WatchSense

On- and Above-Skin Input Sensing through a Wearable Depth Sensor

Srinath Sridhar Max Planck Institute for Informatics, Germany

Anders Markussen University of Copenhagen, Denmark

Antti Oulasvirta Aalto University, Finland

Christian Theobalt Max Planck Institute for Informatics, Germany

Sebastian Boring University of Copenhagen, Denmark

max planck institut informatik

Graphics Vision & Video

Aalto University

UNIVERSITY OF COPENHAGEN


10:10
07:07
20:25
07:49
9:30
10:10

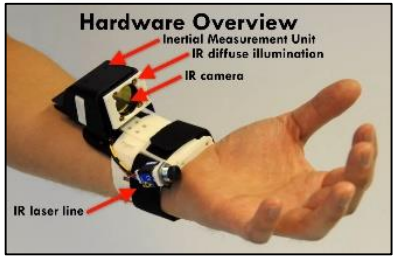
WatchSense →

Selected Previous Work

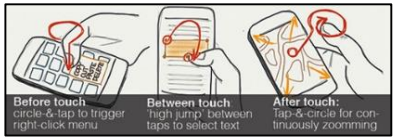
Touch | Mid-air | Mid-air + Touch

AuraSense (UIST 2016)

Digits (UIST 2012)

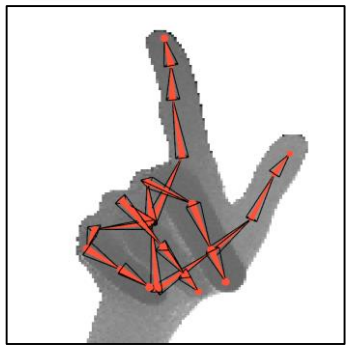


Air+Touch (UIST 2014)

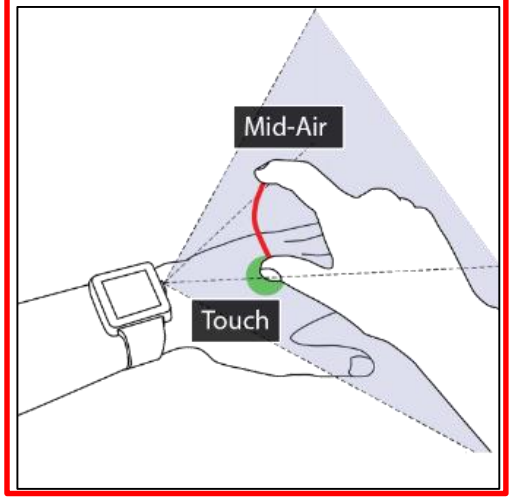


SkinTrack (CHI 2016)
WatchMI (MobileHCI 2016)

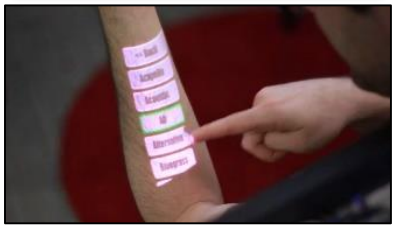
Sridhar et al. (CVPR 2015)



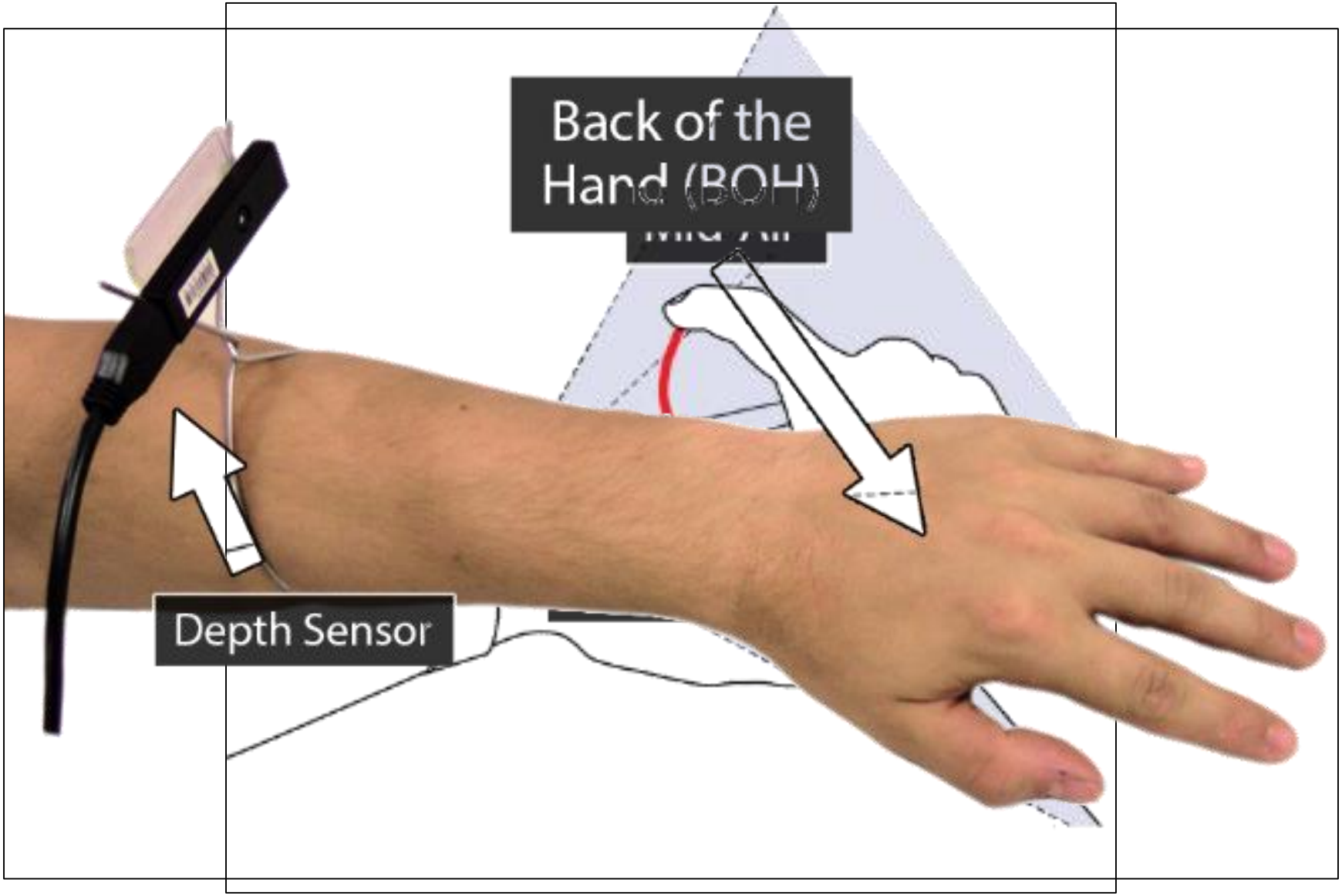
WatchSense (Ours)



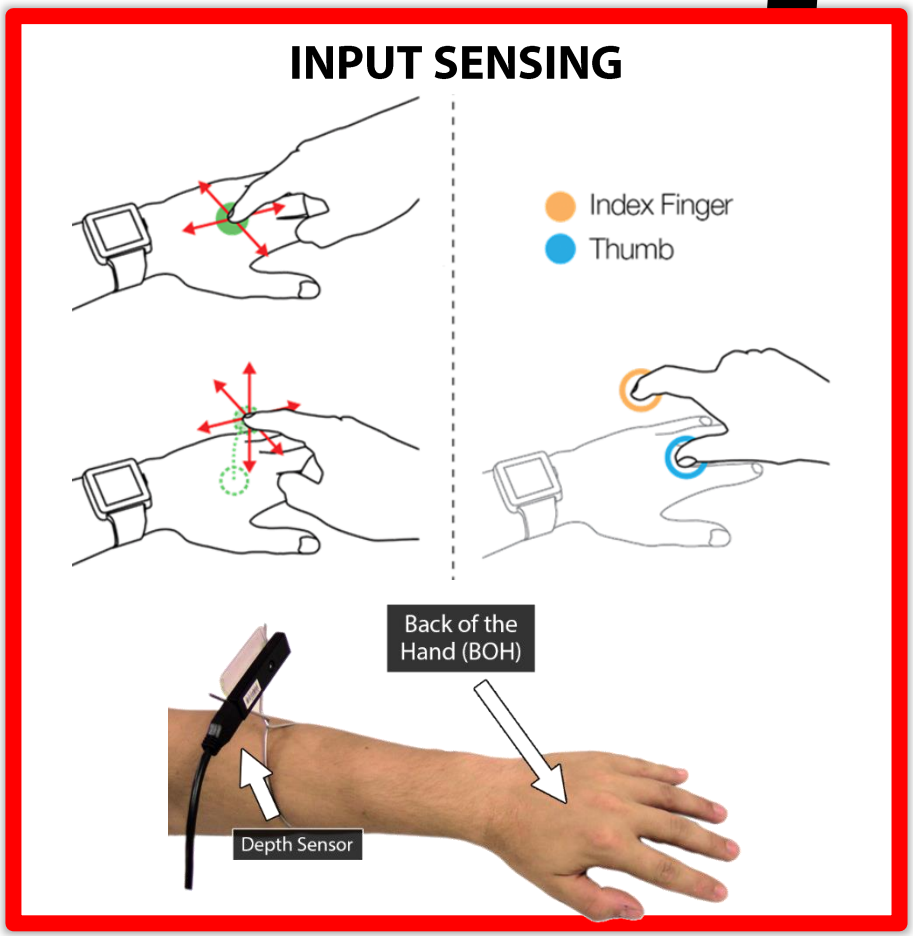
OmniTouch (UIST 2011)

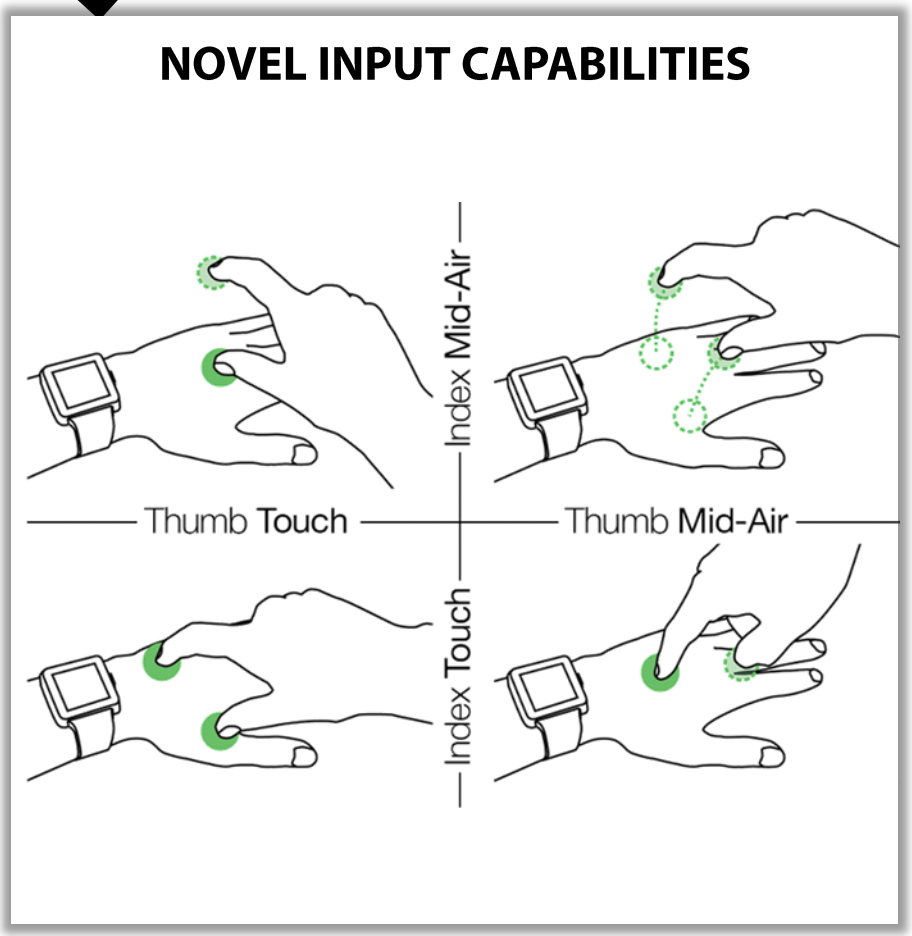


WatchSense Prototype



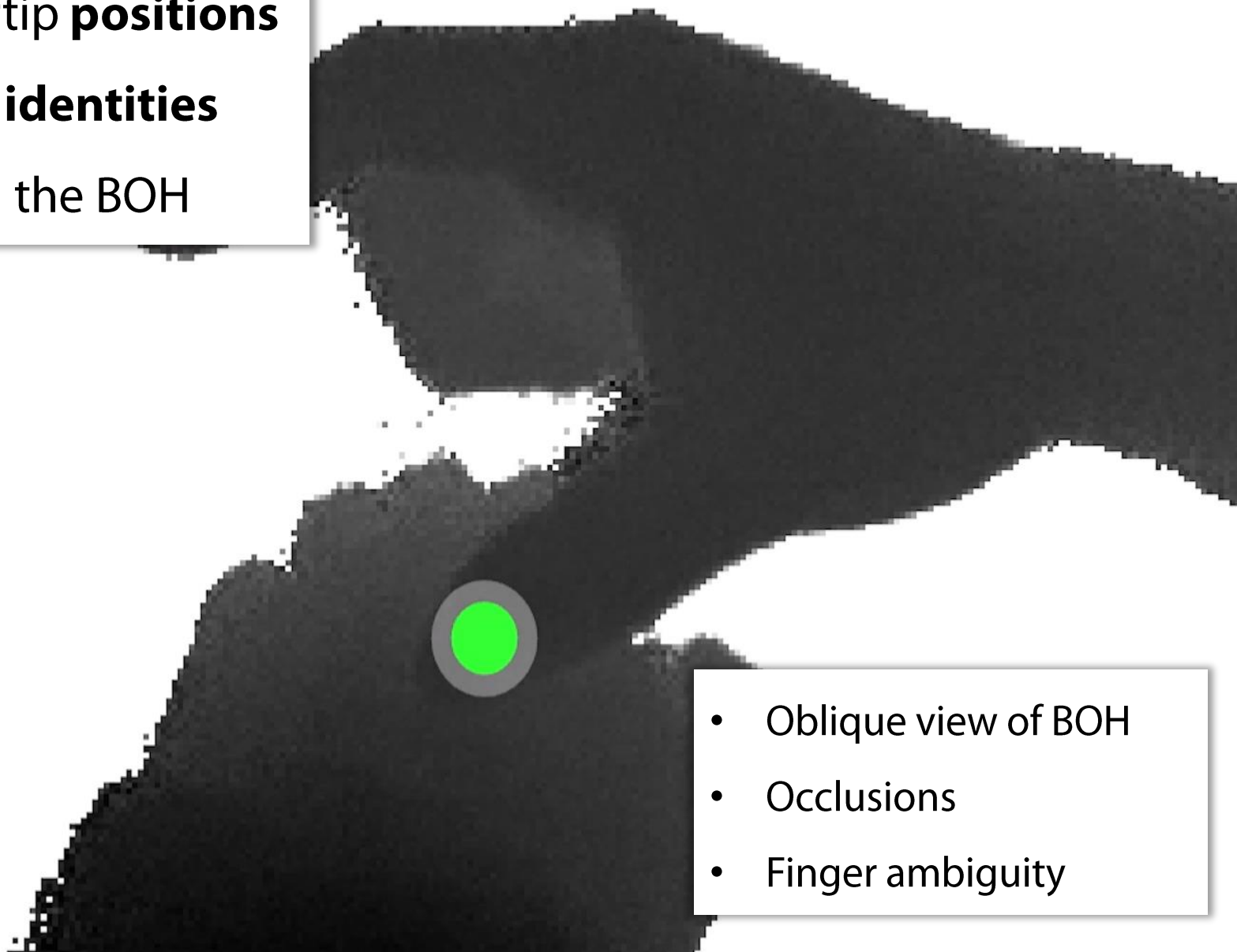
WatchSense


INPUT SENSING
Index Finger
Thumb
Back of the Hand (BOH)
Depth Sensor


NOVEL INPUT CAPABILITIES
Index Mid-Air
Thumb Touch
Thumb Mid-Air
Index Touch

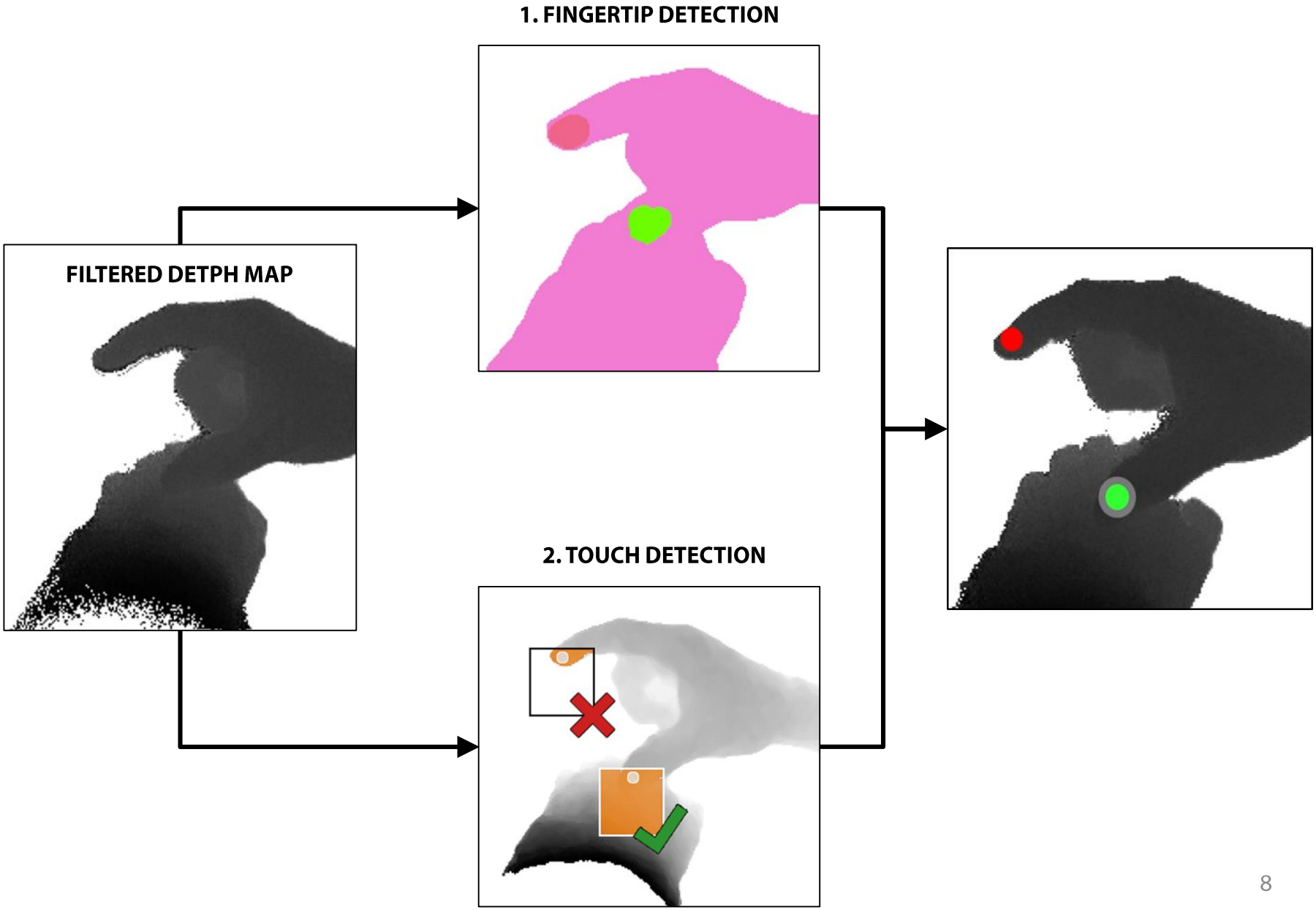
Goals & Challenges

- ✓ **3D** fingertip **positions**
- ✓ Fingertip **identities**
- ✓ **Touch** on the BOH



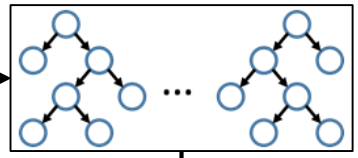
- Oblique view of BOH
- Occlusions
- Finger ambiguity

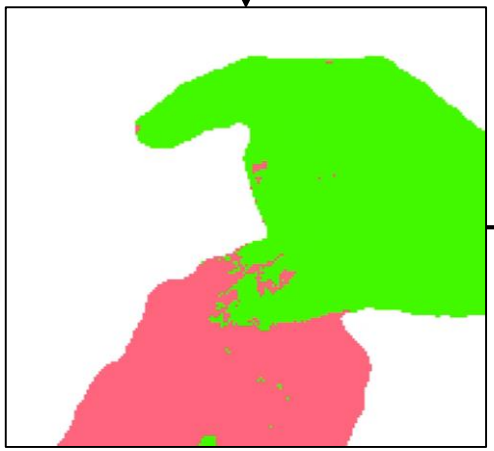
Technical Implementation



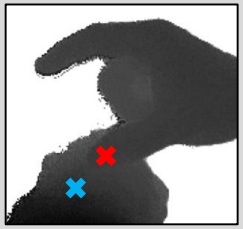
1. Fingertip Detection

HAND SEGMENATION FOREST



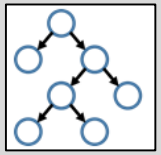


[1]



$$f(I,\mathbf{x}) = d_I\left(\mathbf{x} + \frac{\mathbf{u}}{d_I(\mathbf{x})}\right) - d_I\left(\mathbf{x} + \frac{\mathbf{v}}{d_I(\mathbf{x})}\right)$$

τ



TRAINING DATA

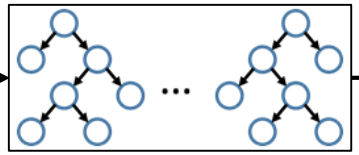
Hand segmentation: 20,000 images
Fingertip detection: 60,000 images

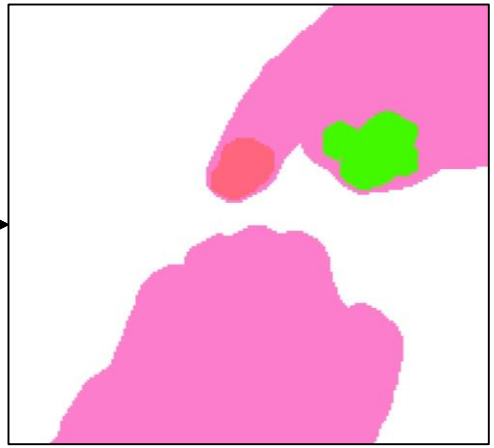
HAND SEGMENTATION

without: 76%

with: 84%

FINGERTIP DETECTION FOREST

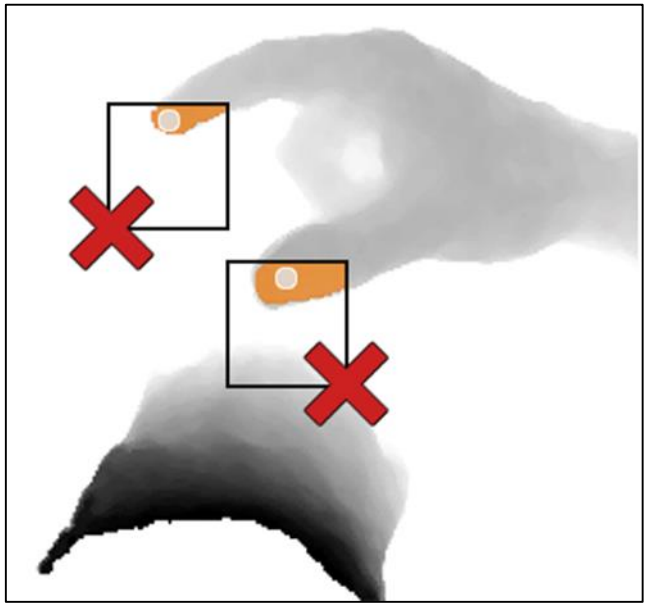




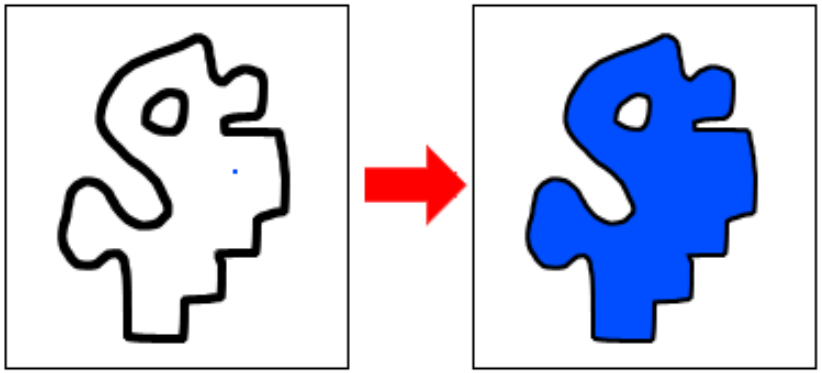
[1] J. Shotton, A. Fitzgibbon, M. Cook, T. Sharp, M. Finocchio, R. Moore, A. Kipman, and A. Blake *Real-time Human Pose Recognition in Parts from Single Depth Images*, CVPR 2011.

2. Touch Detection

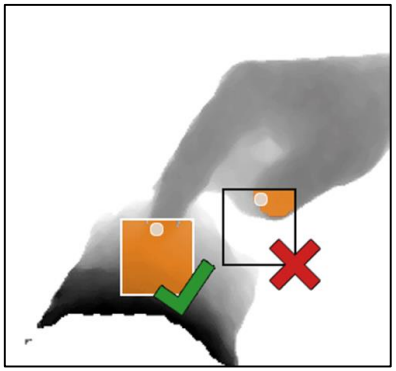
MID-AIR + MID-AIR



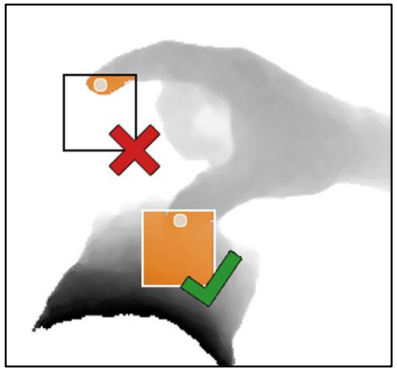
FLOOD FILLING



MID-AIR + TOUCH



TOUCH + MID-AIR



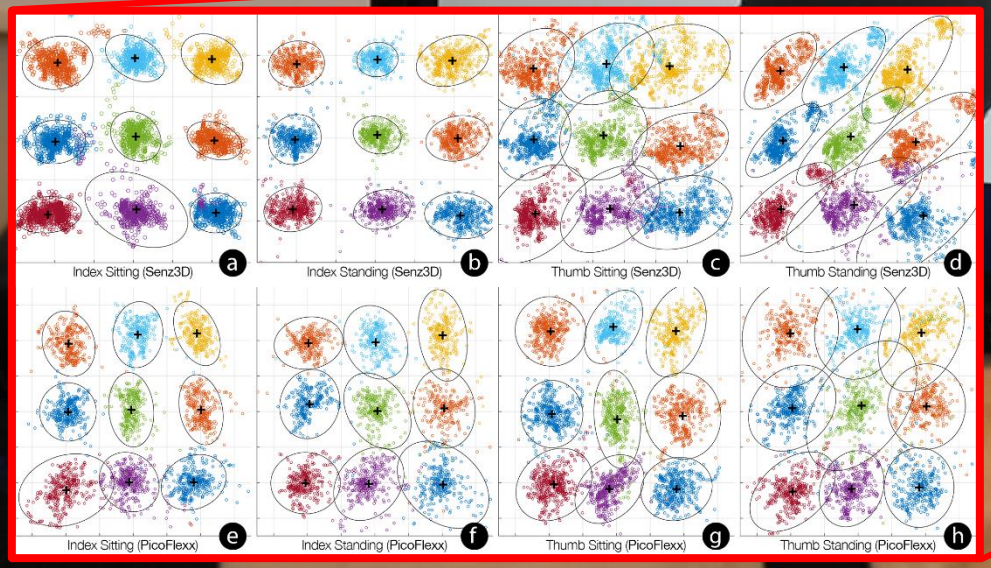
TOUCH TOLERANCE

1-10 mm

OmniTouch (UIST 2011)
20 mm

6.8 mm average deviation

OmniTouch (UIST 2011)
16.2 mm



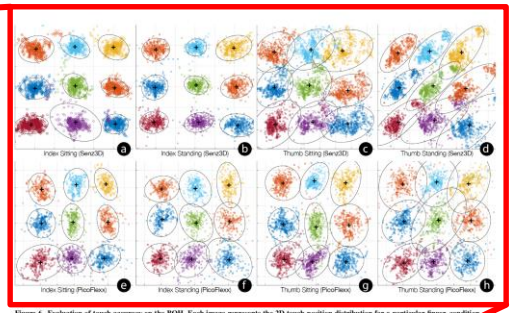


Figure 6. Evaluation of touch accuracy on the BOH. Each image represents the 2D touch position distribution for a particular finger, condition, camera (Senz3D is (a)–(d), PicoFlexx is (e)–(h)). The plots contain all touch points recorded by the tracker during each trial. Ground truth positions are marked with a black plus symbol, and ellipses denote 95% confidence intervals. Index finger performed best for both sitting and standing conditions for all cameras. We attribute the relatively worse performance of the thumb to the lack of sufficient training data for the fingertip classification forest.

Participants: We recruited two right-handed volunteers (62 and 66 years). An evaluation session took 30 minutes.

Design, Task, and Procedure: In order to provide as reliable measurements as possible, two tables were used to support the participant's arms during the evaluation. Participants were seated, resting their arm on one table, the other arm was resting on an adjacent elevation table with the hand hanging over the edge of the table. Before starting the evaluation, the participant's hand was annotated with 9 dots in the same way as in the *touch accuracy* evaluation.

The measurements were recorded through a five step procedure: (1) The elevation table was lowered until the finger touched the BOH. (2) The BOH and finger were aligned to touch a particular dot, (3) the table was elevated to a non-ambiguous hover state, (4) the finger was then lowered in small steps (1 mm) through the area of ambiguity and stopped when a touch state was obtained for more than 2 seconds, and (5) the finger was then elevated in similar steps until a hover state was obtained for more than 2 seconds. Measurements were recorded at the end of steps (4) and (5). The procedure was repeated for all of the nine dots for both fingers leading to 72 total dots.

Results: All measurements of non-ambiguous touch and hover states fell within an interval between 1 mm and 10 mm. This indicates that our algorithm is capable of reliably detecting a touch state at 1 mm distance from the BOH. Further, it reliably detects hovering when the finger is 10 mm away from the surface. Compared to previous state of the art [13], which reported their interval to be between 10 mm and 20 mm, this is a notable improvement.

Random Forest Classification Accuracy
Additionally, we also report accuracy of using random forests for classification. When training our classification forests, we adopted a rigorous cross-validation procedure to tune the parameters. For the best parameters chosen the per-pixel classification accuracy was 77% for fingertip detection, and 98.8% for hand segmentation.

WATCHSENSE-ENABLED APPLICATIONS
To illustrate the novel input capabilities enabled by *WatchSense*, we built several demonstrator applications. We thus explore how *WatchSense* can support existing multitouch interactions such as pinch-to-zoom, as well as open up completely new opportunities, thanks to finger identification and compound interactions. To further showcase flexibility, we show our prototype running on different hardware platforms and depth sensors. We also show cross-platform interaction, i.e., *WatchSense* can run on a mobile device but be used for interaction with another surrounding device (e.g., HoloLens), or even several surrounding devices simultaneously.

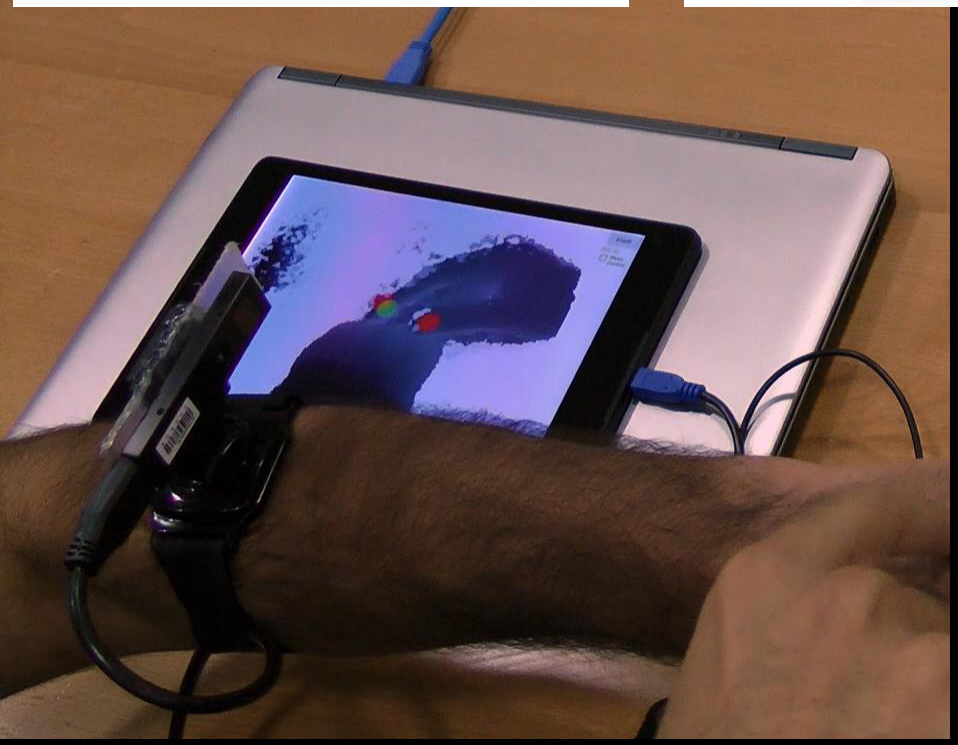
Music Controller: When the *WatchSense* app runs on a mobile device (running Android), it provides a music player con-

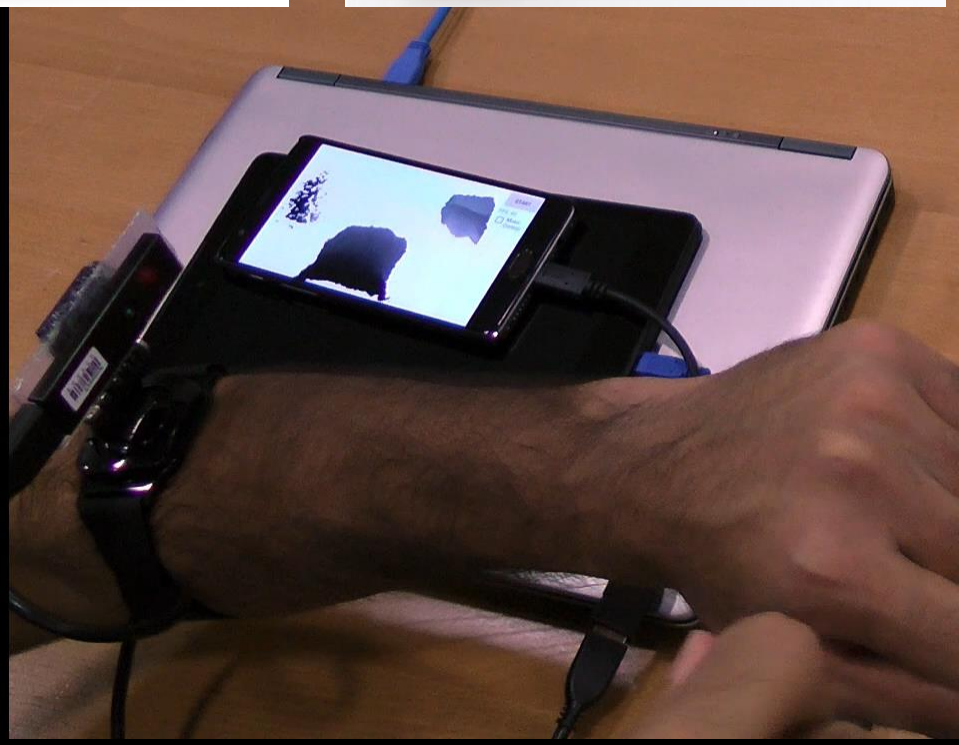
Real-time Performance

INTEL REALSENSE

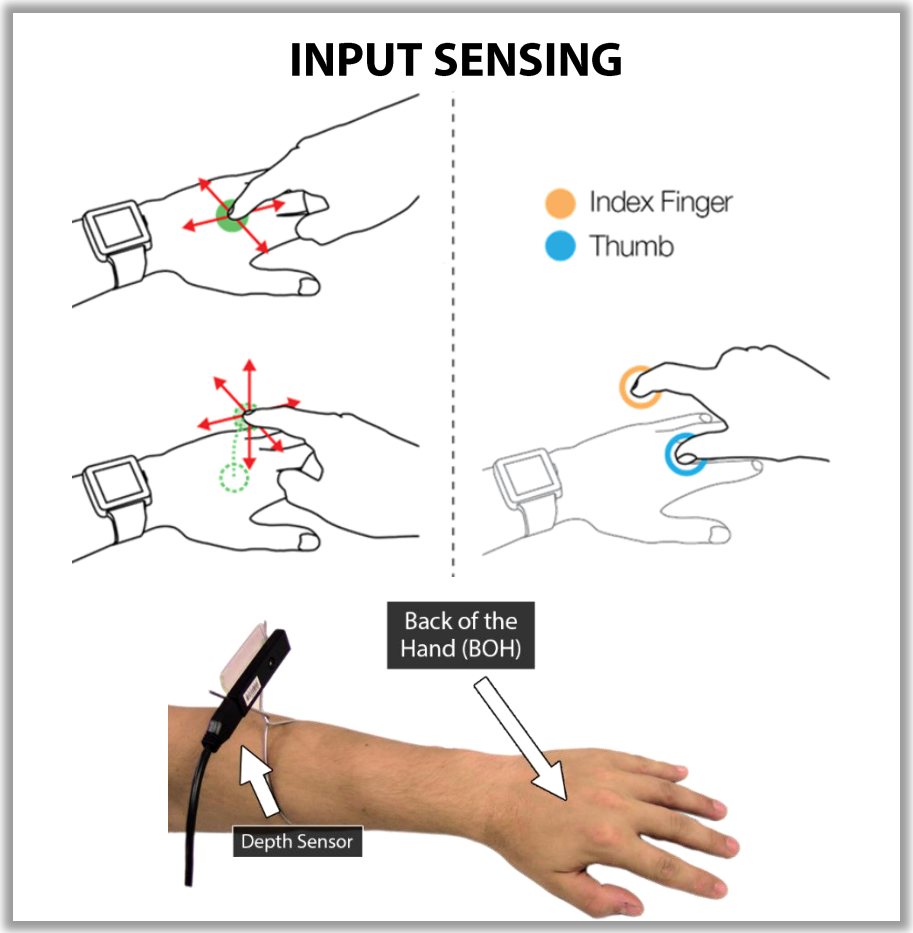
CREATIVE SENZ3D

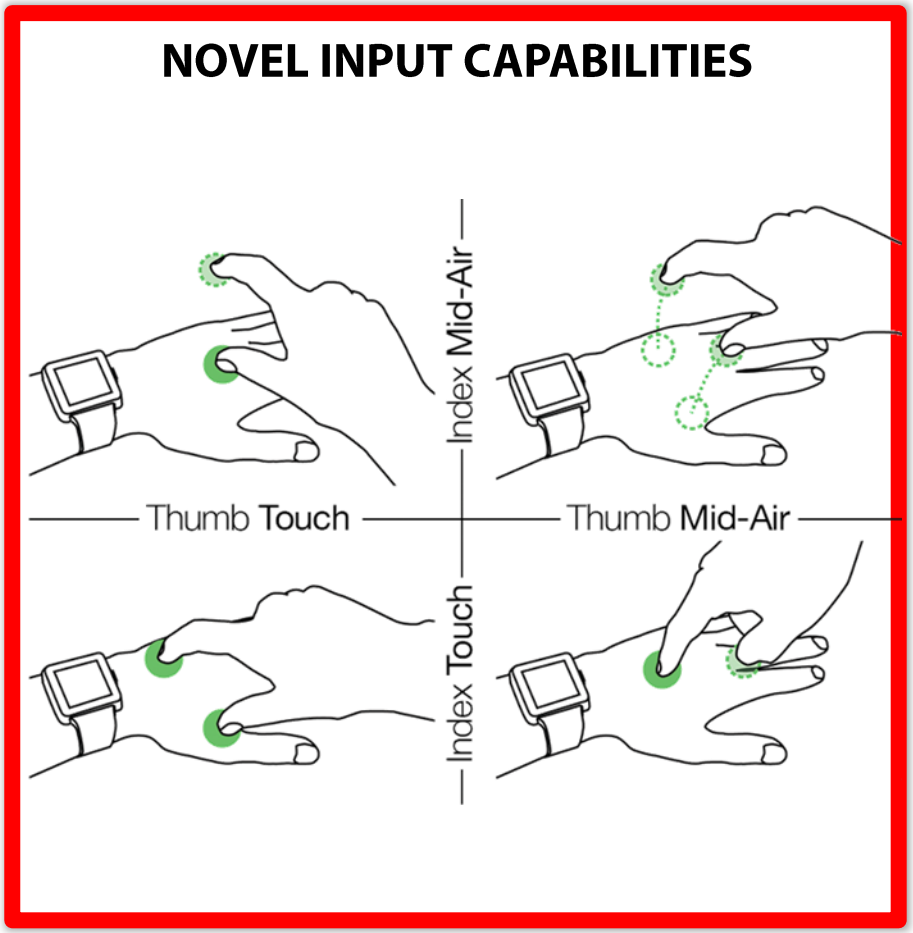
PMD PICOFLEXX



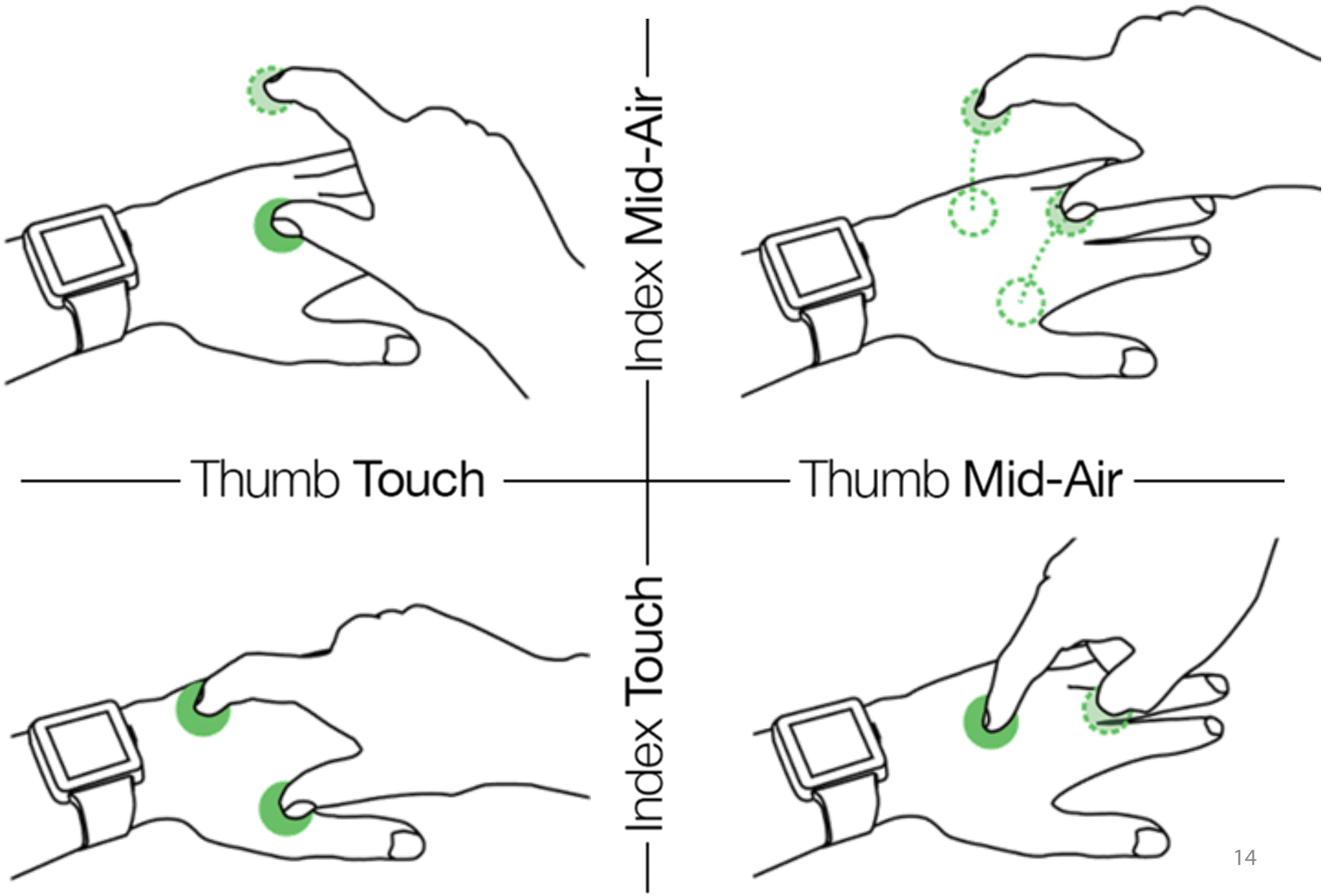


WatchSense


INPUT SENSING
Index Finger
Thumb
Back of the Hand (BOH)
Depth Sensor


NOVEL INPUT CAPABILITIES
Index Mid-Air
Thumb Touch
Thumb Mid-Air
Index Touch

Interaction Opportunities

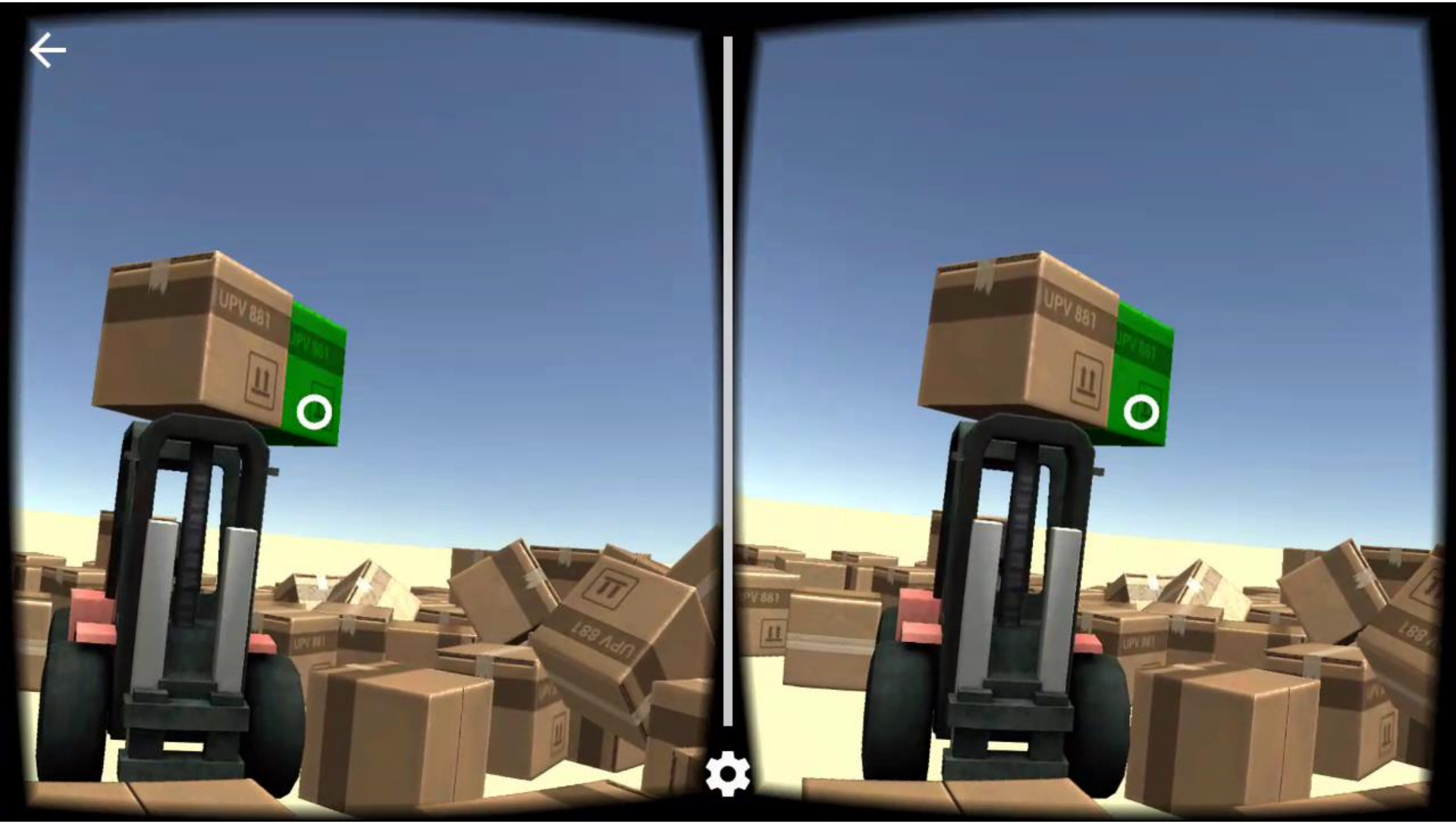



HandPad
19:00
Panning

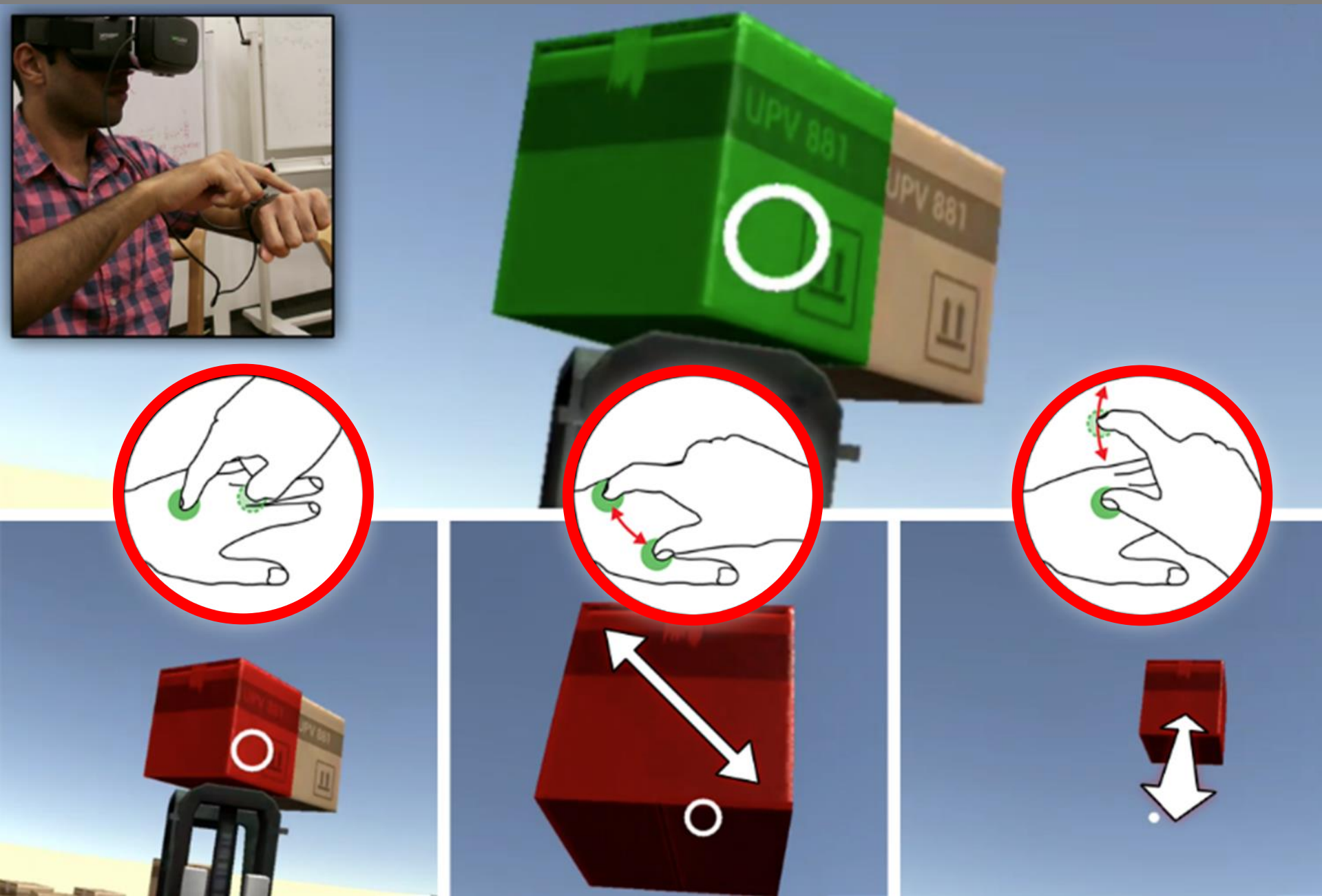

HandPad
19:00
Gramercy
5th Ave
Washington Square Park
Broadway
14th St
6th Ave
Lafayette St
3rd Ave
W Houston St
2nd Ave

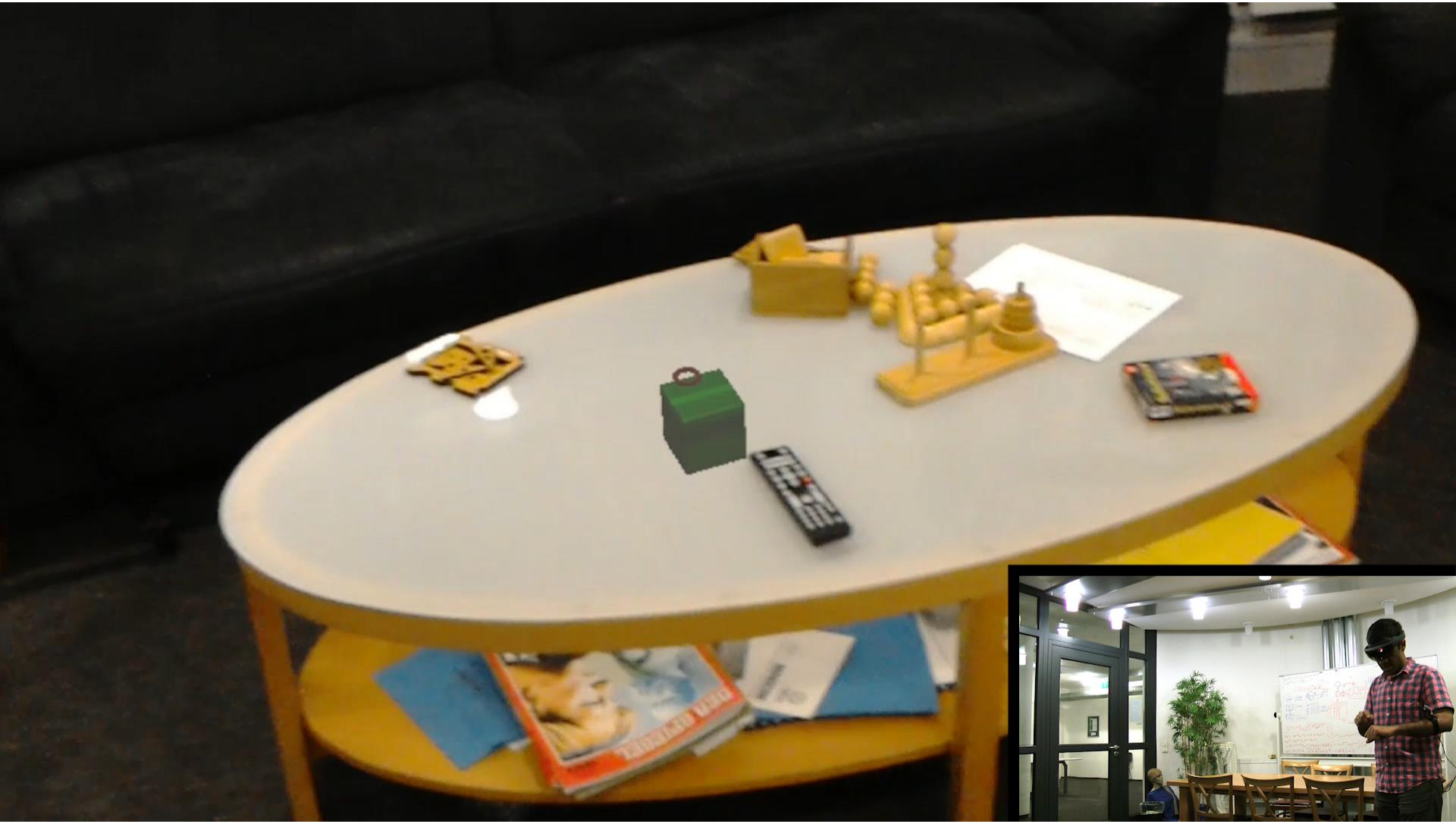
3D Input for AR/VR

CARDBOARD BOXES



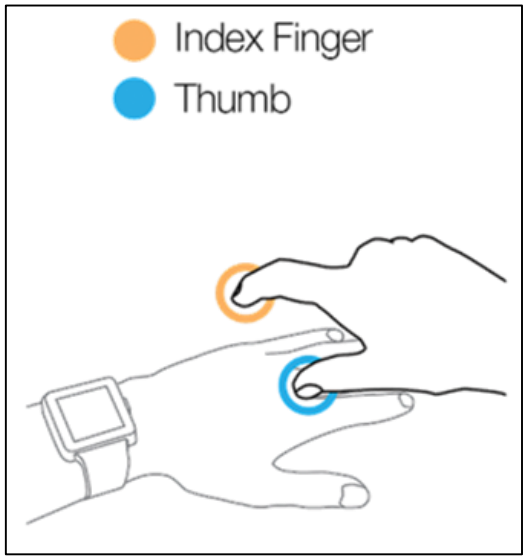
3D Input for VR/AR



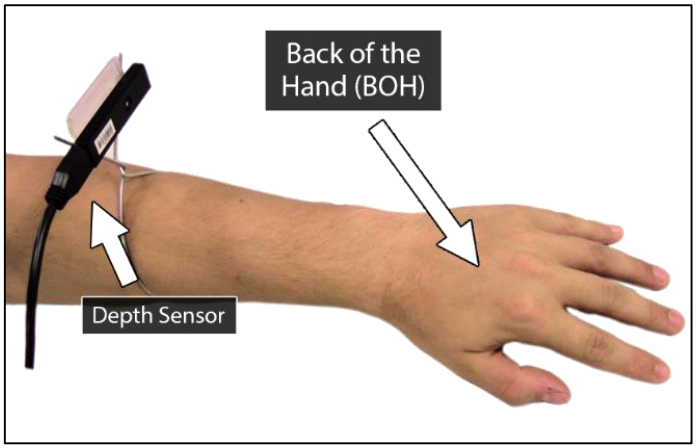


Limitations / Future Work

ONLY TWO FINGERS



BULKY PROTOTYPE



BOH PROJECTION


Extend input space
• On and above the back of the hand
• Always available
Input sensing
• 3D fingertips
• Touch detection
• Fingertip identity
New expressive input
• Touch
• Mid-air
• Mid-air + Touch

Thank you!

handtracker.mpi-inf.mpg.de/projects/WatchSense

ssrinath@stanford.edu

Live demo after the session!




ACKNOWLEDGMENTS

- European Research Council (ERC)

  European Union's Horizon 2020 Research and Innovation Programme

  (grant agreements 335545, 648785, and 637991)
- Sebastian Schuon, Franziska Mueller