LECTURE 10: MOBILE AR

COMP 4010 – Virtual Reality
Semester 5 – 2017

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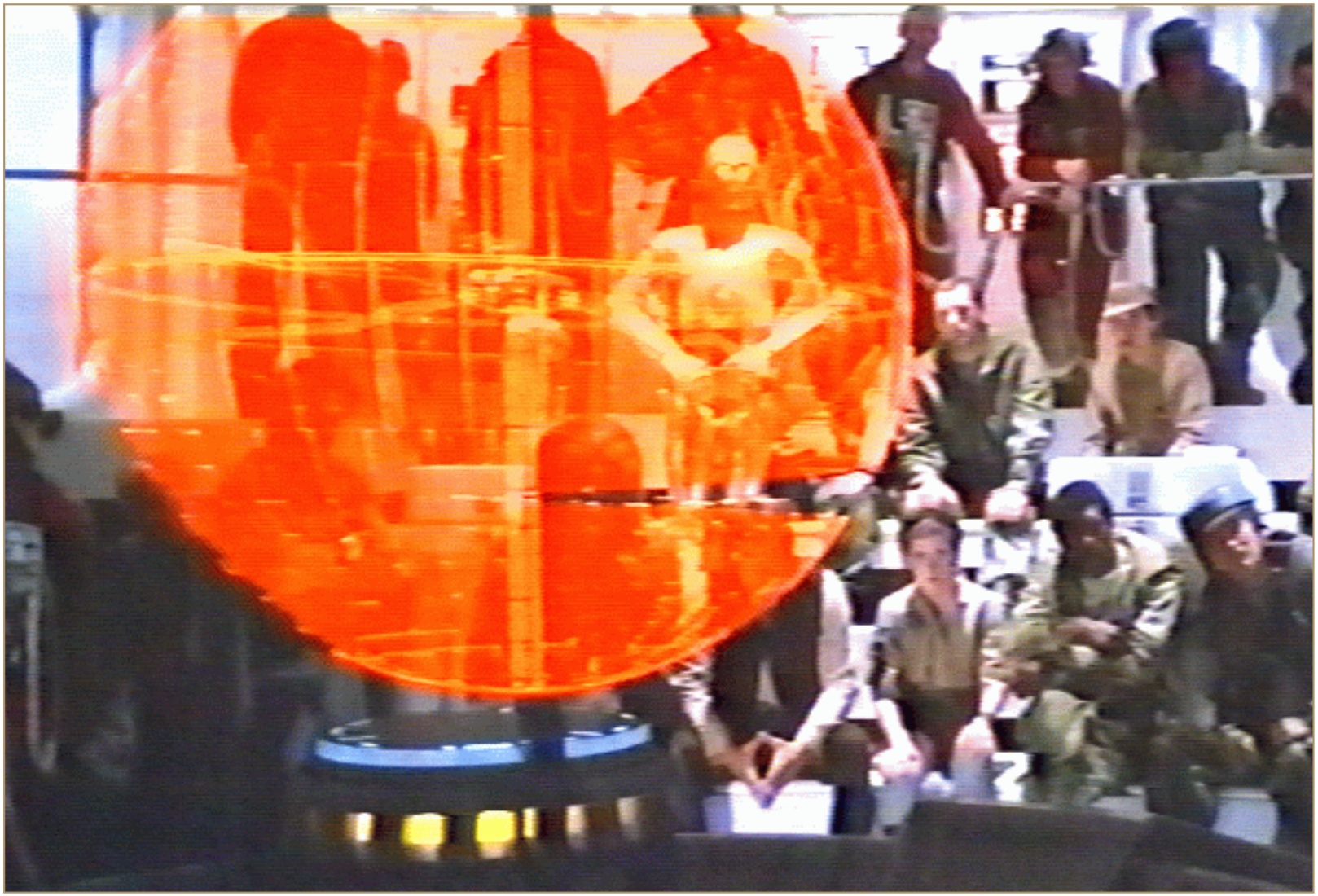
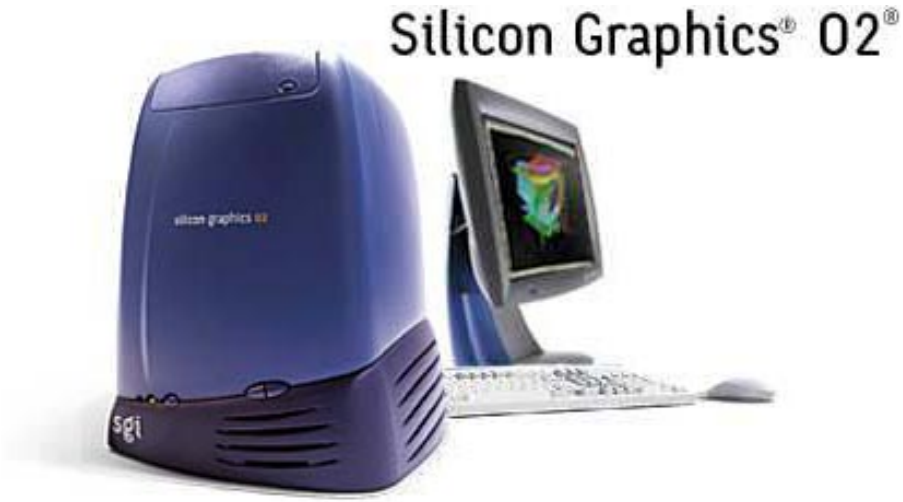
1983 – Star Wars – Collaborative AR



1999 – Shared Space Demo

- Face to face collaborative AR like Star Wars concept

1998: SGI O2



CPU: 300 Mhz
HDD; 9GB
RAM: 512 mb
Camera: VGA 30fps
Graphics: 500K poly/sec

2008: Nokia N95

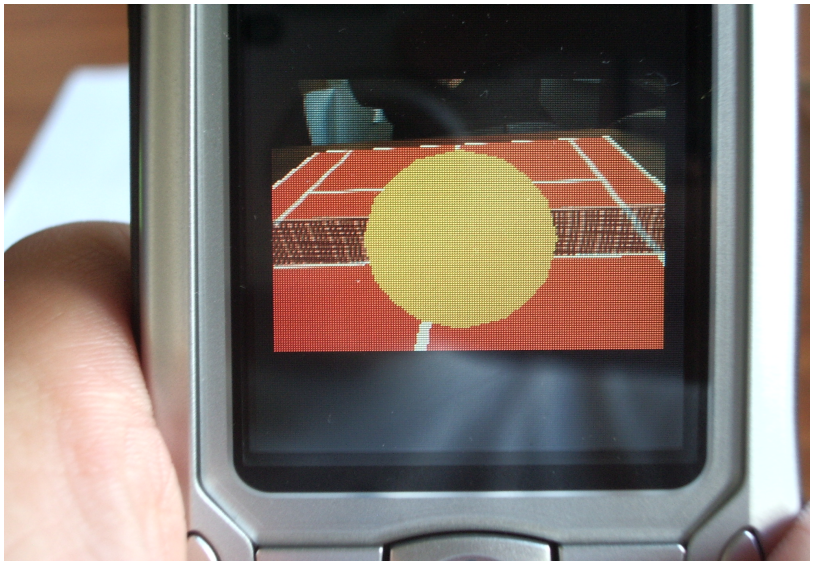
CPU: 332 Mhz
HDD; 8GB
RAM: 128 mb
Camera: VGA 30 fps
Graphics: 2m poly/sec

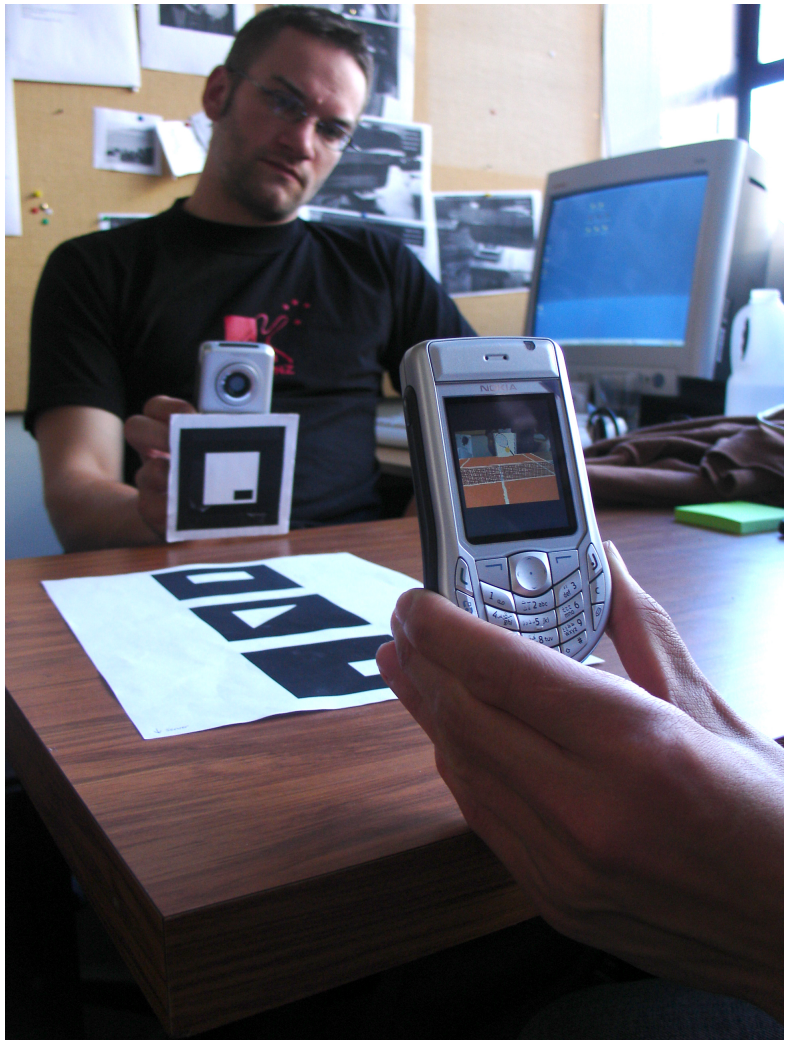
By 2008 phones had the same hardware as used in Shared Space demo

Mobile Phone AR

- Mobile Phones
  - camera
  - processor
  - display
- AR on Mobile Phones
  - Simple graphics
  - Optimized computer vision
  - Collaborative Interaction

2005: Mobile AR version of Shared Space

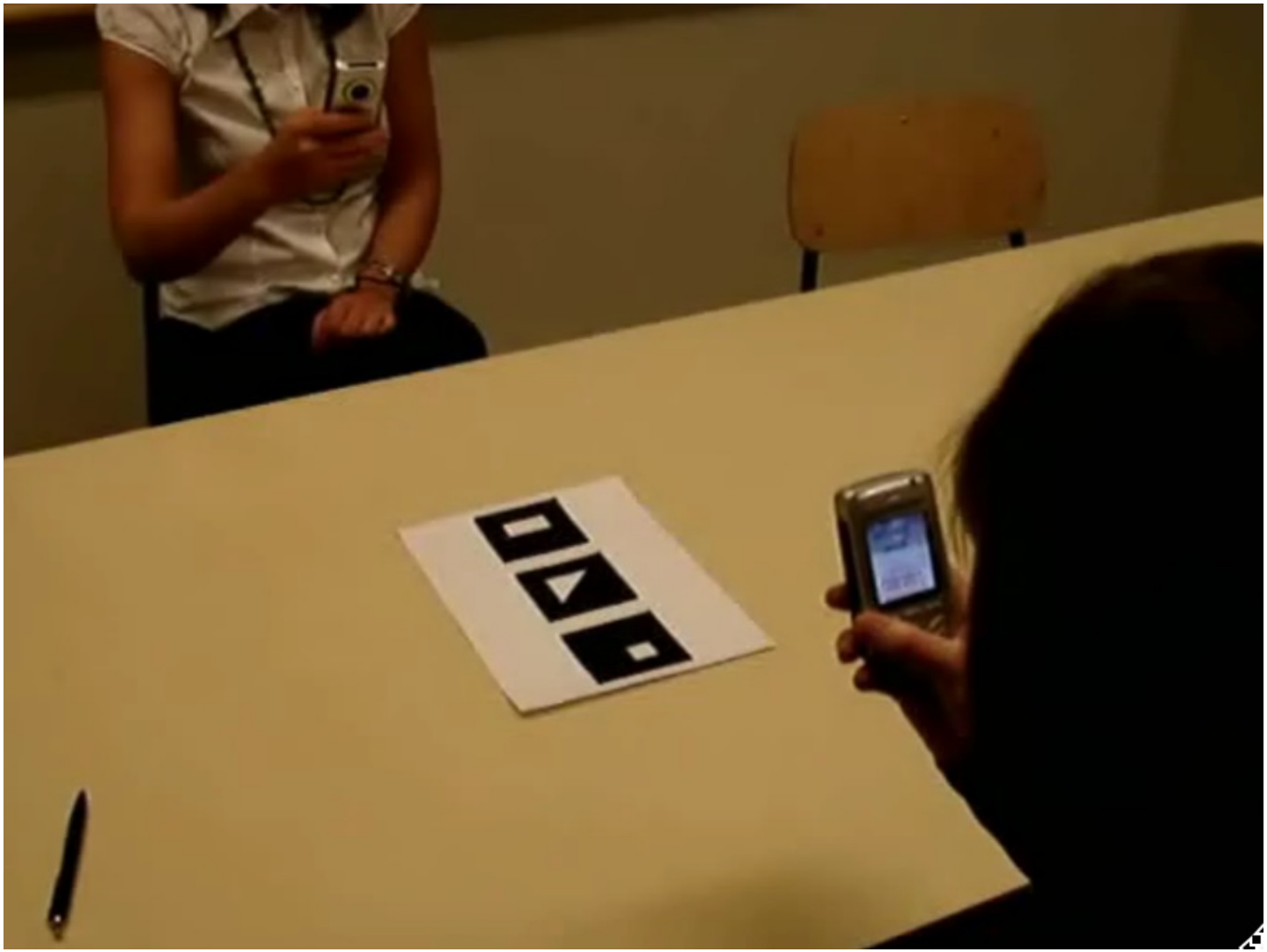




- AR Tennis
  - Shared AR content
  - Two user game
  - Audio + haptic feedback
  - Bluetooth networking

Henrysson, A., Billinghurst, M., & Ollila, M. (2005, October). Face to face collaborative AR on mobile phones. In *Proceedings of ISMAR 2005. Proceedings.* (pp. 80-89). IEEE.

ARTennis Demo

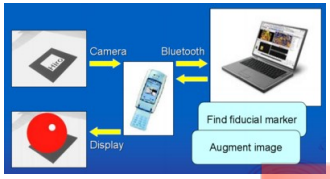


https://www.youtube.com/watch?v=HbsCqvzaRso

Mobile AR History

Evolution of Mobile AR

Camera phone



Camera phone
- Thin client AR

Wearable Computers

Wearable AR

Camera phone
- Self contained AR

Handheld AR Displays

PDAs
-Thin client AR

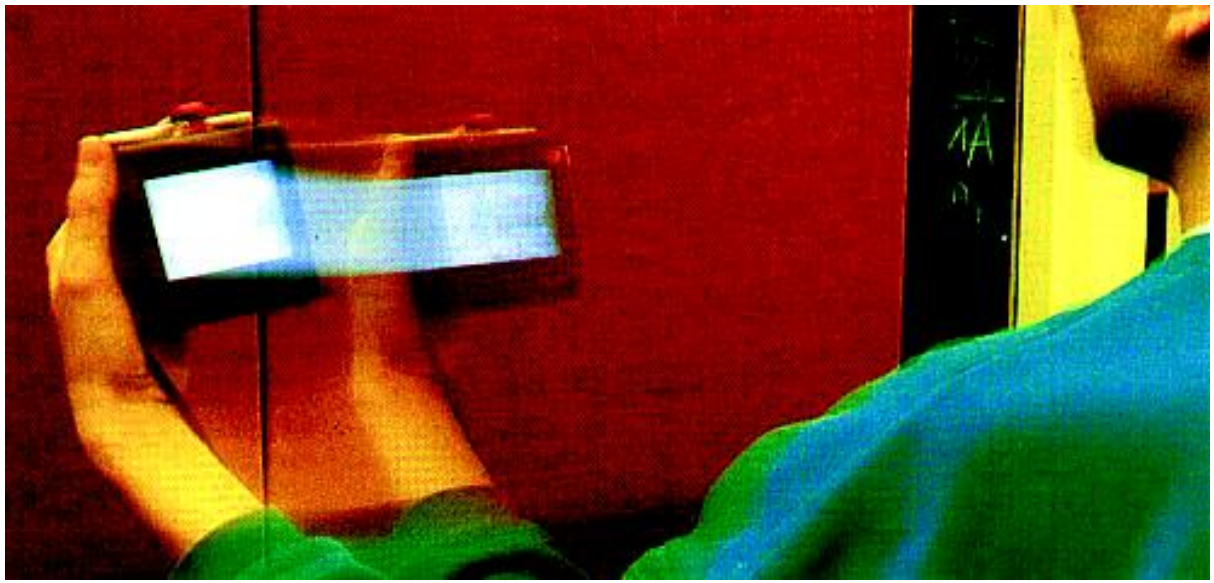
PDAs
-Self contained AR

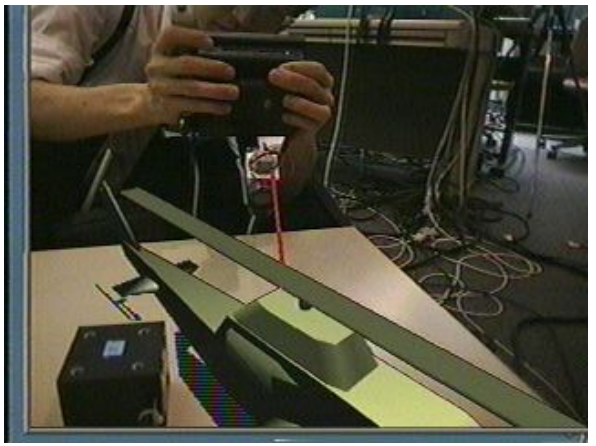
1995 1997 2001 2003 2004

Handheld Displays

Tethered Applications

- Fitzmaurice Chameleon (1994)
- Rekimoto's Transvision (1995)
- Tethered LCD
- PC Processing and Tracking





Example: AR Pad (Mogilev 2002)

Handheld AR Display

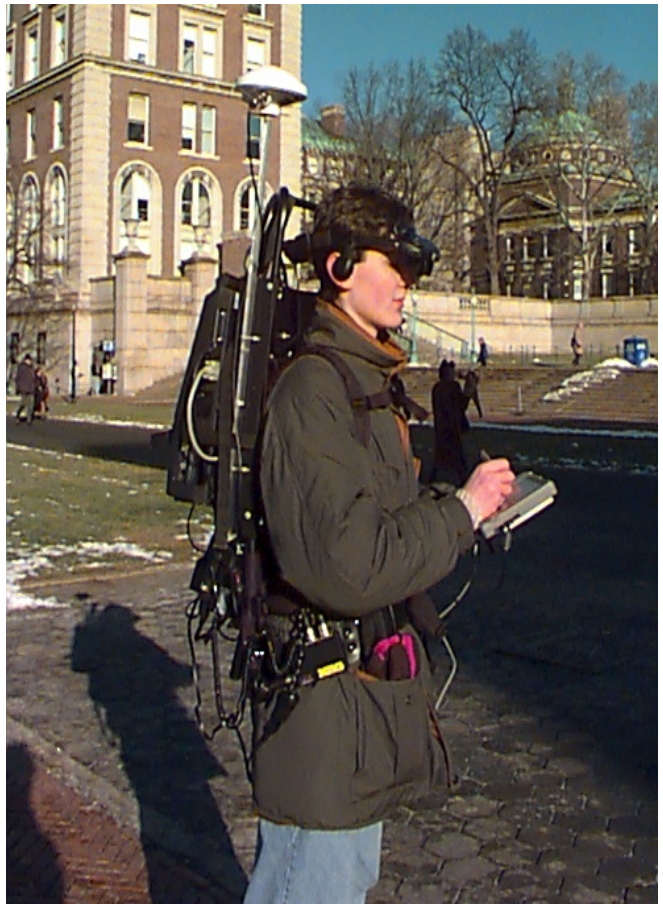
- LCD screen
- Camera
- SpaceOrb 3 DOF controller
- Peripheral awareness
- Viewpoint awareness

Demo: ARpad

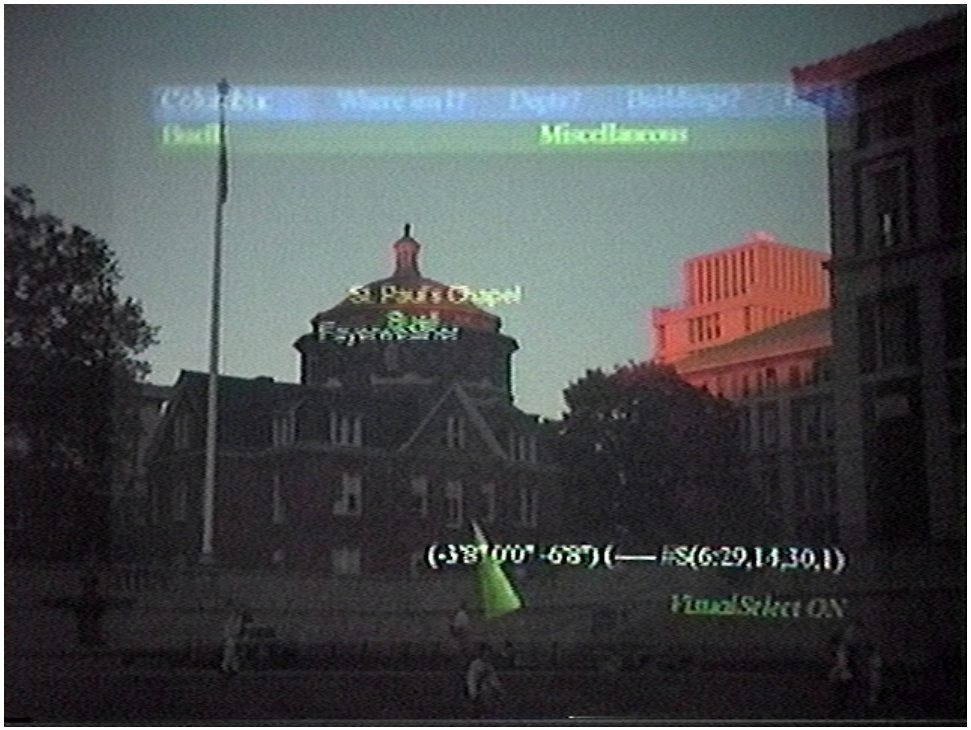
- https://www.youtube.com/watch?v=kC4vTJHCwq4

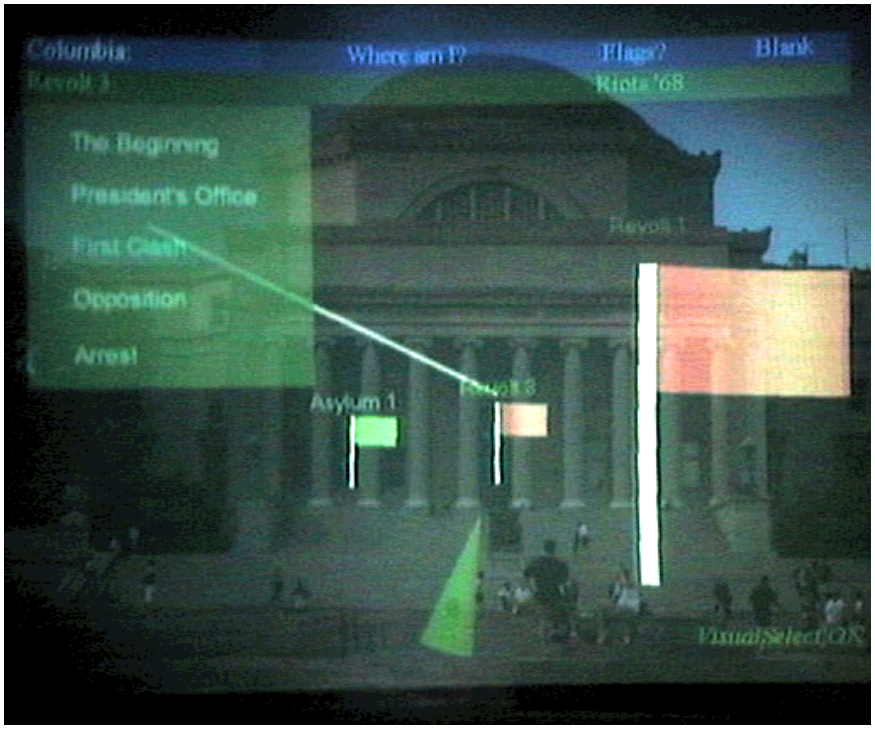
Backpack AR: Touring Machine (1997)

- University of Columbia
  - Feiner, MacIntyre, Höllerer, Webster
- Combines
  - See through head mounted display
  - GPS tracking
  - Orientation sensor
  - Backpack PC (custom)
  - Tablet input



MARS View



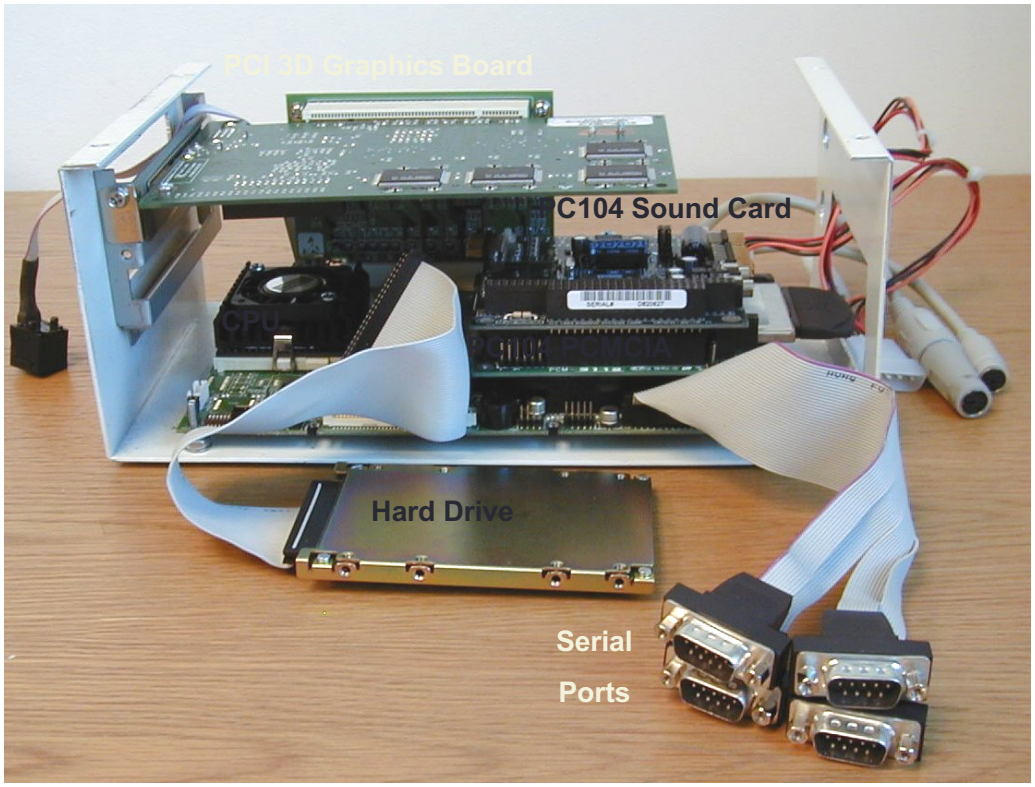


- Virtual tags overlaid on the real world
- “Information in place”

Backpack AR - Hardware

Columbia *Touring Machine*

Example self-built working solution with PCI-based 3D graphics



More Backpack/Wearable AR Systems

1997 Backpack AR

- Feiner's Touring Machine
- AR Quake (Thomas)
- Tinmith (Piekarski)
- MCAR (Reitmayr)
- Bulky, HMD based

Demo: Trimble Backpack AR (2003)

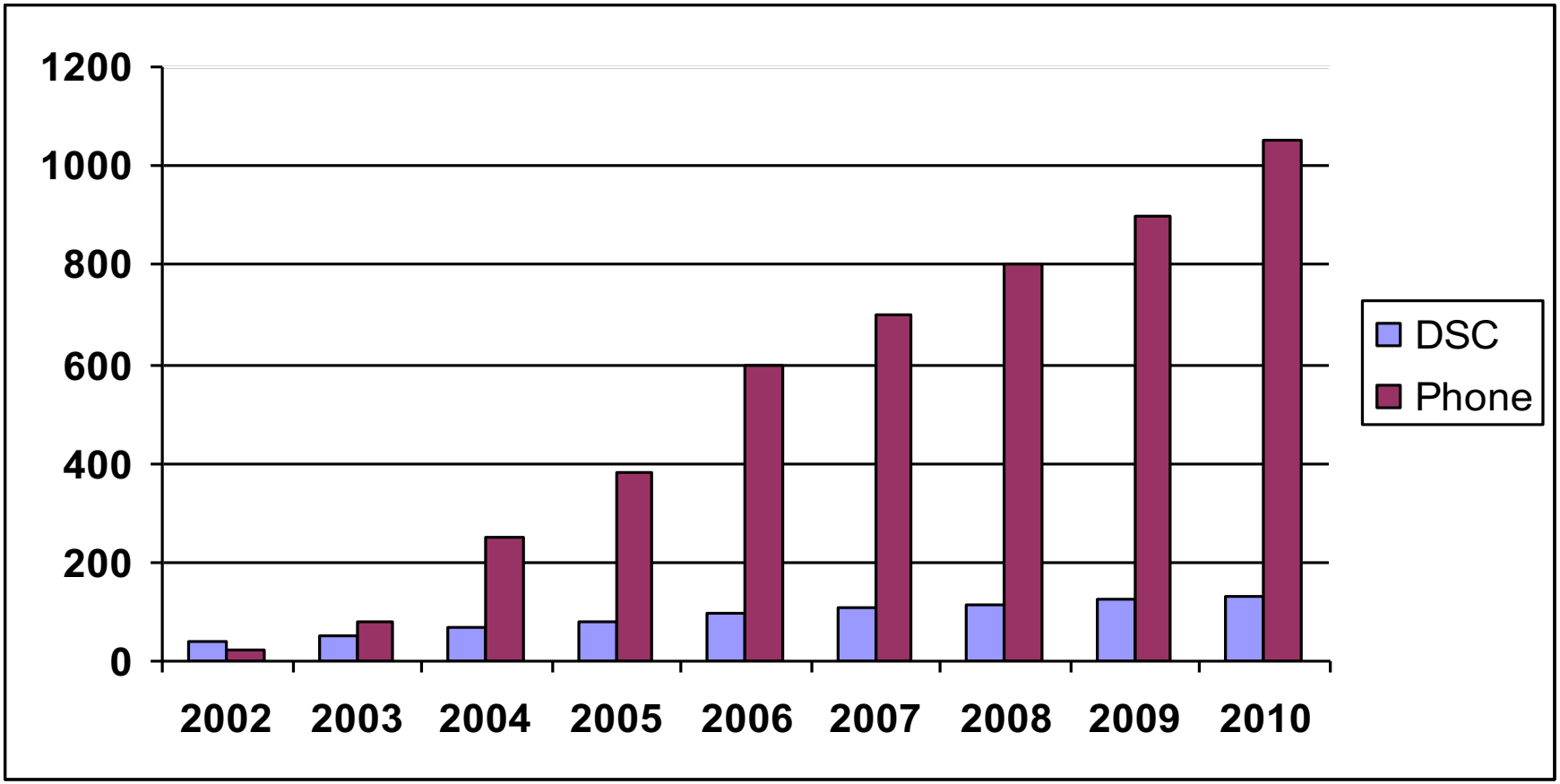
https://www.youtube.com/watch?v=jL3C-OVQKWU

Mobile Phone Cameras

Sharp J-SH04

- 1997 Philip Kahn invents camera phone
- 1999 First commercial camera phone

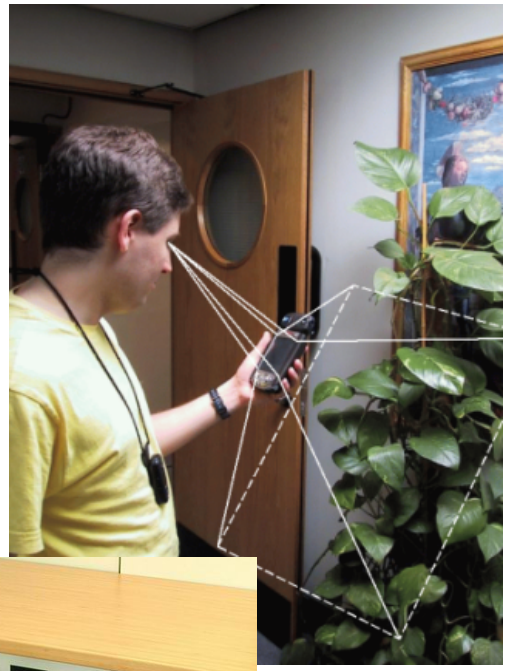
Millions of Camera Phones



Handheld AR – Thin Client

2001 BatPortal (AT&T Cambridge)

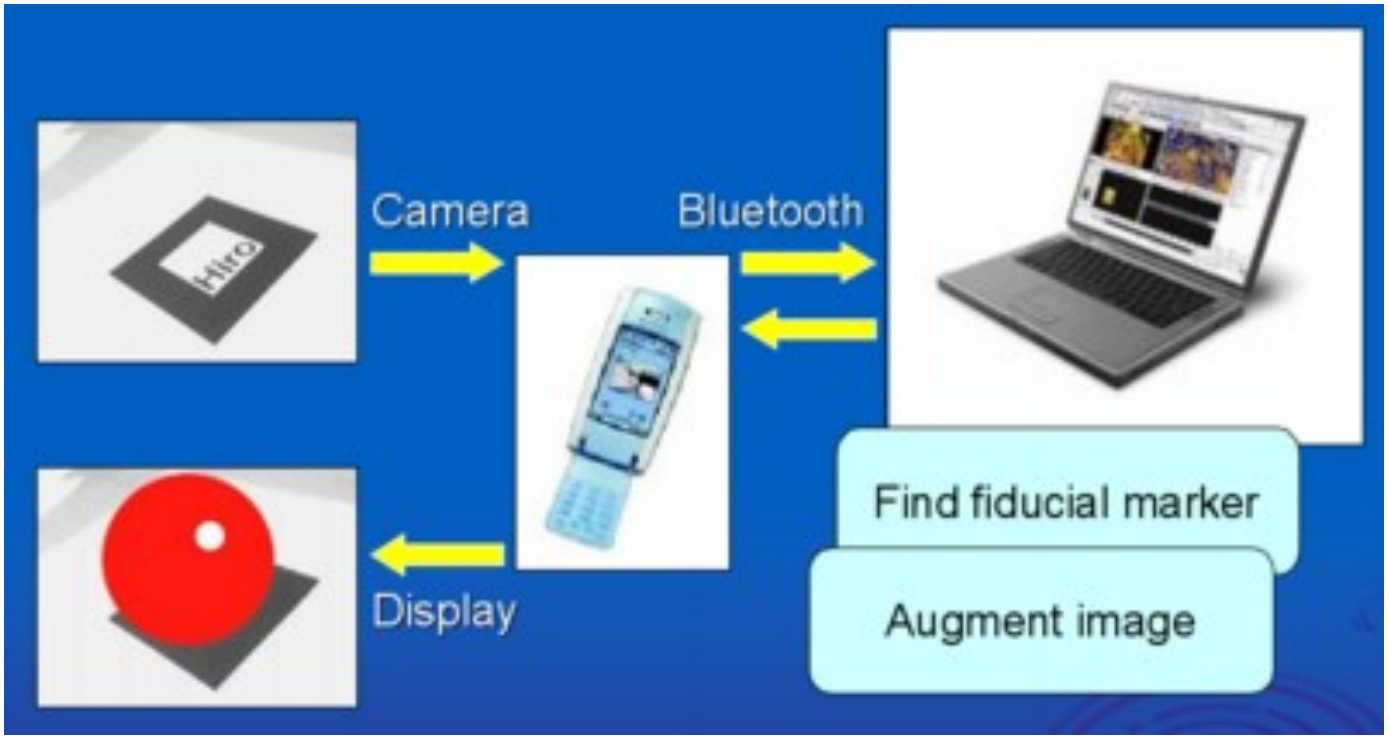
- PDA used as I/O device
- Wireless connection to workstation
- Room-scale ultrasonic tracking (Bat)



2001 AR-PDA (C Lab)

- PDA thin graphics client
- Remote image processing
- www.ar-pda.com

Mobile Phone AR – Thin Client



2003 ARphone (Univ. of Sydney)

- Transfer images via Bluetooth (slow – 30 sec/image)
- Remote processing – AR Server

Early Phone Computer Vision Apps

2003 – Mozzies Game - Best mobile game

Optical motion flow detecting phone orientation

Siemens SX1 – Symbian, 120Mhz, VGA Camera

2005 – Marble Revolution (Bit-Side GmbH)

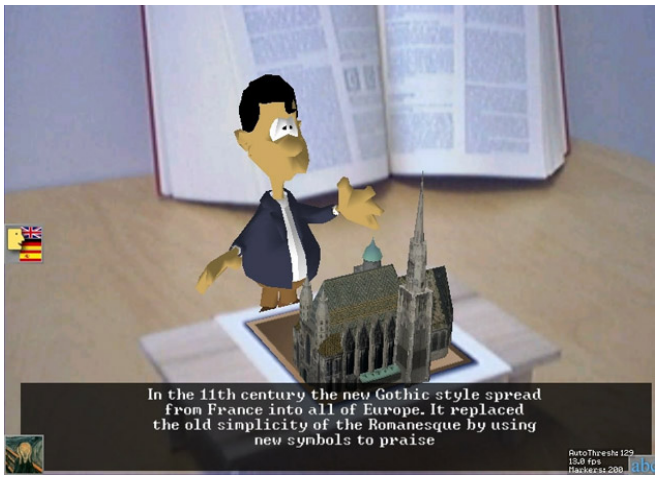
Winner of Nokia's Series 60 Challenge 2005

2005 – SymBall (VTT)

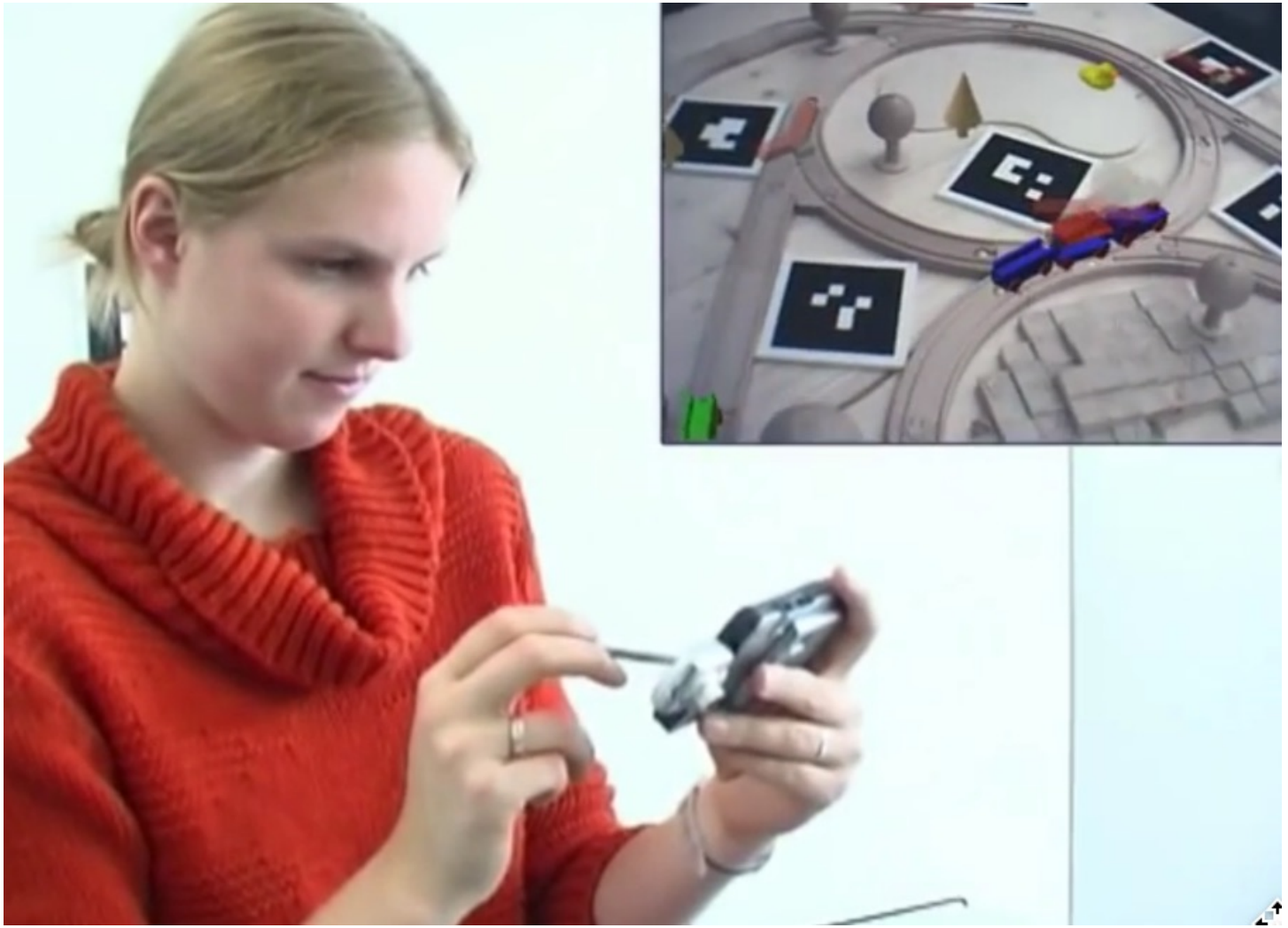
Handheld AR – Self Contained

2003 PDA-based AR

- ARToolKit port to PDA
- Studierstube ported to PDA
- Mr Virtuoso AR character
- Wagner's Invisible Train
  - Collaborative AR



Demo: The Invisible Train

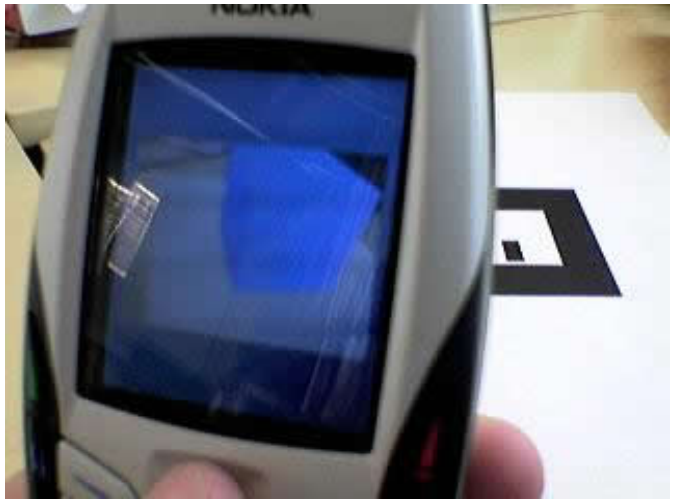


- https://www.youtube.com/watch?v=6LE98k0YMLM

Mobile Phone AR – Self Contained

2004 Mobile Phone AR

- Moehring, Bimber
- Henrysson (ARToolKit)
- Camera, processor, display together



2007 - First Mobile AR Advertising App

- Developed by HIT Lab NZ
- Txt message to download AR application (200K)
- See virtual content popping out of real paper advert
- Tested May 2007 by Saatchi and Saatchi

Demo: AR Advertising

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

2008 - Location Aware Phones

Motorola Droid

Nokia Navigator

Mobile Hardware Sensors Available

- Camera (resolution, fps)
  - Maker based/markerless tracking
  - Video overlap
- GPS (resolution, update rate)
  - Outdoor location
- Compass
  - Indoor/outdoor orientation
- Accelerometer
  - Motion sensing, relative tilt

Sensors Support Real World Overlay

- Tag real world locations
  - GPS + Compass input
  - Overlay graphics data on live video
- Applications
  - Travel guide, gaming, advertising, etc
- Eg: Wikitude (www.wikitude.com)
  - First mobile outdoor AR application
  - iOS, Android based, Public API released
- Other early companies
  - Layar, AcrossAir, Tochnidot, RobotVision, etc

Wikitude – www.wikitude.com

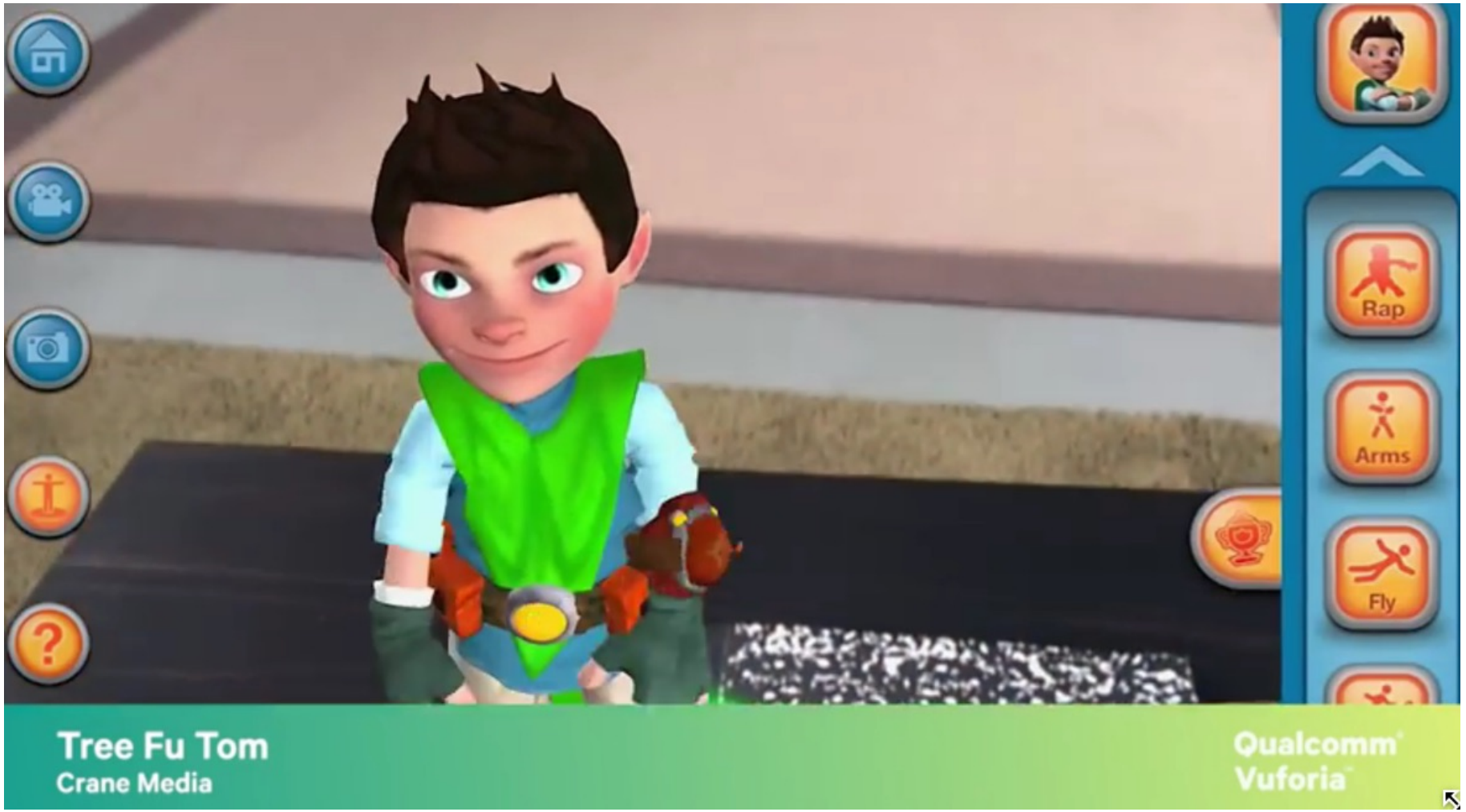
- Overlays Points of Interest on real world
  - GPS, compass data
- Uses data feeds
  - Flickr
  - Wikipedia
  - Google
- Web authoring

Layar – www.layar.com

2010 – Launch of Vuforia

- Qualcomm's image based tracking library (now PTC)
- Computer vision tracking - marker, markerless
- Integrated with Unity 3D game engine
- 200,000+ downloads, 10,000+ apps developed
- http://www.vuforia.com/

Example Vuforia Applications

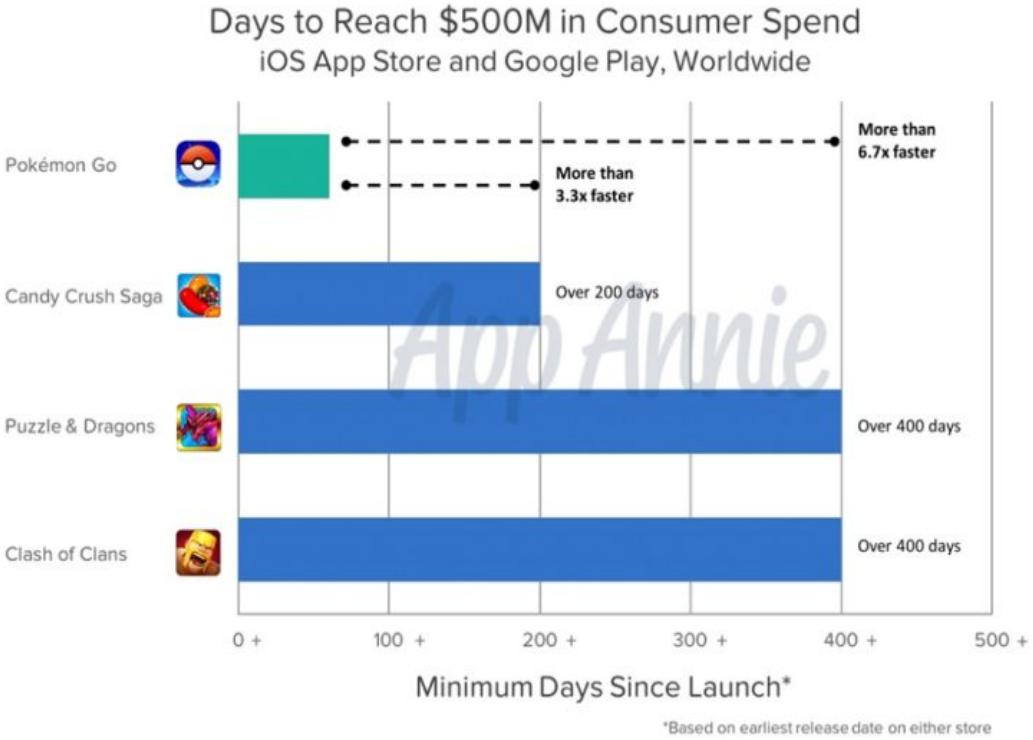


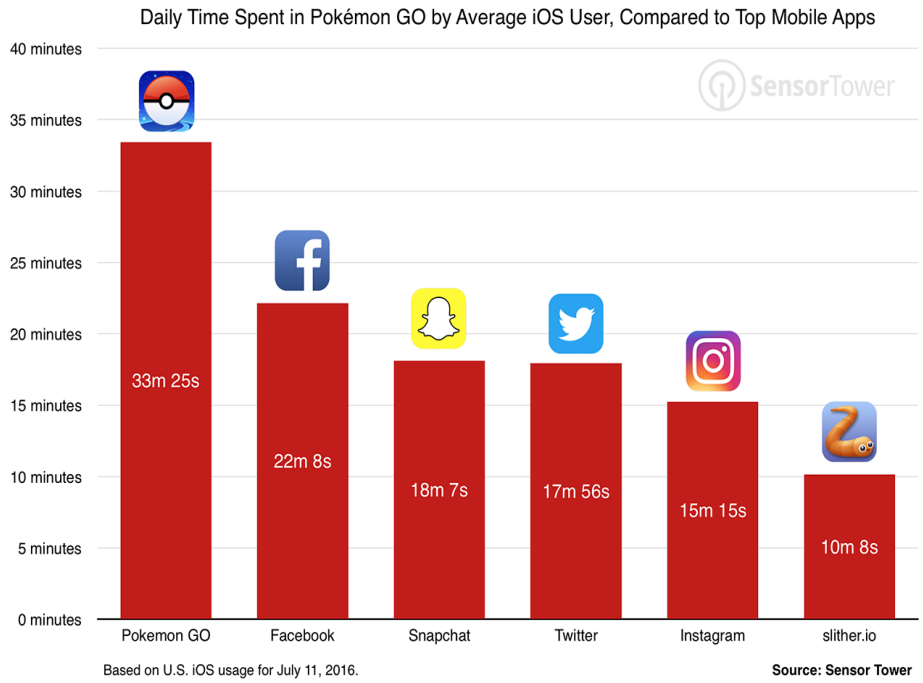
https://www.youtube.com/watch?v=Z567LhV_wsQ

2016: Pokemon GO

Killer Combo: brand + social + mobile + geo-location + AR

Pokemon GO Effect





- Fastest App to reach $500 million in Revenue
  - Only 63 days after launch, > $1 Billion in 6 months
  - Over 500 million downloads, > 25 million DAU
  - Nintendo stock price up by 50% (gain of $9 Billion USD)

2017 - Release of ARKit/Arcore SDKs

- Visual/Inertial Tracking for mobile phones
  - Combines camera + IMU input for robust hybrid tracking
- Very accurate relative tracking
- Easy integration with game engines

Demo: ARKit

https://www.youtube.com/watch?v=6xDyVBsBtX8

Mobile AR State of the Art

- Thousands of Mobile AR apps
  - Number of users predicted to grow to 1 Billion by 2020
- Hardware available
  - Phones, Tablets, Head mounted displays
- Software Tools
  - Tracking: Vuforia, ARKit SDK, etc
  - Authoring tools: Unity, AR Creator, Entiti, etc
- Rapidly Growing market

Mobile AR Browsers

Mobile Augmented Reality Applications

Layar

Wikitude

WikEye

Nokia Point & Find

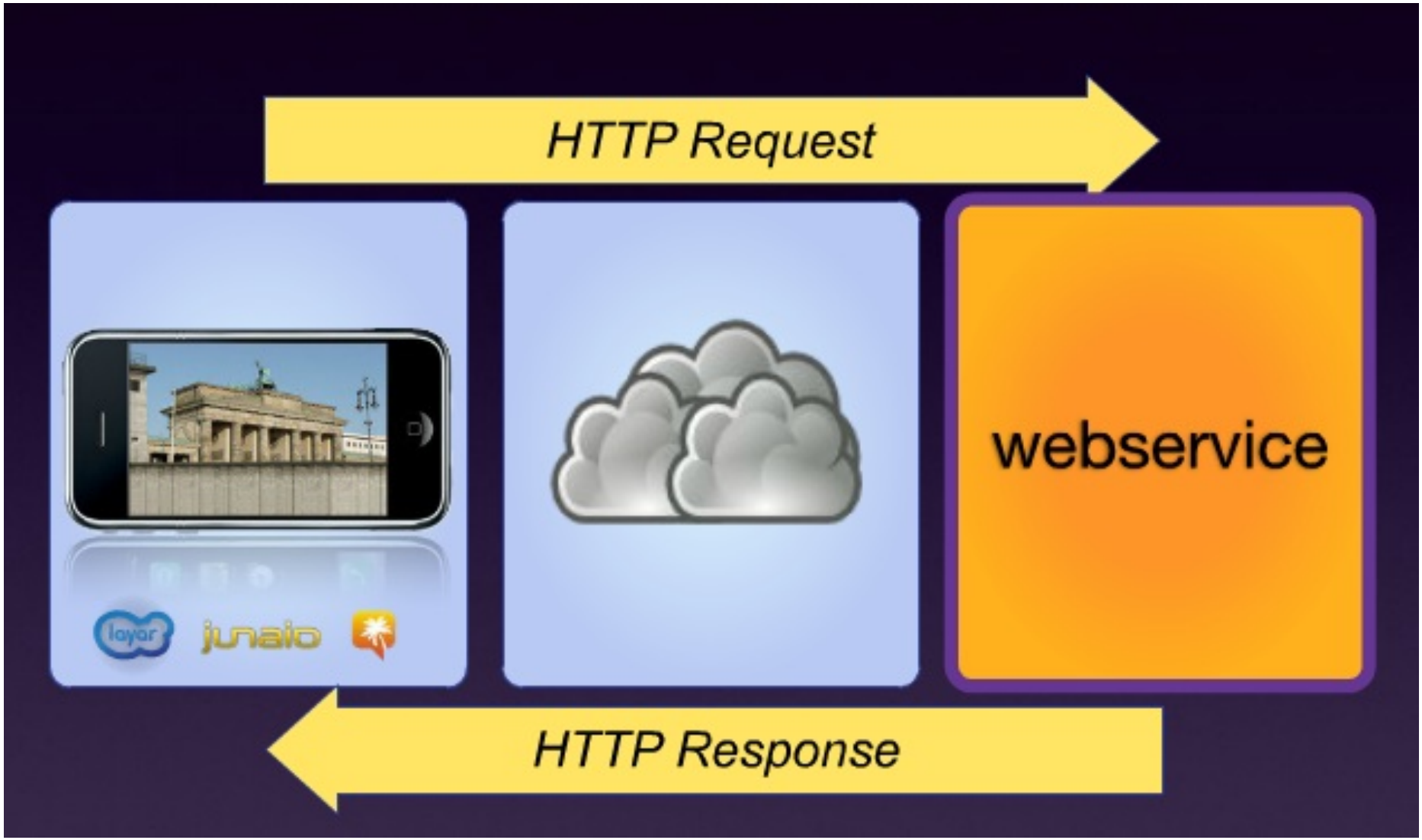
Google Goggles

Image courtesy of VentureBeat

AR Browsers

- AR equivalent of web browser
  - Request and serve up content
- Commercial outdoor AR applications
  - Aurasma, Junaio, Layar, Wikitude, etc
- All have their own language specifications
  - Wikitude – ARML
  - Junaio – XML, AREL

Typical AR Browser Architecture



Example: Nokia City Lens (2015)

- Similar features to more recent AR Browsers

Demo: Nokia City Lens

https://www.youtube.com/watch?v=V69fYmpvQNI

Junaio AR Penguin Navigation

Demo: Junaio AR Penguin Navigation

https://www.youtube.com/watch?v=IK4-zPD_25U

How an AR Browser Works

Example: Junaio AR Browser Demos

https://www.youtube.com/watch?v=AS9vFMY-zdk

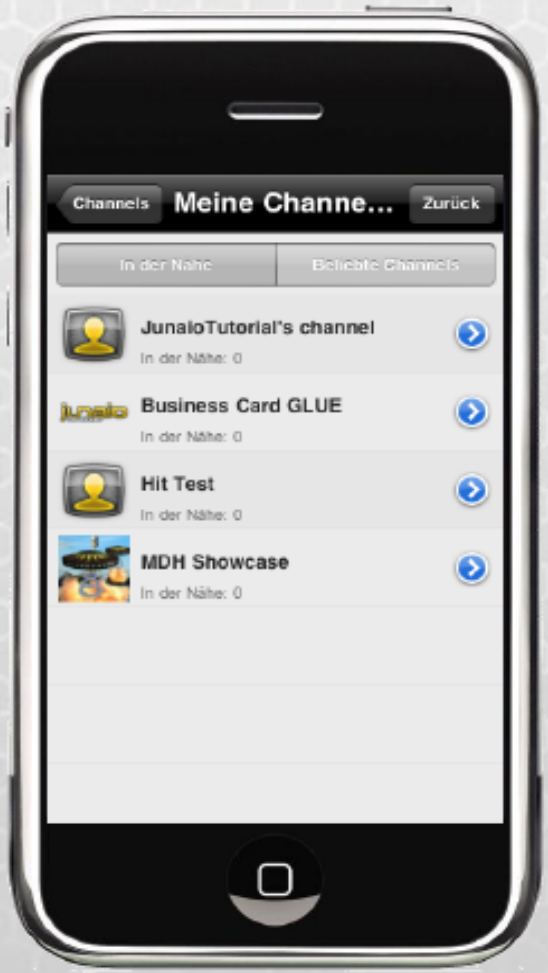
This is how it works exactly…

NOTE: Junaio has been discontinued, but other browsers work the same

2.1. POI Search

Request POI Information from your channel
- A user opens your channel
- A user moves a certain distance
- Predefined refresh time

User opens Channel

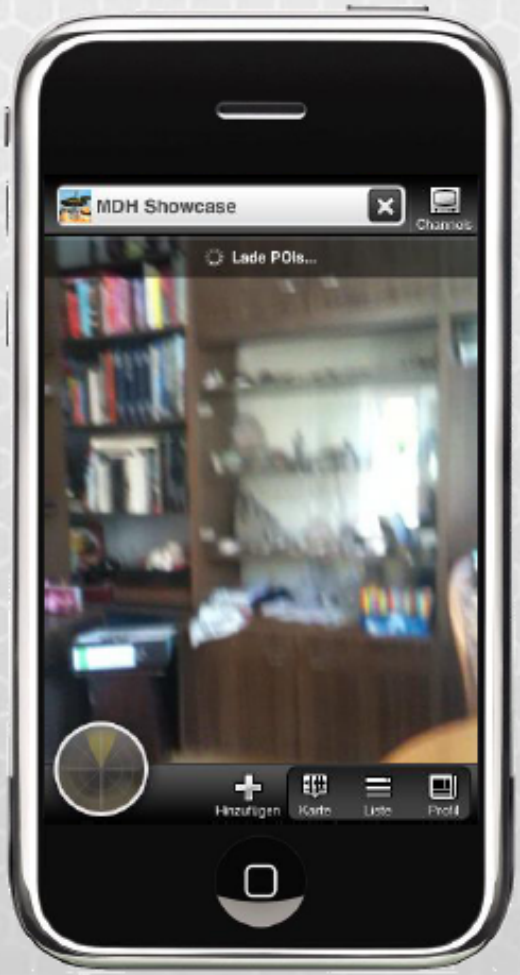


POI Search - http://www.junaio.com/publisher/poissearch

2.1. POI Search

Send Requests with parameters:
- Position and orientation of user
- Unique ID of each user
- (radius and amount of results)

User opens Channel → „pois/search“ - request to server



POI Search - http://www.junaio.com/publisher/poissearch

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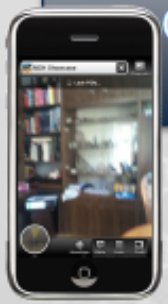
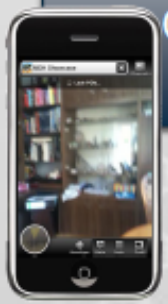


User opens Channel → „pois/search“ - request to Server → Forward to callback URL of channel

junaio

POI Search - http://www.junaio.com/publisher/poissearch

2.1. POI Search



User opens Channel

„pois/search“ - request to Server

Forward to callback URL of channel

junaio

Create POI Information

POI Search - http://www.junaio.com/publisher/poissearch

2.1. POI Search

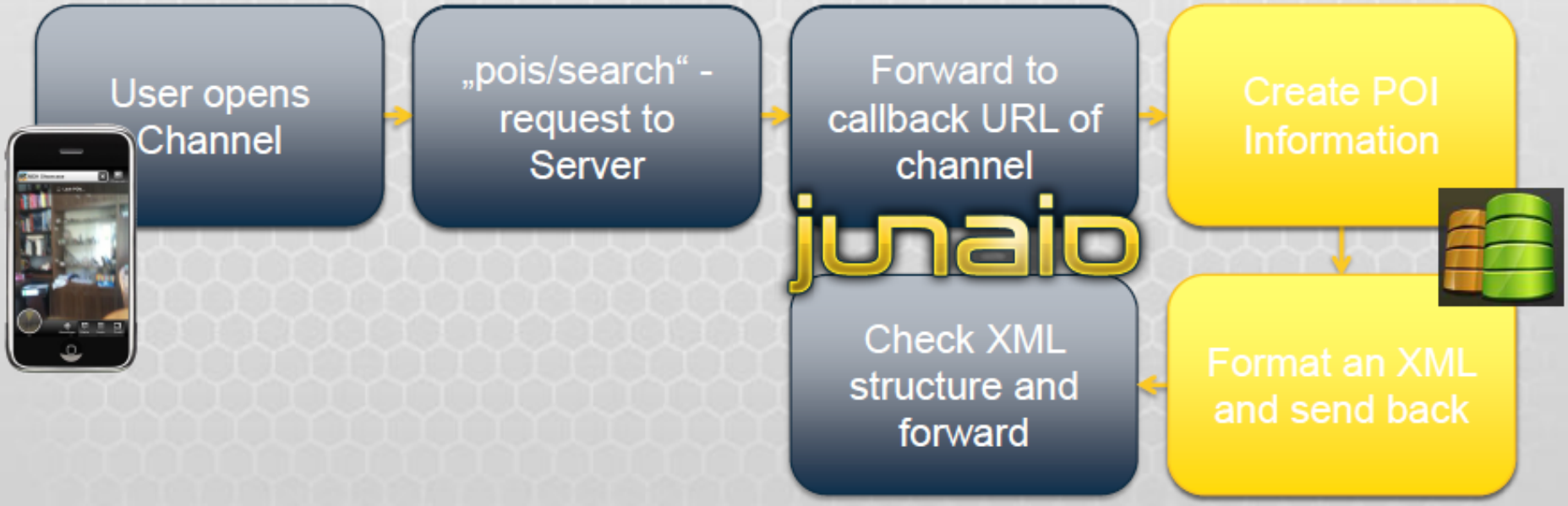
POI Search - http://www.junaio.com/publisher/poissearch

2.1. POI Search

```
<?xml version="1.0" encoding="UTF-8"?>
  <results>
    <poi id=„1" interactionfeedback="click">
      <name><![CDATA[Ein UFO]]></name>
      <author>metaio GmbH</author>
      <date/>
      <l>48.161036,11.55107,0</l>
      <o>0,0,0</o>
      <mime-type>model/md2</mime-type>
      <mainresource>http://www.junaio.com/publisherDownload/tutorial/ufo3.md2_enc</mainresource>
      <route>false</route>
      <s>8</s>
      <force3d>true</force3d>
      <resources>
        <resource>http://www.junaio.com/publisherDownload/tutorial/texture_ufo.png</resource>
      </resources>
      <behaviours>
        <behaviour type="idle">
          <length>0</length>
          <node_id>idle</node_id>
        </behaviour>
      </behaviours>
    </poi>
  </results>
```

POI Search - http://www.junaio.com/publisher/poissearch

2.1. POI Search



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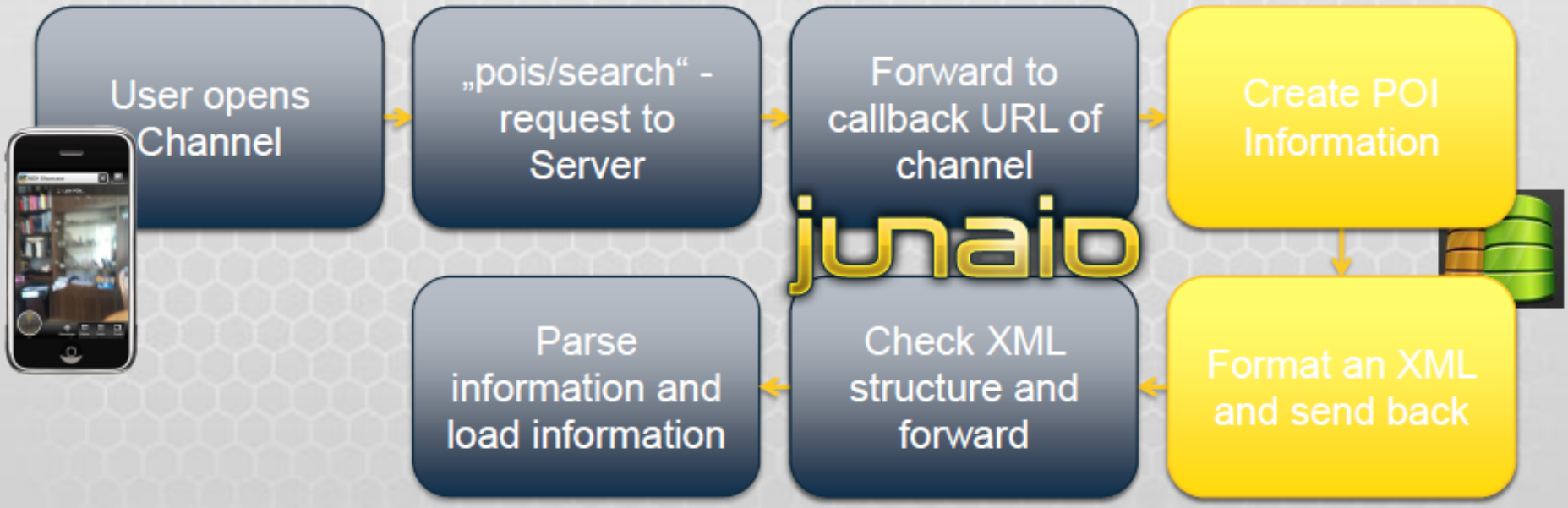

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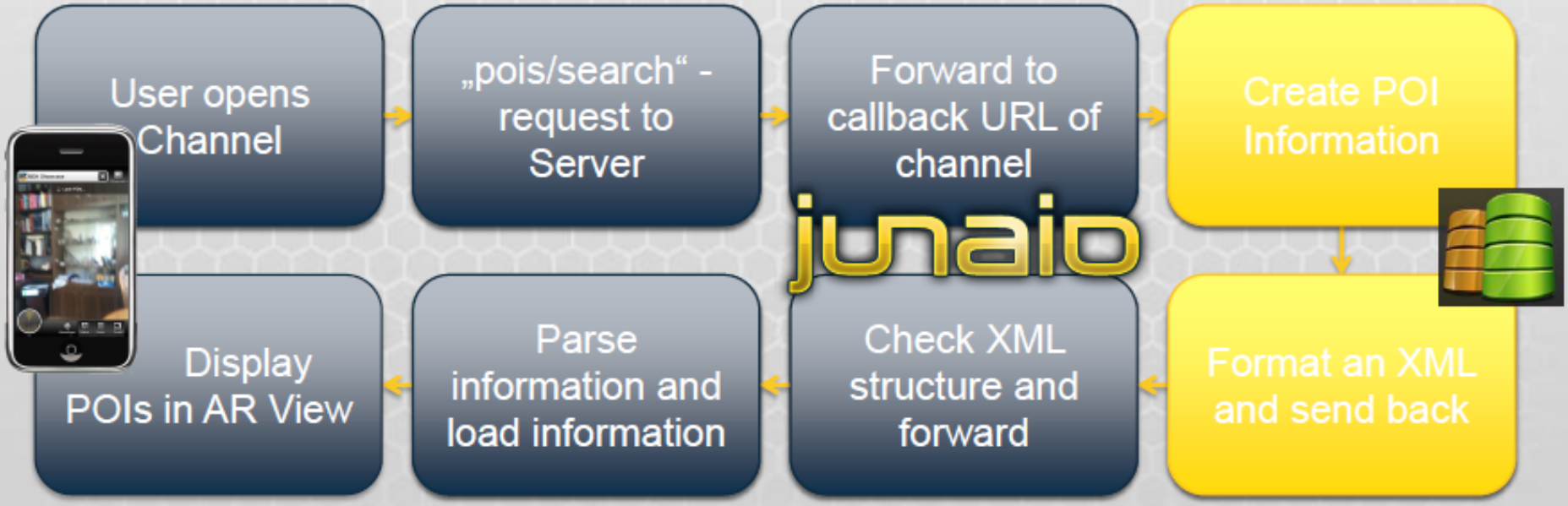
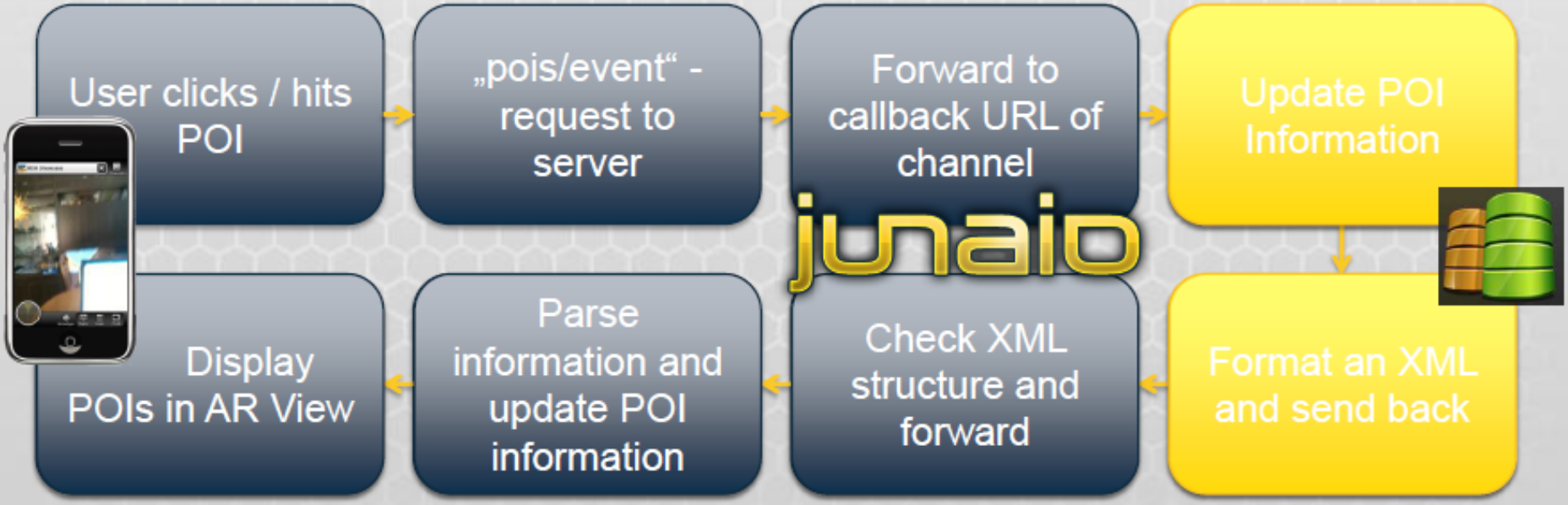


POI Search - http://www.junaio.com/publisher/poissearch

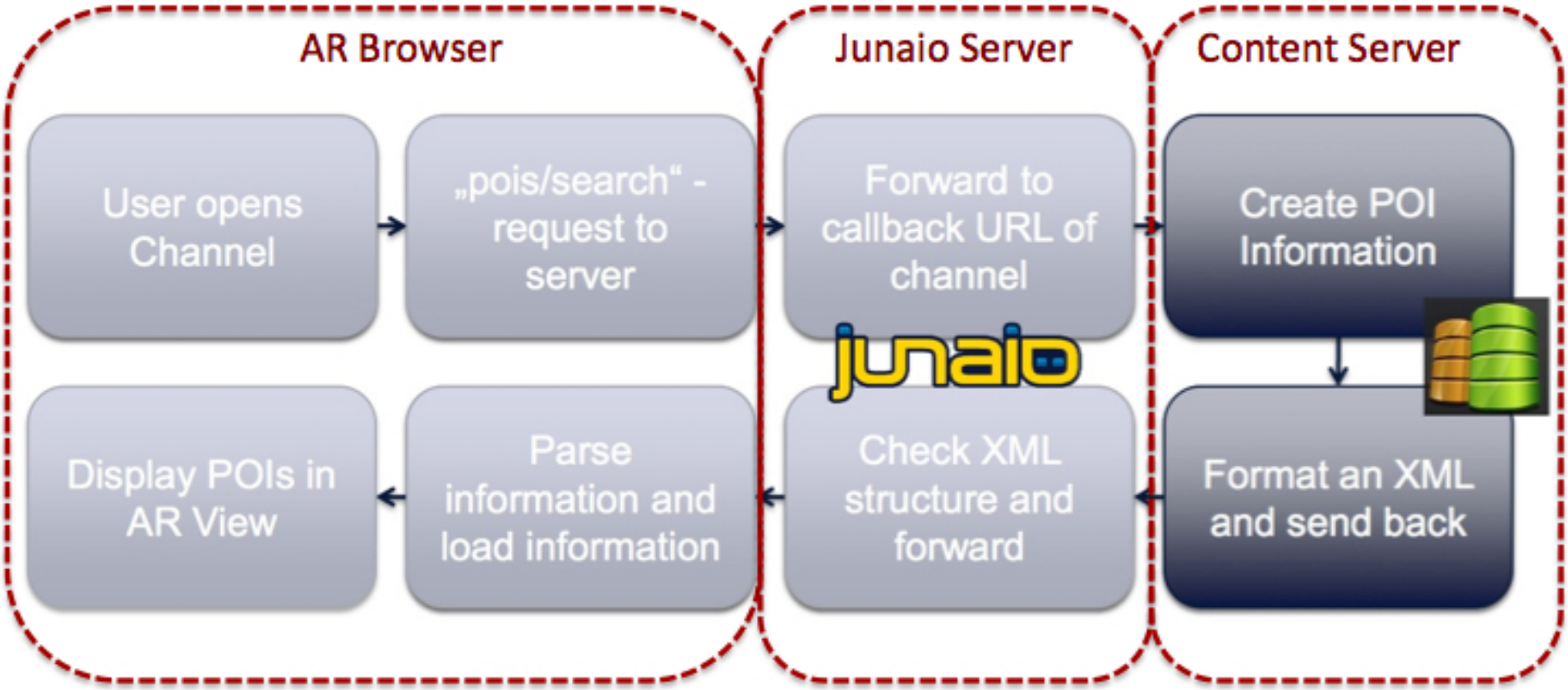
2.2. POI Event

Pois event request is sent upon user interaction
- Click on a POI
- „Hit“ a POI
- Parameters sent: location, orientation, user ID, POI ID of interaction

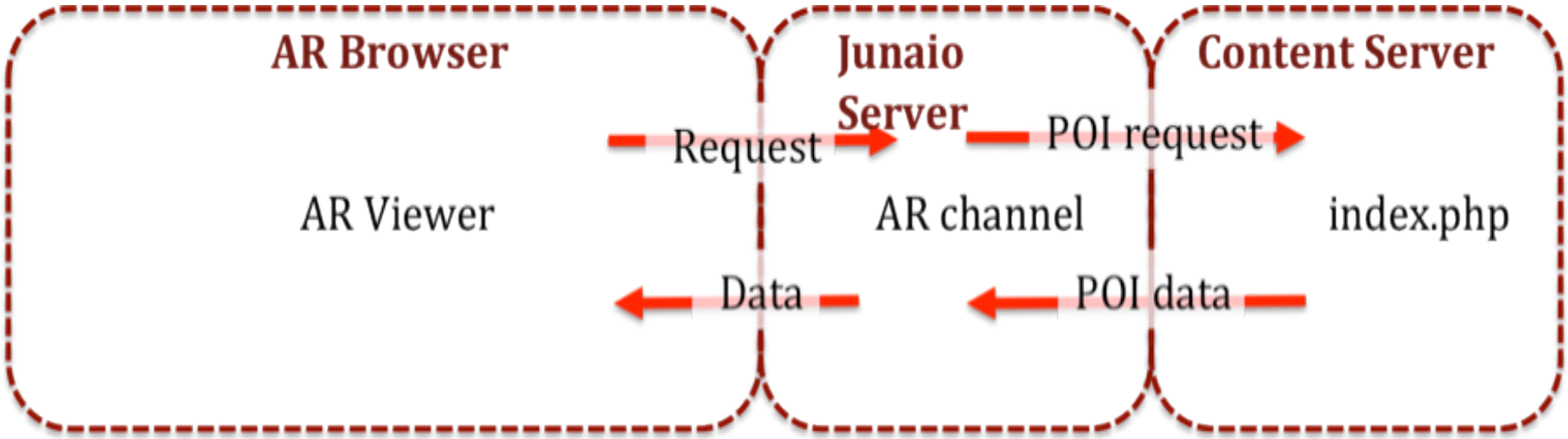


POI Event - http://www.junaio.com/publisher/poisevent

Back-end Servers



Overall AR Browser Data Flow



Typical of mobile AR Browsers

Mobile AR Interface Design

Mobile AR Interface Guidelines

- Consider your user
- Follow good HCI principles
- Adapt HCI guidelines for handhelds
- Design to device constraints
- Design for Micro-Interactions
- Design for perceptual issues
- Use Design Patterns

Consider Your User

- Consider context of user
  - Physical, social, emotional, cognitive, etc.

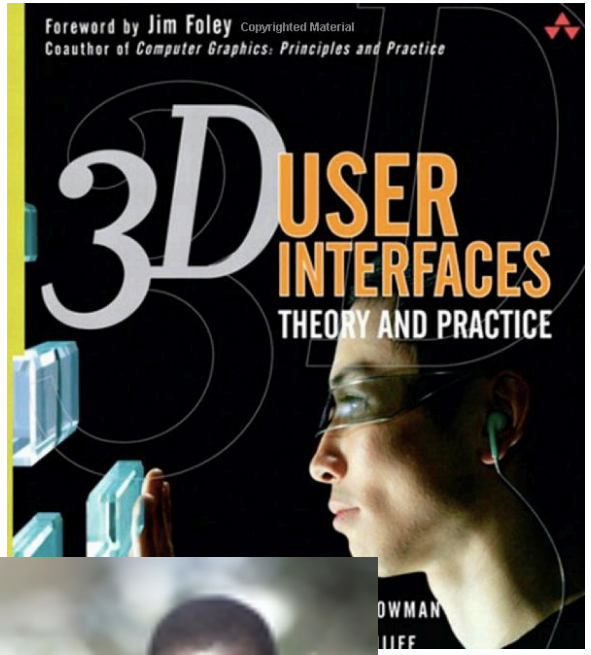
- Mobile Phone AR User
  - Probably Mobile
  - One hand interaction
  - Short application use
  - Need to be able to multitask
  - Use in outdoor or indoor environment
  - Want to enhance interaction with real world

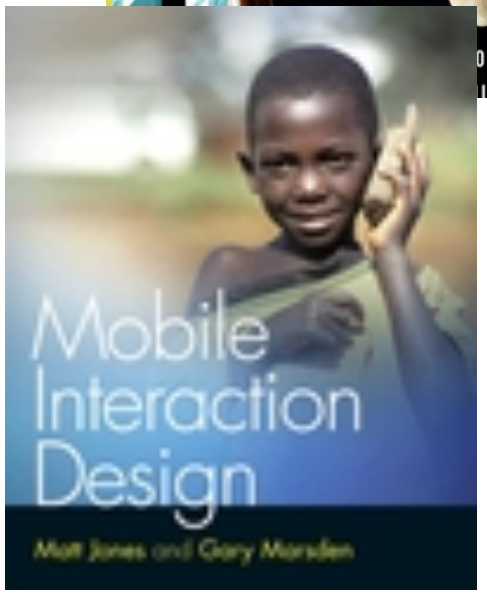
Follow Good HCI Principles

- Provide good conceptual model/Metaphor
  - customers want to understand how UI works
- Make things visible
  - if object has function, interface should show it
- Map interface controls to customer's model
  - infix -vs- postfix calculator -- whose model?
- Provide feedback
  - what you see is what you get!

Adapting Existing Guidelines

- Mobile Phone AR
  - Phone HCI Guidelines
  - Mobile HCI Guidelines
- HMD Based AR
  - 3D User Interface Guidelines
  - VR Interface Guidelines
- Desktop AR
  - Desktop UI Guidelines





Example: Apple iOS Interface Guidelines

- Make it obvious how to use your content.
- Avoid clutter, unused blank space, and busy backgrounds.
- Minimize required user input.
- Express essential information succinctly.
- Provide a fingertip-sized target for all controls.
- Avoid unnecessary interactivity.
- Provide feedback when necessary

From: https://developer.apple.com/ios/human-interface-guidelines/

Applying Principles to Mobile AR

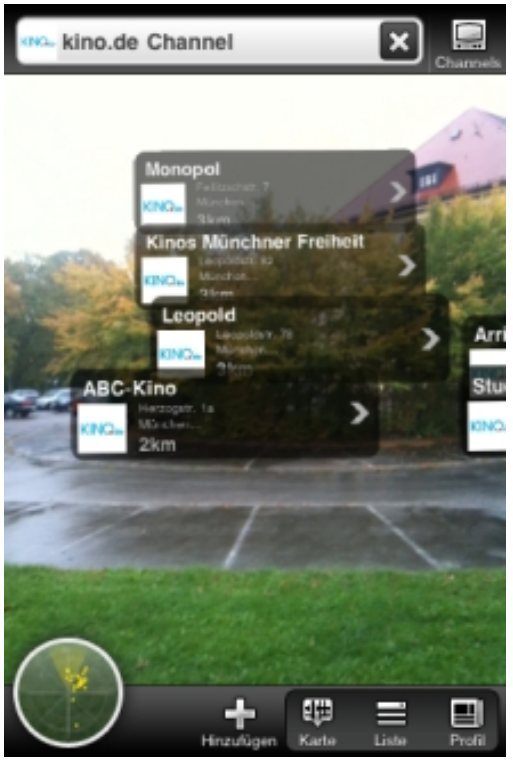
- Clean
- Large Video View
- Large Icons
- Text Overlay
- Feedback

AR vs. Non AR Design

Characteristics	Non-AR Interfaces	AR Interfaces
Object Graphics	Mainly 2D	Mainly 3D
Object Types	Mainly virtual objects	Both virtual and physical objects
Object behaviors	Mainly passive objects	Both passive and active objects
Communication	Mainly simple	Mainly complex
HCI methods	Mainly explicit	Both explicit and implicit

- Design Guidelines
  - Design for 3D graphics + Interaction
  - Consider elements of physical world
  - Support implicit interaction

Maps vs. AR Browser View



- Google Maps
  - 2D, mouse driven, text/image heavy, exocentric
- AR Browser
  - 3D, location driven, simple graphics, egocentric

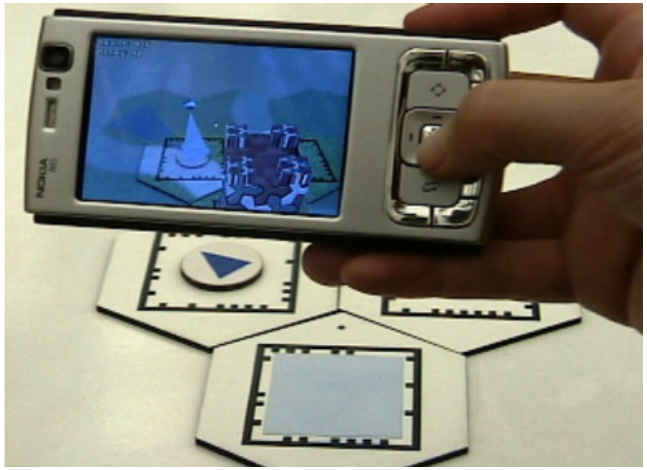
Design to Device Constraints

- Understand the platform and design for limitations
  - Hardware, software platforms
- E.g. Handheld AR game with visual tracking
  - Use large screen icons
  - Consider screen reflectivity
  - Support one-hand interaction
  - Consider the natural viewing angle
  - Do not tire users out physically
  - Do not encourage fast actions
  - Keep at least one tracking surface in view

Art of Defense Game

Handheld AR Constraints/Affordances

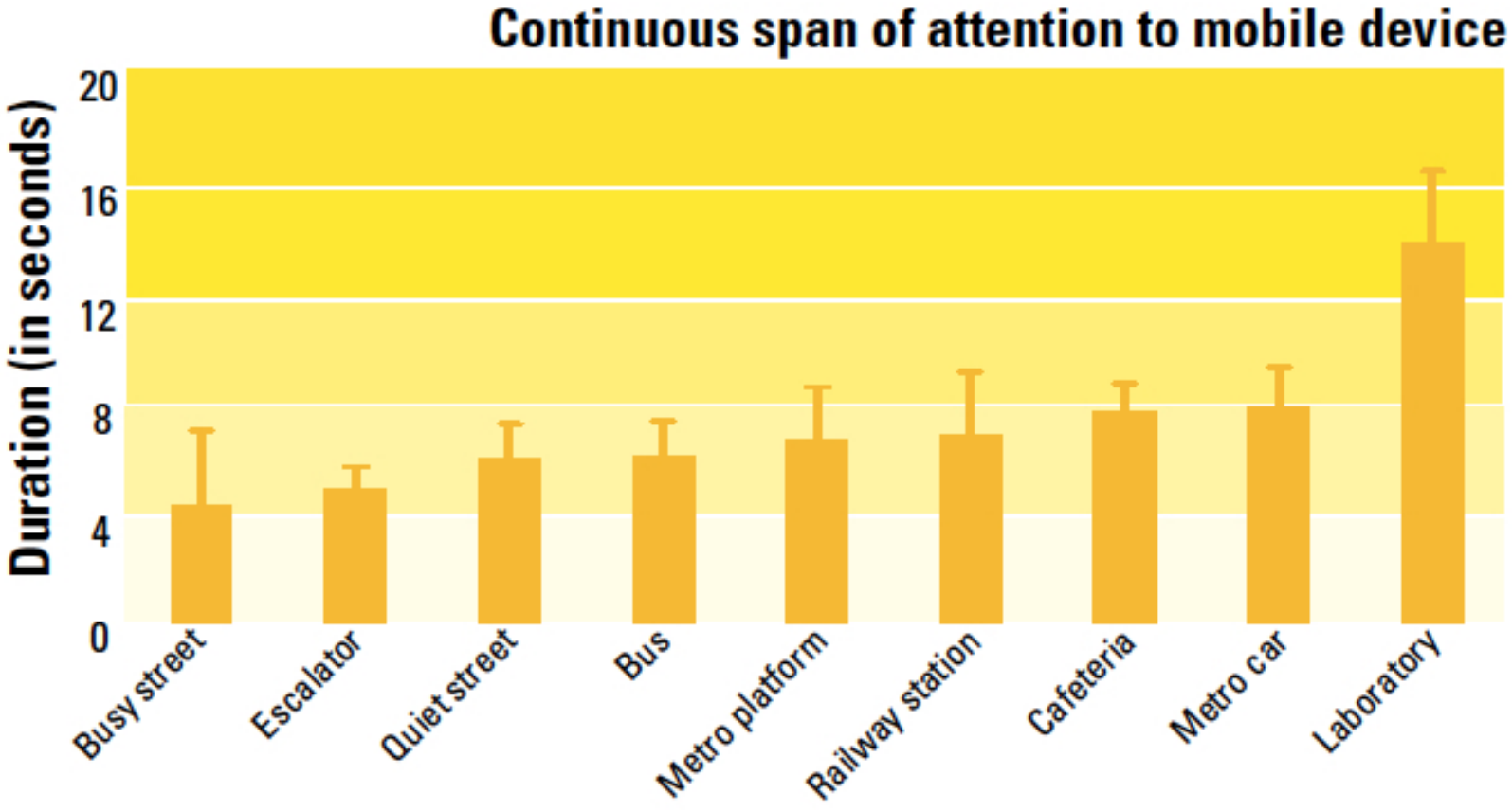
- Camera and screen are linked
  - Fast motions a problem when looking at screen
  - Intuitive “navigation”
- Phone in hand
  - Two handed activities: awkward or intuitive
  - Extended periods of holding phone tiring
  - Awareness of surrounding environment
- Small screen
  - Extended periods of looking at screen tiring
  - In general, small awkward platform
- Vibration, sound
  - Can provide feedback when looking elsewhere



Micro-Interactions

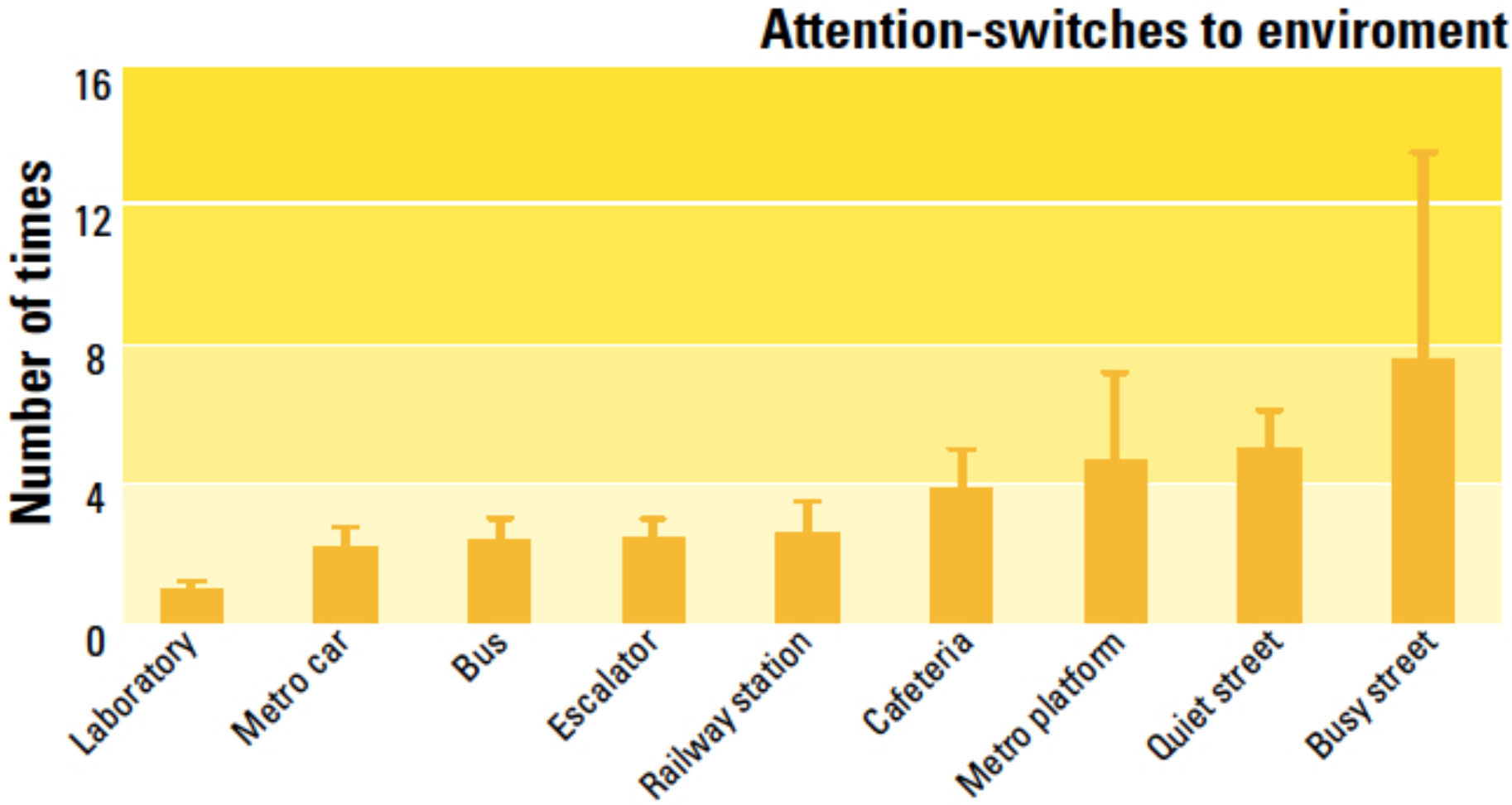
- Using mobile phones people split their attention between the display and the real world

Time Looking at Screen



Oulasvirta, A. (2005). The fragmentation of attention in mobile interaction, and what to do with it. *interactions*, *12*(6), 16-18.

Dividing Attention to World



- Number of times looking away from mobile screen

Design for Micro Interactions

- Design interaction for less than a few seconds
  - Tiny bursts of interaction
  - One task per interaction
  - One input per interaction
- Benefits
  - Use limited input
  - Minimize interruptions
  - Reduce attention fragmentation

Mobile AR and Perception

- Creating the illusion that virtual images are seamlessly part of the real world
  - Must match real and virtual cues
    - Depth, occlusion, lighting, shadows..



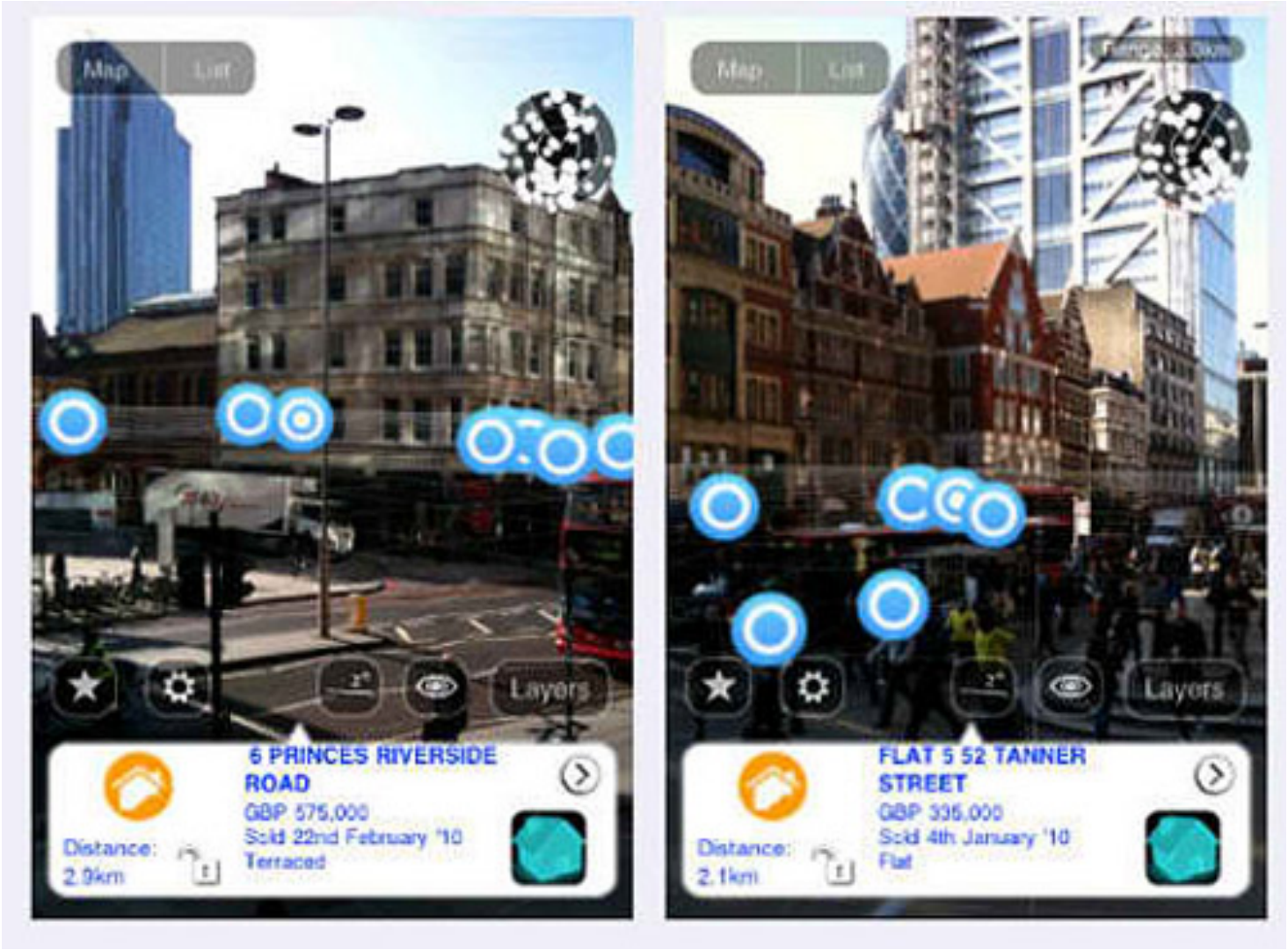
Mobile AR as Perception Problem

- Goal of AR to fool human senses – create illusion that real and virtual are merged
- Depth
  - Size
  - Occlusion
  - Shadows
  - Relative motion
  - Etc..

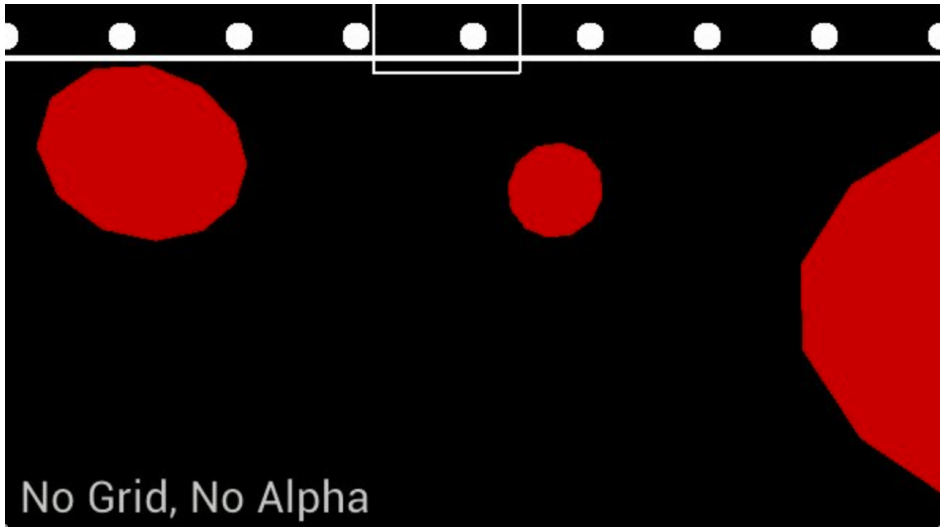
Possible Depth Cues

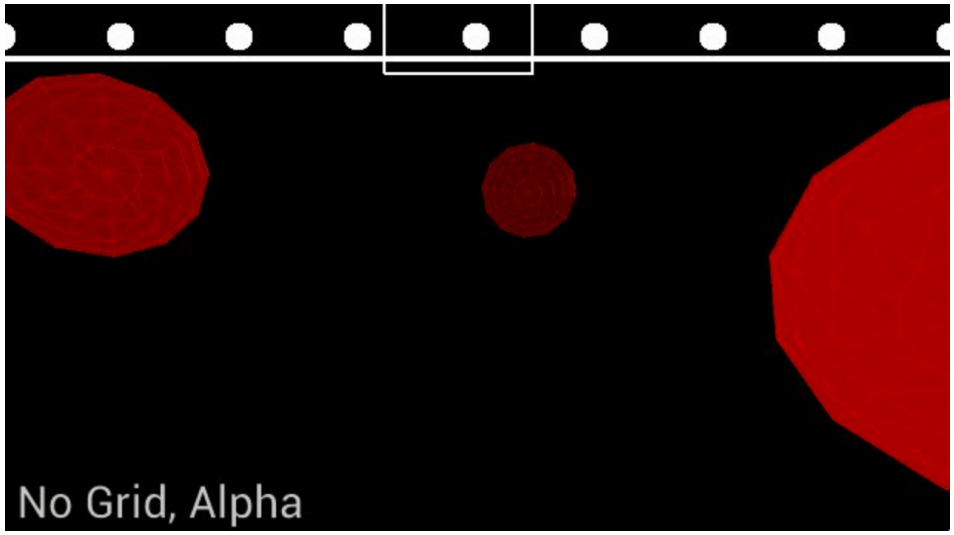
- Pictorial: visual cues
  - Occlusion, texture, relative brightness
- Kinetic: motion cues
  - Relative motion parallax, motion perspective
- Physiological: motion cues
  - Convergence, accommodation
- Binocular disparity: two different eye images

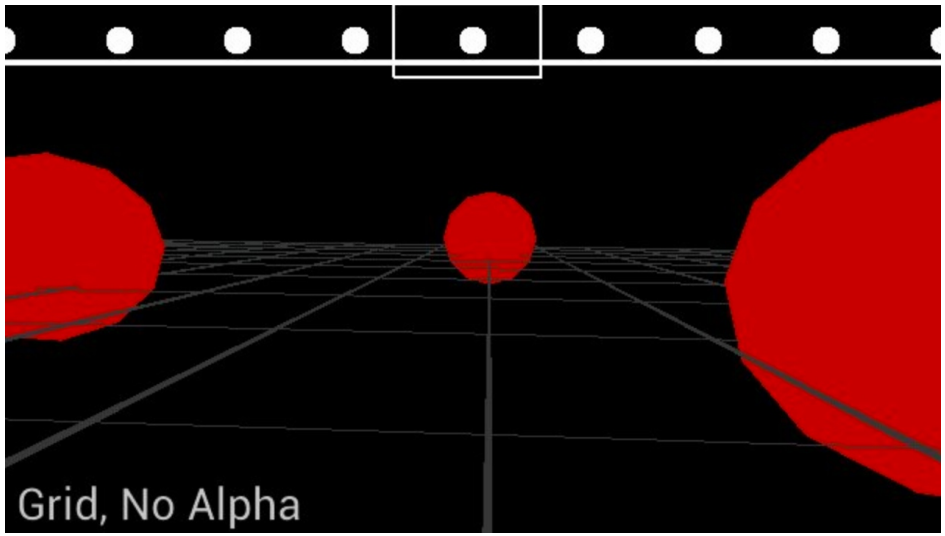
Which of these POI are near or far?

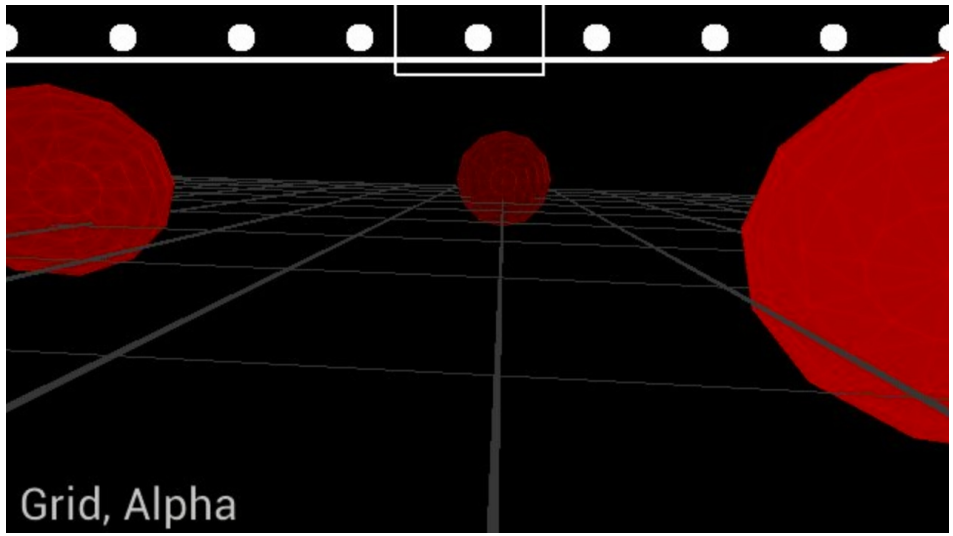


Use Depth Cues









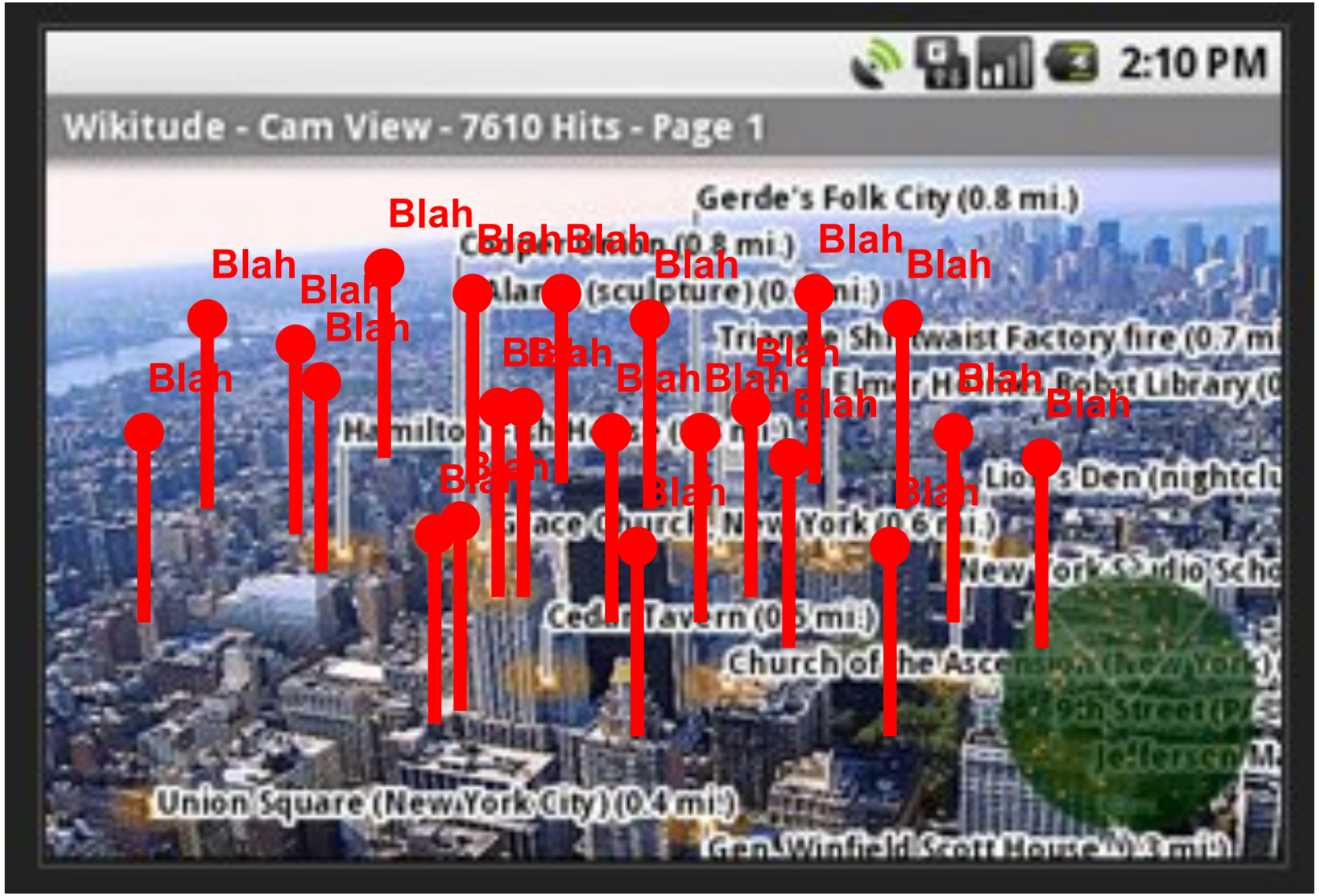
Information Presentation

- Consider
  - The amount of information
    - Clutter, complexity
  - The representation of information
    - Navigation cues, POI representation
  - The placement of information
    - Head, body, world stabilized
  - Using view combinations
    - Multiple views

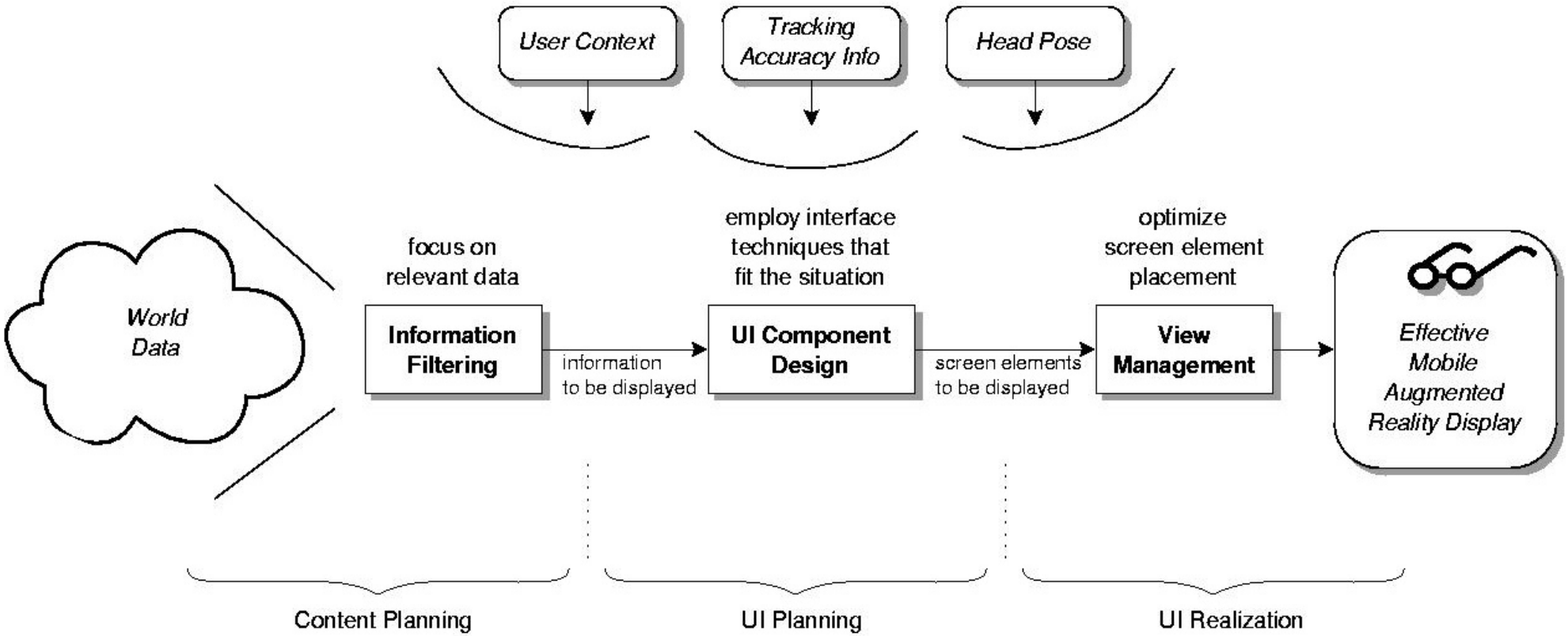
Example: Twitter 360

- www.twitter-360.com
- iPhone application
- See geo-located tweets in real world
- Twitter.com supports geo tagging

But: Information Clutter from Many Tweets

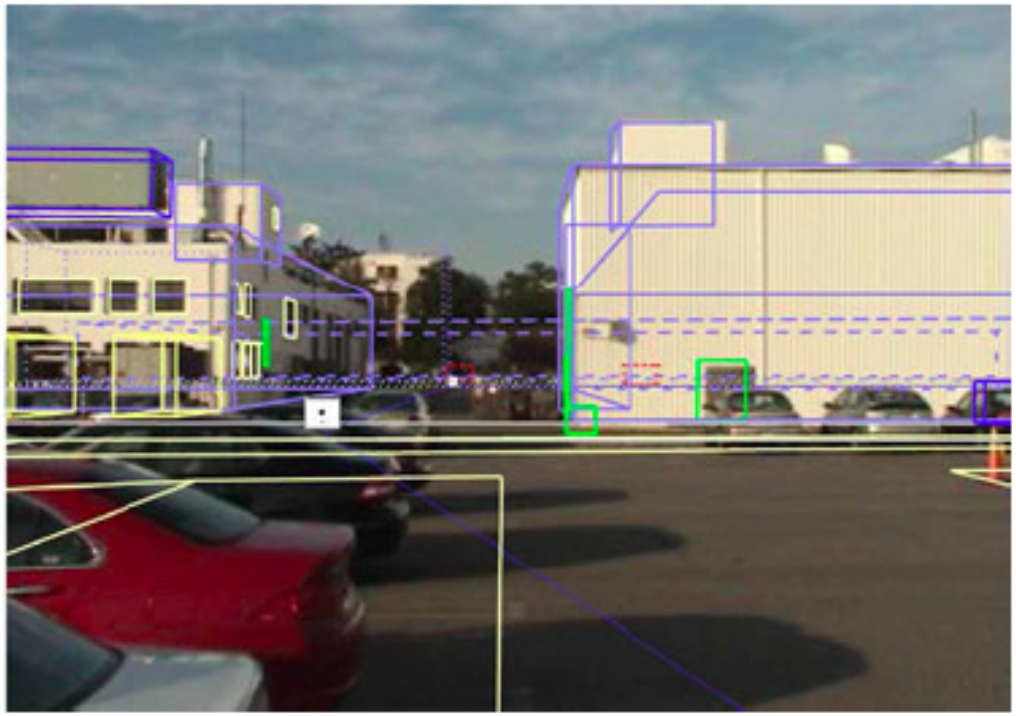


Solution: Information Filtering



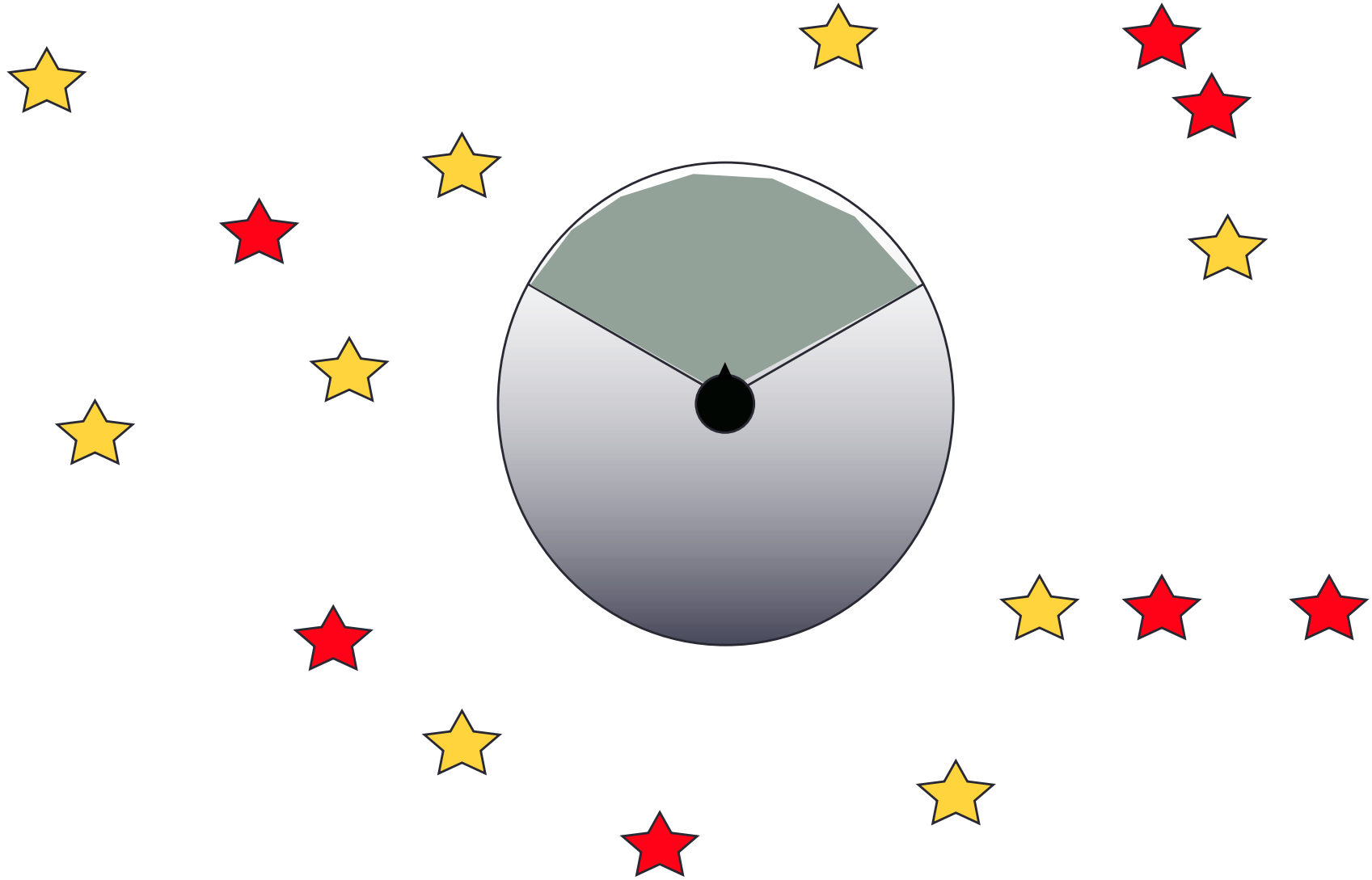
Information Filtering

Before



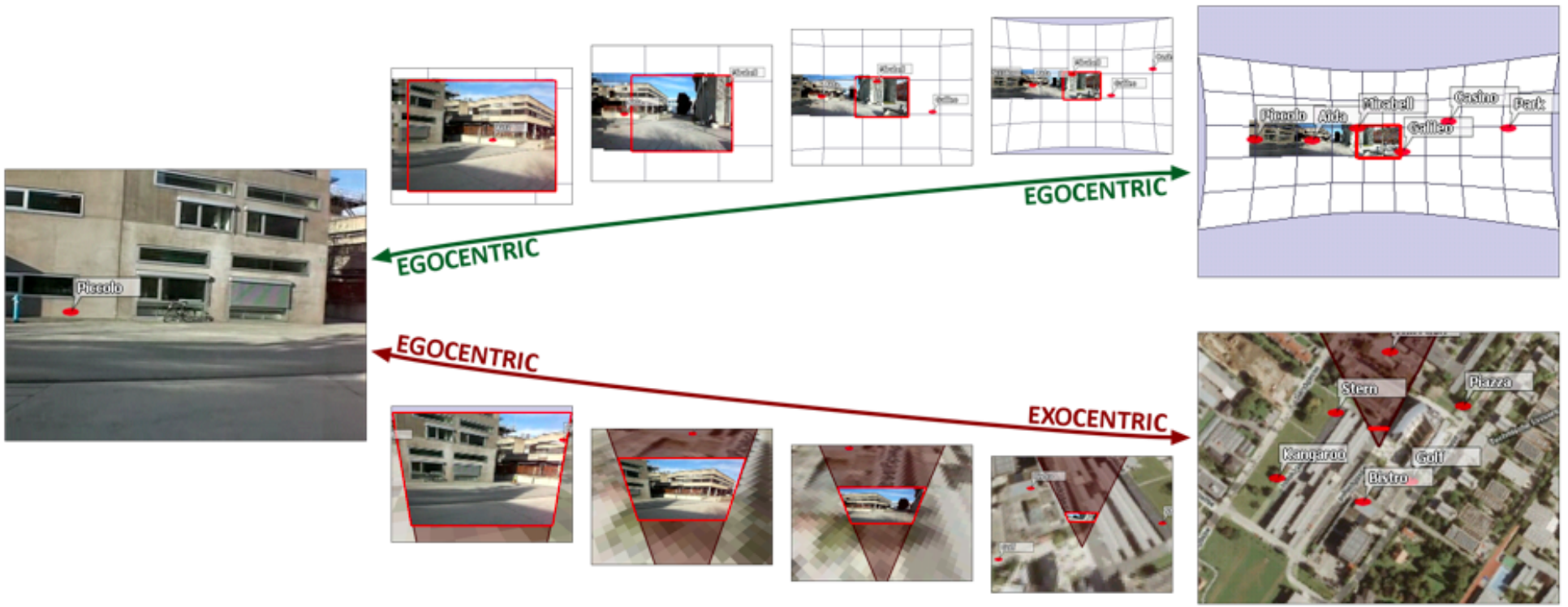
After

Outdoor AR: Limited FOV

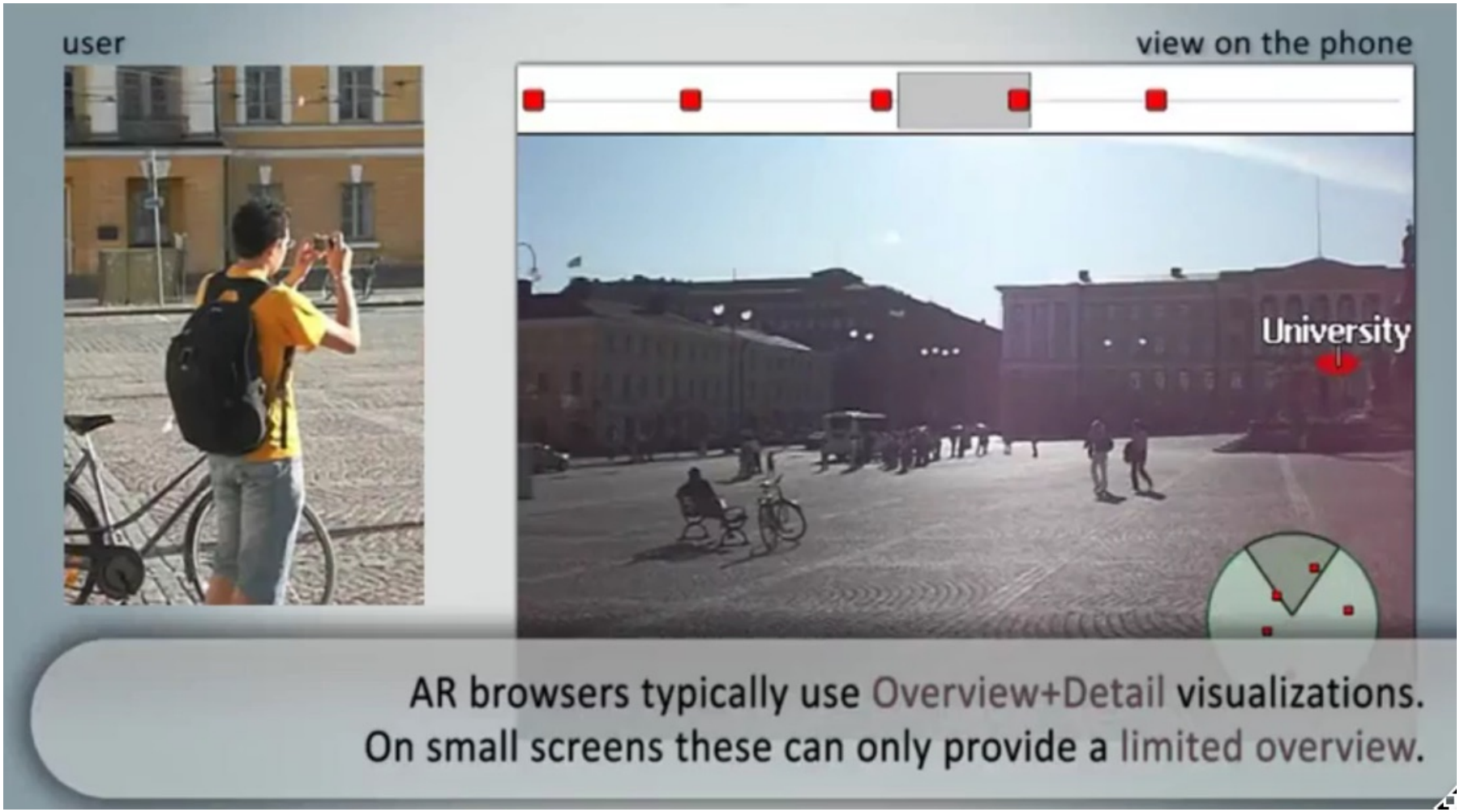


Zooming Views

- Show POI outside FOV
- Zooms between map and panorama views



Demo: Zooming Views



- https://www.youtube.com/watch?v=JLxLH9Cya20

Design Patterns

“**Each pattern describes a problem which occurs over and over** again in our environment, and then describes the core of the solution to that problem in such a way that you can use this solution a million times over, without ever doing it the same way twice.”

– Christopher Alexander et al.

Use Design Patterns to Address Reoccurring Problems

C.A. Alexander, A Pattern Language, Oxford Univ. Press, New York, 1977.

Handheld AR Design Patterns

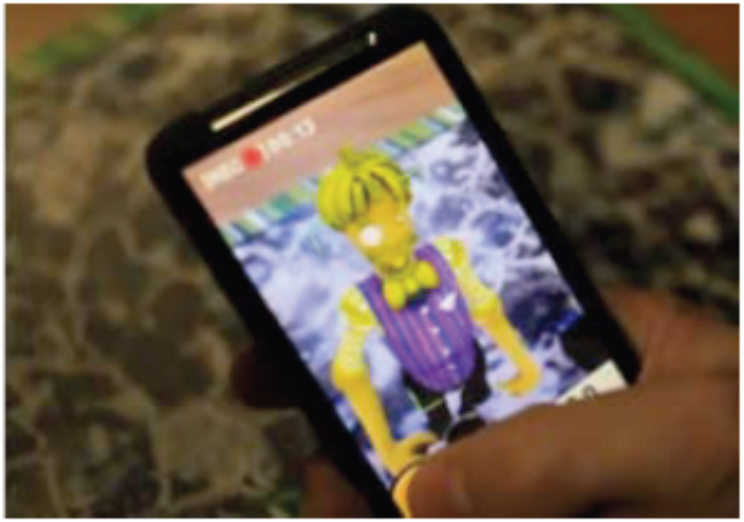
*A&S = awareness and skills

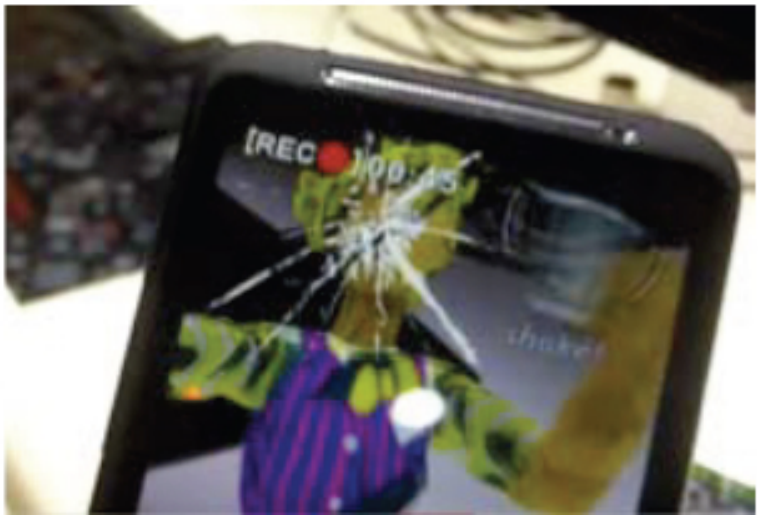
Title	Meaning	Embodied Skills
Device Metaphors	Using metaphor to suggest available player actions	Body A&S Naïve physics
Control Mapping	Intuitive mapping between physical and digital objects	Body A&S Naïve physics
Seamful Design	Making sense of and integrating the technological seams through game design	Body A&S
World Consistency	Whether the laws and rules in physical world hold in digital world	Naïve physics Environmental A&S
Landmarks	Reinforcing the connection between digital-physical space through landmarks	Environmental A&S
Personal Presence	The way that a player is represented in the game decides how much they feel like living in the digital game world	Environmental A&S Naïve physics
Living Creatures	Game characters that are responsive to physical, social events that mimic behaviours of living beings	Social A&S Body A&S
Body constraints	Movement of one's body position constrains another player's action	Body A&S Social A&S
Hidden information	The information that can be hidden and revealed can foster emergent social play	Social A&S Body A&S

Demo: Design Patterns

https://www.youtube.com/watch?v=3_3GlviyVN0

Example: Seamless Design

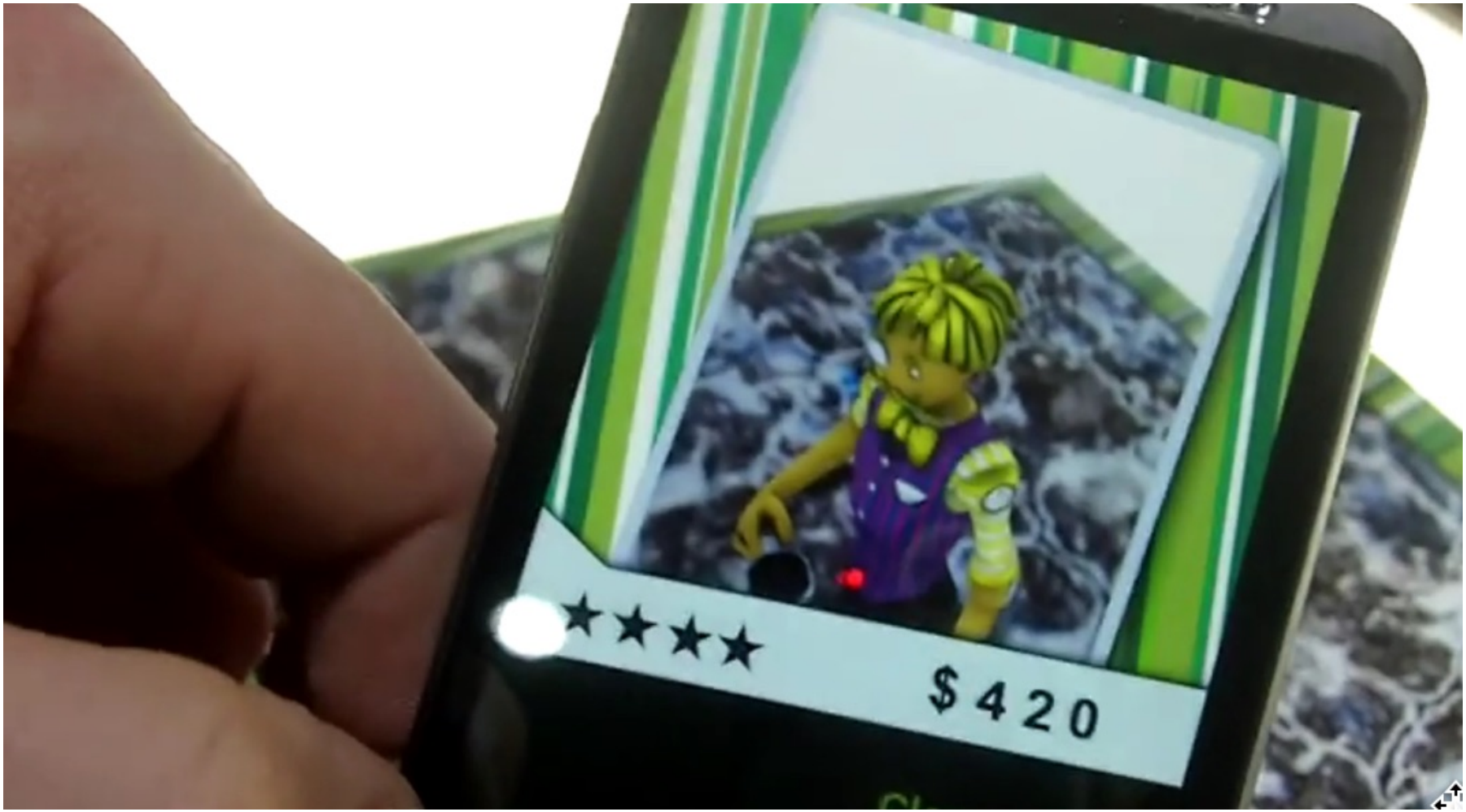




- Design to reduce seams in the user experience
  - Eg: AR tracking failure, change in interaction mode
- Paparazzi Game
  - Change between AR tracking to accelerometer input

Yan Xu , et.al. , Pre-patterns for designing embodied interactions in handheld augmented reality games, Proceedings of the 2011 IEEE International Symposium on Mixed and Augmented Reality--Arts, Media, and Humanities, p.19-28, October 26-29, 2011

Demo: Paparazzi Game



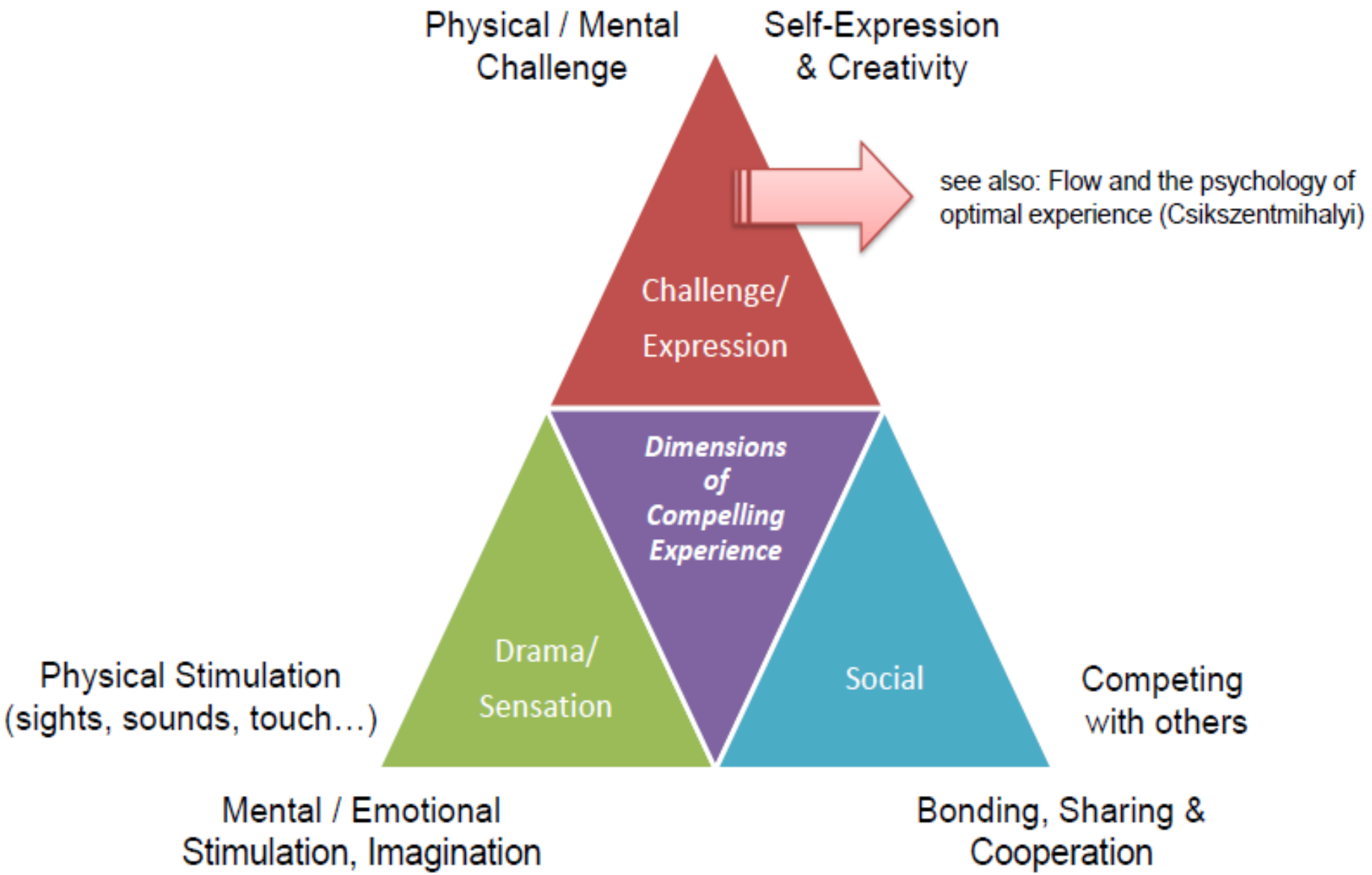
- https://www.youtube.com/watch?v=MIGH5WGMnbs

Example: Living Creatures

- Virtual creatures should respond to real world events
  - eg. Player motion, wind, light, etc
  - Creates illusion creatures are alive in the real world
- Sony EyePet
  - Responds to player blowing on creature

Mobile AR Game Design

what makes a compelling experience?



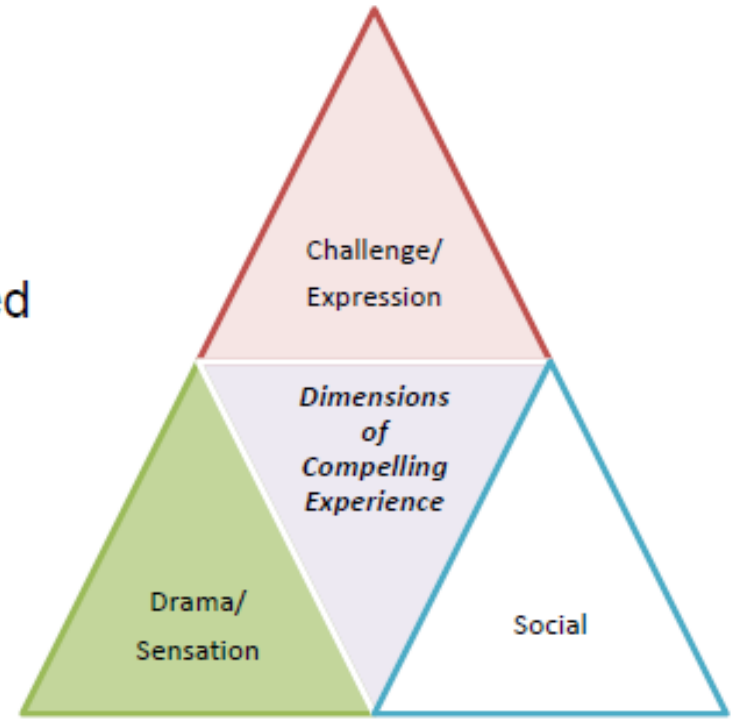
LIGHTNINGLABORATORIES
Strategic Innovation

ref: Hull, Reid "Experience Design for Pervasive Computing"

the reality of AR experiences today

What works:
* Physical engagement
* Visually captivating
* Emotional “wow” factor
* Invisible stories, revealed

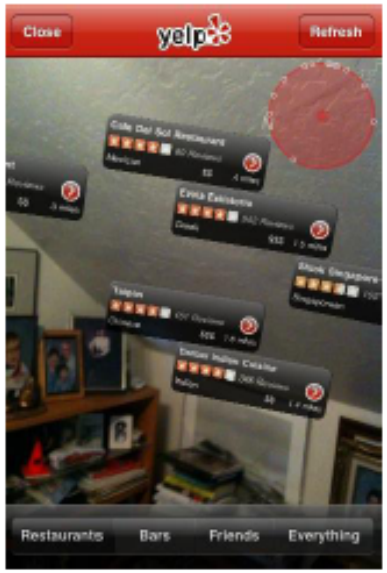
What doesn’t:
* Awkward use models
* No flow opportunities
* No social dimension
* Point experiences only



mobile AR issues & limitations

Technical limitations

- Sensor accuracy (GPS, compass etc)
- Indoor positioning
- Line of sight
- Device constraints (display, form factor, weight, battery, processor, network)
- Lack of interoperable standards e.g. for location (lat/long/alt, CRS, orientation)
- Relative positioning
- Object recognition & tracking
- Graphics issues (lighting, transparency, occlusion)



Use model issues

- Unnatural physical position
- Ambiguous social signals
- Cognitive model

Authoring limitations

- Platform specific
- Low level tools, complex workflow
- Focus on point interactions; no support for stories or interesting interactivity

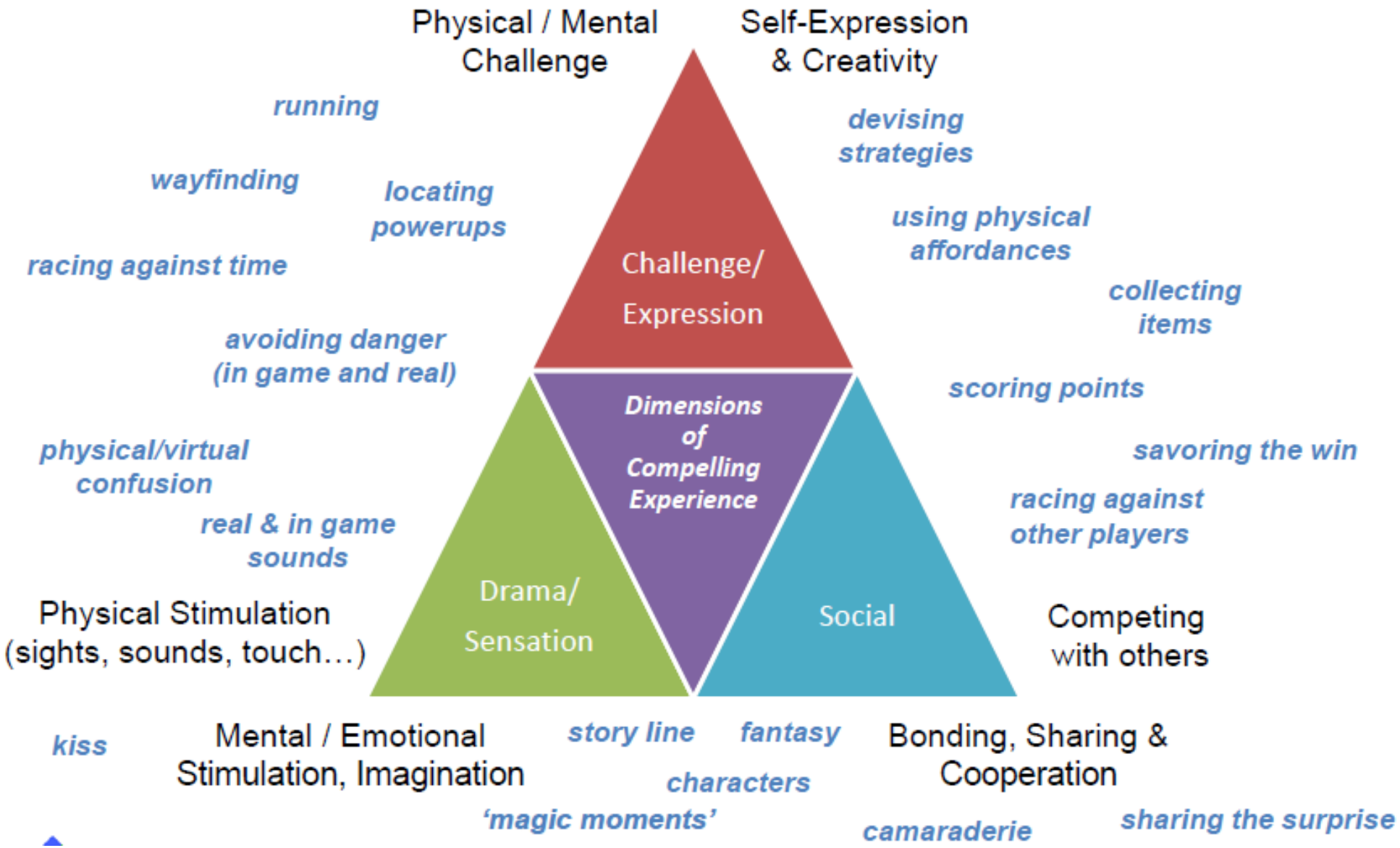
visionary example: AR gaming HP concept video

HP vision video Roku's Reward: http://www.youtube.com/watch?v=vCCyfkGKL_w

Demo: Roku's Reward

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

what makes a compelling AR experience?



mobile AR experience design practices

1. Understand limitations and design around them
2. Design for challenge, expression and flow
3. Design for physical sensation & emotional drama
4. Design for social bonding, sharing, competition
5. Bring an interdisciplinary media production mindset

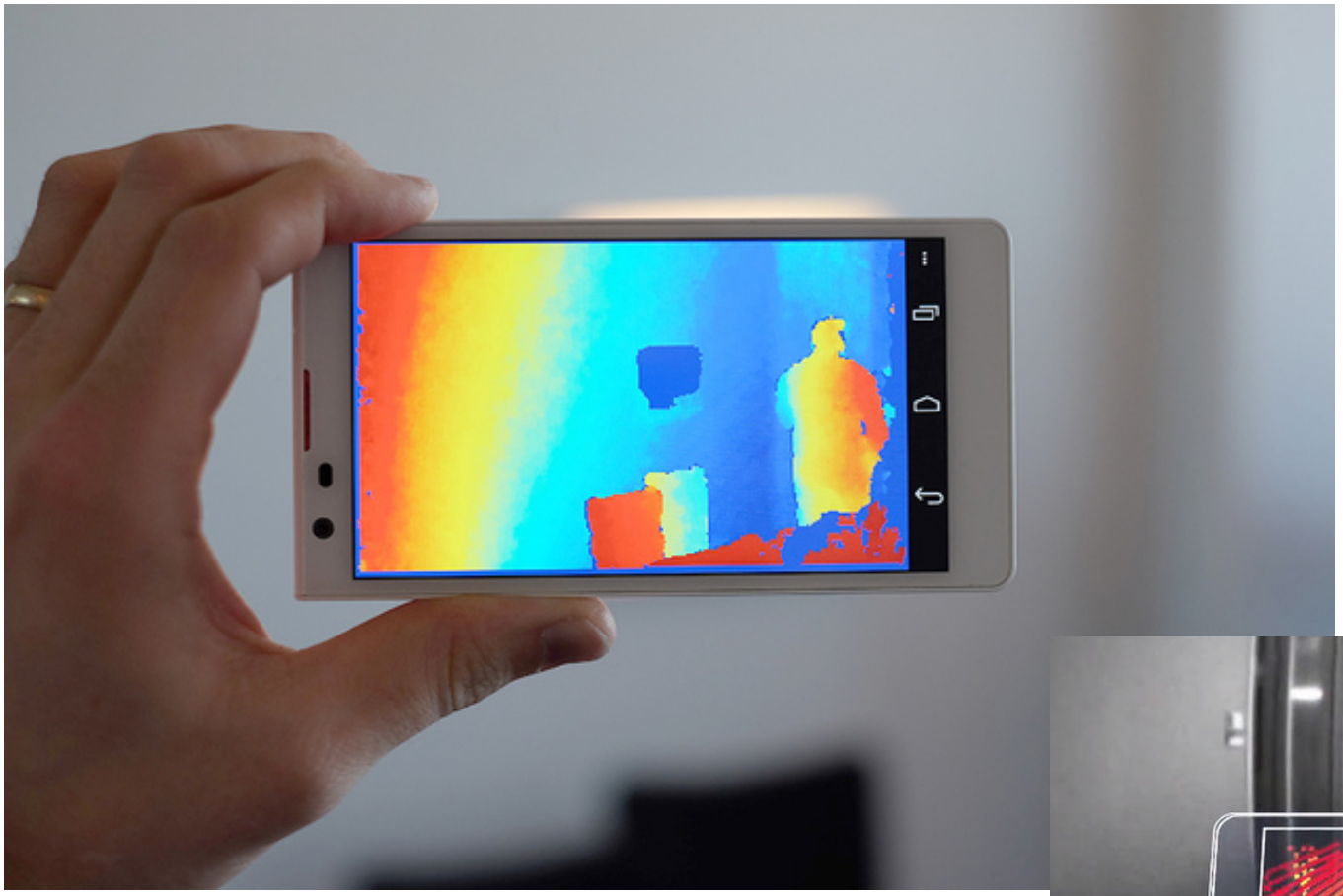
Research Directions

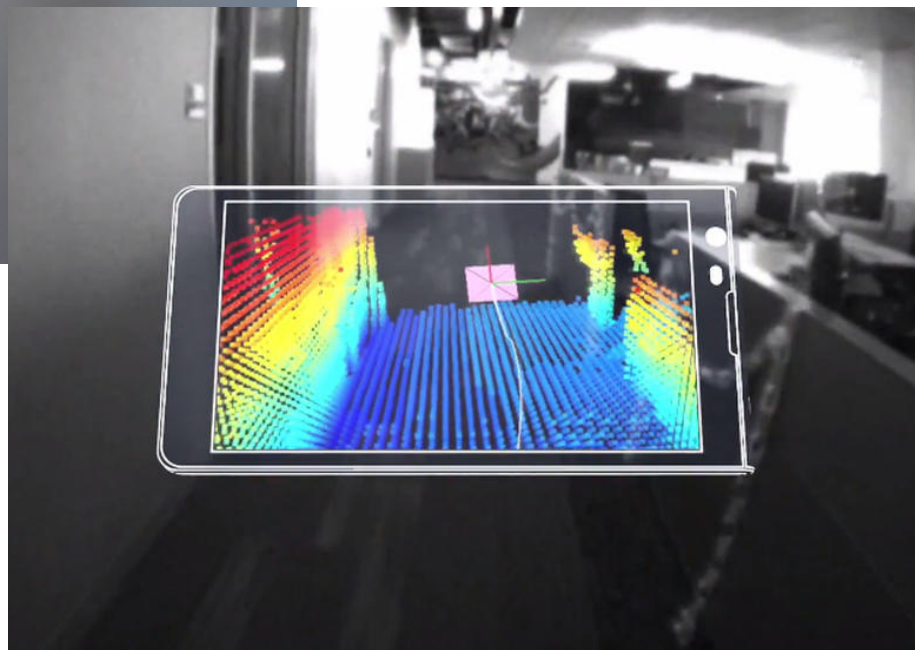
Research Directions

- Tracking
  - Markerless tracking, hybrid tracking
- Interactions
  - Displays, input devices, gesture
- Applications
  - Collaboration
- Ubiquitous AR
  - Mobile AR + Ubiquitous Computing

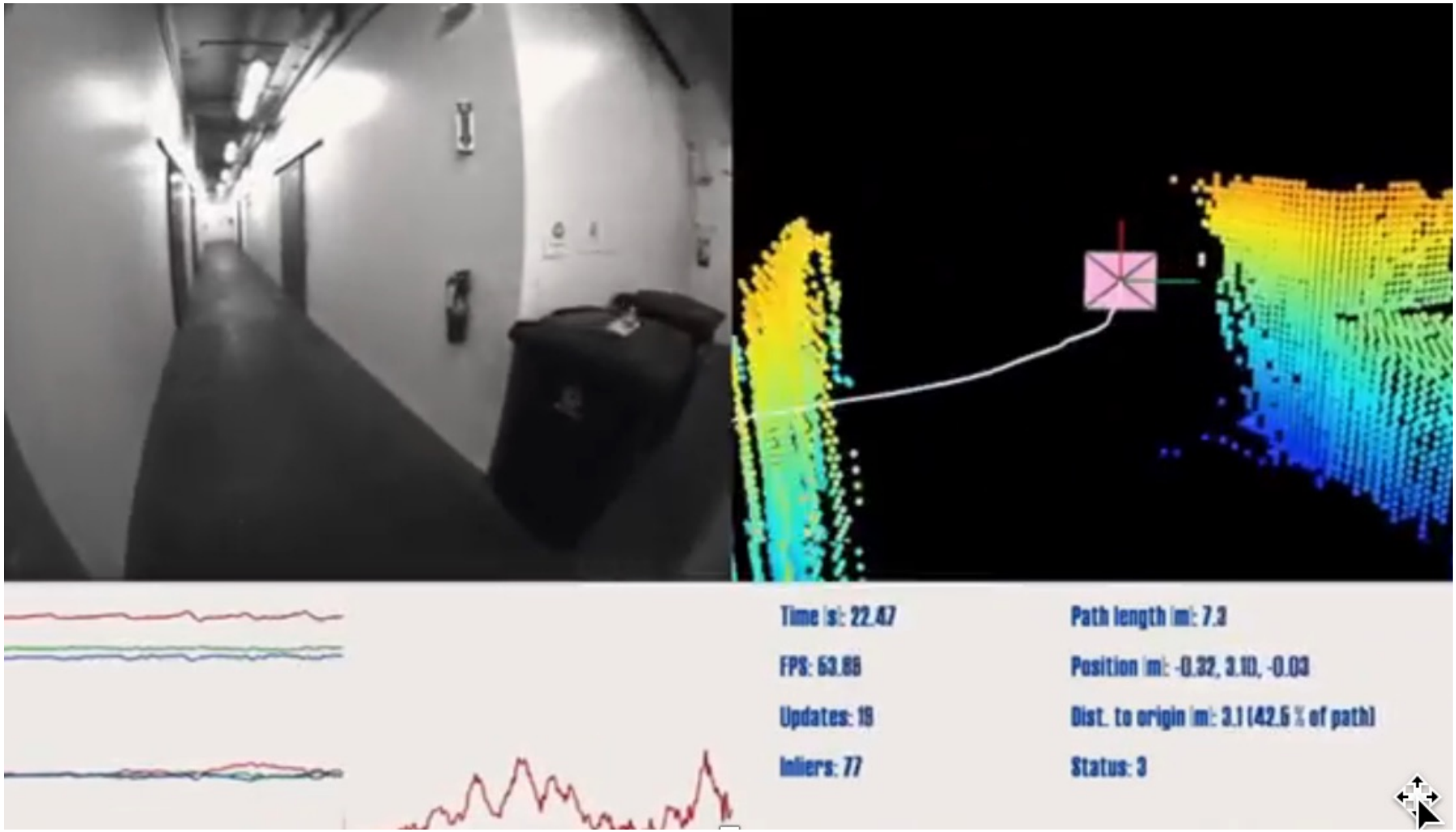
Project Tango

- Smart phone + Depth Sensing
- Sensors
  - Gyroscope/accelerometer/compass
  - 180º field of view fisheye camera
  - An infrared projector.
  - 4 MP RGB/IR camera





Project Tango Overview

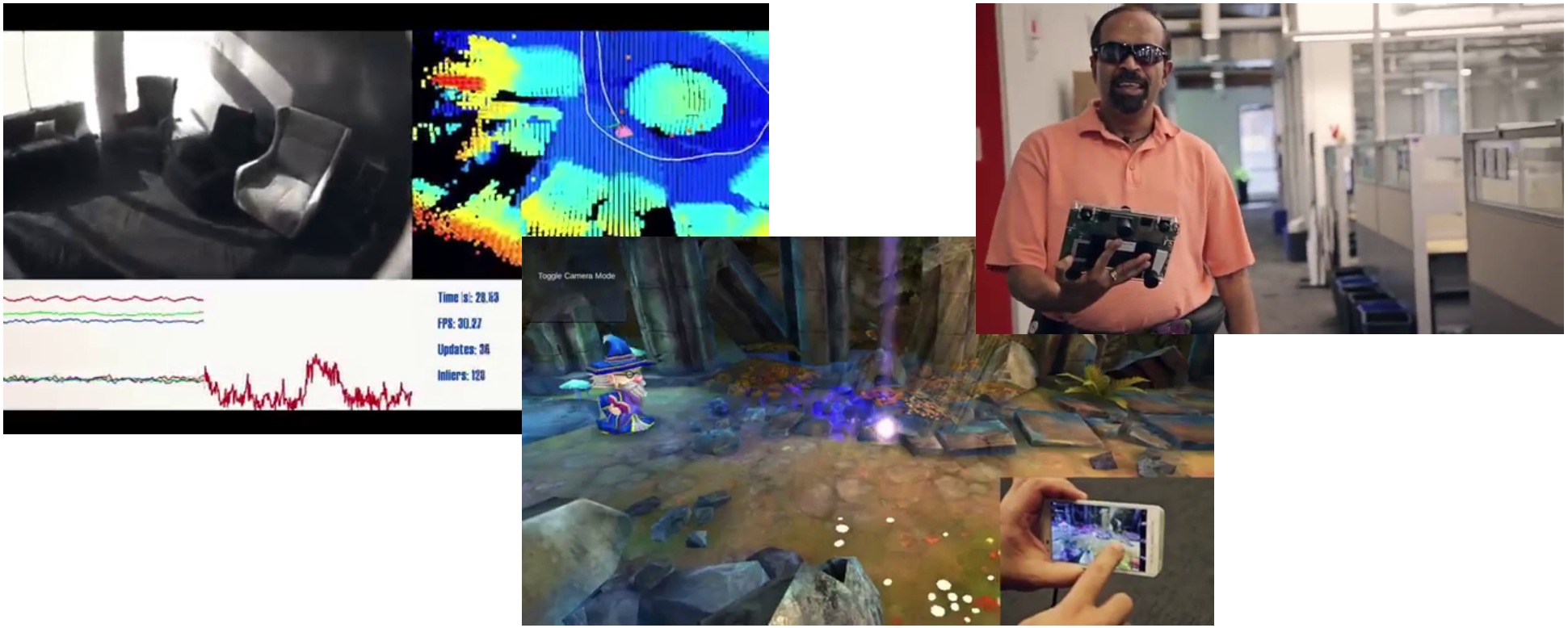


- https://www.youtube.com/watch?v=OsEgnIA8AD8

How it Works

- Sensors
  - 4MP RGB/IR camera : can capture full color images and detect IR reflections.
  - IR Depth Sensor : Used to measure depths with IR pulse
  - Tracking Camera : To track objects
- 3 Basic operations
  - In real time can map depth of environment
  - Measure depth accurately using IR pulse
  - Create a 3D model of the environment real time

Applications

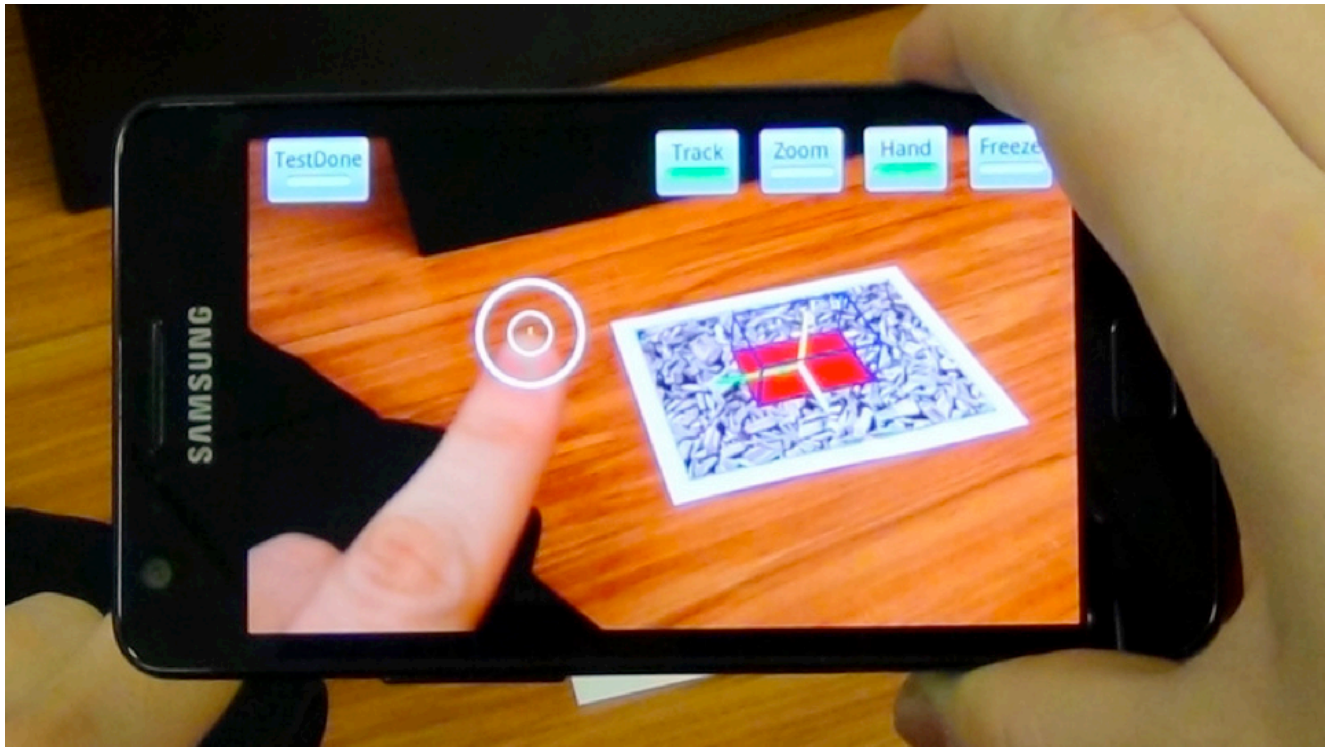


- Indoor tracking, games, disability, etc

Gestural interfaces

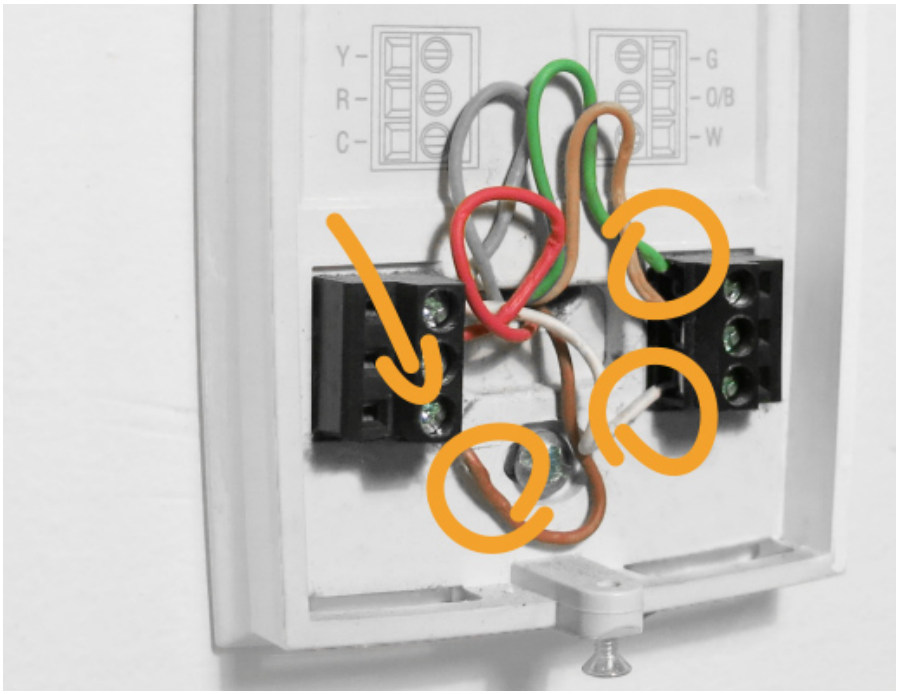
- 1. Micro-gestures
  - (unistroke, smartPad)
- 2. Device-based gestures
  - (tilt based examples)
- 3. Embodied interaction
  - (eye toy)

Natural Gesture Interaction on Mobile



- Use mobile camera for hand tracking
  - Fingertip detection

Remote Collaboration

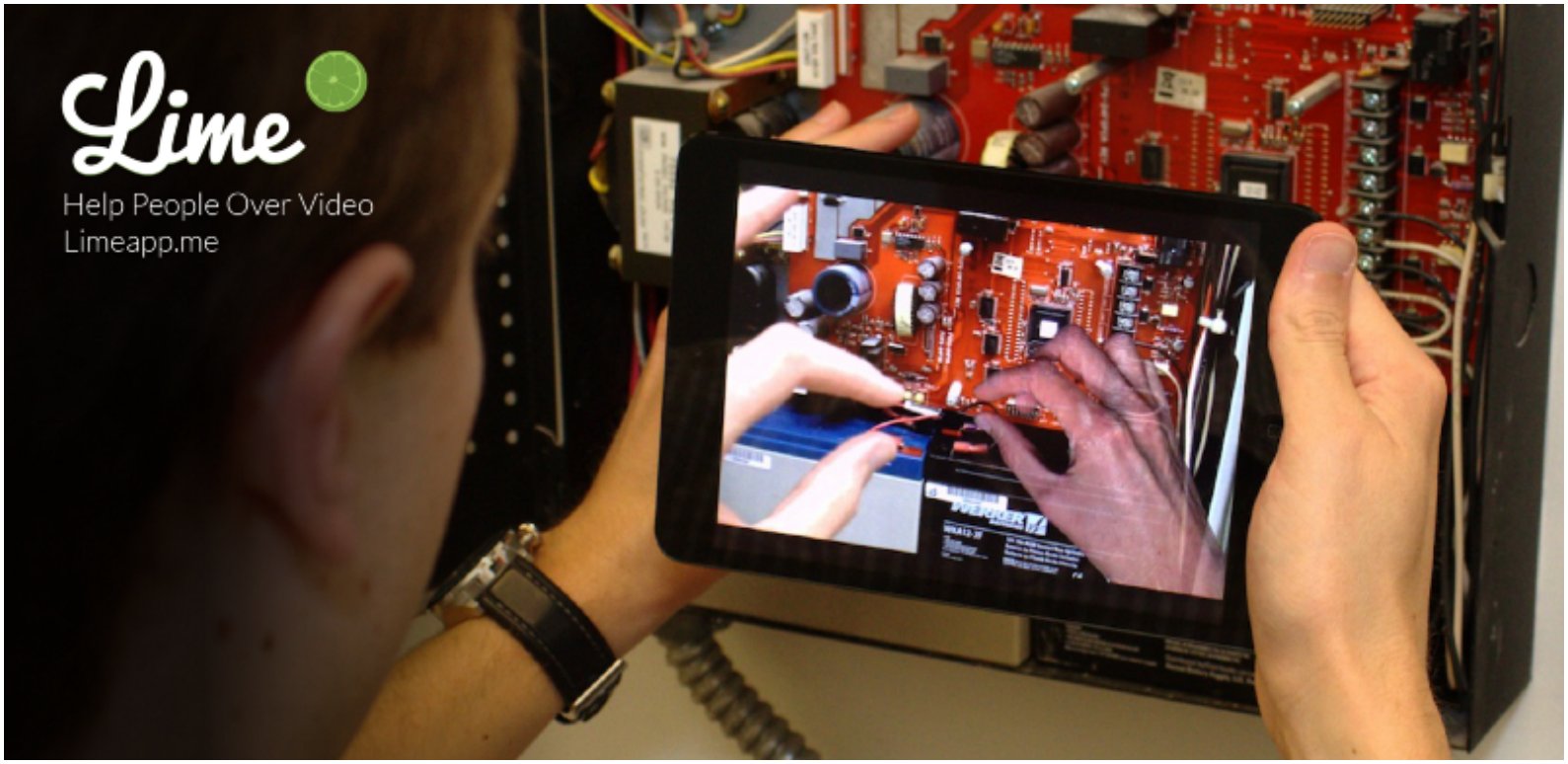


- Mobile AR offers new types of remote collaboration
- E.g. Vuforia's project chalk
  - Virtual annotation of live video from remote collaboration
  - Using SLAM tracking to space stabilize the annotations

Demo: Project Chalk

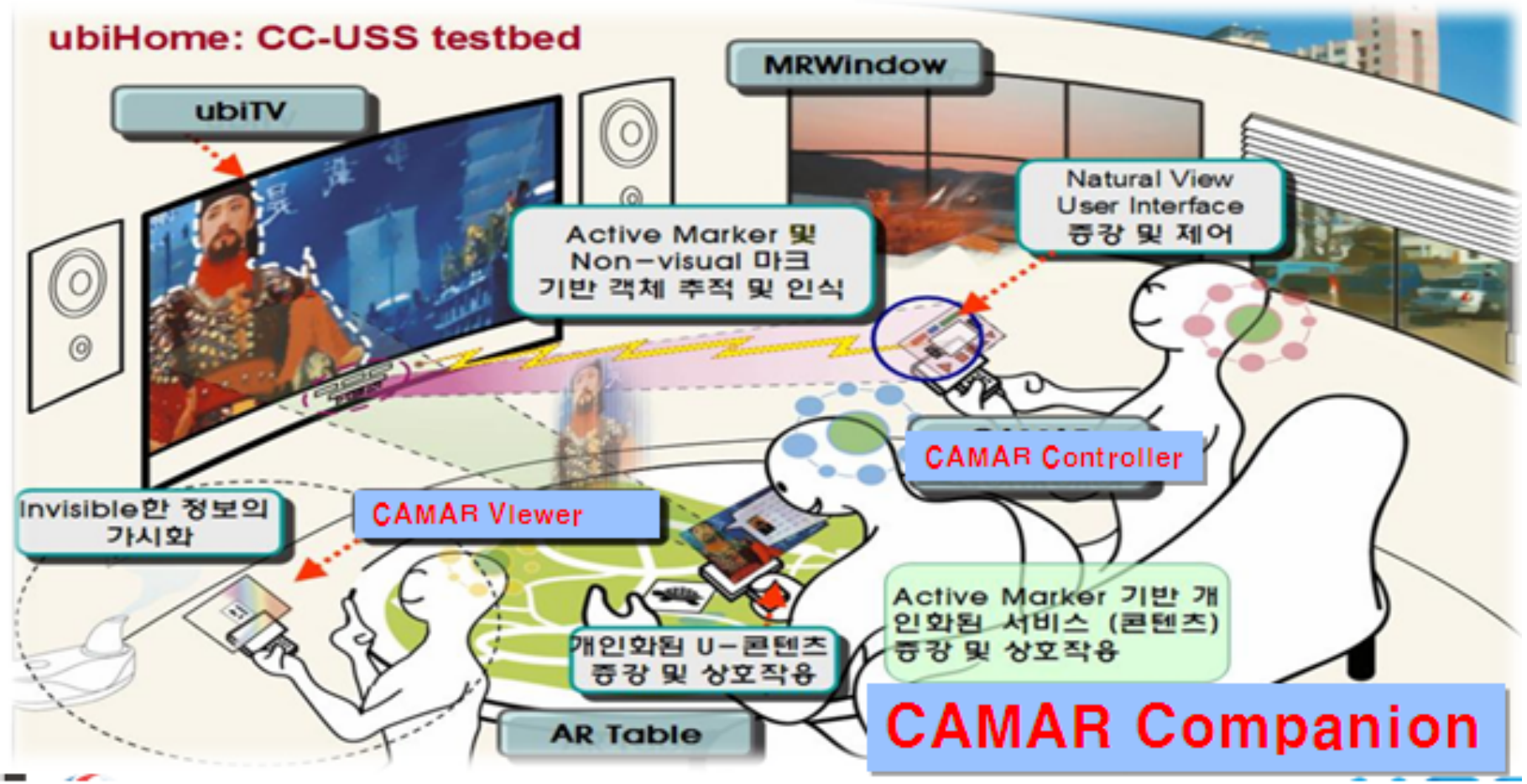
https://www.youtube.com/watch?v=C-7gXStKByE&t=29s

Vipaar Lime - https://www.vipaar.com/



- Remote collaboration on handheld
  - Remote users hands appear in live camera view

Ubiquitous AR (GIST, Korea)

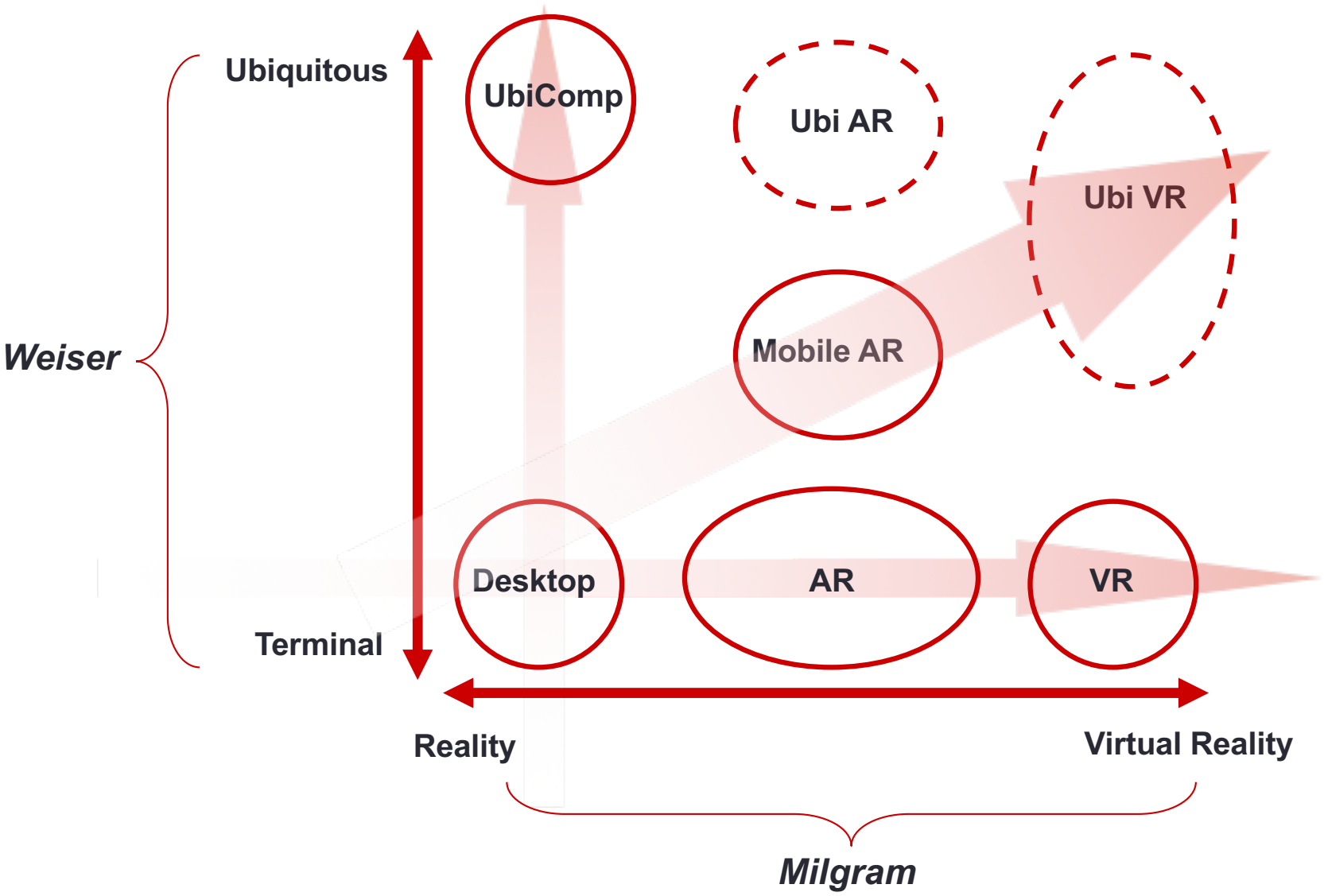


- How does your AR device work with other devices?
- How is content delivered?

CAMAR - GIST

(CAMAR: Context-Aware Mobile Augmented Reality)

Trend Towards Ubiquitous AR



Conclusions

Mobile AR

- Has a long history going back over 20+ years
- Current phones are powerful enough to create compelling mobile AR experiences
  - Wide range of sensors
  - Tracking software such as ARKit/ARcore available
- Many useful design guidelines available
  - Adapt existing mobile HCI guides, develop new guidelines
- Opportunities for future research
  - Tracking, interaction, collaboration, etc.

www.empathiccomputing.org

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