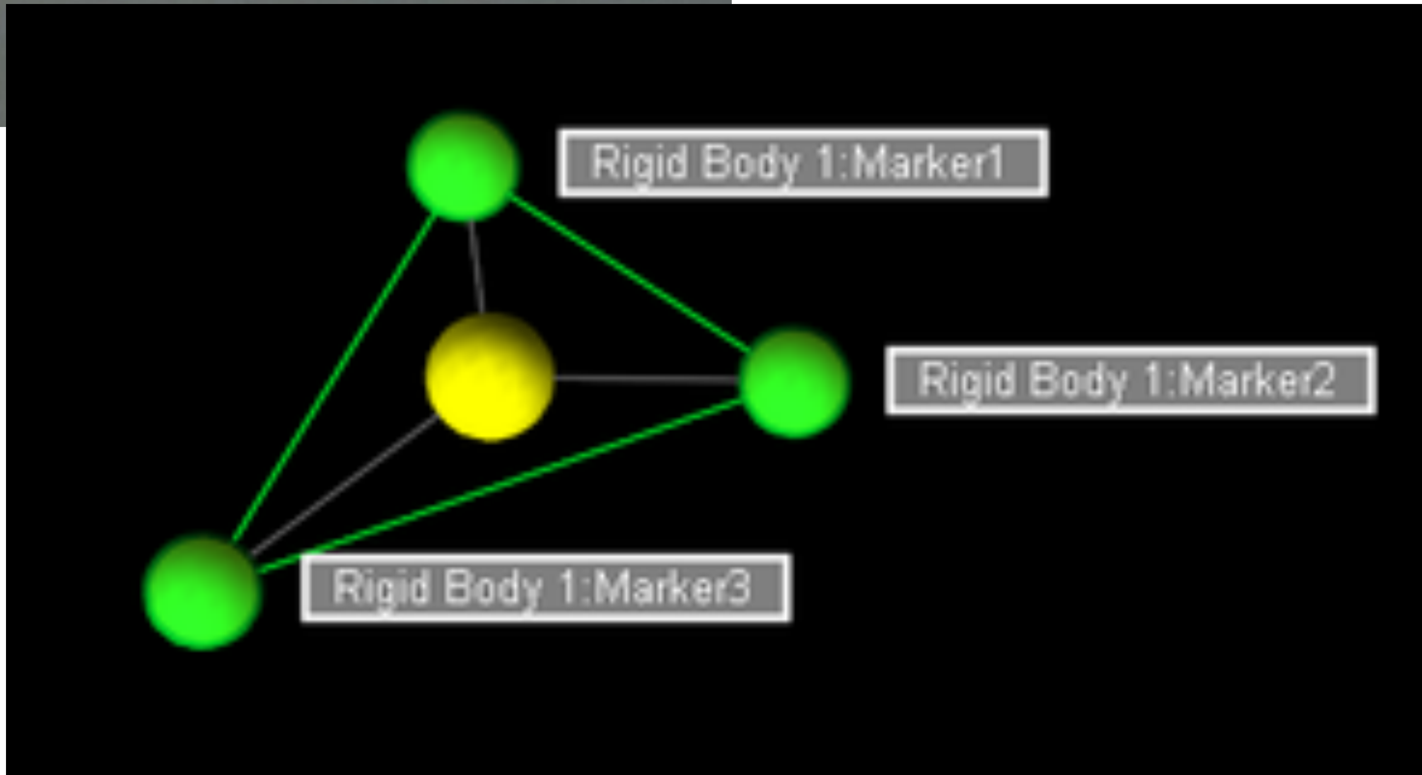




predefine multiple marker positions on the model



rigid bodies offer
already registered
multi-marker arrangements



passive markers are **great:**
they require **no power / battery.**

what are some of the **drawbacks**
of using passive markers?

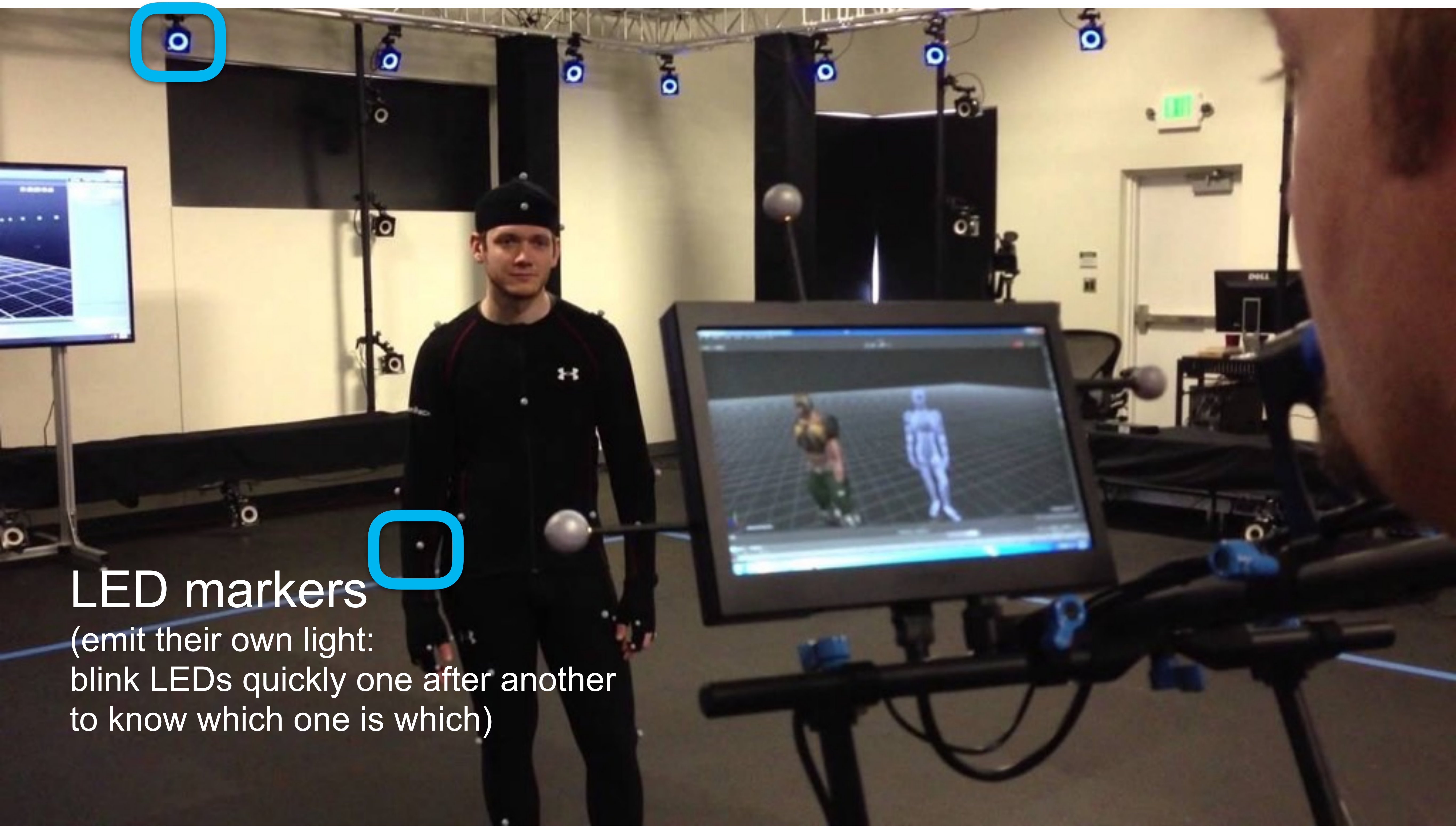
<30s brainstorming>

markers **cannot be identified.**
they all look the same to the camera.

optical tracking:

active markers

infra-red cameras



we use this a lot **for research projects**

Continuous Interactive Fabrication

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ABSTRACT
Several systems have illustrated the concept of interactive fabrication, i.e. rather than working through a digital editor, users make edits directly on the physical workpiece. However, so far the interaction has been limited to *turn-taking*, i.e., users first perform a command and *then* the system responds with physical feedback. In this paper, we explore how to extend interactive fabrication to make the workpiece change *while* the user is manipulating it.

We present FormFab, the first interactive fabrication systems that provides such *continuous* physical feedback. To accomplish this, FormFab does not add or subtract material but instead reshapes it (*formative* fabrication). A heat gun attached to a robotic arm warms up a thermoplastic sheet until it becomes compliant; users then control a pneumatic system that applies either pressure or vacuum thereby pushing the material outwards or pulling it inwards. As users interact, they see the workpiece change continuously.

By providing continuous interaction, FormFab enables users to explore an *entire shape parameter* with a single interaction. This improves over existing turn-taking systems that only allow exploring a *single option* per turn.

We explain FormFab's hardware and software, provide a walkthrough that illustrates the system's interactive capabilities, and discuss the design and interaction space.

Author Keywords: personal fabrication; interactive fabrication; direct manipulation; 3D modeling tools.

[under submission]

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

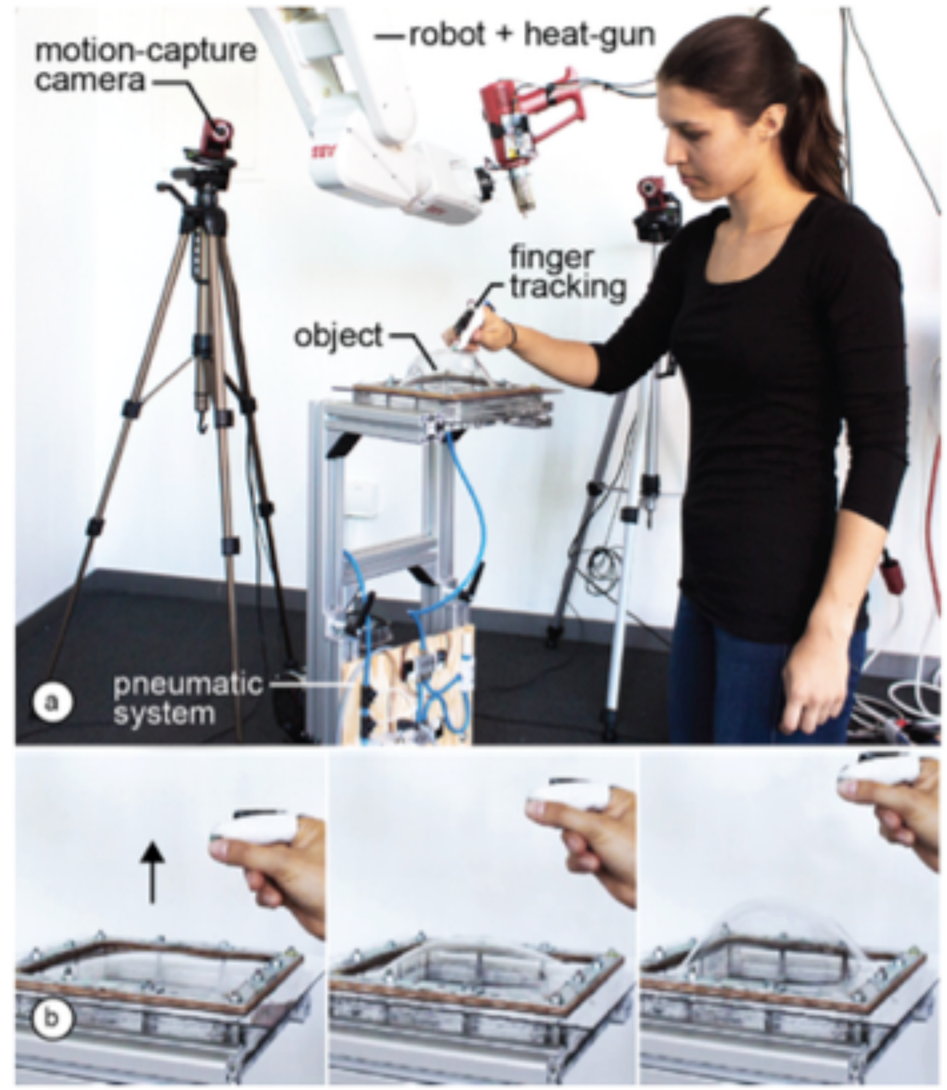
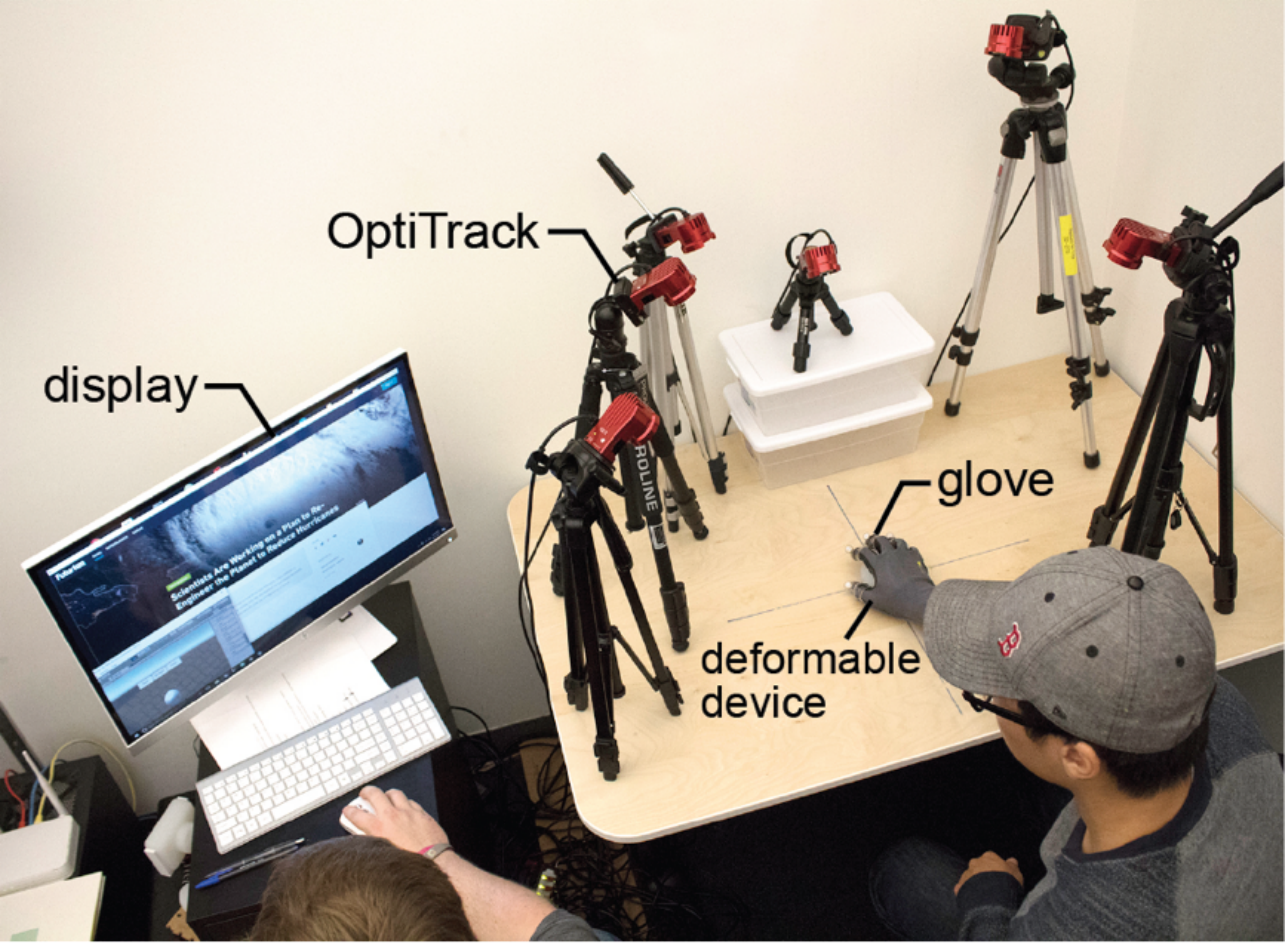


Figure 1: FormFab provides users with continuous physical feedback: A heat gun attached to a robotic arm warms up the workpiece. Once the material has become compliant, the user's hand gesture interactively controls a pneumatic system that applies pressure or vacuum, pushing the material outwards or pulling it inwards.

INTRODUCTION
Recently, Willis et al. [29] proposed the concept of *Interactive Fabrication*. The key idea is to bring the principles of

Early interactive fabrication systems, such as *Shaper* [29], *CopyCAD* [3], and *constructable* [11], allow for hands-on



we use this a lot **for research projects**

A Prototyping Tool for Integrating Energy Supplying Components into Deformable Devices

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ABSTRACT

With recent advances in fabricating flexible electronics, deformable user interfaces are becoming more common in HCI. For deformable devices, traditional methods of supplying energy can be problematic: rigid plug-and-socket connectors create undesirable stresses inside the soft material, energy harvesting mechanisms based on free oscillations and rigid gears are constrained, and embedded inductive power transfer coils become detuned during bending.

In this paper, we demonstrate how to adapt these energy supply methods for deformable devices. The key idea is to incorporate knowledge of how the user interacts with the device, i.e. how the device deforms. To facilitate the process, we contribute an end-to-end prototyping system for deformable devices: designers model the device and export it for physical prototyping. Interaction data collected with a motion capture system is then used to calculate a stress distribution across the device. The system then recommends locations for placement of the energy-supplying components.

INTRODUCTION

Since the early 2000s, HCI researchers envision a future in which devices will no longer be rigid but deformable (*Organic User Interfaces* [7]). Moving away from rigid objects and being able to squeeze, stretch, and twist [illegible]es, including an increased input space (*Gummi* [23]), output space (*Surflex* [4]), and better ergonomics [7].

With recent advances in *flexible electronics* [16],

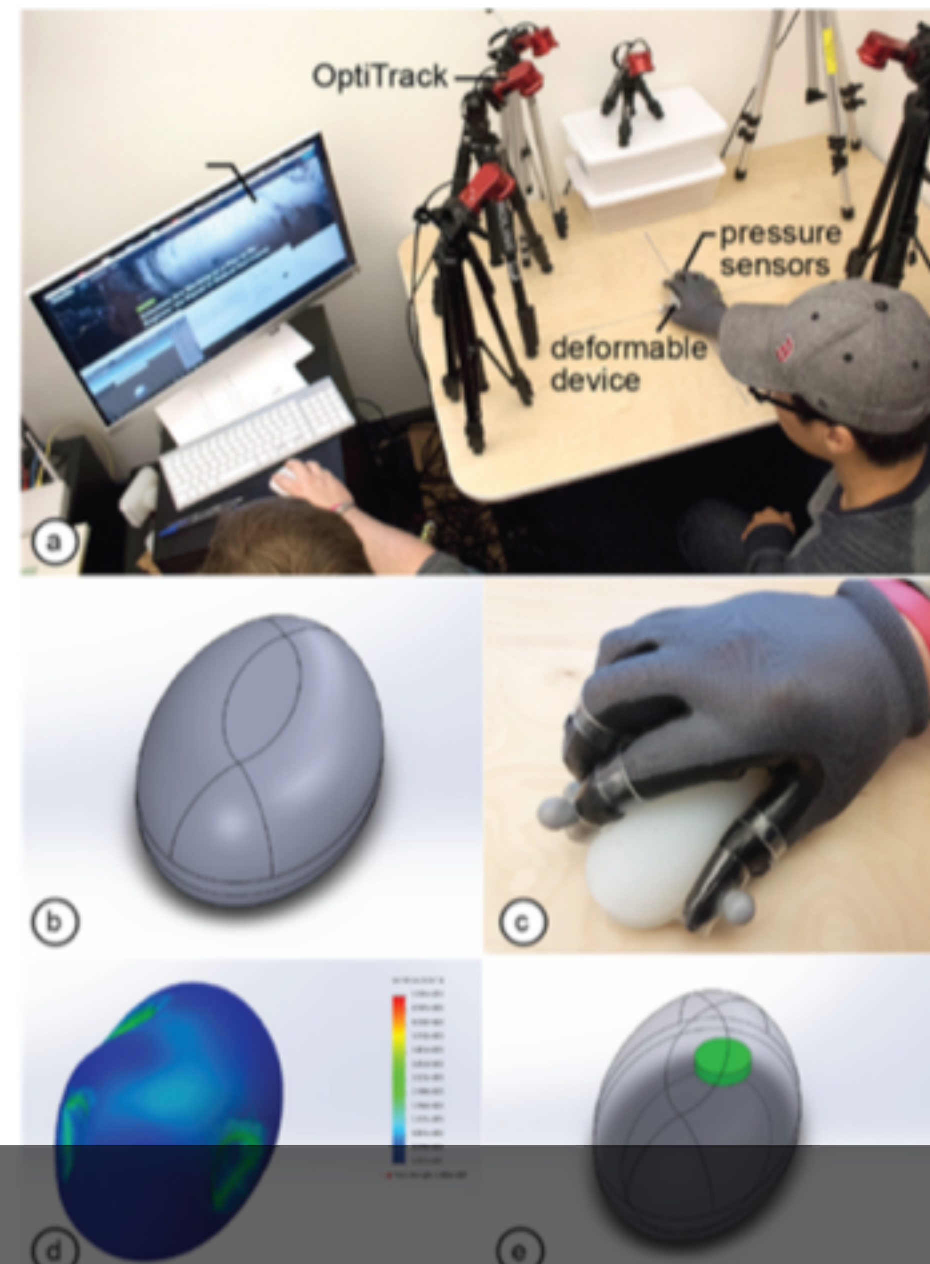
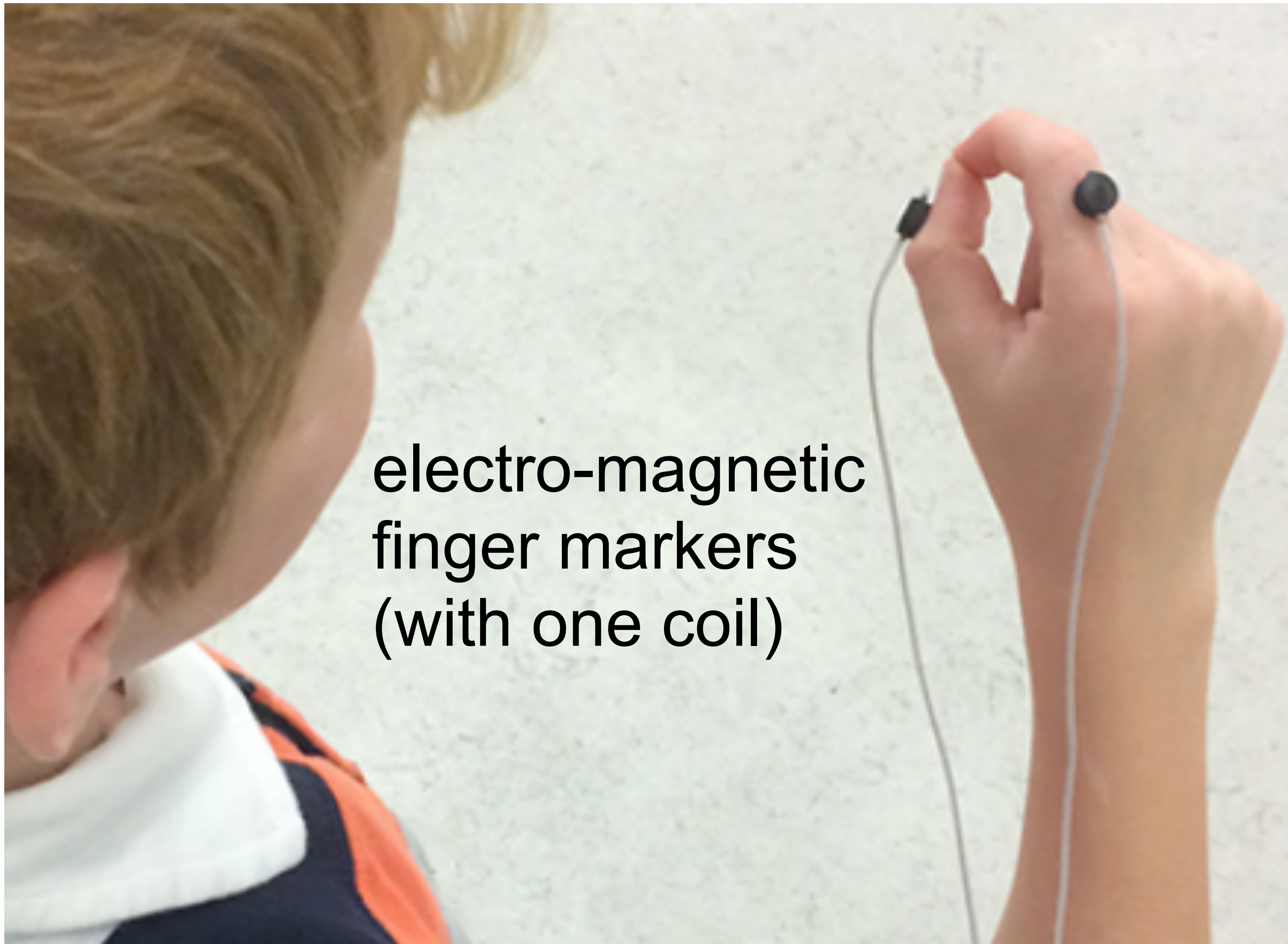


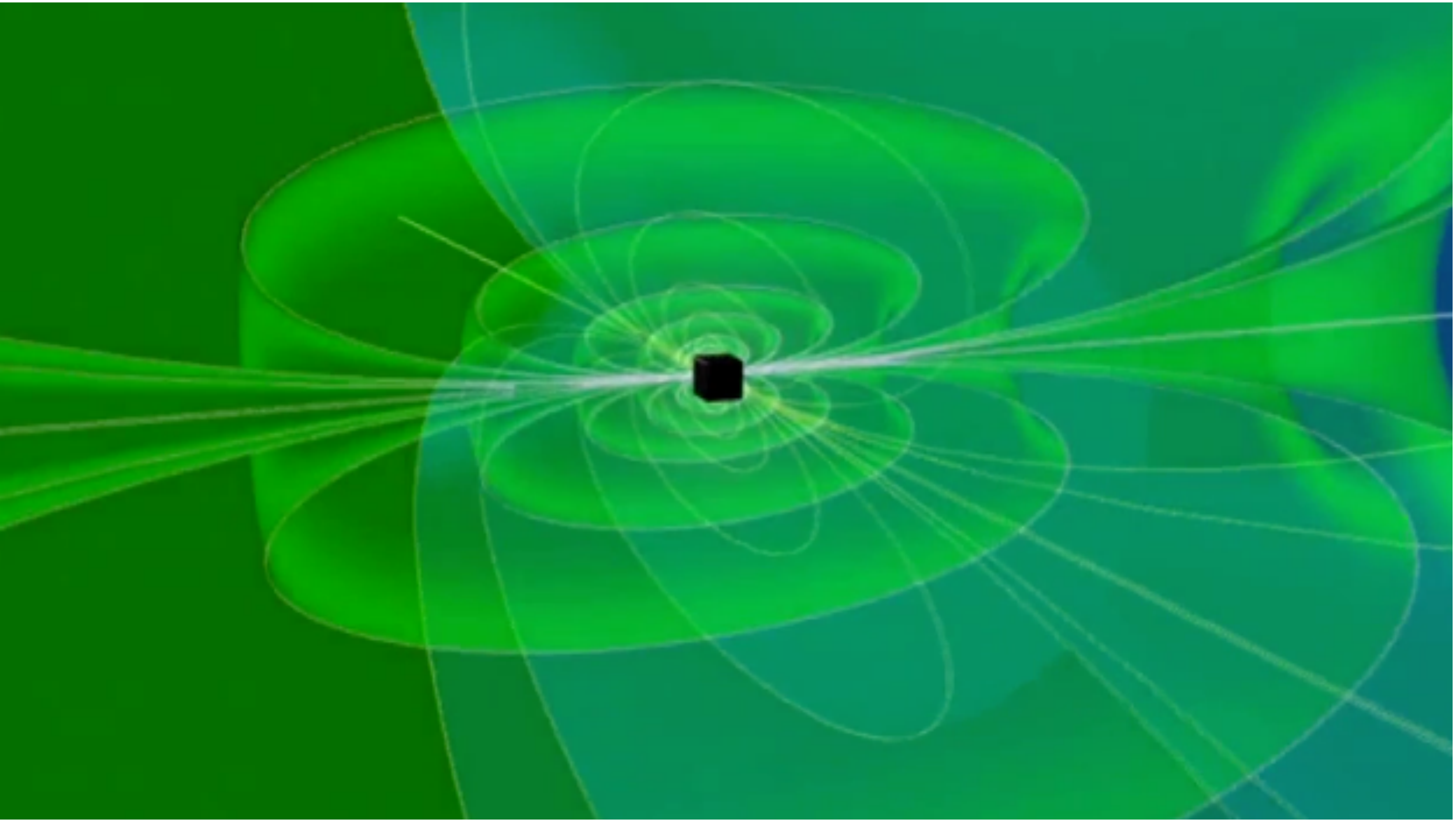
Figure 1. (a) Our prototyping system facilitates the placement of energy supplying components for deformable devices by recording live interaction data from users. Designers only

[under submission]

electro-magnetic tracking

magnetic field generator
(transmitter) with two coils





- emits **electro-magnetic field**
- calculate relative **intensity of current of the coils**
- **size of field** varies depending on power of tracker
- **larger field** = larger tracking range

Polhemus Fastrak:

- $12k+ for the tracker and $200 for each marker

G4™

G4 is a wireless motion tracking system that delivers full 6DOF tracking, providing both position and orientation without hybrid technologies.

View Product »

LIBERTY™

High speed, industry leading accuracy, and scalable. Updating at 240Hz per second, full 6DOF with virtually no latency.

View Product »

PATRIOT™

PATRIOT is the perfect cost effective, full 6DOF motion tracking solution for applications requiring up to two sensors.

View Product »

SCOUT™

The latest revolution in head tracking, SCOUT is in full rate production, providing the HMCS Accuracy in Live Military Aircraft.

View Product »

LIBERTY™ LATUS™

The LIBERTY LATUS provides the perfect 6DOF solution for tracking applications that require coverage over a large area.

View Product »

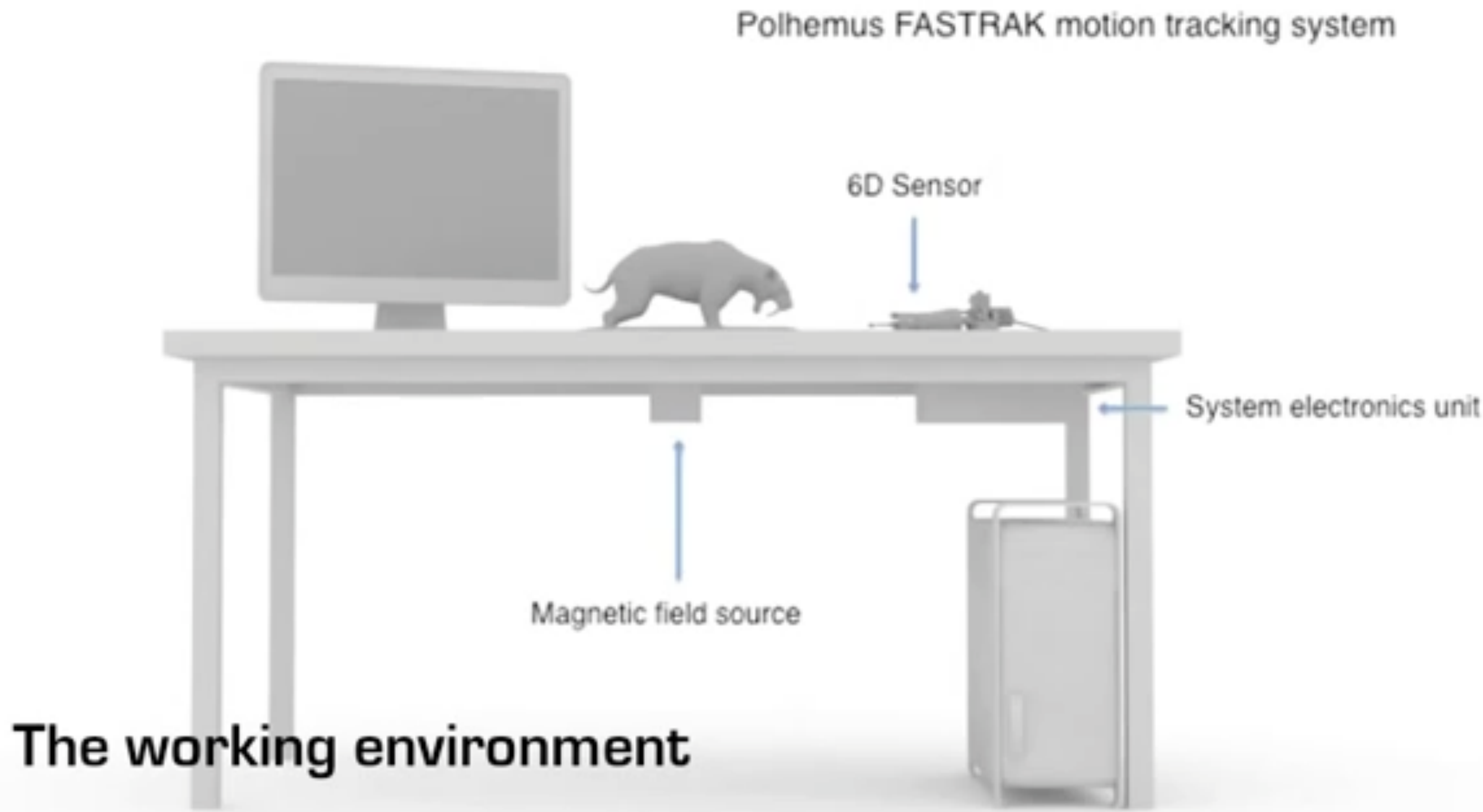
FASTRAK®

FASTRAK set the gold standard in motion tracking years ago, and remains a top seller. This 6DOF product is an award-winning tracker.

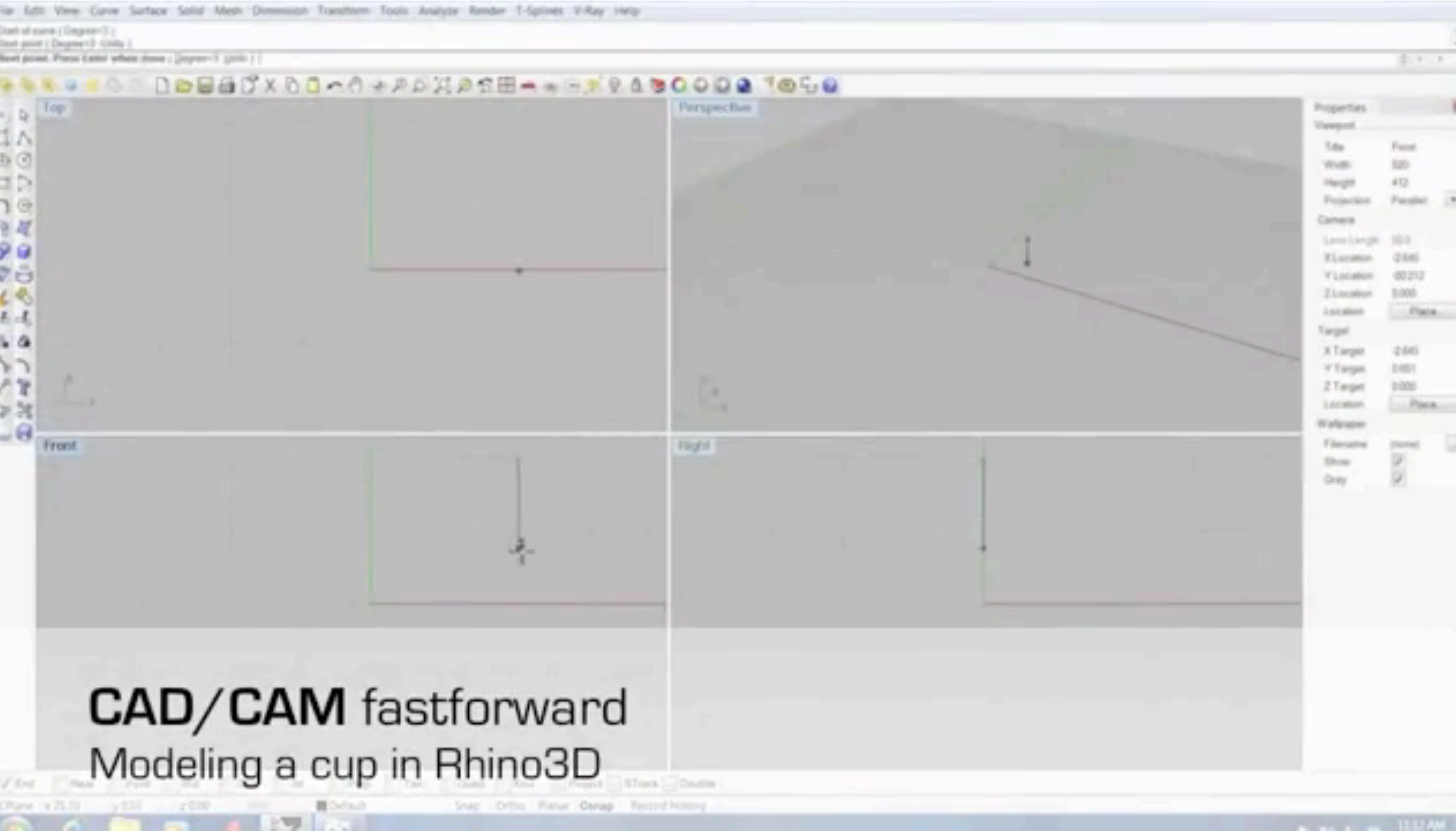
View Product »

benefits & drawbacks:

- **no occlusion** of markers
  - you can hide the tracking hardware
  - you can track through walls and people
- single source, **no cameras to align**
- **doesn't scale well** with higher number of markers (difficult to decode the magnetic field)
- sensitive to **magnetic and electrical interference**


Polhemus FASTRAK motion tracking system
6D Sensor
System electronics unit
Magnetic field source
The working environment

[2013 FreeD]


CAD/CAM fastforward
Modeling a cup in Rhino3D

The FreeD parts

Human-computer Interaction for Hybrid Carving

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ABSTRACT
In this paper we explore human-computer interaction for carving, building upon our previous work with the FreeD digital sculpting device. We contribute a new tool design (FreeD V2), with a novel set of interaction techniques for the fabrication of static models: personalized toolpaths, manual overriding, and physical merging of virtual models. We also present techniques for fabricating dynamic models, which may be altered directly or parametrically during fabrication. We demonstrate a semi-autonomous operation and evaluate the performance of the tool. We end by discussing synergistic cooperation between human and machine to ensure accuracy while preserving the expressiveness of manual practice.

Author Keywords
Computer-Aided Design (CAD); Craft; Digital Fabrication; Carving; Milling.

ACM Classification Keywords
H.5.2 Information interfaces and presentation: User Interfaces; I.3.8 Computer Graphics: Applications

INTRODUCTION
This paper contributes an application of a digital sculpting device for hybrid carving, using a revised version of the FreeD tool (FreeD V2), previously discussed in [21]. FreeD enabled users to make physical artifacts with virtual control, and FreeD V2 adds manual and computational design modi-

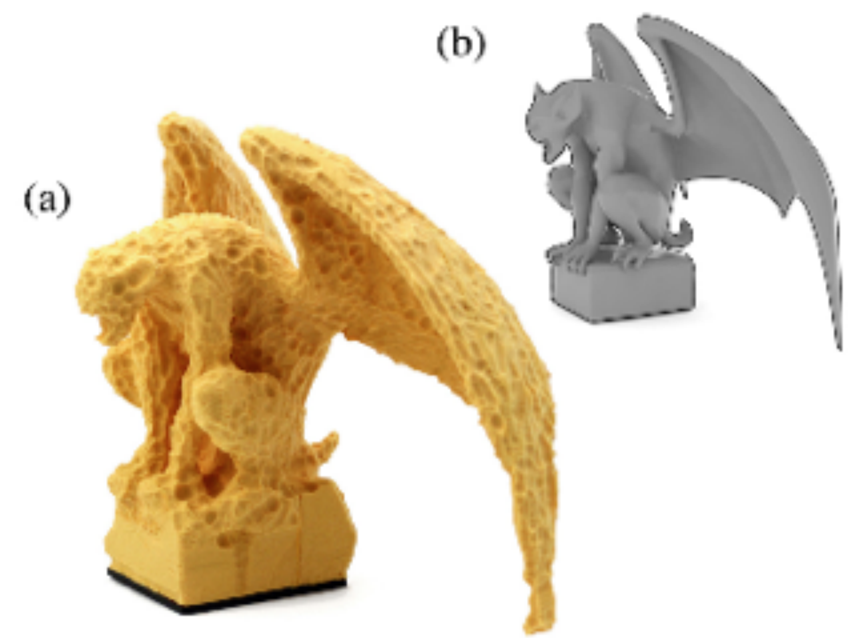


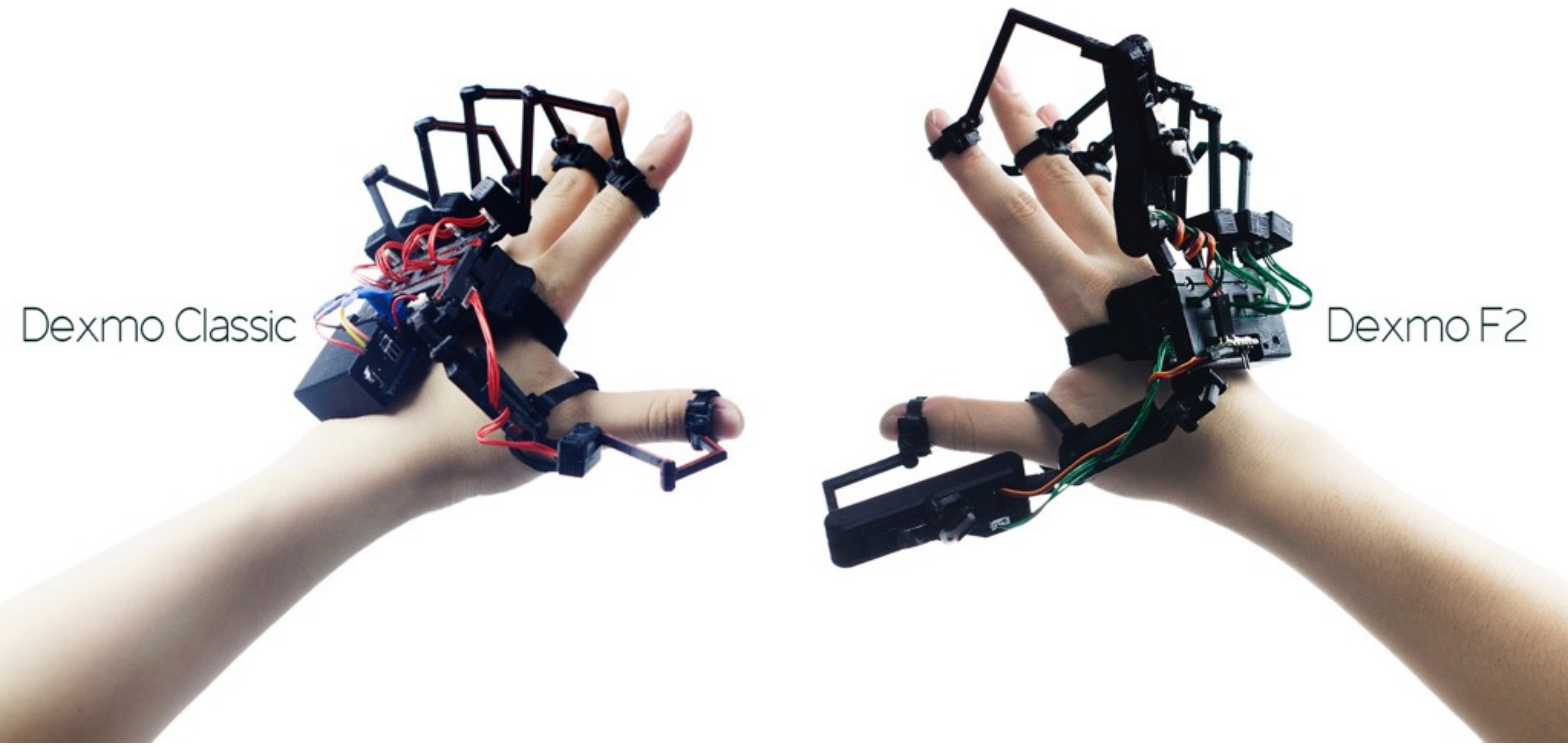
Figure 1. A gargoyle sculpture (with a wingspan of 280mm) made with the FreeD V2 (a) based on a complex CAD model (b).

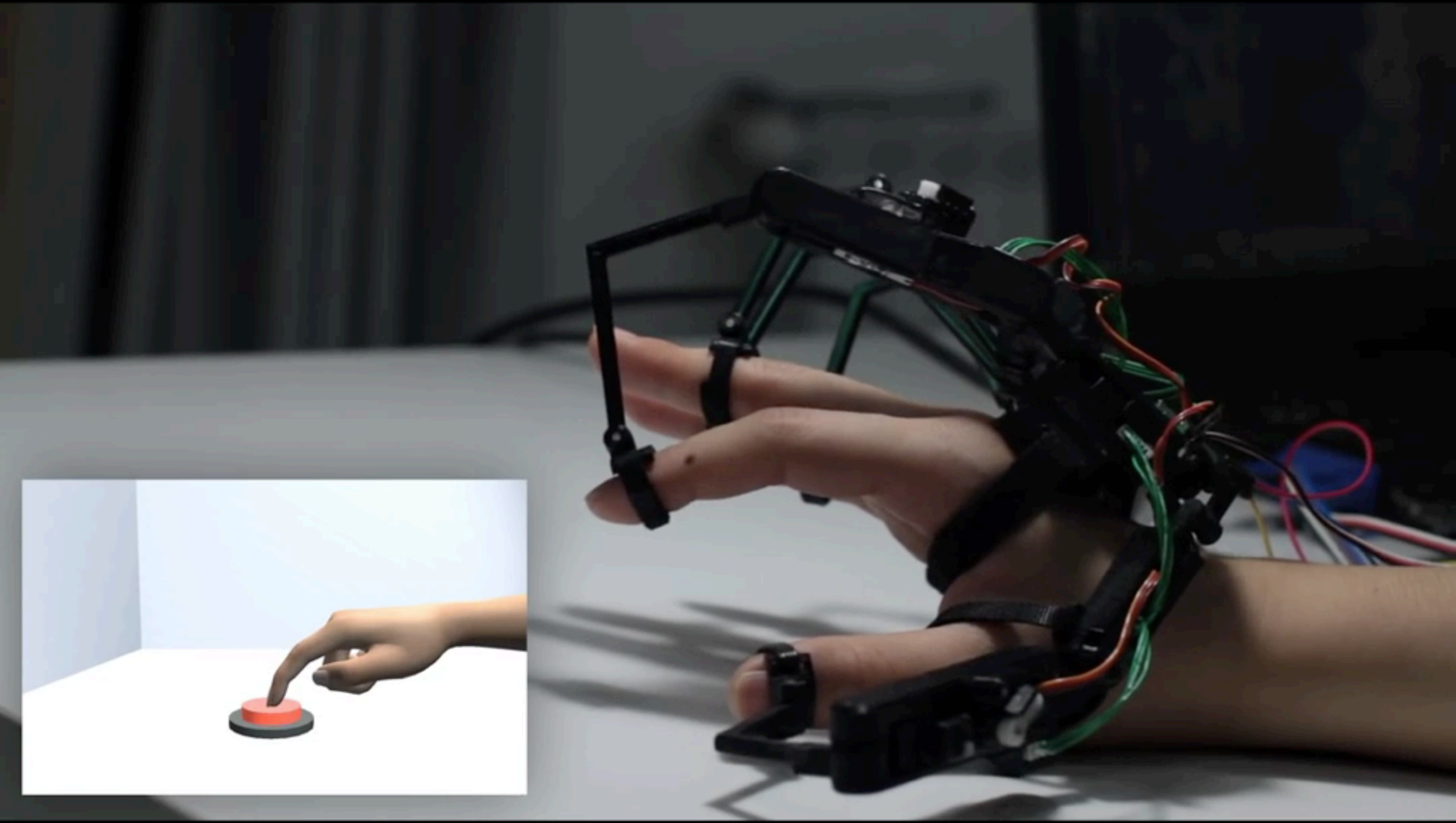
modes of interaction such as switching between virtual models through the work; overriding the computer; deforming a virtual model while making it; or searching interactively for an optimal parametric model. In addition, the new tool can operate independently for tasks such as semi-automatic texture rendering.

In the next section, we discuss our previous efforts and related work, and in the subsequent section titled *The FreeD V2 Design*, we present the new version of the FreeD, focusing on revisions from the early version. In *Modes of collaboration and interaction*, we present three operational modes: static (rigid)

mechanical motion

(exoskeleton tracking)


Dexmo Classic
Dexmo F2



but picking up objects and feel their shape and sizes.

Dexmo: An Inexpensive and Lightweight Mechanical Exoskeleton for Motion Capture and Force Feedback in VR

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Per Ola Kristensson
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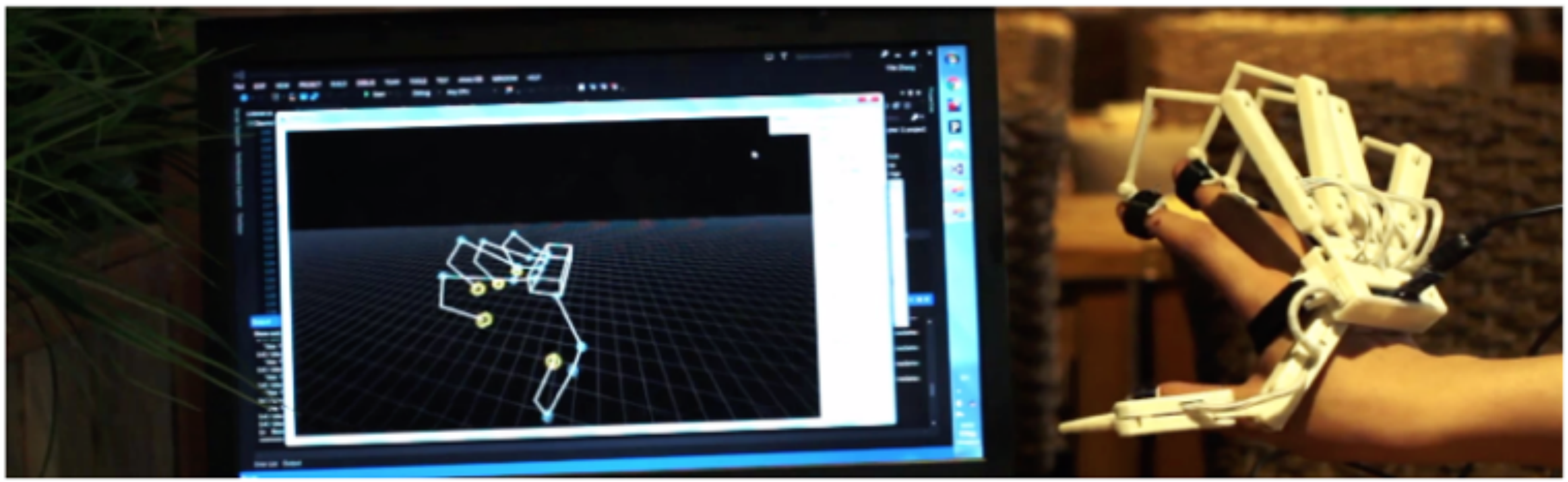


Figure 1. A person using Dexmo to control a virtual exoskeleton model in virtual reality.

ABSTRACT

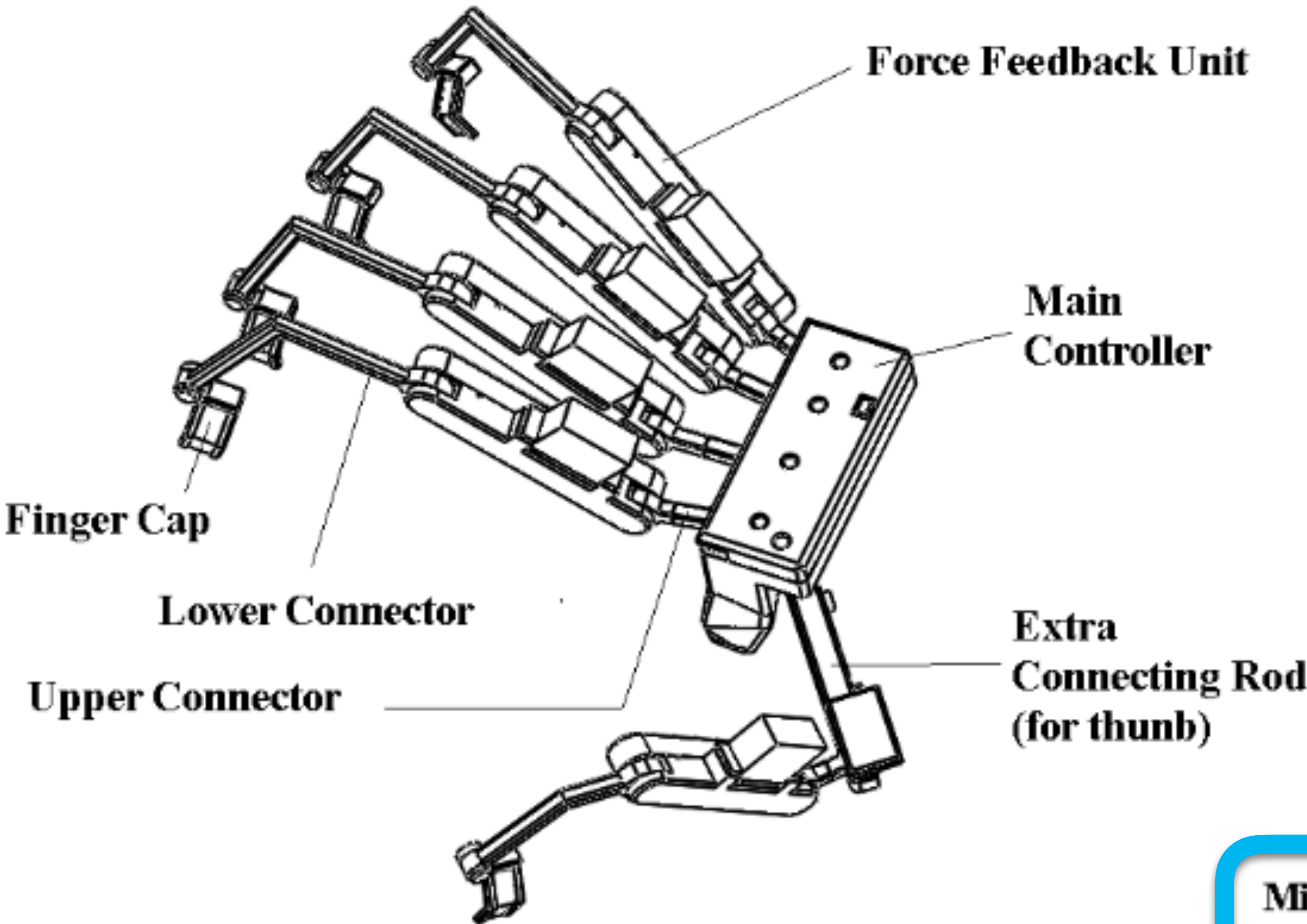
We present Dexmo: an inexpensive and lightweight mechanical exoskeleton system for motion capturing and force feedback in virtual reality applications. Dexmo combines multiple types of sensors, actuation units and link rod structures to provide users with a pleasant virtual reality experience. The device tracks the user's motion and uniquely provides passive force feedback. In combination with a 3D graphics rendered environment, Dexmo provides the user with a realistic sensation of interaction when a user is for example grasping an object. An initial evaluation with 20 participants demonstrate that the device is working reliably and that the addition of force feedback resulted in a significant reduction in error rate. Informal comments by the participants were overwhelmingly positive.

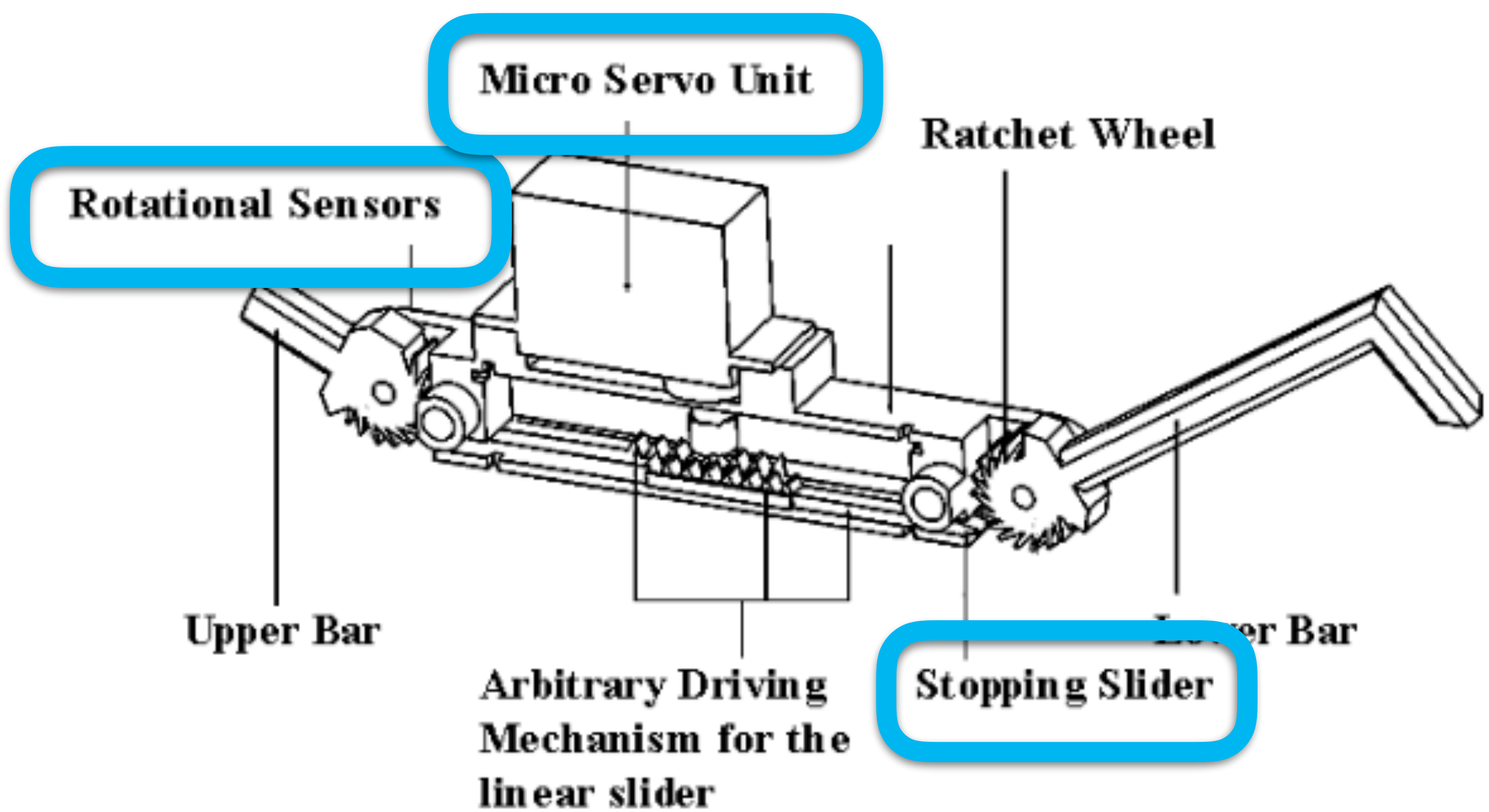
CHI 2016

INTRODUCTION

There are many ways for people to bring their motion into the the virtual world, however, there is little feedback *back* to the real world. Current force feedback devices are bulky, non-portable, expensive and difficult to manufacture. There is still a lack of a light, easy-to-use and affordable force feedback approach for people to touch or sense in the digital world.

In this paper we present Dexmo, a mechanical exoskeleton that is a lightweight, inexpensive, compact, reliable and safe solution for providing force feedback and motion capture in augmented and virtual reality environments. Figure 1 illustrates a user wearing Dexmo and using it to interact with a virtual world. Rather than applying torque control at each individual joint of the exoskeleton directly, Dexmo uses a micro


Force Feedback Unit
Main
Controller
Finger Cap
Lower Connector
Upper Connector
Extra
Connecting Rod
(for thunb)


Micro Servo Unit
Ratchet Wheel
Rotational Sensors
Upper Bar
er Bar
Arbitrary Driving
Mechanism for the
linear slider
Stopping Slider

benefits & drawbacks:

- tracking and haptic feedback **combined**
- **no occlusion**
- **infinite tracking volume**
- **low-cost**

inertial systems

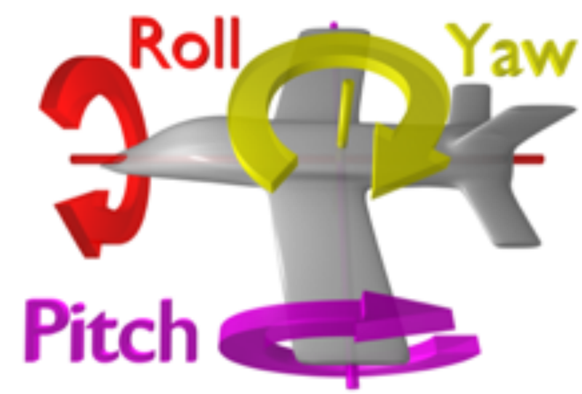
(IMUs)

IMU sensor data mapped onto a bio-mechanical model

[Perception Neuron]

Inertial Measurement Unit (IMU):

- **linear acceleration:** accelerometer
- **rotational rate:** gyroscope
- **heading reference** (optional): magnetometer
- 3-axis sensors for: pitch, roll, yaw



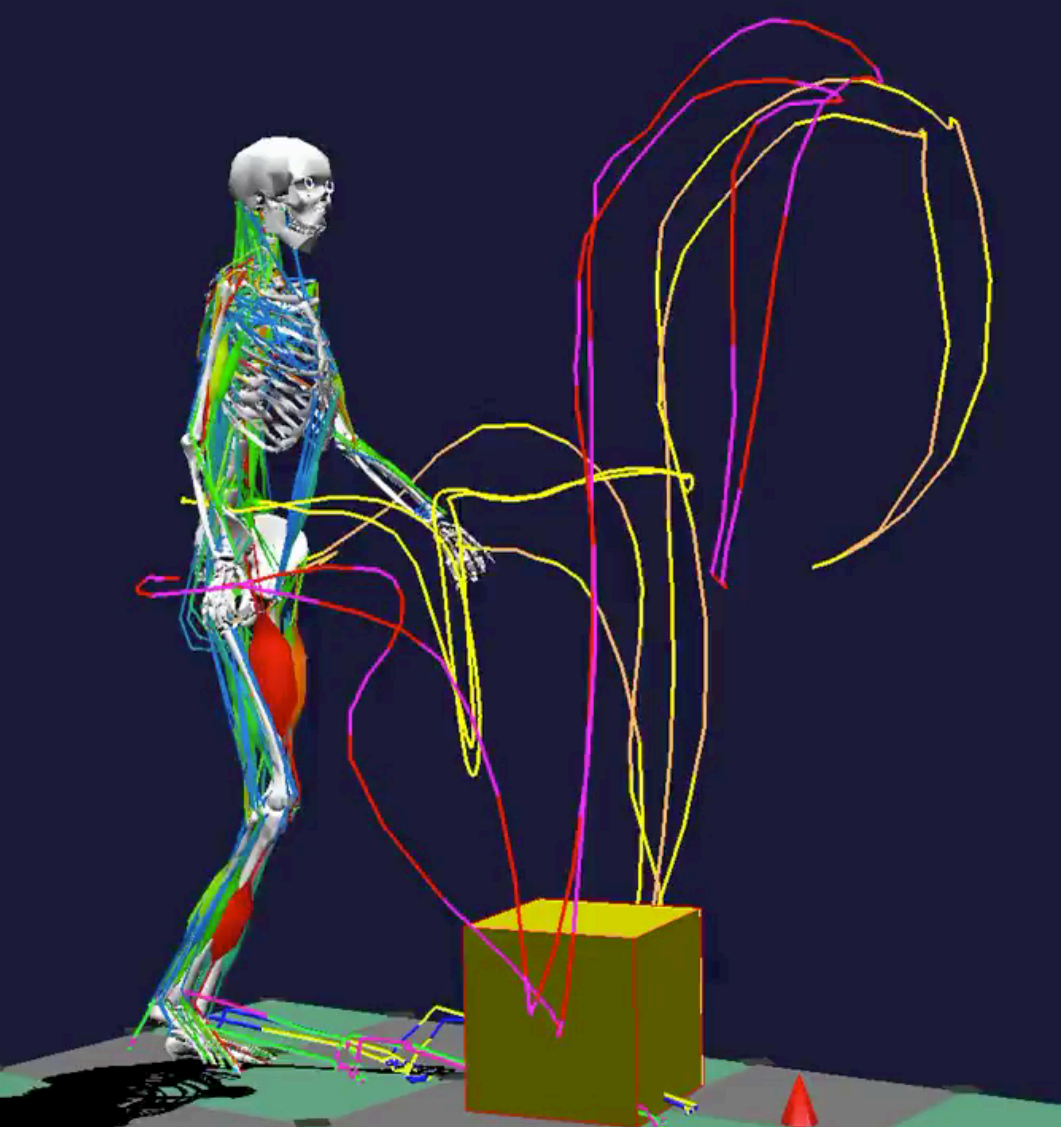
18 Neuron + BoB

$1,599.00 USD

*Packages are shipped from Miami, Florida, United States. Please note we charge sales tax for all shipments to Florida.

- 1 +

ADD TO CART

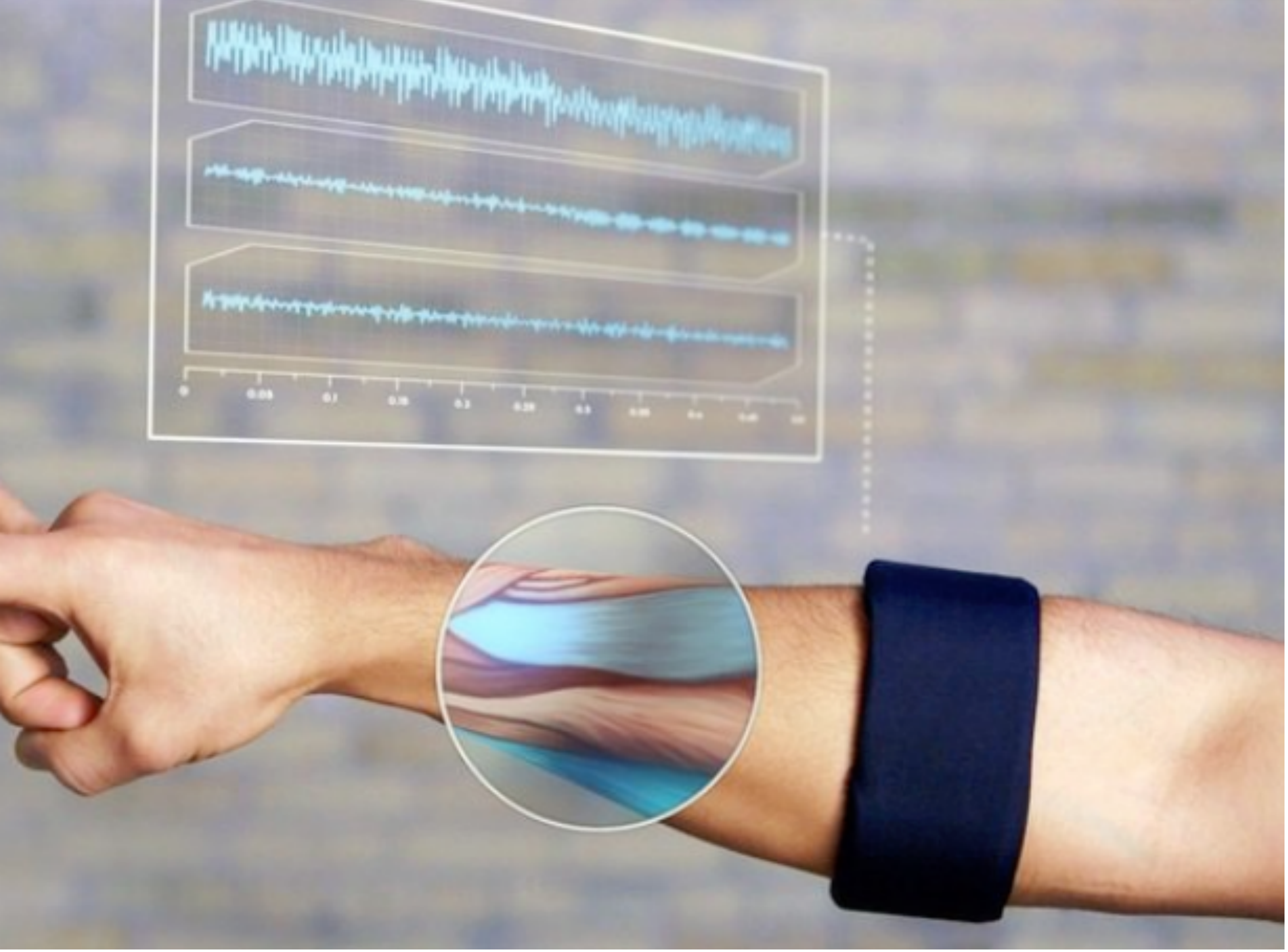


[Perception Neuron]

benefits & drawbacks:

- **no occlusion** and **no noise** from electro/magnetic
- **infinite tracking** volume
- **low cost** ($1,000+)
- **no absolute position** of the user
- **lower accuracy**

electro-muscle



- Myo tracking band on the forearm
- based on **EMG** (tiny voltage from muscle activation)
- includes accelerometer and gyro for overall motion

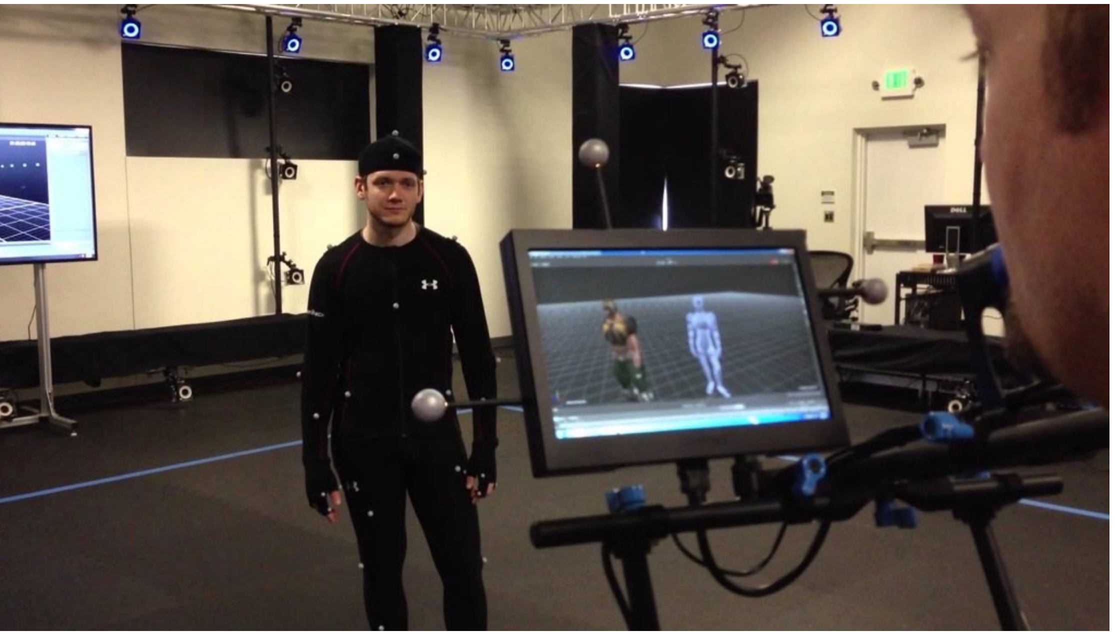
benefits & drawbacks:

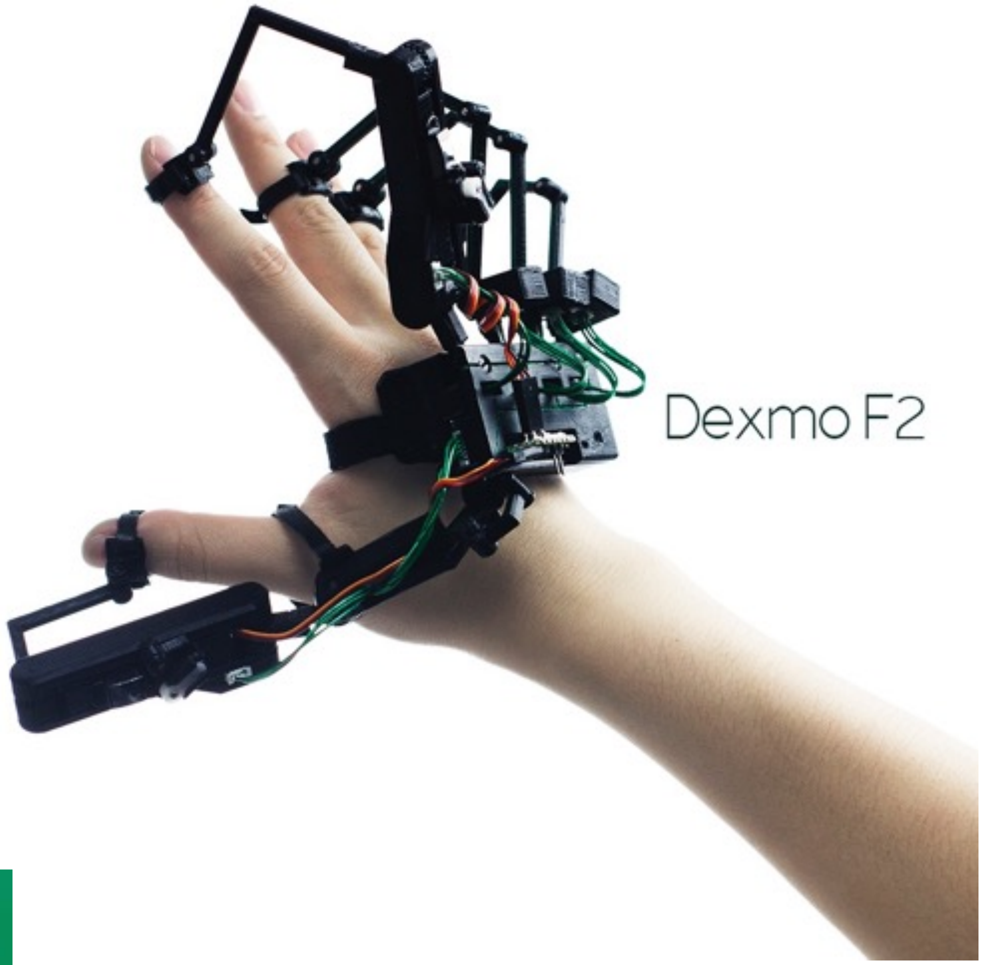
- no occlusion
- infinite tracking volume
- low-cost
- mapping from muscle activation to actual movement

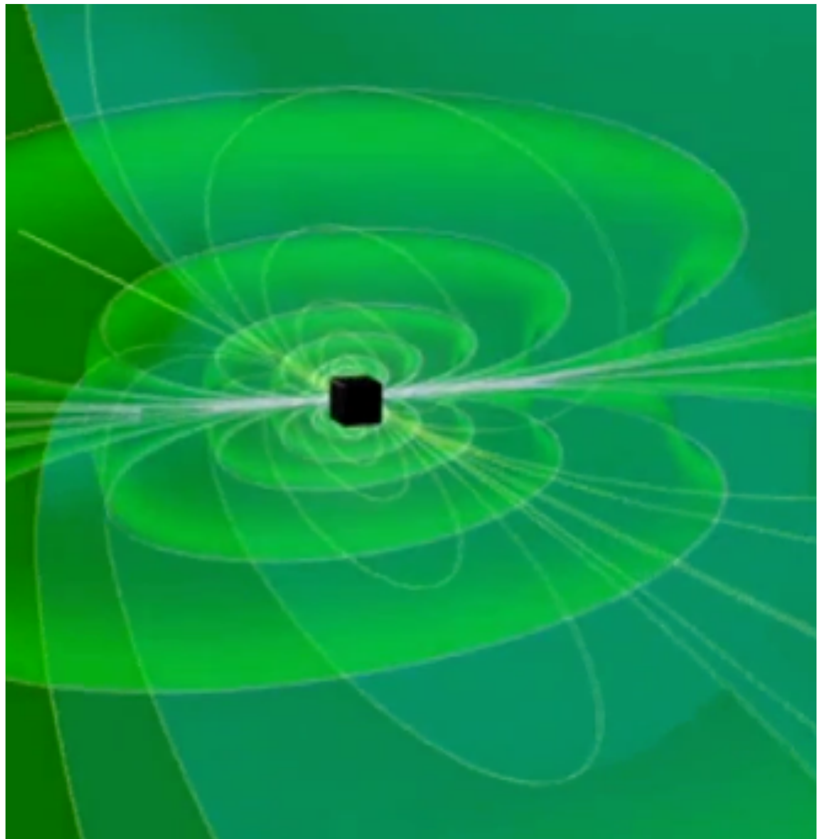
summary

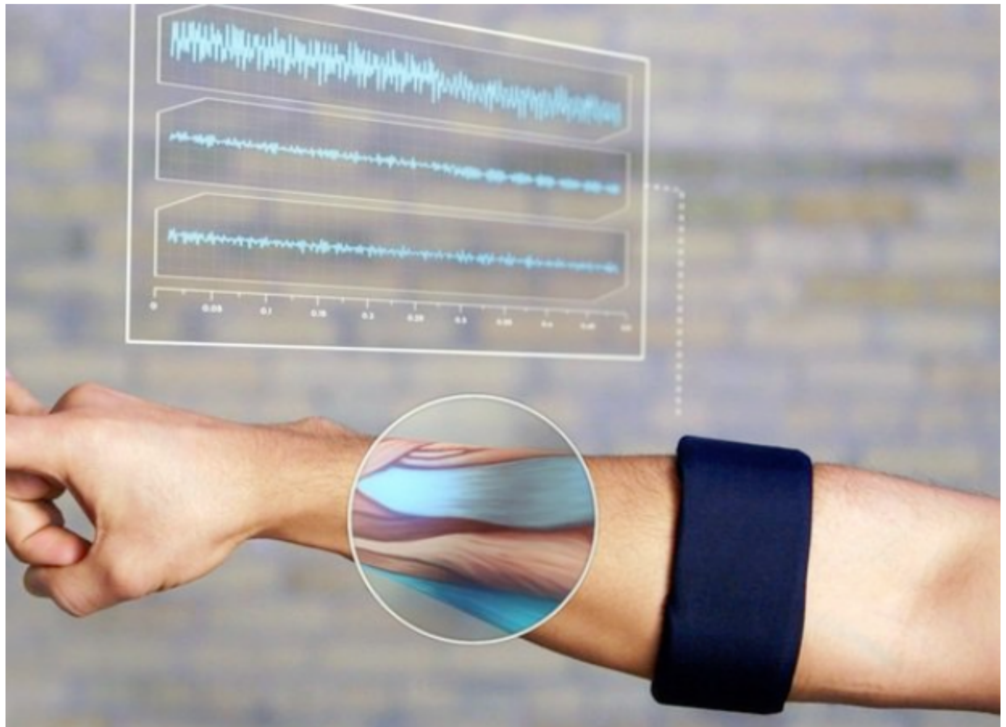
how to select a system?

- depends on your use case
- and how much money you have









end.