LECTURE 12: RESEARCH DIRECTIONS IN AR AND VR

COMP 4010 – Virtual Reality
Semester 5 – 2017

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University of
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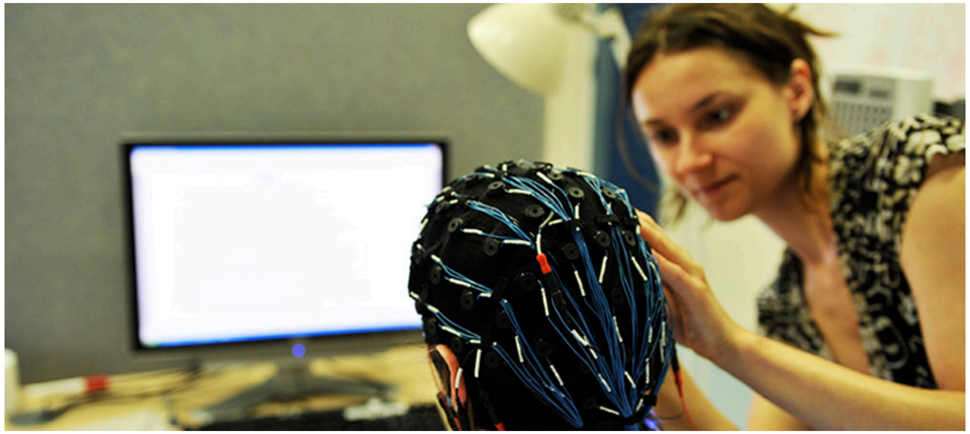
Key Technologies for VR Systems

- Visual Display
  - Stimulate visual sense
- Audio/Tactile Display
  - Stimulate hearing/touch
- Tracking
  - Changing viewpoint
  - User input
- Input Devices
  - Supporting user interaction

Many Directions for Research



- Research in each of the key technology areas for VR
  - Display, input, tracking, graphics, etc.
- Research in the phenomena of VR
  - Psychological experience of VR, measuring Presence, etc..
- Research in tools for VR
  - VR authoring tools, automatic world creation, etc.
- Research in many application areas
  - Collaborative/social, virtual characters, medical, education, etc.

Future Visions of VR: Ready Player One

- https://www.youtube.com/watch?v=LiK2fhOY0nE

Today vs. Tomorrow

	VR in 2017	VR in 2045
Graphics	High quality	Photo-realistic
Display	110-150 degrees	Total immersion
Interaction	Handheld controller	Full gesture/body/gaze
Navigation	Limited movement	Natural
Multiuser	Few users	Millions of users

Augmented Reality

- Defining Characteristics [Azuma 97]
  - Combines Real and Virtual Images
    - Both can be seen at the same time
  - Interactive in real-time
    - The virtual content can be interacted with
  - Registered in 3D
    - Virtual objects appear fixed in space

Azuma, R. T. (1997). A survey of augmented reality. Presence, 6(4), 355-385.

Future Vision of AR: IronMan

- https://www.youtube.com/watch?v=Y1TEK2Wf_e8

Key Enabling Technologies

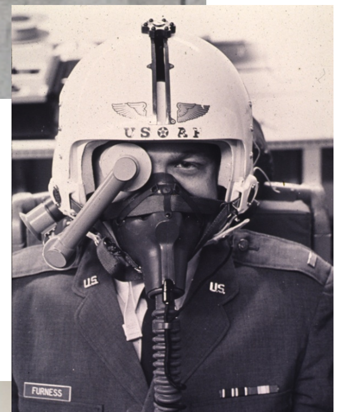
1. Combines Real and Virtual Images
   → Display Technology
2. Registered in 3D
   → Tracking Technologies
3. Interactive in real-time
   → Interaction Technologies

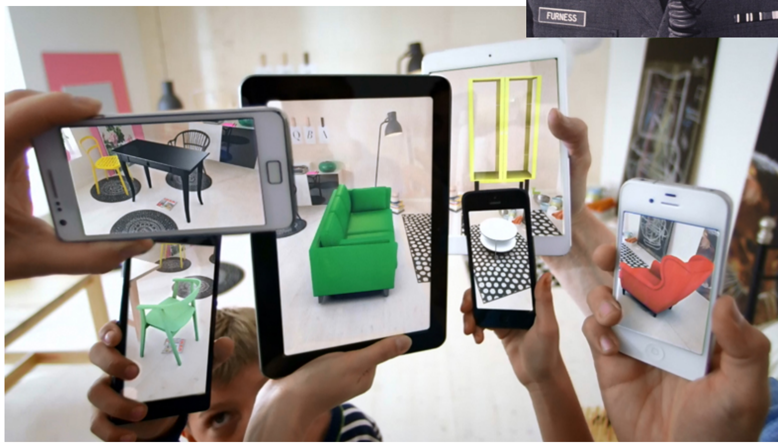
Future research can be done in each of these areas

DISPLAY

Evolution in Displays

- Past
  - Bulky Head mounted displays
- Current
  - Handheld, lightweight head mounted
- Future
  - Projected AR
  - Wide FOV see through
  - Retinal displays
  - Contact lens





Wide FOV See-Through (3+ years)

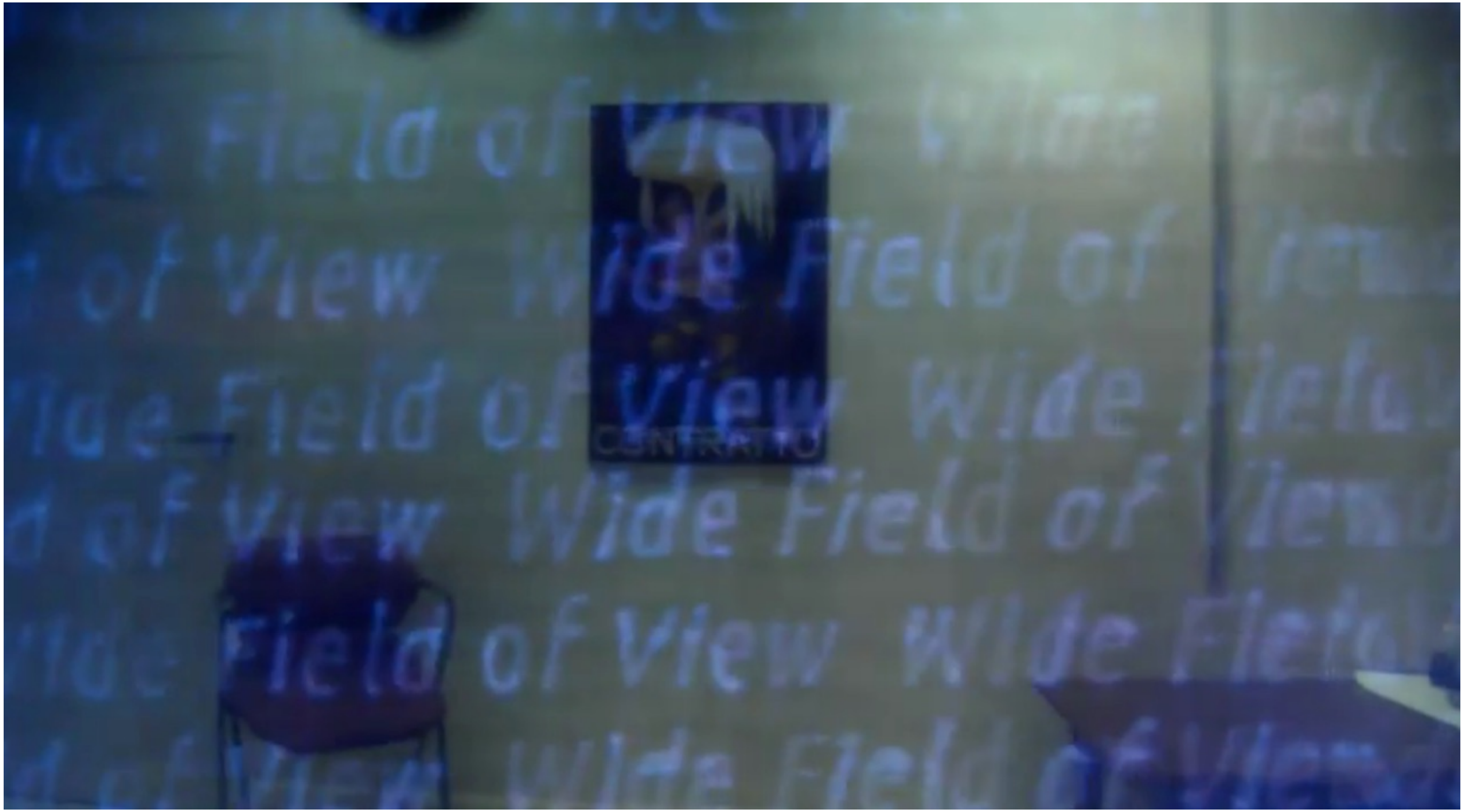
- Waveguide techniques
  - Wider FOV
  - Thin see through
  - Socially acceptable

Lumus DK40

- Pinlight Displays
  - LCD panel + point light sources
  - 110 degree FOV
  - UNC/Nvidia

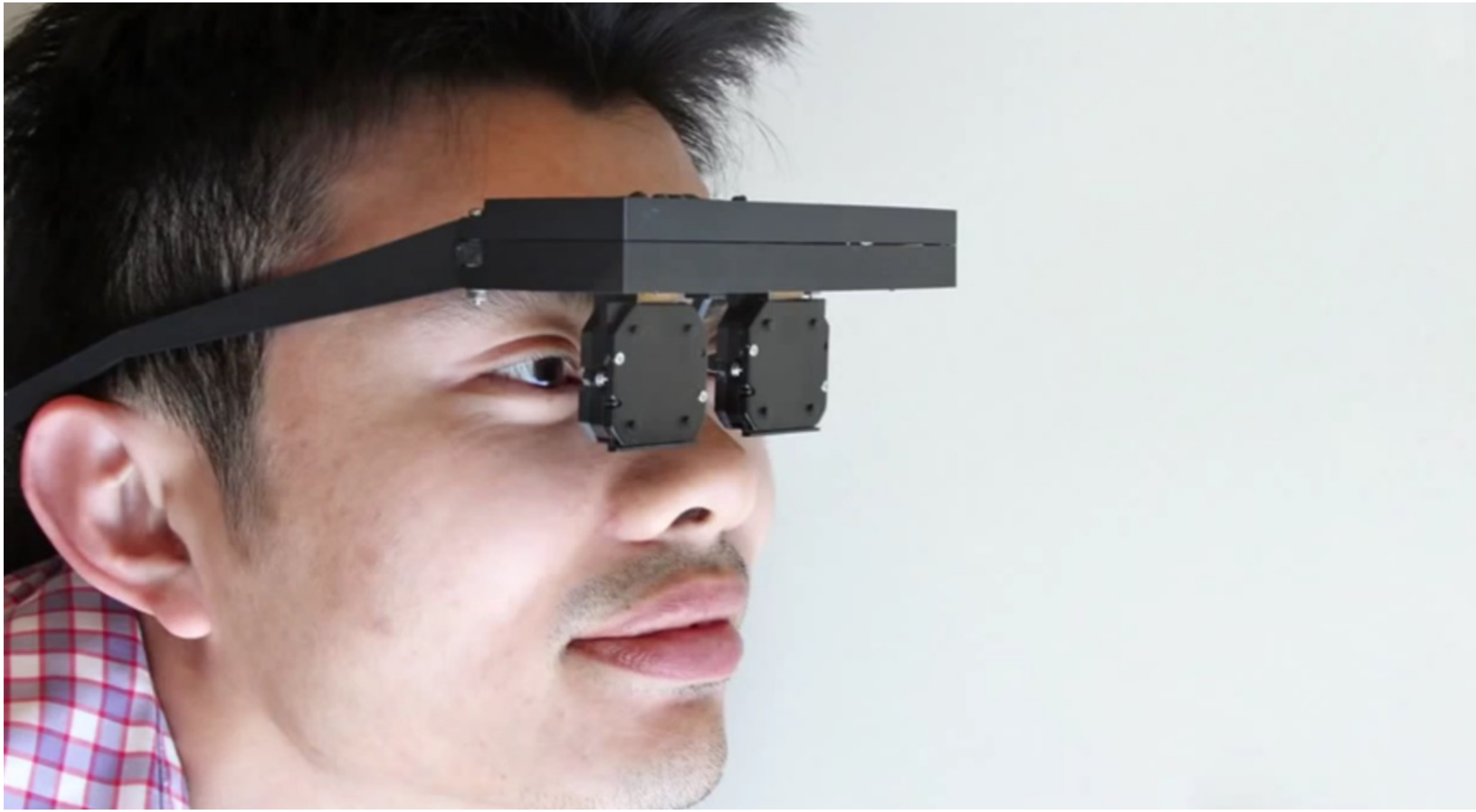
Maimone, A., Lanman, D., Rathinavel, K., Keller, K., Luebke, D., & Fuchs, H. (2014). Pinlight displays: wide field of view augmented reality eyeglasses using defocused point light sources. In *ACM SIGGRAPH 2014 Emerging Technologies* (p. 20). ACM.

Pinlight Display Demo



https://www.youtube.com/watch?v=tJULL1Oou9k

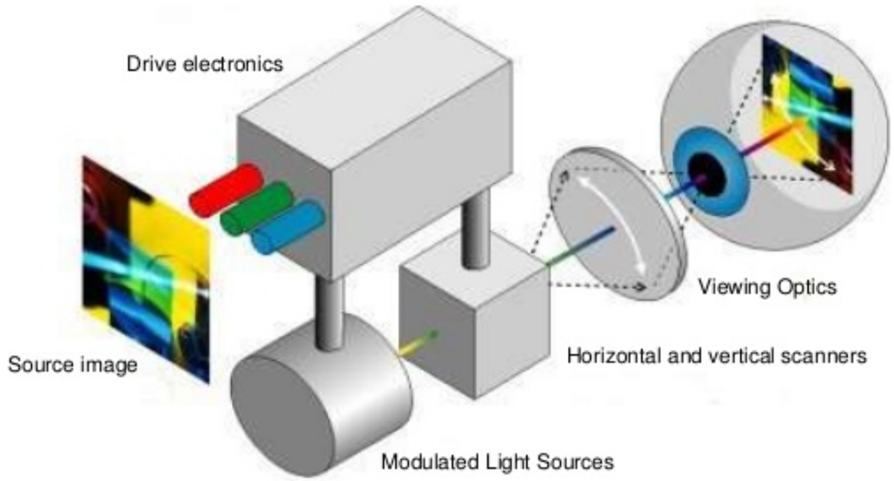
Light Field Displays



https://www.youtube.com/watch?v=J28AvVBZWbg

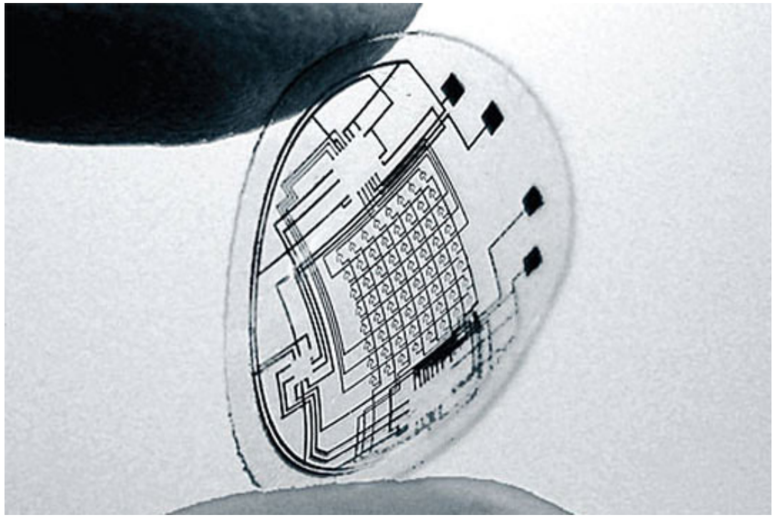
Retinal Displays (5+ years)

- Photons scanned into eye
  - Infinite depth of field
  - Bright outdoor performance
  - Overcome visual defects
  - True 3D stereo with depth modulation
- Microvision (1993-)
  - Head mounted monochrome
- MagicLeap (2013-)
  - Projecting light field into eye

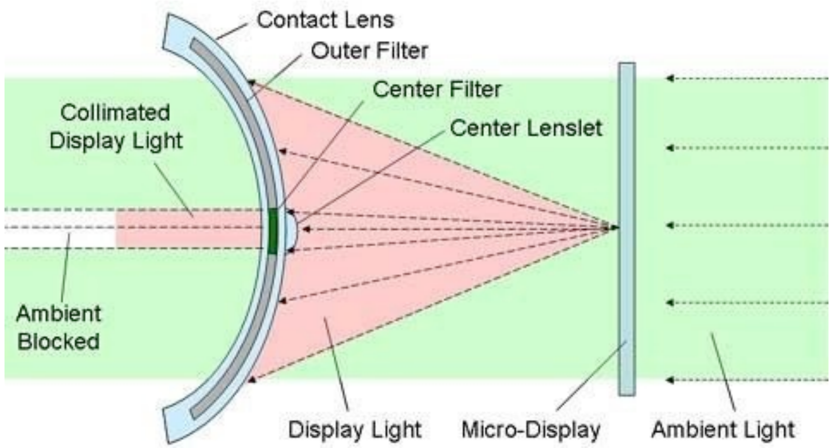


Contact Lens (10 – 15 + years)

- Contact Lens only
  - Unobtrusive
  - Significant technical challenges
    - Power, data, resolution
  - Babak Parviz (2008)



- Contact Lens + Micro-display
  - Wide FOV
  - socially acceptable
  - Innovega (innovega-inc.com)

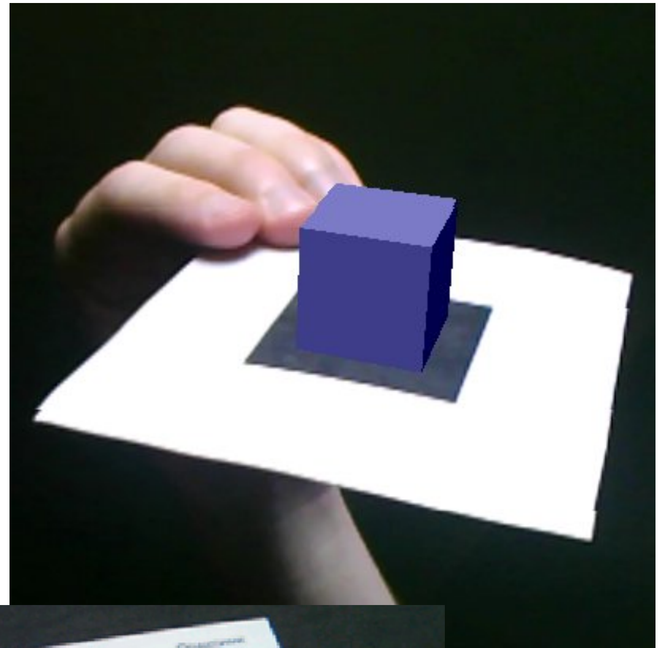


http://spectrum.ieee.org/biomedical/bionics/augmented-reality-in-a-contact-lens/

TRACKING

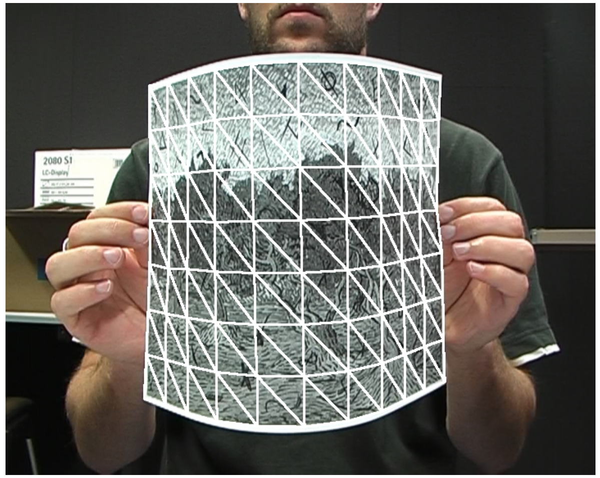
Evolution of Tracking

- Past
  - Location based, marker based,
  - magnetic/mechanical
- Present
  - Image based, hybrid tracking
- Future
  - Ubiquitous
  - Model based
  - Environmental



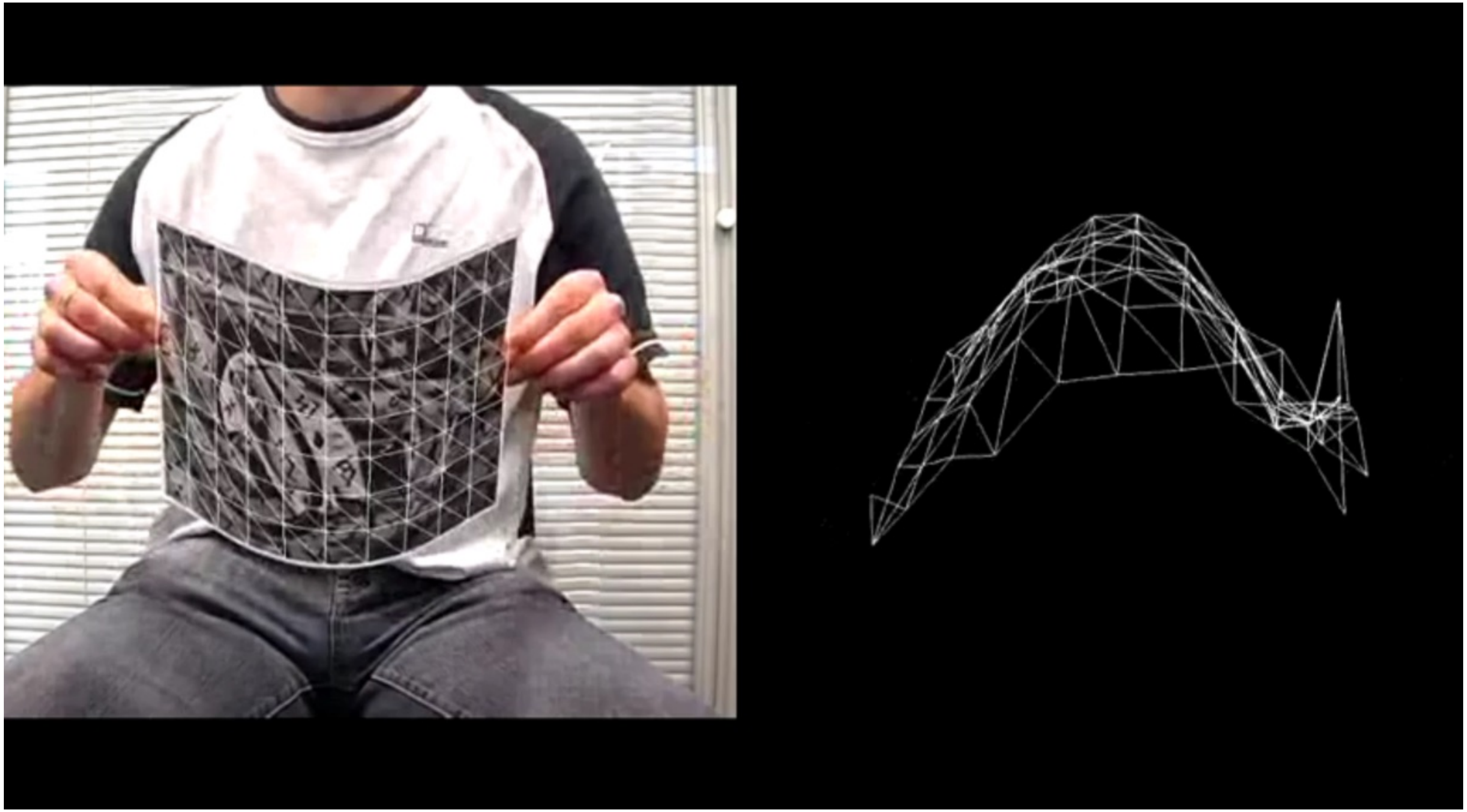
Model Based Tracking (1-3 yrs)

- Track from known 3D model
  - Use depth + colour information
  - Match input to model template
  - Use CAD model of targets
- Recent innovations
  - Learn models online
  - Tracking from cluttered scene
  - Track from deformable objects



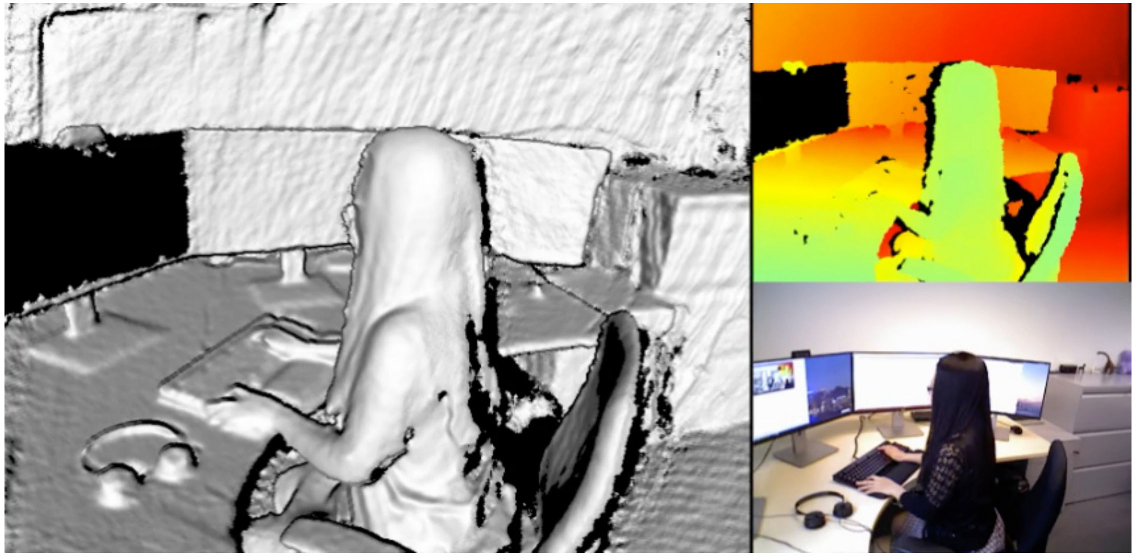
Hinterstoisser, S., Lepetit, V., Ilic, S., Holzer, S., Bradski, G., Konolige, K., & Navab, N. (2013). Model based training, detection and pose estimation of texture-less 3D objects in heavily cluttered scenes. In *Computer Vision–ACCV 2012* (pp. 548-562). Springer Berlin Heidelberg.

Deformable Object Tracking



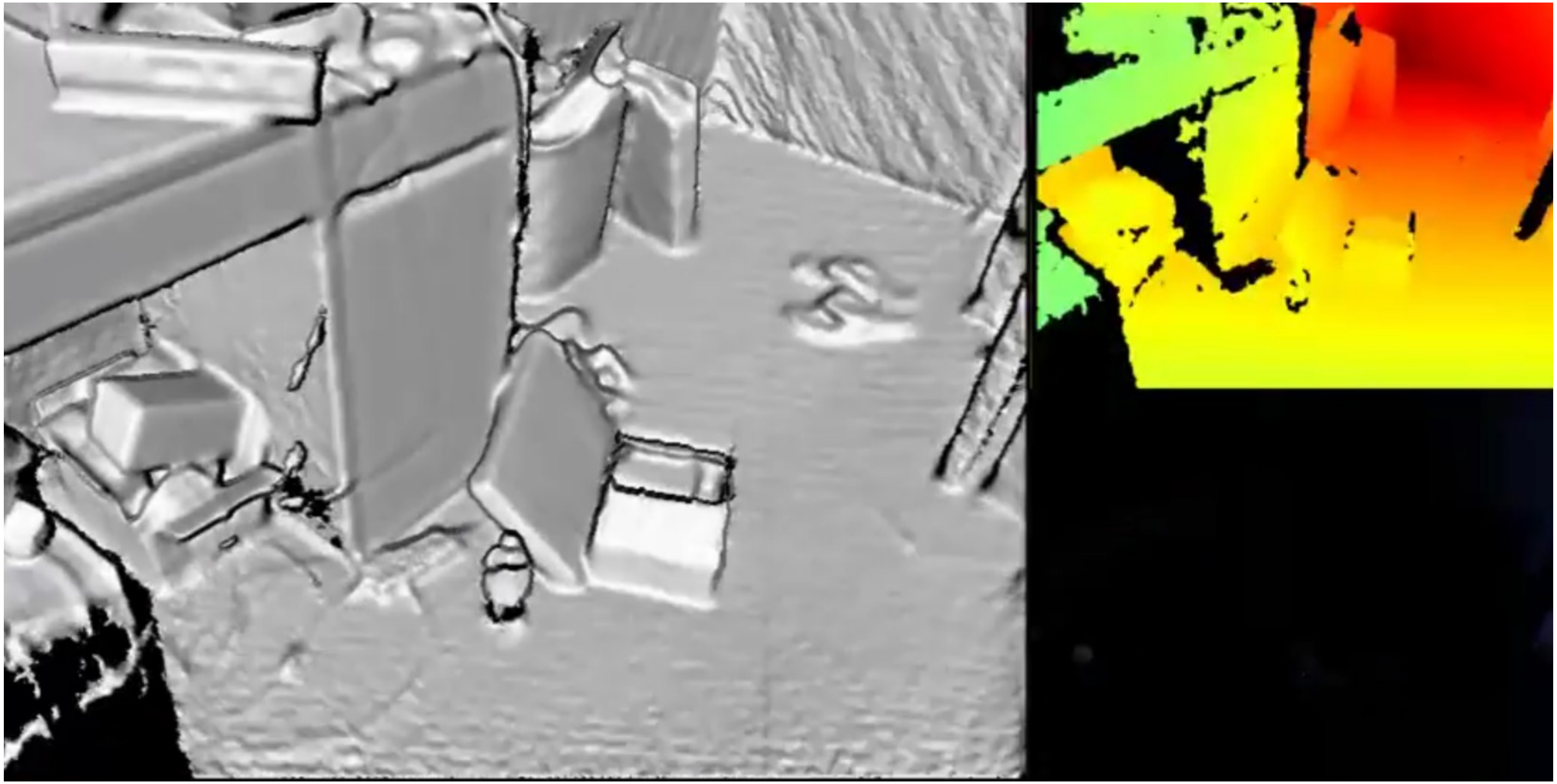
https://www.youtube.com/watch?v=KThSoK0VTDU

Environmental Tracking (3+ yrs)



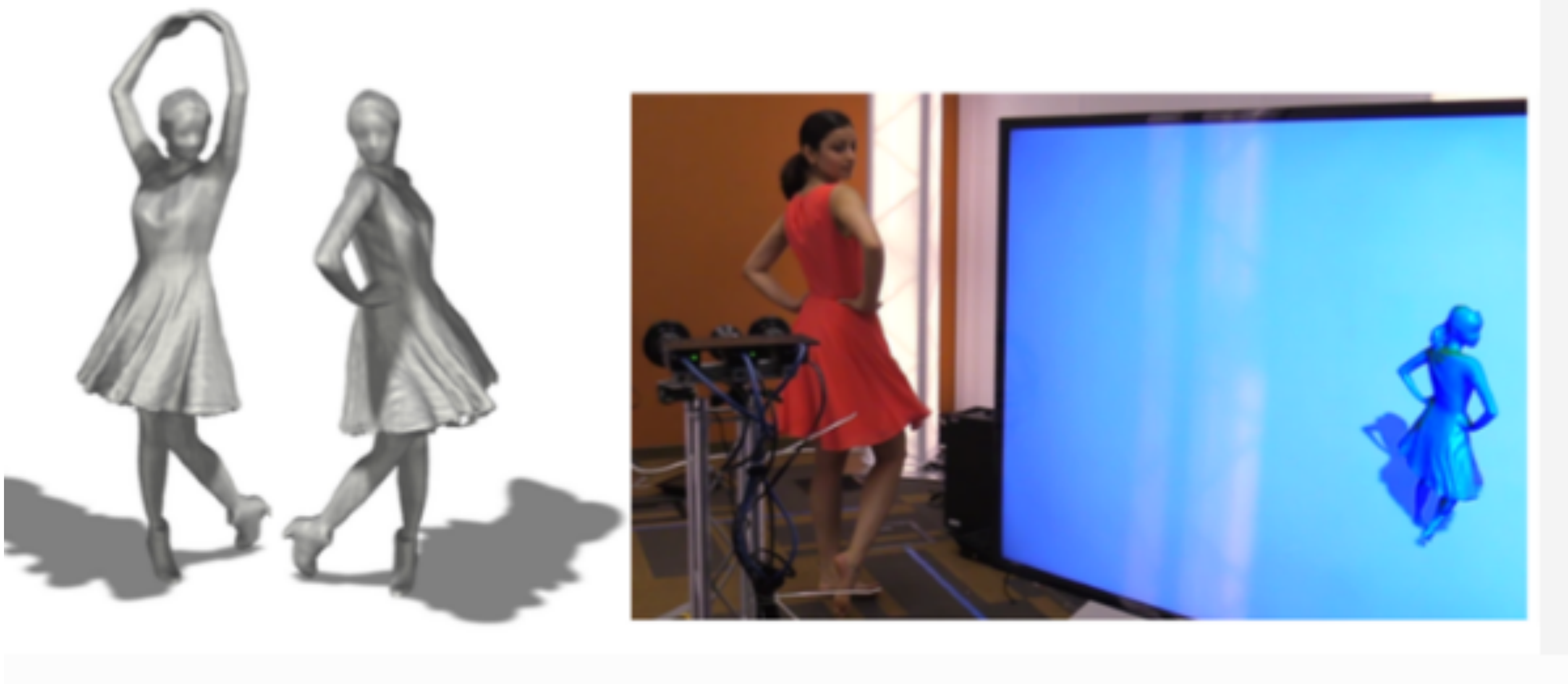
- Environment capture
  - Use depth sensors to capture scene & track from model
- InifinitAM (www.robots.ox.ac.uk/~victor/infinitam/)
  - Real time scene capture on mobiles, dense or sparse capture
  - Dynamic memory swapping allows large environment capture
  - Cross platform, open source library available

InfinitAM Demo



https://www.youtube.com/watch?v=47zTHHxJjQU

Fusion4D (2016)

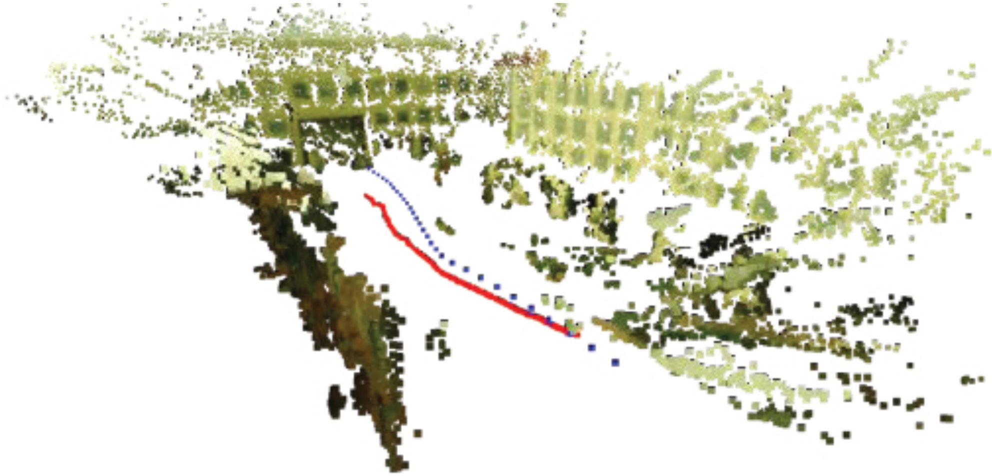


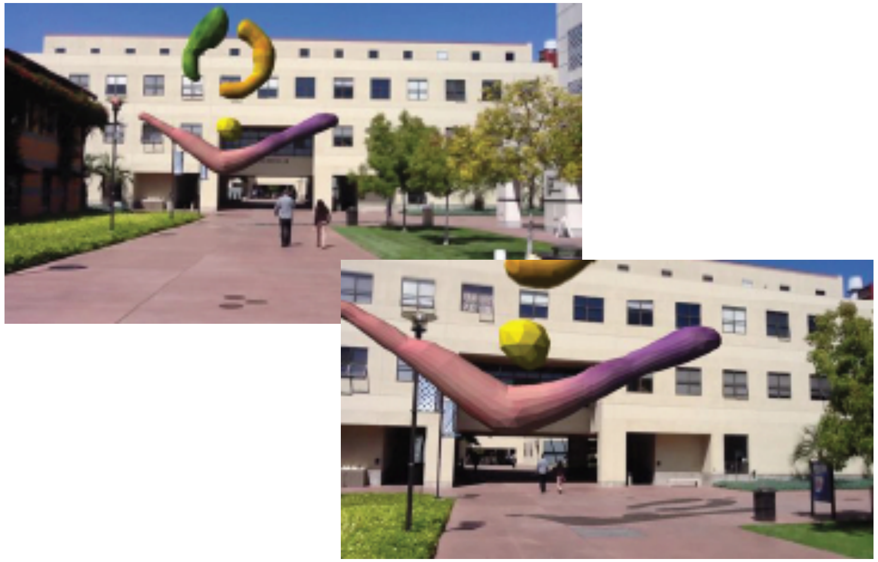
- Shahram Izhadi (Microsoft + perceptiveIO)
- Real capture and dynamic reconstruction
- RGBD sensors + incremental reconstruction

Fusion4D Demo

- https://www.youtube.com/watch?v=rnz0Kt36mOQ

Wide Area Outdoor Tracking (5+ yrs)





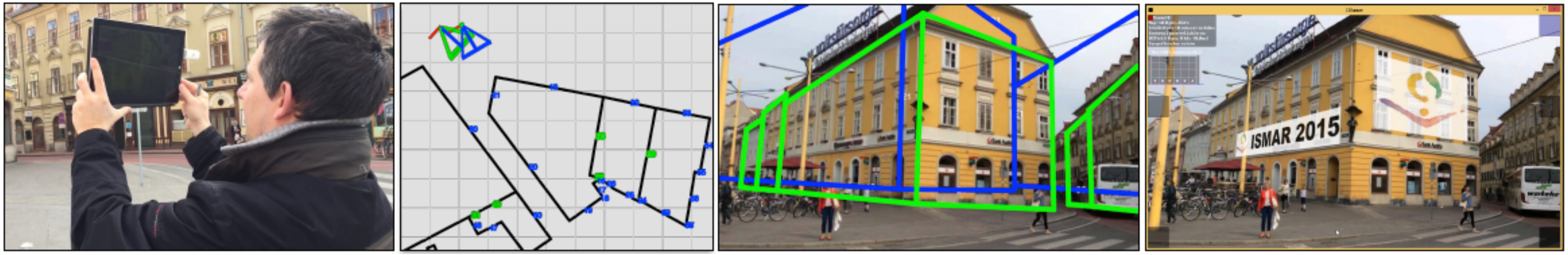
- Process
  - Combine panorama's into point cloud model (offline)
  - Initialize camera tracking from point cloud
  - Update pose by aligning camera image to point cloud
  - Accurate to 25 cm, 0.5 degree over very wide area

Ventura, J., & Hollerer, T. (2012). Wide-area scene mapping for mobile visual tracking. In *Mixed and Augmented Reality (ISMAR), 2012 IEEE International Symposium on* (pp. 3-12). IEEE.

Wide Area Outdoor Tracking

https://www.youtube.com/watch?v=8ZNN0NeXV6s

Outdoor Localization using Maps



- Use 2D building footprints and approximate height
- Process
  - Sensor input for initial position orientation
  - Estimate camera orientation from straight line segments
  - Estimate camera translation from façade segmentation
  - Use pose estimate to initialise SLAM tracking
- Results – 90% < 4m position error, < 3^{o} angular error

Arth, C., Pirchheim, C., Ventura, J., Schmalstieg, D., & Lepetit, V. (2015). Instant outdoor localization and SLAM initialization from 2.5 D maps. *IEEE transactions on visualization and computer graphics*, *21*(11), 1309-1318.

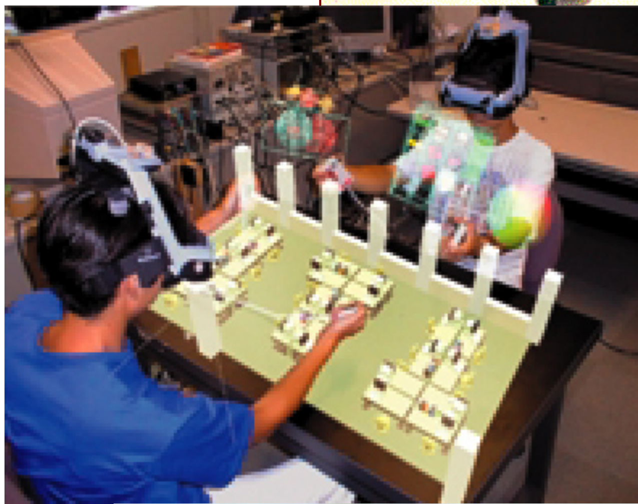
Demo: Outdoor Tracking

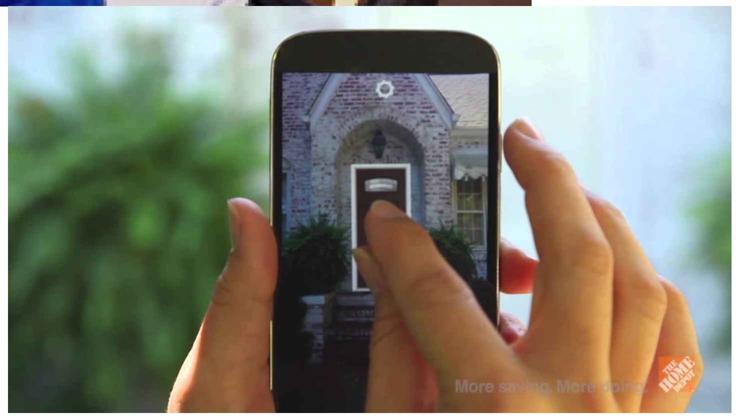
- https://www.youtube.com/watch?v=PzV8VKC5buQ

INTERACTION

Evolution of Interaction

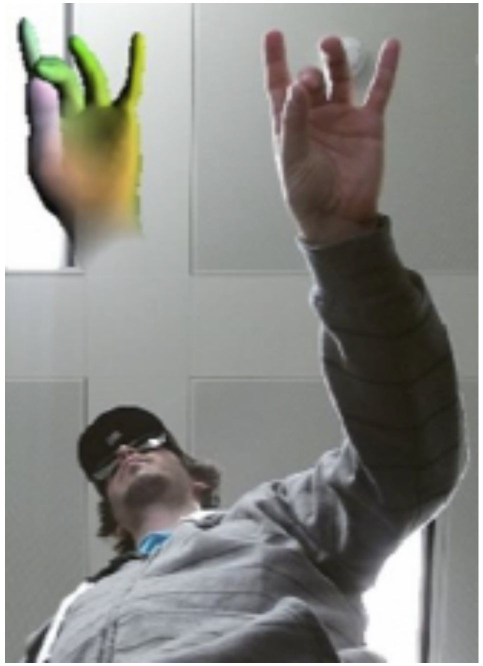
- Past
  - Limited interaction
  - Viewpoint manipulation
- Present
  - Screen based, simple gesture
  - tangible interaction
- Future
  - Natural gesture, Multimodal
  - Intelligent Interfaces
  - Physiological/Sensor based





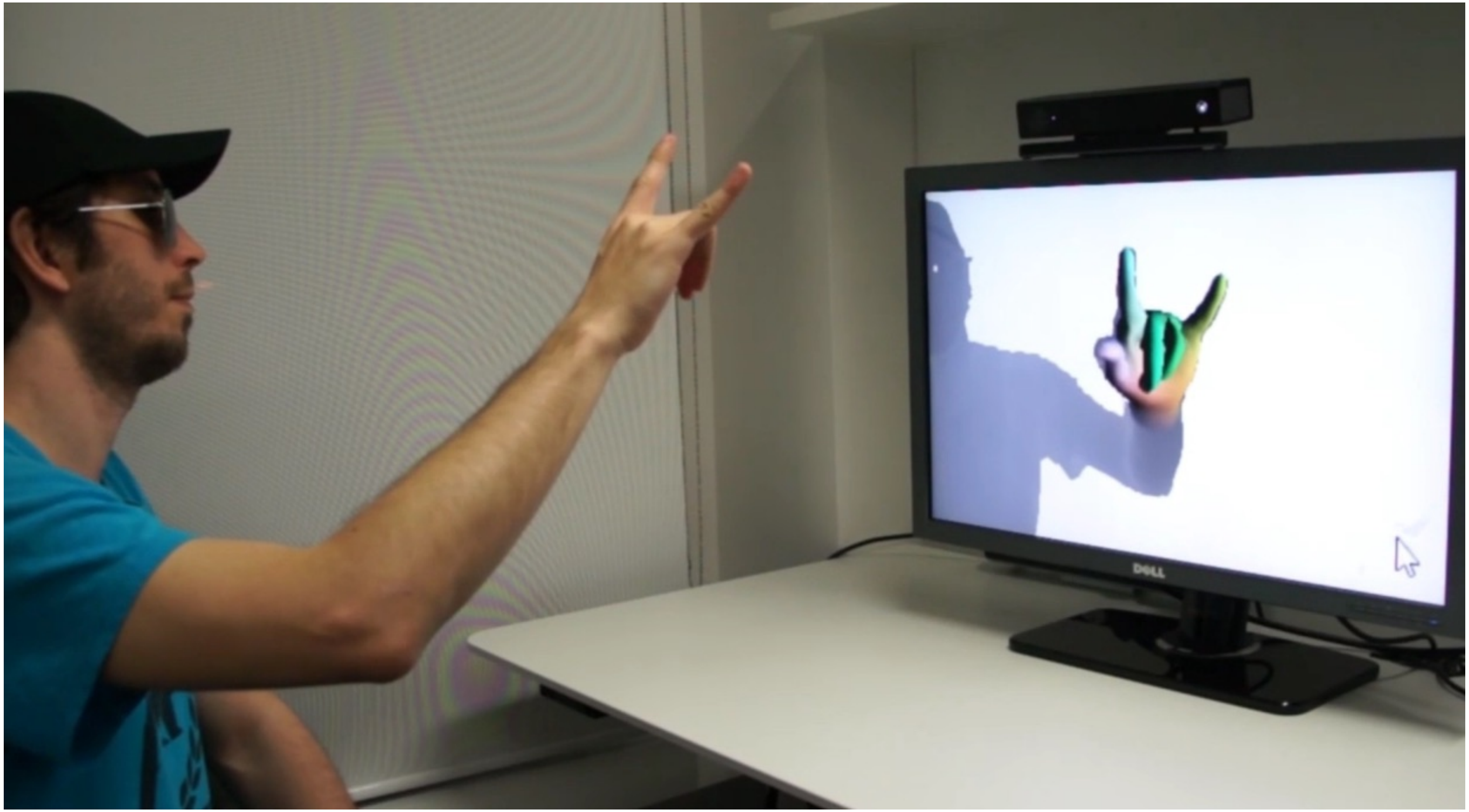
Natural Gesture (2-5 years)

- Freehand gesture input
  - Depth sensors for gesture capture
  - Move beyond simple pointing
  - Rich two handed gestures
- Eg Microsoft Research Hand Tracker
  - 3D hand tracking, 30 fps, single sensor
- Commercial Systems
  - Meta, MS Hololens, Occulus, Intel, etc



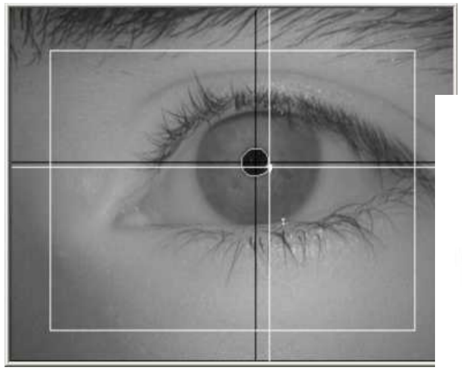
Sharp, T., Keskin, C., Robertson, D., Taylor, J., Shotton, J., Leichter, D. K. C. R. I., ... & Izadi, S. (2015, April). Accurate, Robust, and Flexible Real-time Hand Tracking. In *Proc. CHI* (Vol. 8).

Hand Tracking Demo



https://www.youtube.com/watch?v=QTz1zQAnMcU

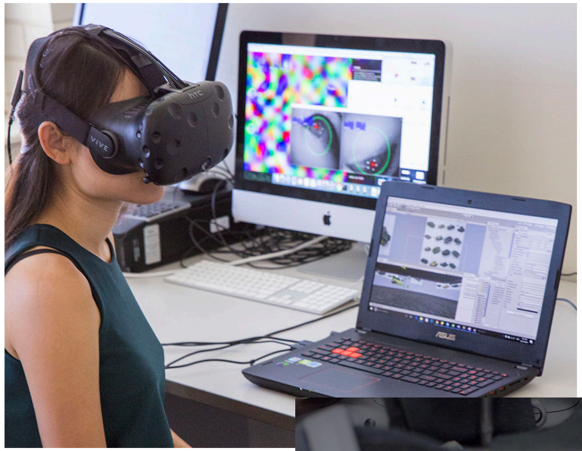
Example: Eye Tracking Input




- Smaller/cheaper eye-tracking systems
- More HMDs with integrated eye-tracking
- Research questions
  - How can eye gaze be used for interaction?
  - What interaction metaphors are natural?
  - What technology can be used for eye-tracking
  - Etc..

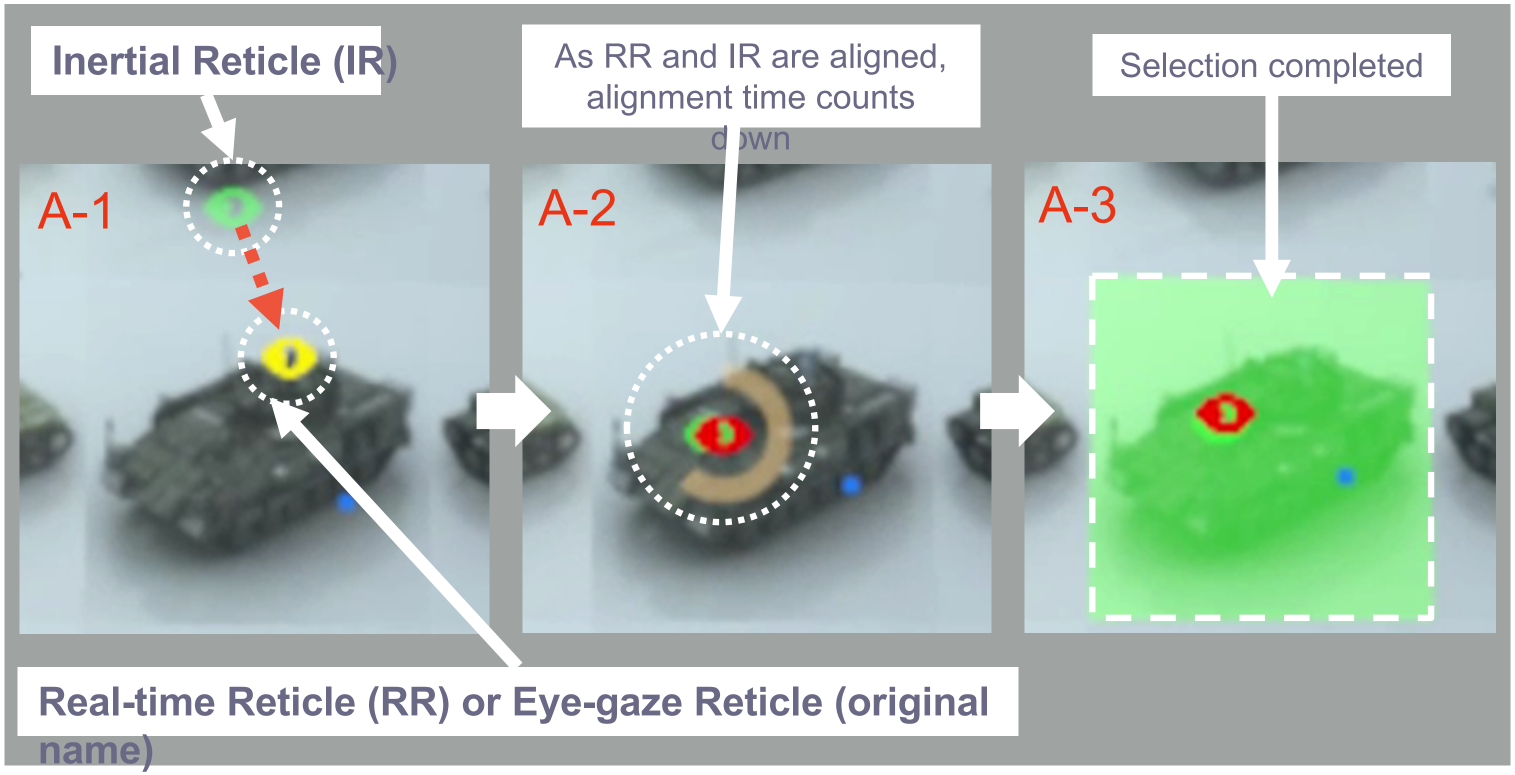
Eye Gaze Interaction Methods

- Gaze for interaction
  - Implicit vs. explicit input
- Exploring different gaze interaction
  - Duo reticles – use eye saccade input
  - Radial pursuit – use smooth pursuit motion
  - Nod and roll – use the vestibular ocular reflex
- Hardware
  - HTC Vive + Pupil Labs integrated eye-tracking
- User study to compare between methods for 3DUI

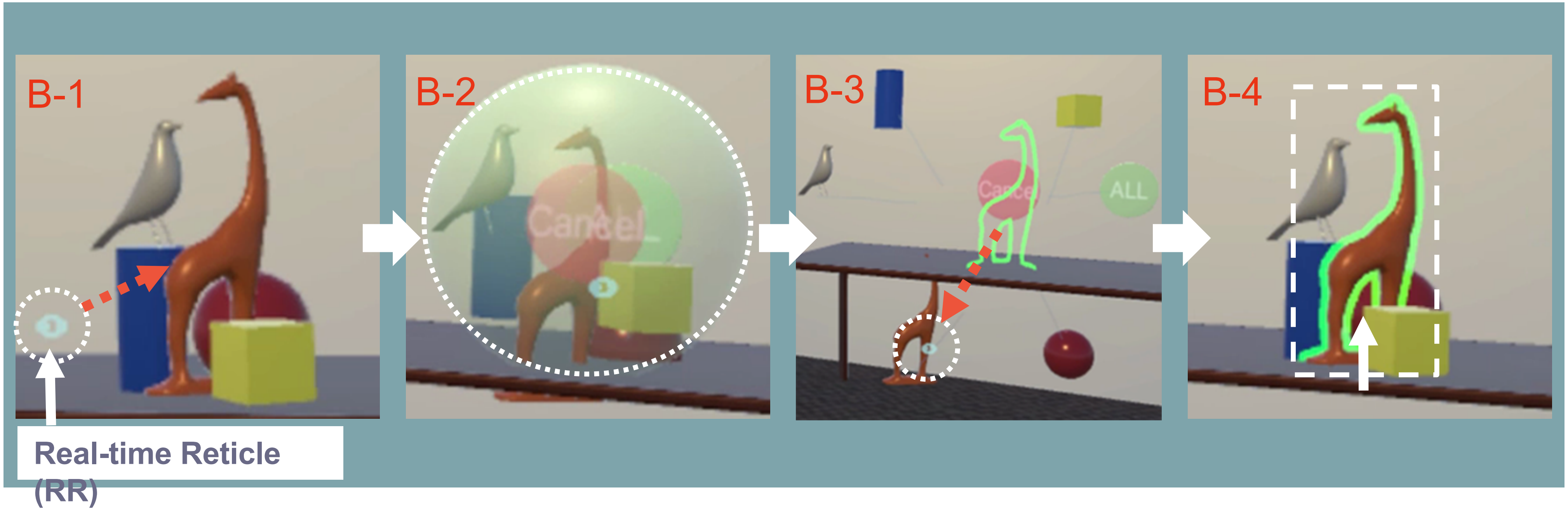


Piumsomboon, T., Lee, G., Lindeman, R. W., & Billinghurst, M. (2017, March). Exploring natural eye-gaze-based interaction for immersive virtual reality. In *3D User Interfaces (3DUI), 2017 IEEE Symposium on* (pp. 36-39). IEEE.

Duo-Reticles (DR)

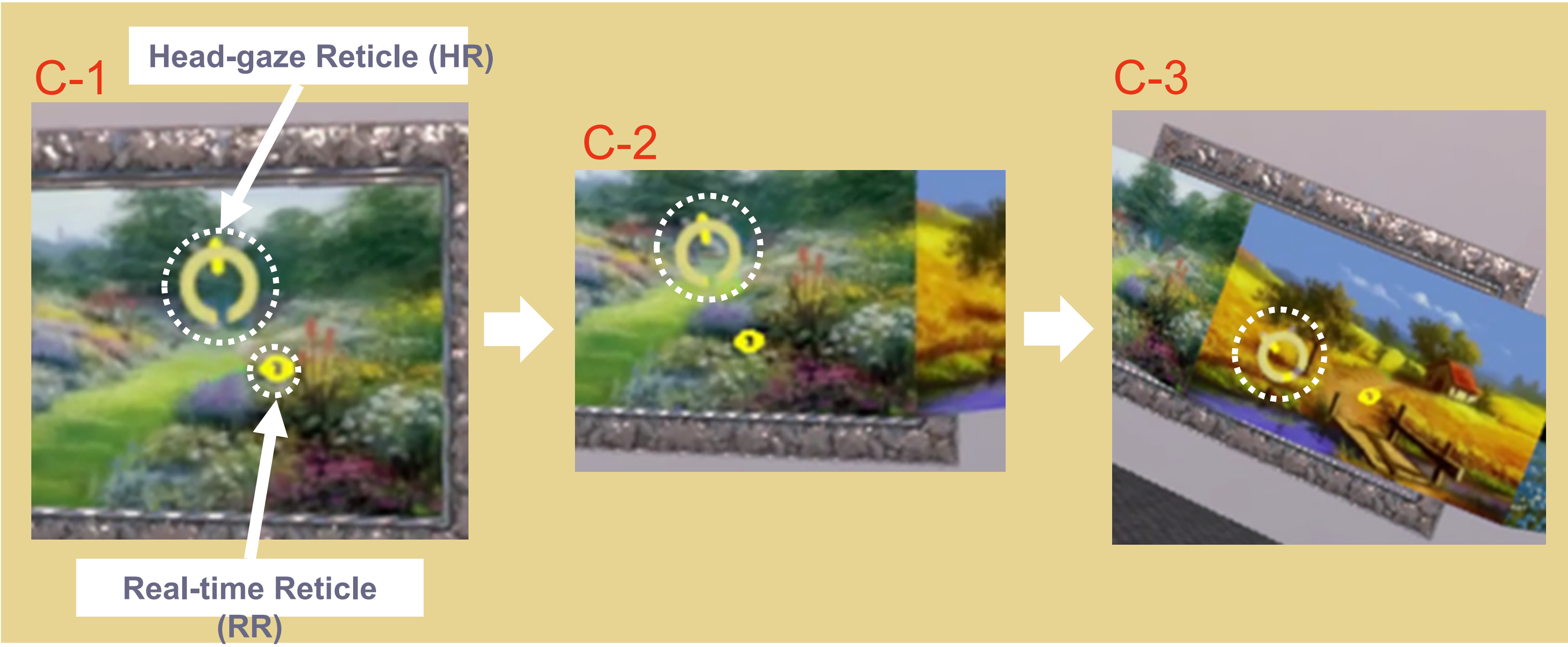


Radial Pursuit (RP)



$$d_{min} = \min(d_0, d_1, \ldots, d_k), d_i = \sum_{t=t_{initial}}^{n} |p(i)_t - p'_t|$$

Nod and Roll (NR)



Demo: Eye gaze interaction methods

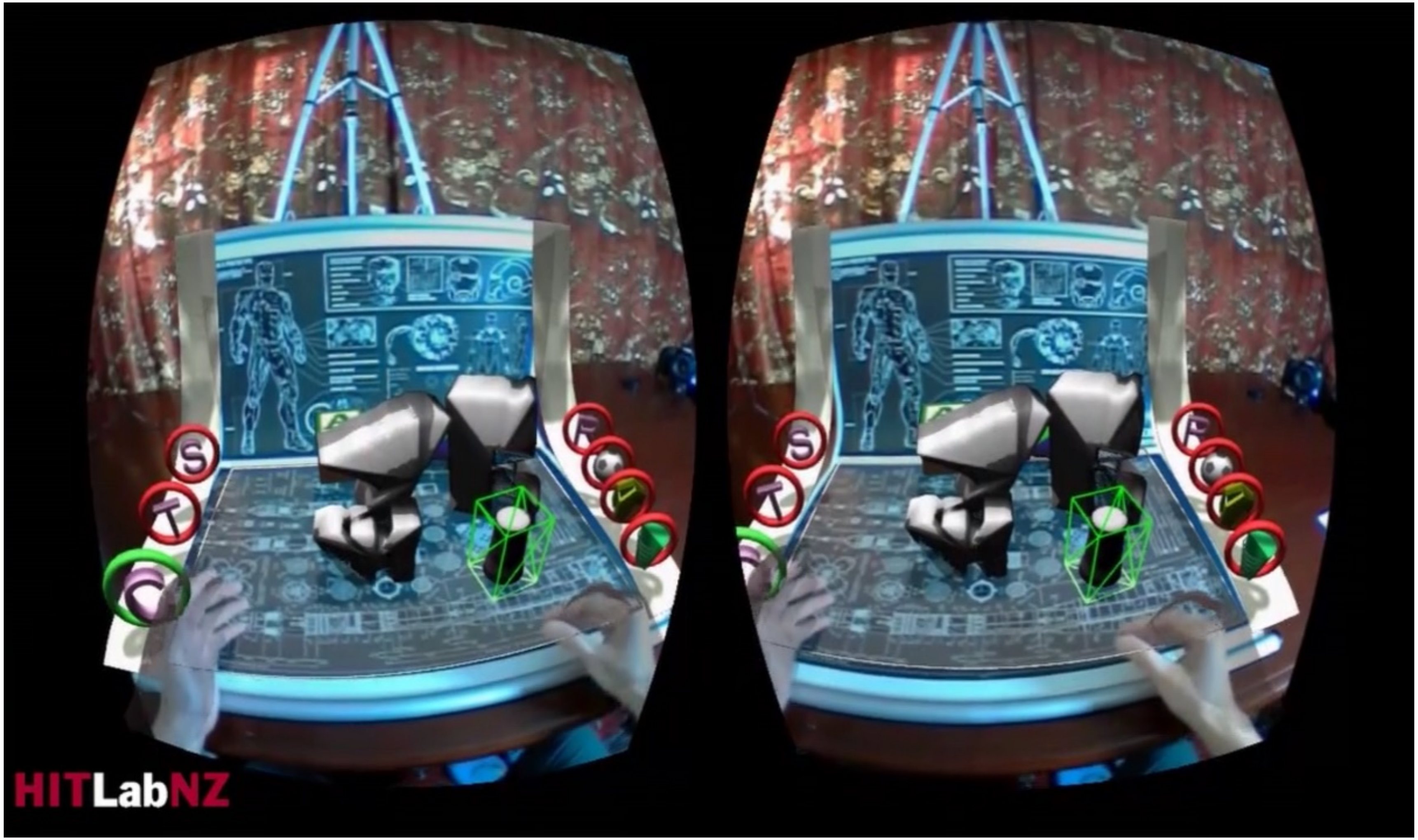
- https://www.youtube.com/watch?v=EpCGqxkmBKE

Multimodal Input (5+ years)

- Combine gesture and speech input
  - Gesture good for qualitative input
  - Speech good for quantitative input
  - Support combined commands
    - “Put that there” + pointing
- Eg HIT Lab NZ multimodal input
  - 3D hand tracking, speech
  - Multimodal fusion module
  - Complete tasks faster with MMI, less errors

Billinghurst, M., Piumsomboon, T., & Bai, H. (2014). Hands in Space: Gesture Interaction with Augmented-Reality Interfaces. *IEEE computer graphics and applications*, (1), 77-80.

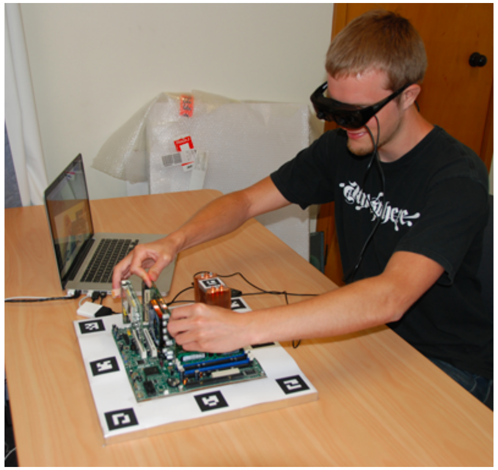
HIT Lab NZ Multimodal Input

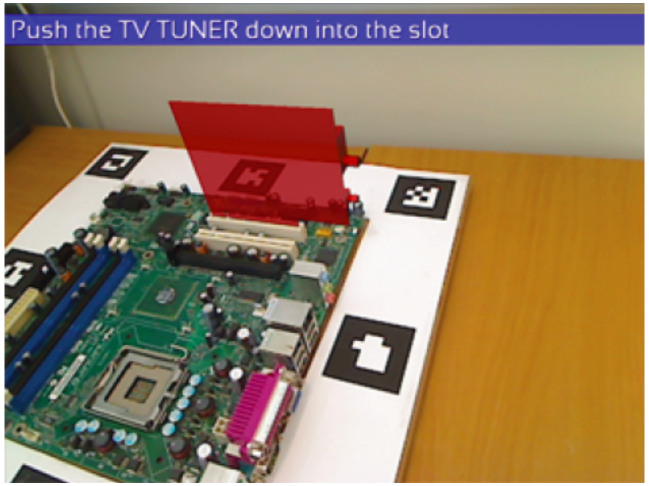


https://www.youtube.com/watch?v=DSsrzMxGwcA

Intelligent Interfaces (10+ years)

- Move to Implicit Input vs. Explicit
  - Recognize user behaviour
  - Provide adaptive feedback
  - Support scaffolded learning
  - Move beyond check-lists of actions
- Eg AR + Intelligent Tutoring
  - Constraint based ITS + AR
  - PC Assembly (Westerfield (2015)
    - 30% faster, 25% better retention





Westerfield, G., Mitrovic, A., & Billinghurst, M. (2015). Intelligent Augmented Reality Training for Motherboard Assembly. *International Journal of Artificial Intelligence in Education*, *25*(1), 157-172.

COLLABORATION

Collaborative VR Systems

Altspace VR

Facebook Spaces

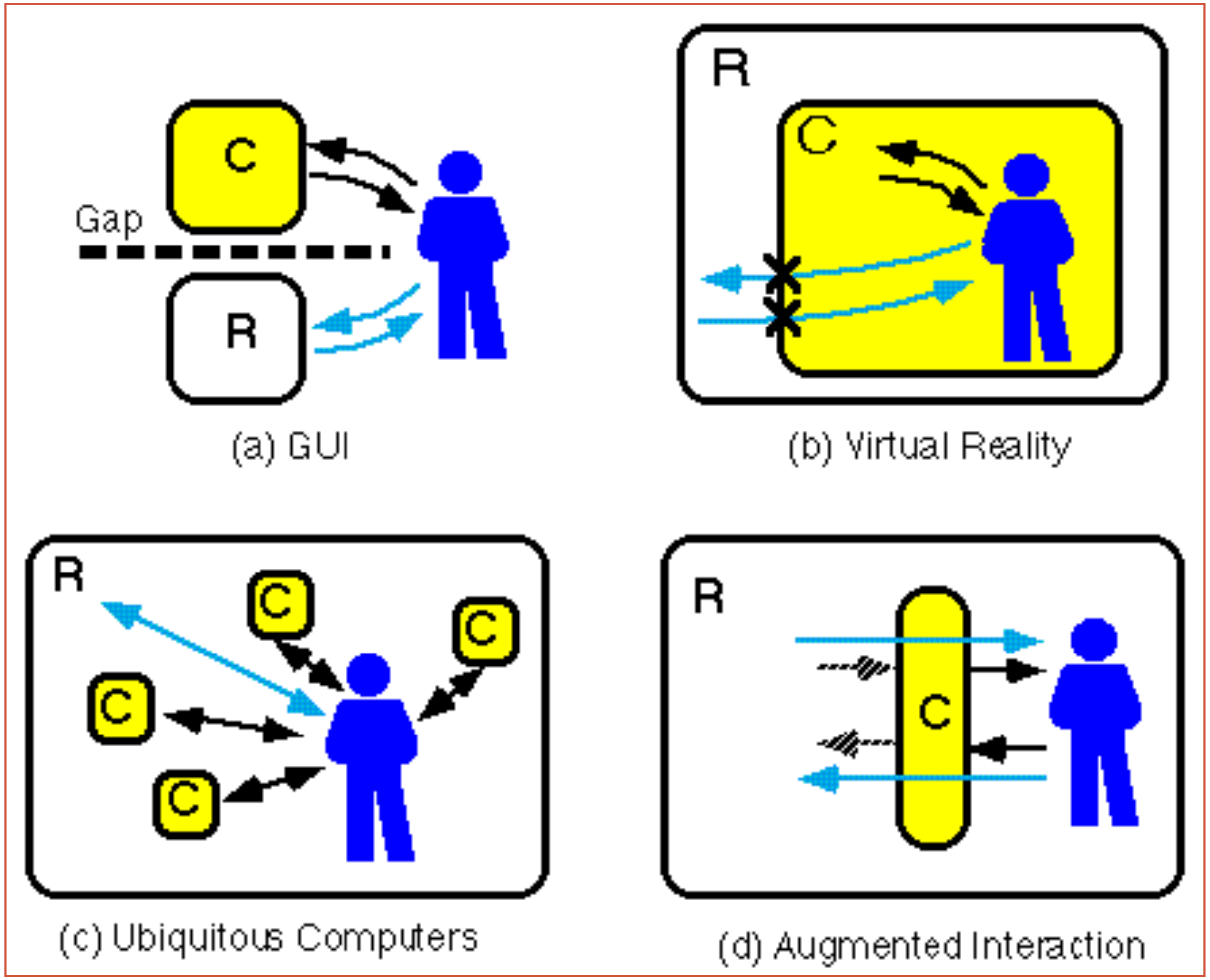
- Directions for research
  - Scalability – towards millions of users
  - Graphics – support for multiple different devices
  - User representation – realistic face/body input
  - Support for communication cues – messaging, recording, etc
- Goal: Collaboration in VR as good/better than FtF

Demo: High Fidelity

- https://www.youtube.com/watch?v=-ivL1DDwUK4

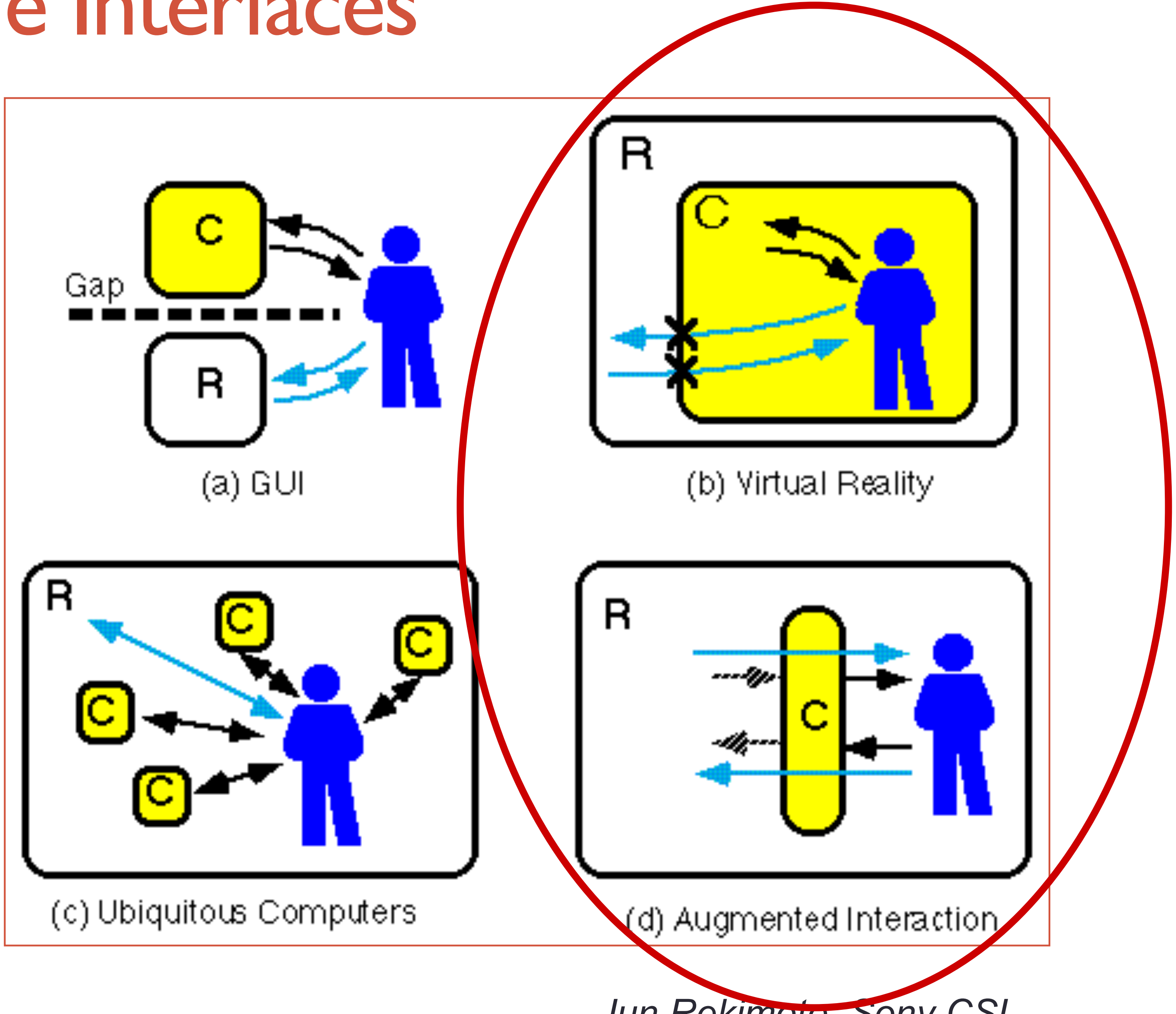
ENHANCED EXPERIENCES

Crossing Boundaries



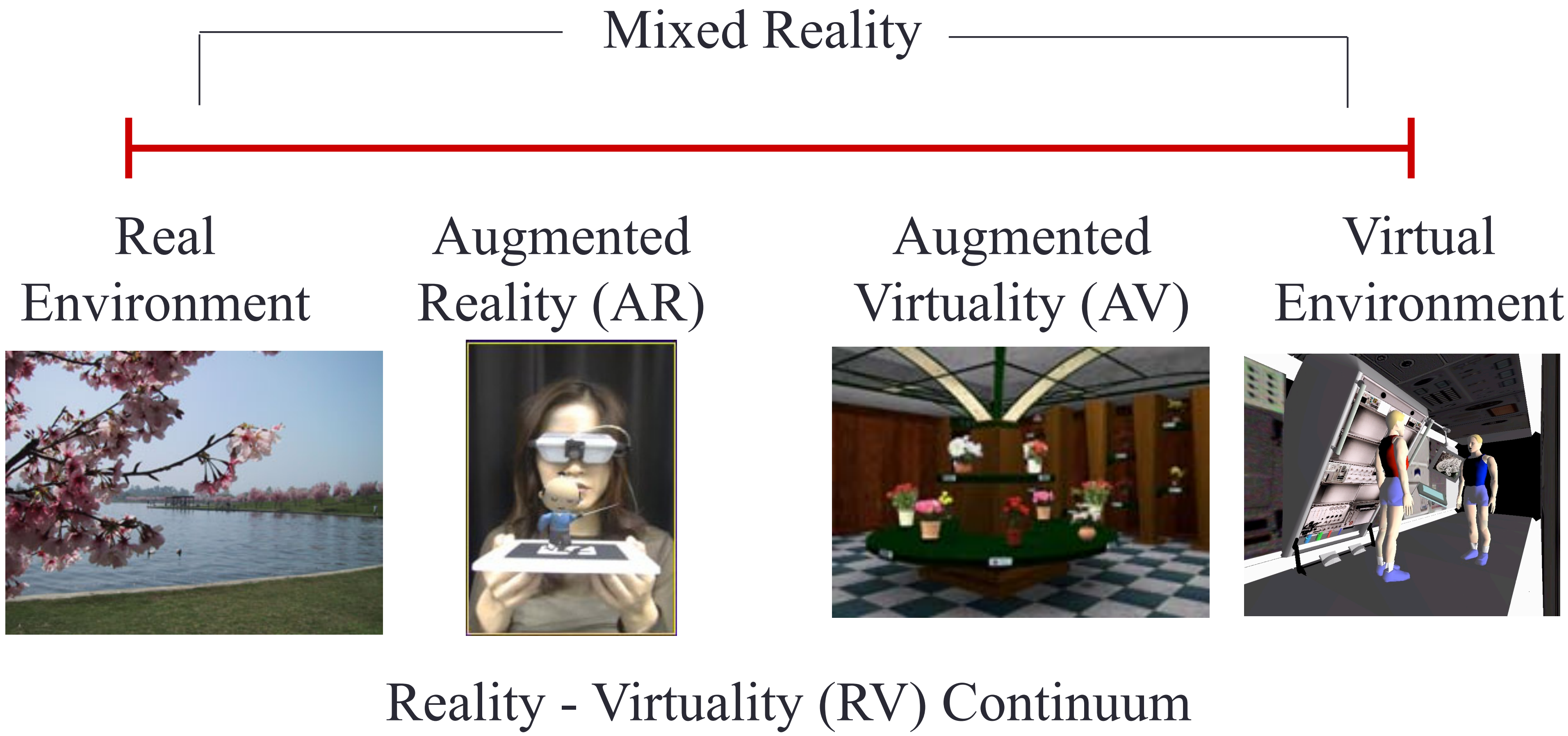
Jun Rekimoto, Sony CSL

Invisible Interfaces



Jun Rekimoto, Sony CSL

Milgram’s Reality-Virtuality continuum



The MagicBook

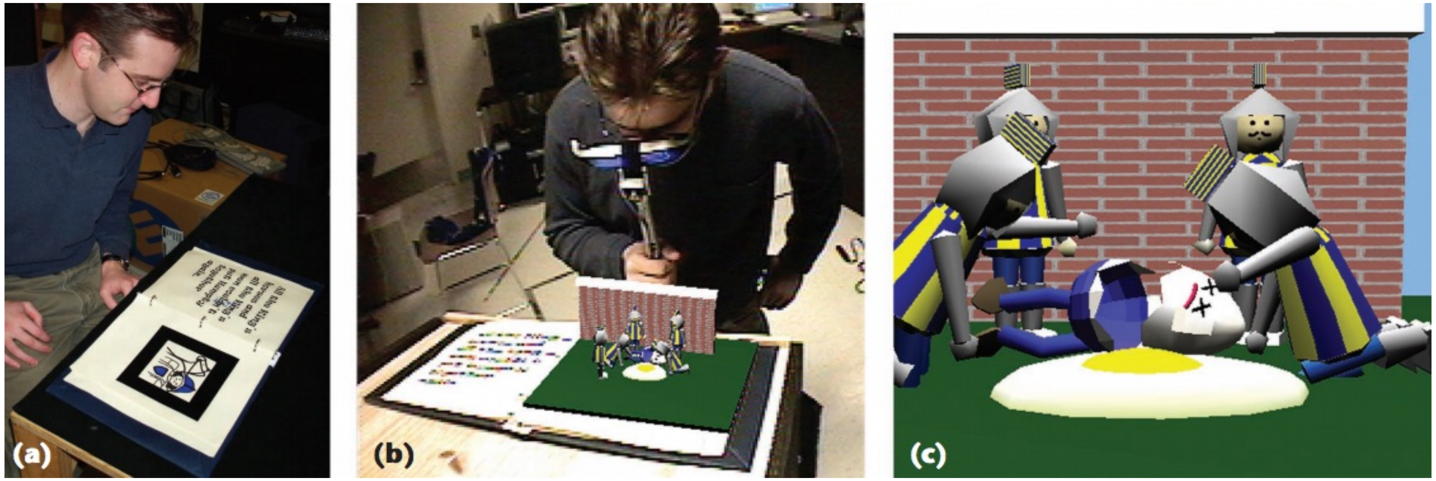
Reality

Augmented Reality (AR)

Augmented Virtuality (AV)

Virtuality

The MagicBook



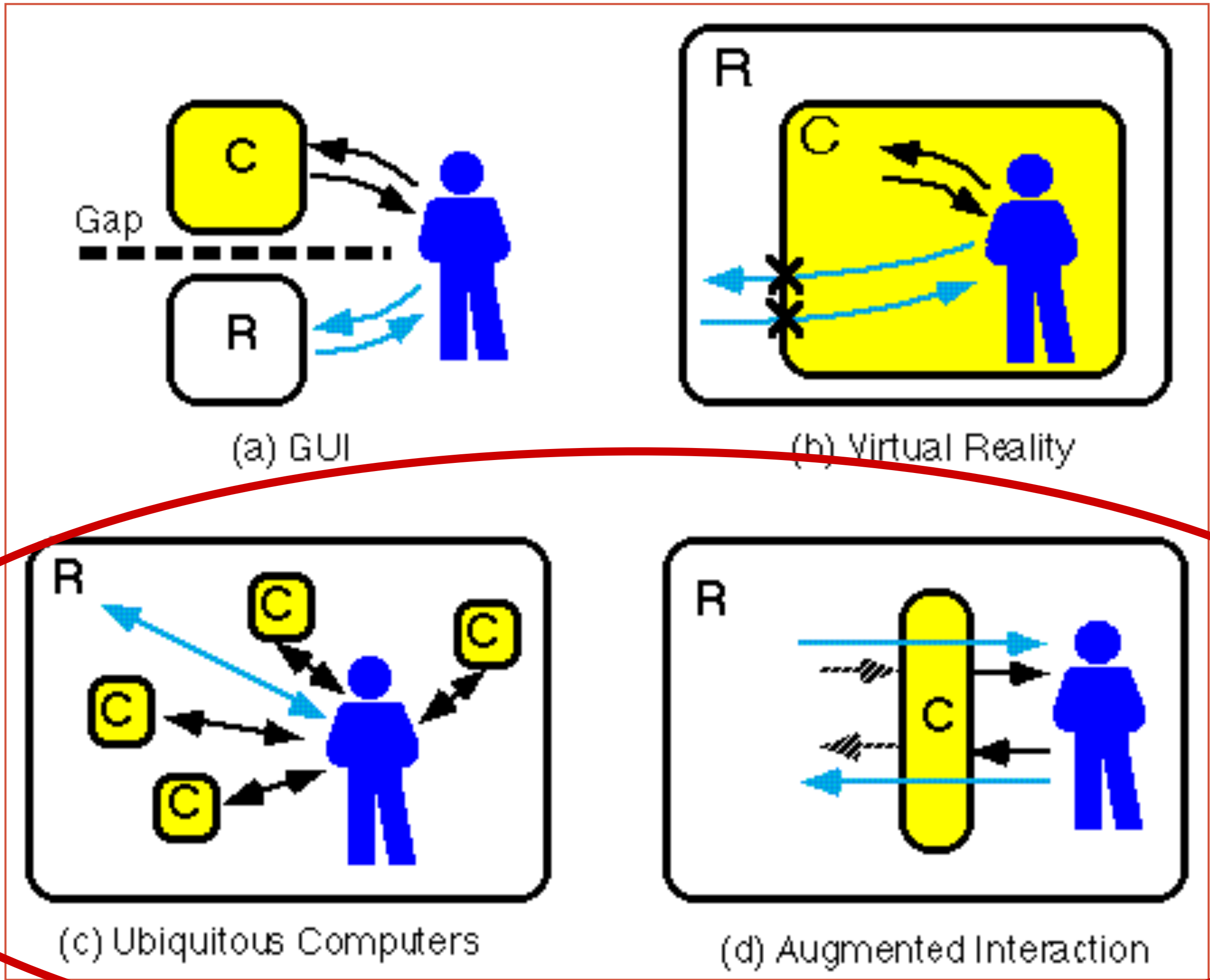
- Using AR to transition along Milgram's continuum
  - Moving seamlessly from Reality to AR to VR
- Support for Collaboration
  - Face to Face, Shared AR/VR, Multi-scale
- Natural interaction
  - Handheld AR and VR viewer

Billinghurst, M., Kato, H., & Poupyrev, I. (2001). The MagicBook: a transitional AR interface. *Computers & Graphics*, *25*(5), 745-753.

Demo: MagicBook

- https://www.youtube.com/watch?v=tNMljw0F-aw

Invisible Interfaces

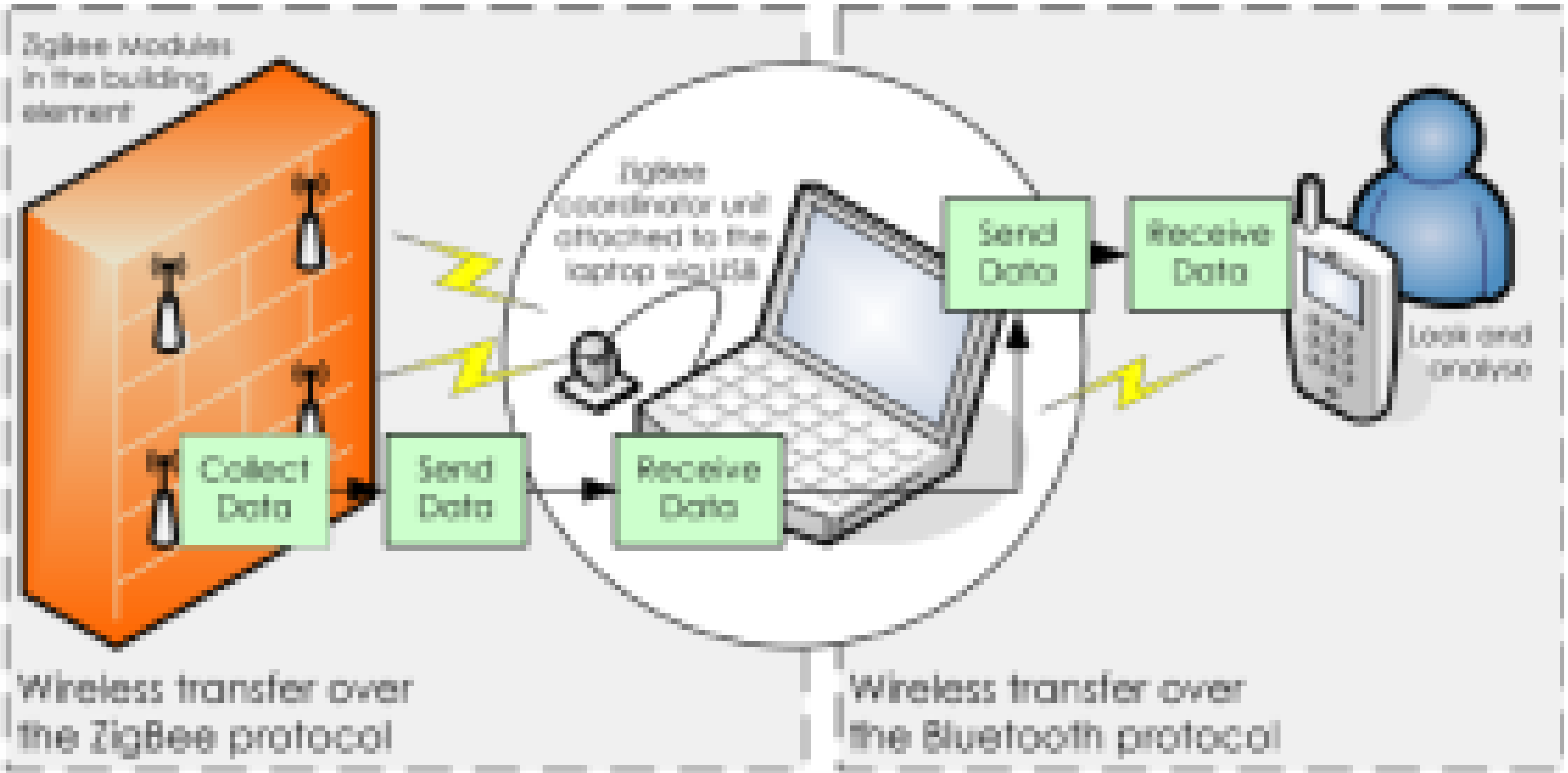


Jun Rekimoto, Sony CSL

Example: Visualizing Sensor Networks

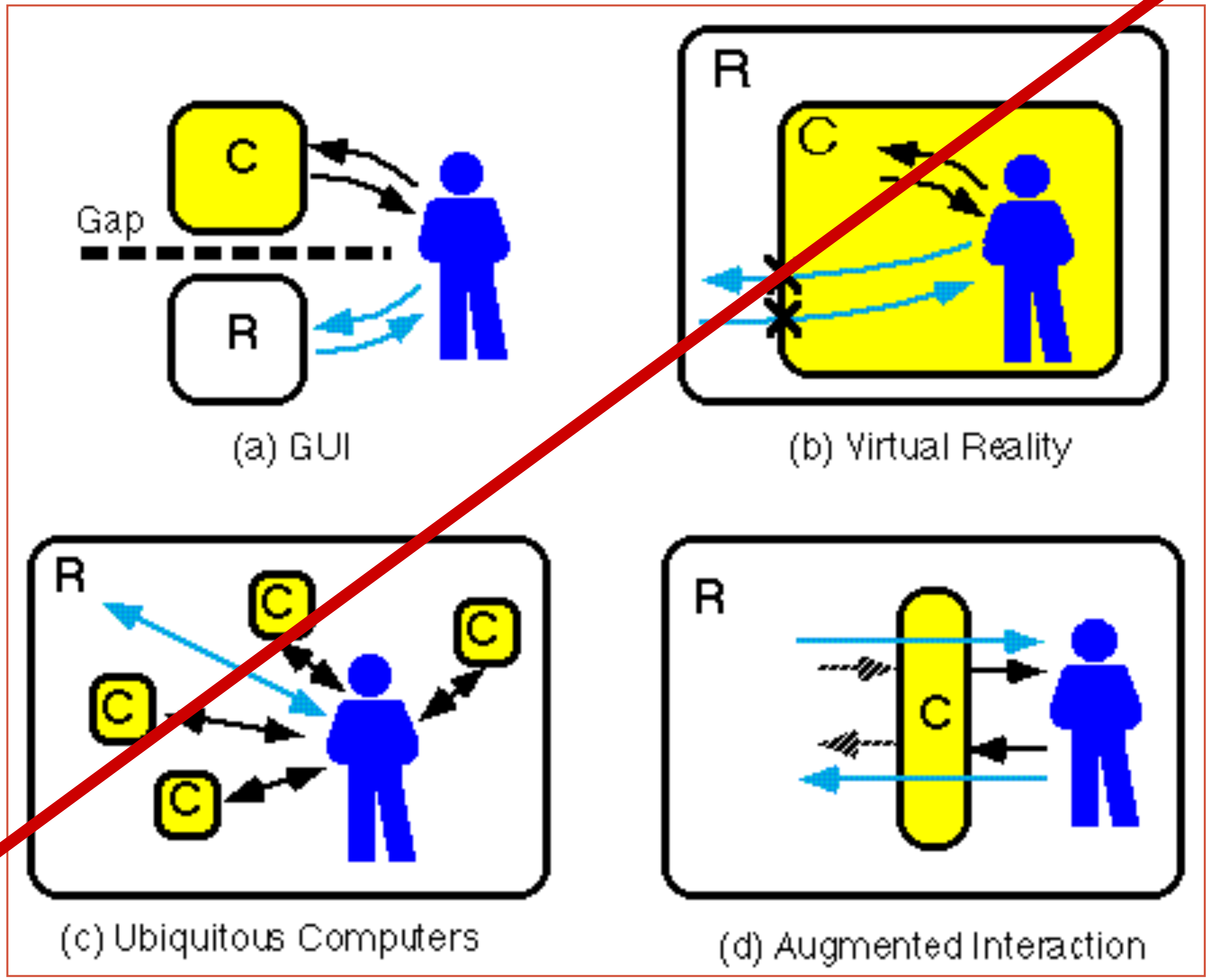
- Rauhala et. al. 2007 (Linkoping)
- Network of Humidity Sensors
  - ZigBee wireless communication
- Use Mobile AR to Visualize Humidity

Rauhala, M., Gunnarsson, A. S., & Henrysson, A. (2006). A novel interface to sensor networks using handheld augmented reality. In *Proceedings of the 8th conference on Human-computer interaction with mobile devices and services*(pp. 145-148). ACM.


ZigBee Modules
in the building
element
ZigBee
coordinator unit
attached to the
laptop via USB
Collect
Data
Send
Data
Receive
Data
Send
Data
Receive
Data
Look and
analyse
Wireless transfer over
the ZigBee protocol
Wireless transfer over
the Bluetooth protocol

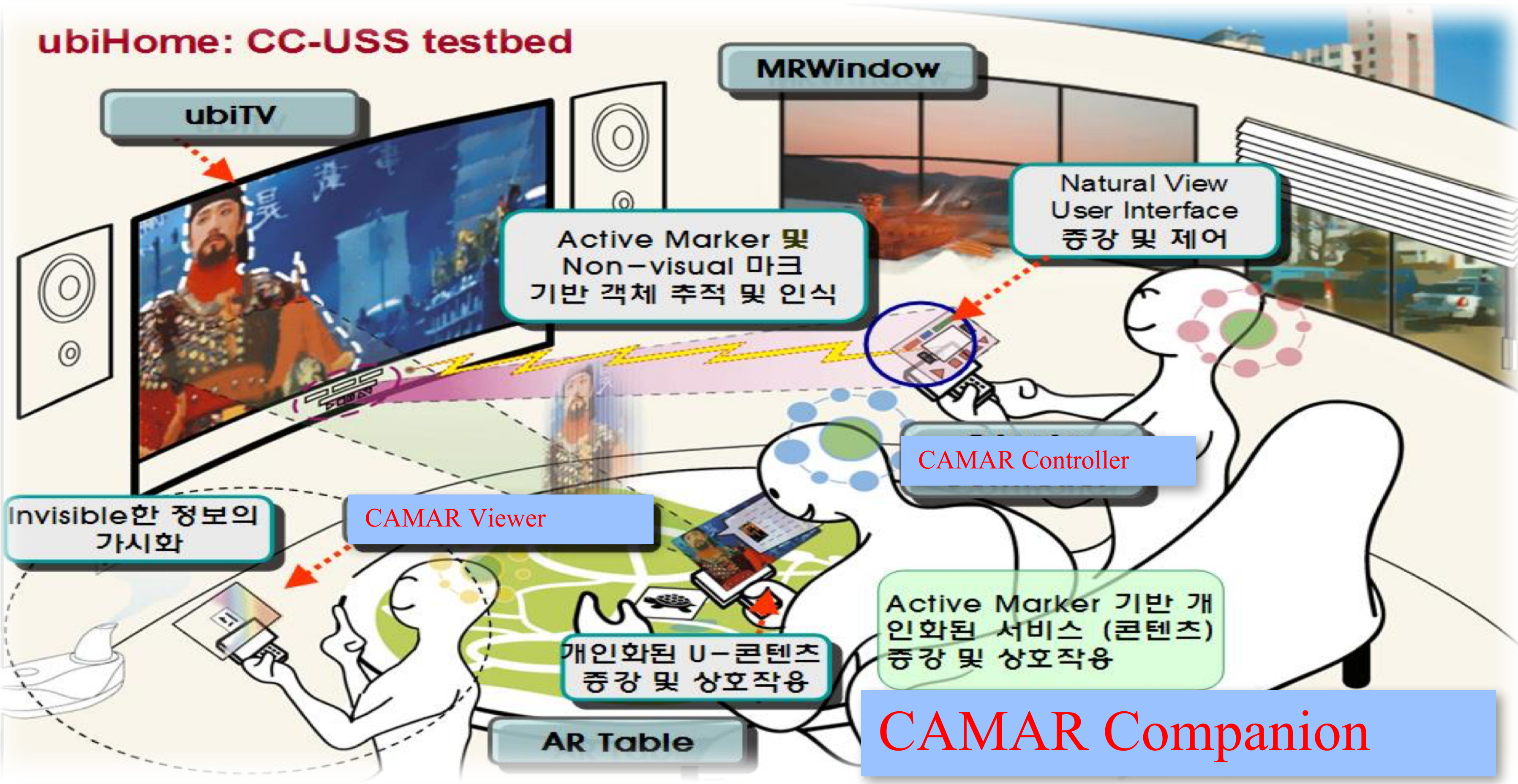
- Humidity information overlaid on real world shown in mobile AR

Invisible Interfaces



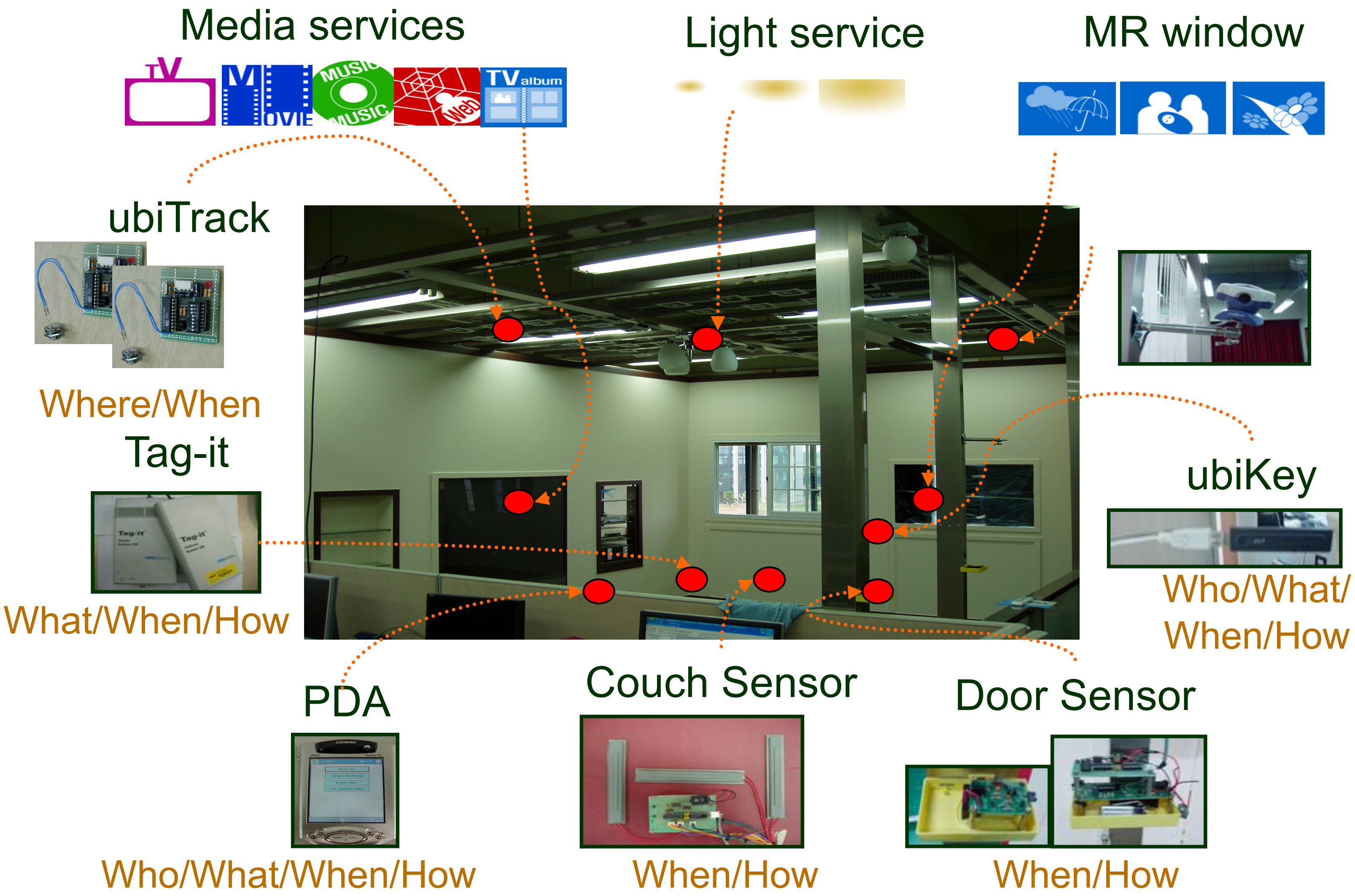
Jun Rekimoto, Sony CSL

UbiVR – CAMAR



GIST - Korea

ubiHome @ GIST

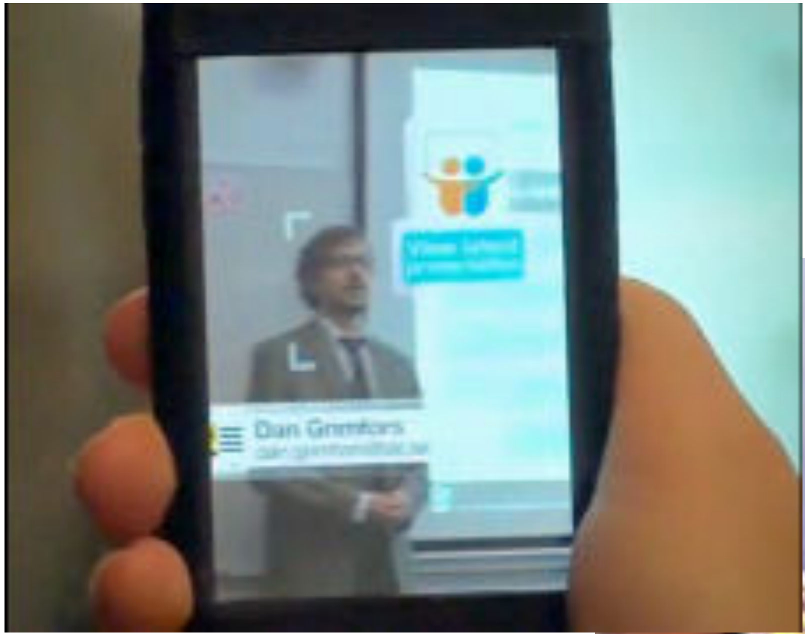


SOCIAL ACCEPTANCE

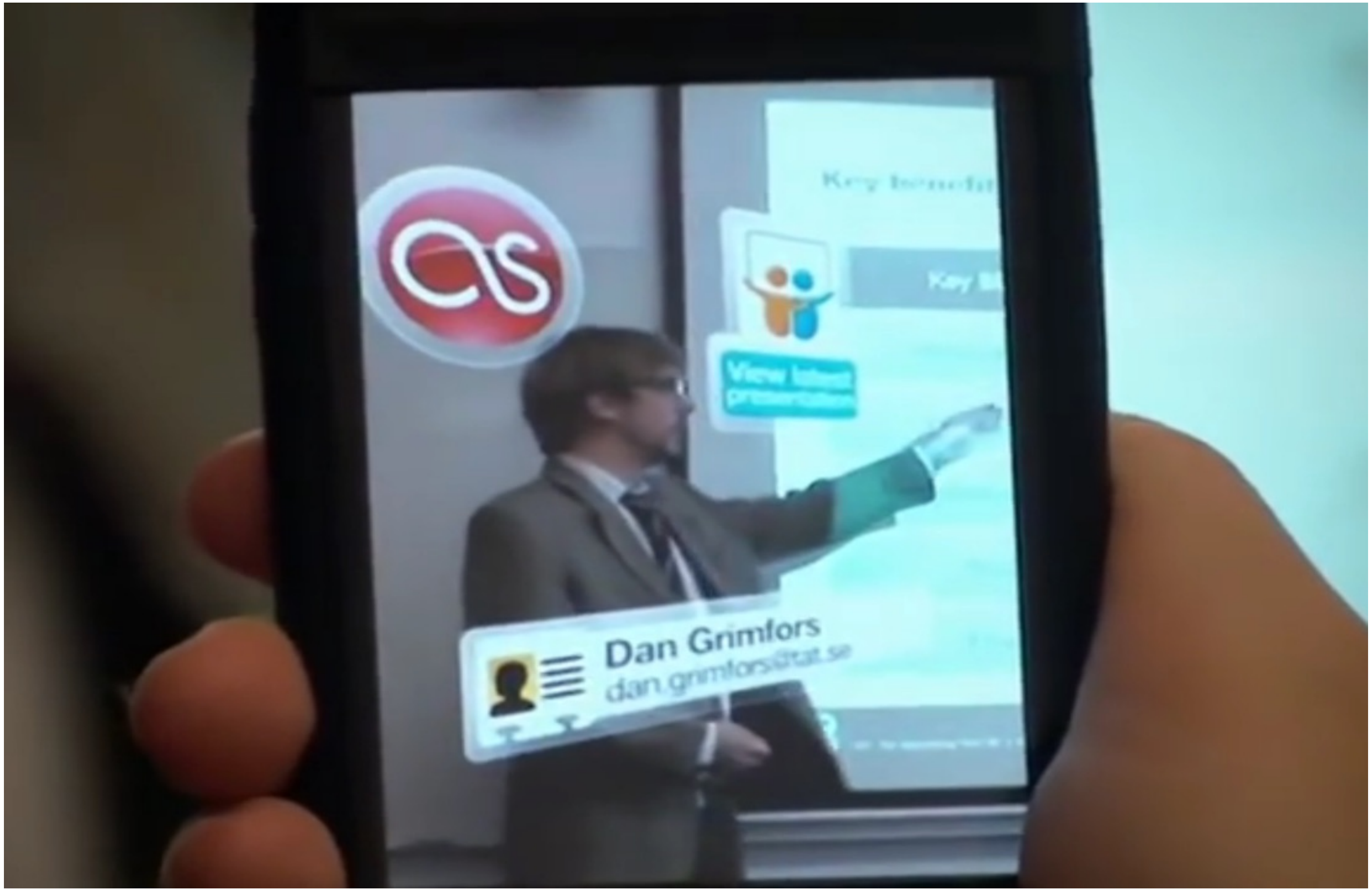
Example: Social Acceptance

- People don’t want to look silly
  - Only 12% of 4,600 adults would be willing to wear AR glasses
  - 20% of mobile AR browser users experience social issues
- Acceptance more due to Social than Technical issues
  - Needs further study (ethnographic, field tests, longitudinal)

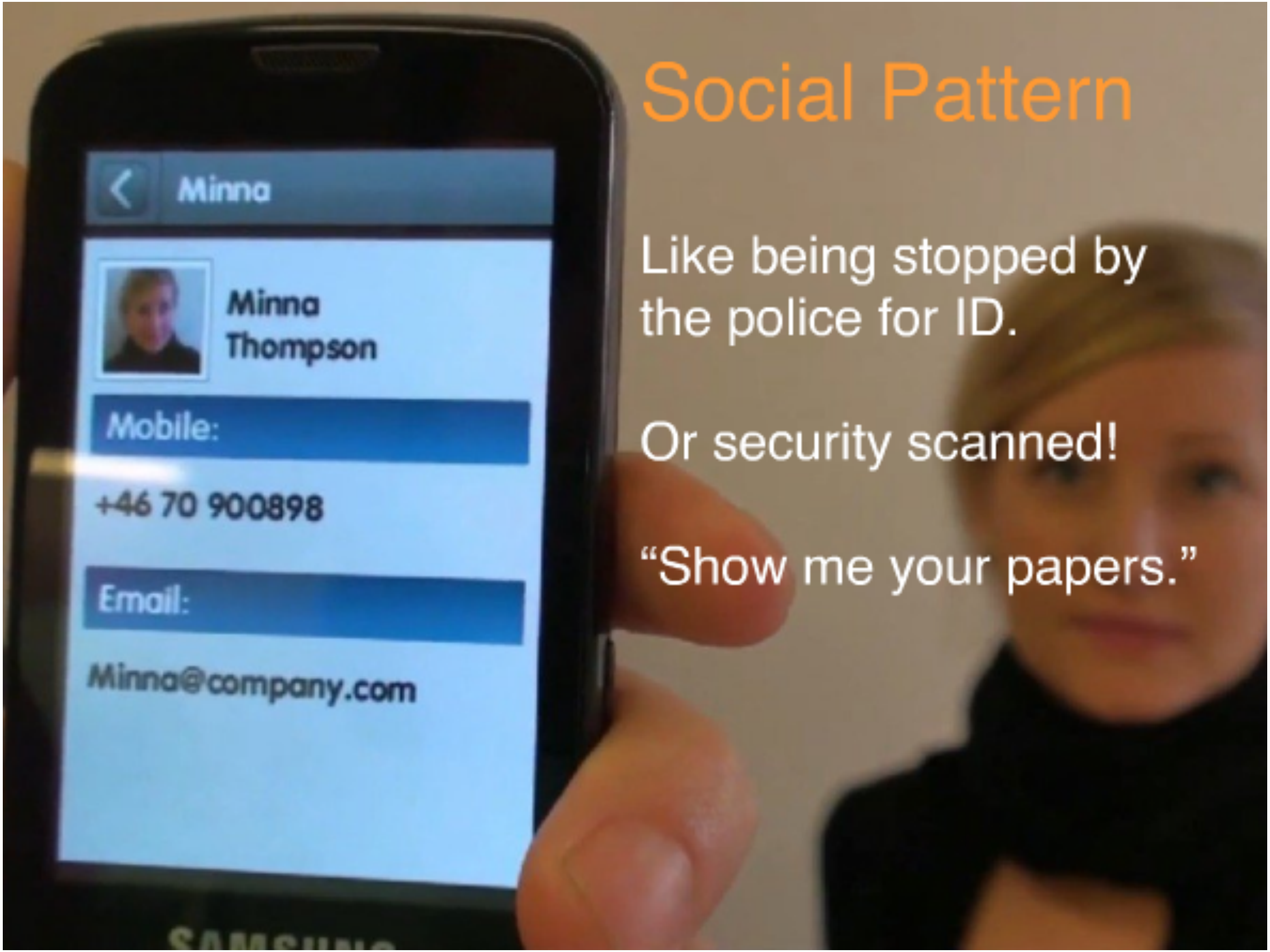
TAT Augmented ID



TAT AugmentedID

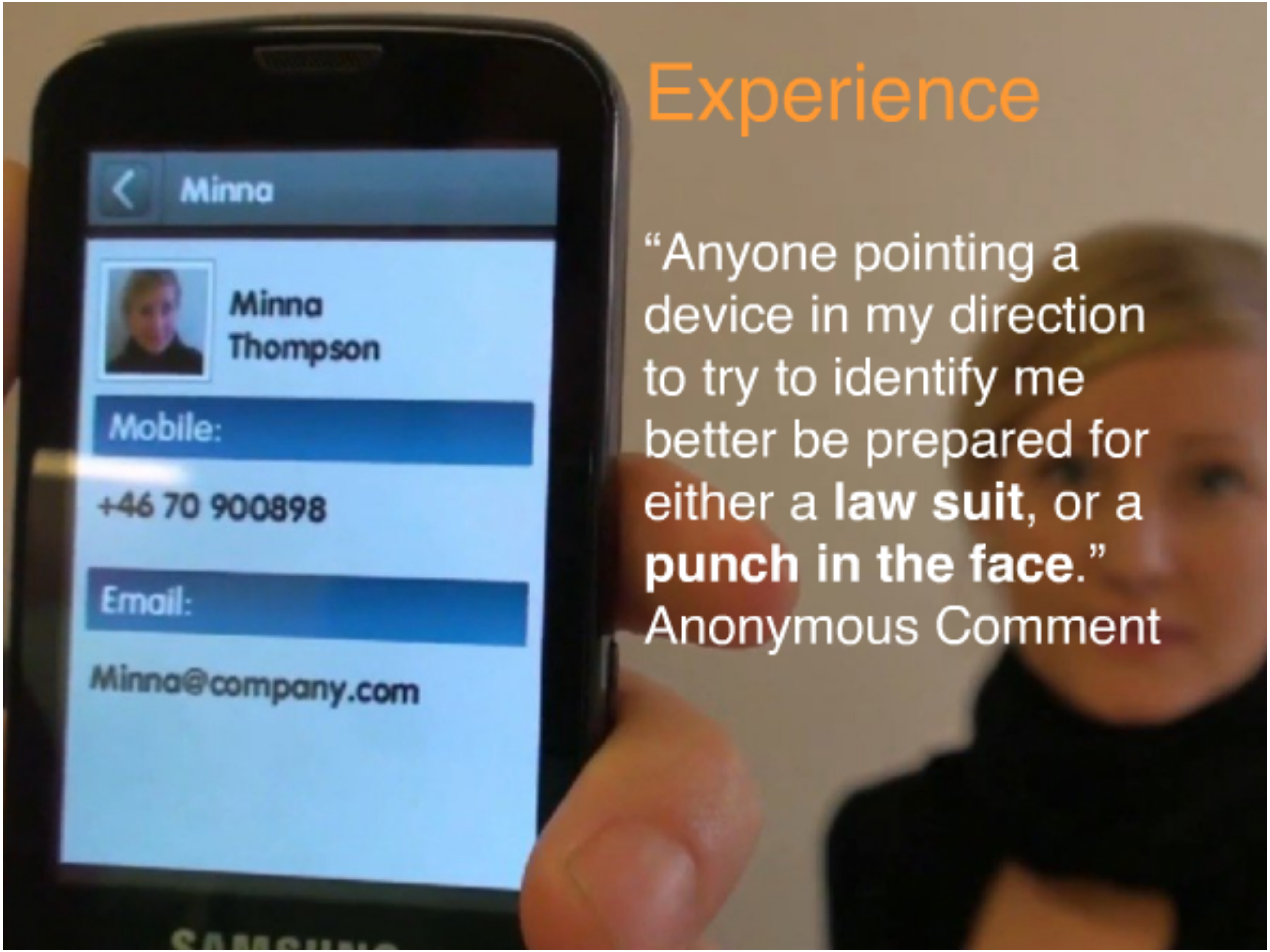


https://www.youtube.com/watch?v=tb0pMeg1UN0


Social Pattern
Like being stopped by the police for ID.
Or security scanned!
“Show me your papers.”
Minna
Minna Thompson
Mobile:
+46 70 900898
Email:
Minna@company.com

Experience

“Anyone pointing a device in my direction to try to identify me better be prepared for either a **law suit**, or a **punch in the face**.”
Anonymous Comment



CONCLUSIONS

Research Needed in Many Areas

- Collaborative Experiences
  - VR/AR teleconferencing
- Social Acceptance
  - Overcome social problems with AR/VR
- Cloud Services
  - Cloud based storage/processing
- Authoring Tools
  - Easy content creation for non-experts for AR/VR
- Etc..

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