

# Mobile Information Systems

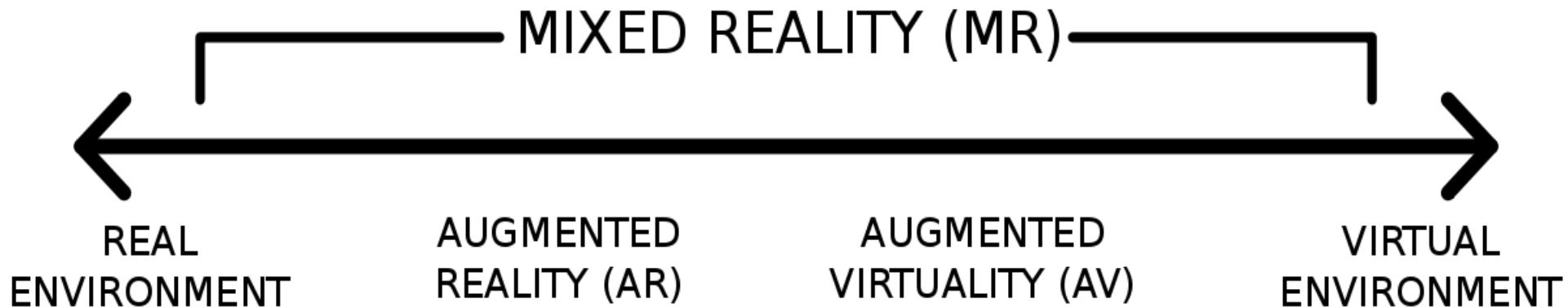
## Lecture 09: Mixed Reality

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Aalborg University

# Augmented Reality (AR)

Image source (CC): [https://en.wikipedia.org/wiki/Mixed\\_reality#/media/File:Reality-Virtuality\\_Continuum.svg](https://en.wikipedia.org/wiki/Mixed_reality#/media/File:Reality-Virtuality_Continuum.svg)

- Part of the “Virtuality Continuum” (see below)
  - Milgram & Kishino, “A Taxonomy of Mixed Reality Visual Displays”, 1994
- Subclass of *mixed reality*
  - Roughly categorized by ratio between real and virtual content



# Augmented Reality (AR) (2)

- Definition/characteristics
  - R. Azuma, “A Survey of Augmented Reality”, 1997
    - Mix of *real-world* and *virtual* visual information
    - Information can be *interacted* with in *real-time*
    - Real & virtual elements *spatially aligned* in 3D

## → Requirements:

- Visual input (real world) & output (virtual)
- User input & fast graphics (to enable interaction)
- 6D head tracking (for spatial alignment)

# Is this AR?

Image source (FU):

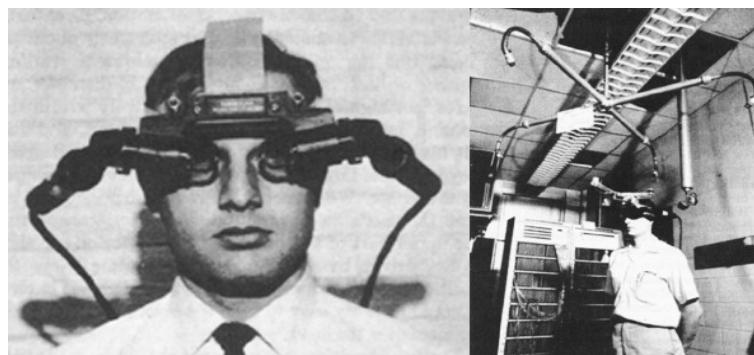
<http://archive.wired.com/culture/culturereviews/magazine/16-01/found>



# AR: History & Pioneers

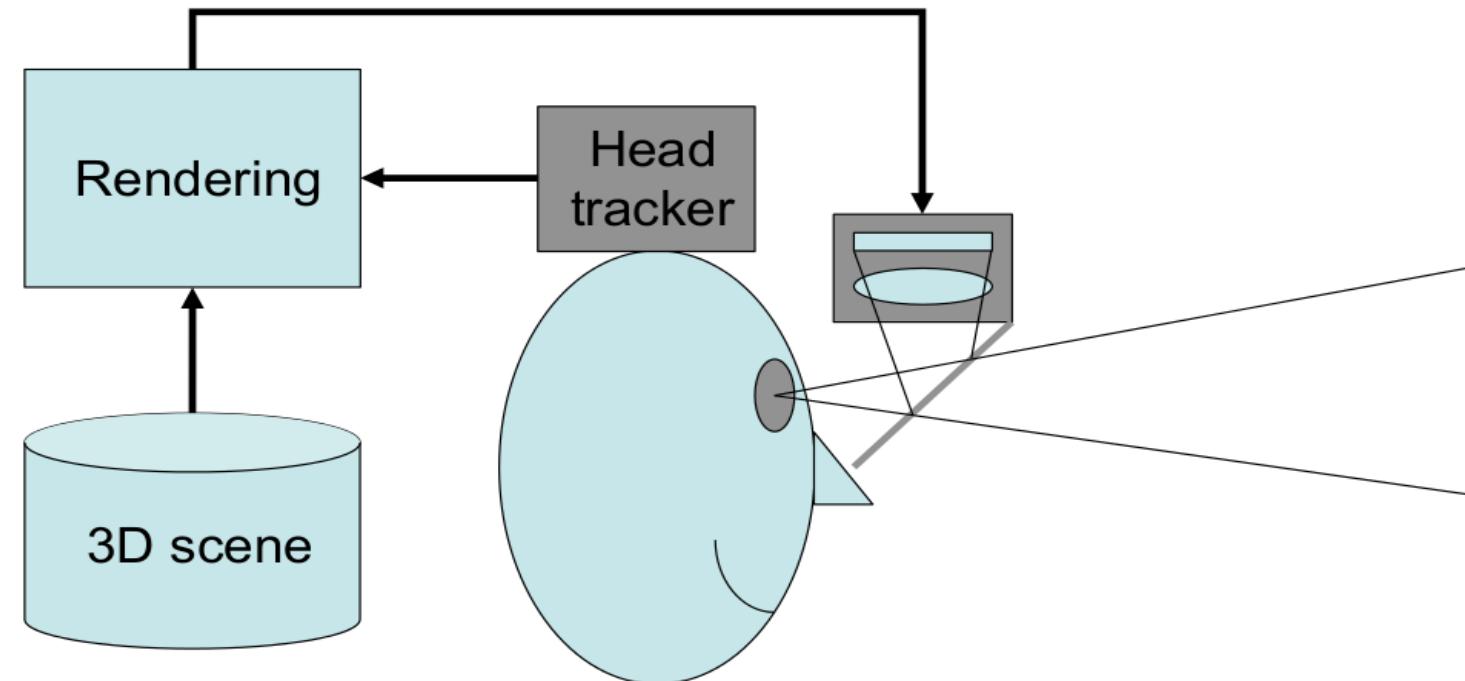
Image sources (FU): [https://louislau91 \[...\] /sword\\_of\\_damocles.jpeg](https://louislau91 [...] /sword_of_damocles.jpeg), [http://eyetap.org \[...\] /wearables.html](http://eyetap.org [...] /wearables.html)

- 1901: first mention of idea in novel (“The Master Key” by L. Frank Baum)
- 1968: first head-mounted display (HMD) (“The Sword of Damocles” by Ivan Sutherland)
- 1980: first wearable HMD by Steve Mann



# HMD: optical see-through (1)

Image source (FU): LMU Lecture by J. Wagner

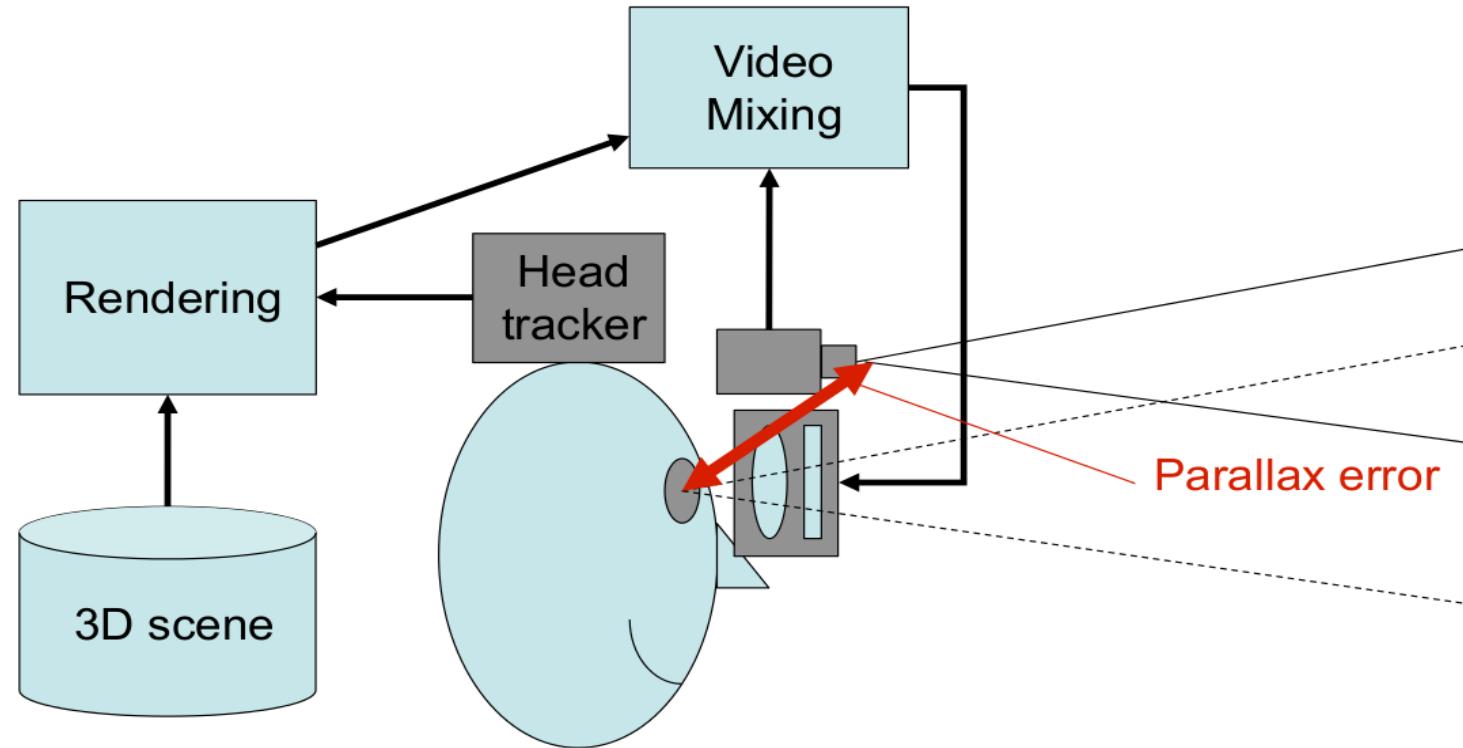


# HMD: optical see-through (2)

- Use “beam combiner” + focus optics to overlay display image over real-world view
- Pro:
  - Direct view of real world
  - Eye can focus at different distances
- Contra:
  - (Mostly) not able to “cover” objects (problem with 3D occlusion, i.e. real object behind virtual one)
  - Lag/alignment issues reality virtual content more obvious

# HMD: video see-through (1)

Image source (FU): LMU Lecture by J. Wagner



# HMD: video see-through (2)

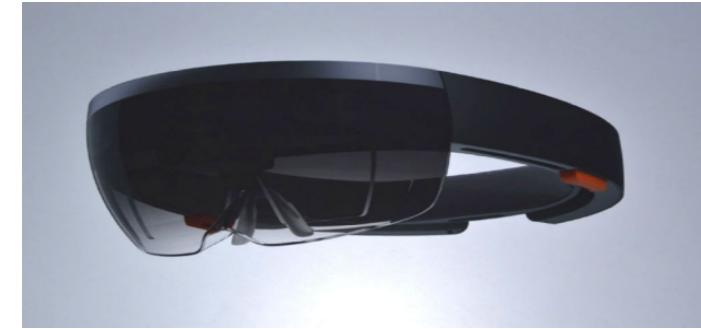
- Similar to VR displays (cf. lecture 5) + camera
- Pro:
  - Possible to use camera image for tracking  
→ less lag, better alignment real virtual
  - Real objects can be hidden/substituted
- Contra:
  - Parallax error camera display
  - Similar problems to VR displays (motion sickness)
  - Single focus distance

# Commercial HMDs for AR

Image source (CC): <https://www.flickr.com/photos/jiff01/15867880743/>

Image source (CC): <http://photozou.jp/photo/show/124201/256868351>

- Optical see-through:
  - Google Glass, North Focals (*not AR!*)
  - Microsoft Hololens →
  - Magic Leap
- Video see-through:
  - Smartphone goggles (Google Cardboard, Samsung Gear VR)
  - Meta Quest 3, Lenovo Mirage Solo →
  - VR Headset + add-on cameras



# Issues with HMDs

- Brightness (esp. for outdoor/sunlit context)
- Field of view (FOV)
  - Human FOV nearly 180°, many HMDs only ~ 20°
- Weight/comfort (can induce headaches)
- Lag between ...
  - real and virtual content
  - head and image movement
- Safety – what if video see-through fails while you're crossing the street?

# Issues with Cardboard & Co.

Image source (CC): <https://www.flickr.com/photos/othree/14519574116>

- Only single camera on almost all devices  
→ no 3D view for AR possible, “flat screen effect”
- (Mostly) no positional tracking, only rotation  
→ higher probability of motion sickness
- Unpredictable device capabilities
- Uncomfortable weight distribution
- Touchscreen inaccessible



# Heads-up displays (HUDs)

Image source (CC): [https://en.wikipedia.org/wiki/Head-up\\_display#/media/File:E60hud.JPG](https://en.wikipedia.org/wiki/Head-up_display#/media/File:E60hud.JPG)

Image source (CC): [https://en.wikipedia.org/.../File:C-130J\\_Co\\_Pilot%27s\\_Head-up\\_display.jpg](https://en.wikipedia.org/.../File:C-130J_Co_Pilot%27s_Head-up_display.jpg)

- Mostly used in vehicles (car, airplane)
  - Navigational information, speed, horizon etc.
  - Not always spatially aligned (cf. left image)
  - Uses beam combiner (windshield) + 2D display



# Augmented Diminished Reality?

Image source (FU): <http://wearcam.org/maninventions-password-stefanosmannaz13/mannglas.htm>

- Not adding, but removing real-world content?

- Any plausible scenario?

→ HDR welding mask/goggles

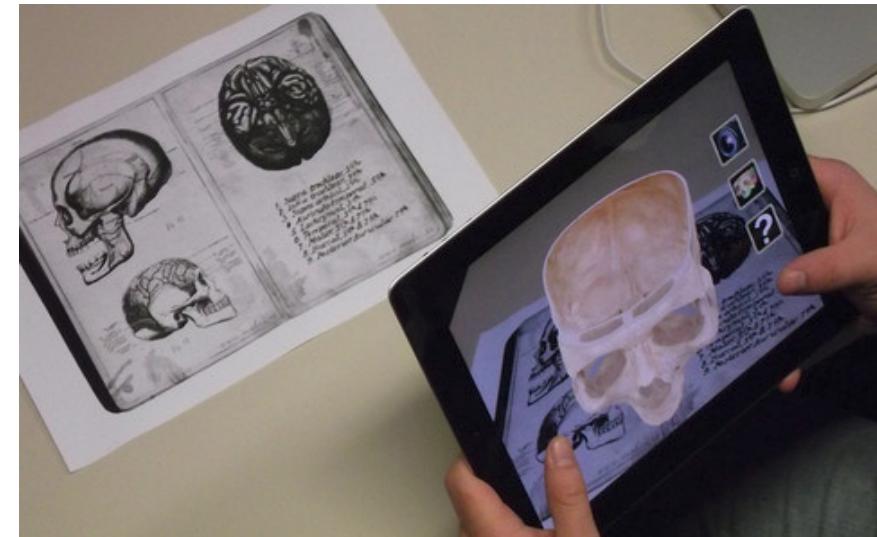
- Filters out welding arc
  - Other details remain visible



# Mobile devices as AR displays

Image source (CC): [https://en.wikipedia.org/.../File:App\\_iSkull,\\_an\\_augmented\\_human\\_skull.jpg](https://en.wikipedia.org/.../File:App_iSkull,_an_augmented_human_skull.jpg)

- Uses “window into virtual world” metaphor
- Usually no 3D display
  - Except with tricks like Google Cardboard
  - Parallax issues
- Primary problem:  
location/tracking



# AR: tracking & localization

- Fundamental requirement for AR:  
stable & reliable head/view tracking
- Multiple different approaches:
  - GPS + IMU
  - Vision-based
    - Stereo/depth cameras
    - SLAM algorithms

# Tracking: GPS + IMU

Image source (CC): <https://www.flickr.com/.../>, <https://www.flickr.com/.../27972275293>

- Sensor fusion for 6D pose (geo coordinates)
  - 3D position from GPS, 3D orientation from IMU
  - (Relatively) low accuracy & position
  - Requires additional environment information
- Best suited for large-scale applications, e.g. buildings
- Examples: Pokemon Go, Layar, Wikitude Browser



# Tracking: vision-based

- Primary goal (again): retrieve 6D pose
  - Secondary goal: create environment map
  - Enables interaction *with* environment
- ... using specialized hardware:
  - Add-on stereo cameras/depth cameras
  - iPad Pro (tablet with depth cam)
- ... for arbitrary devices (single RGB cam):
  - Marker-based (fiducial/image)
  - SLAM algorithms

# Tracking: vision – stereo/depth

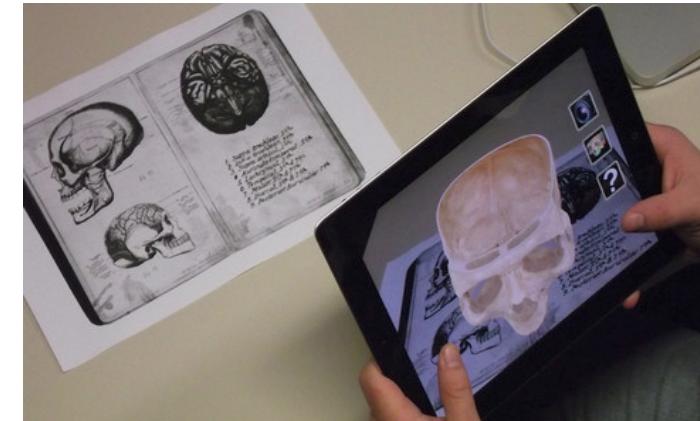
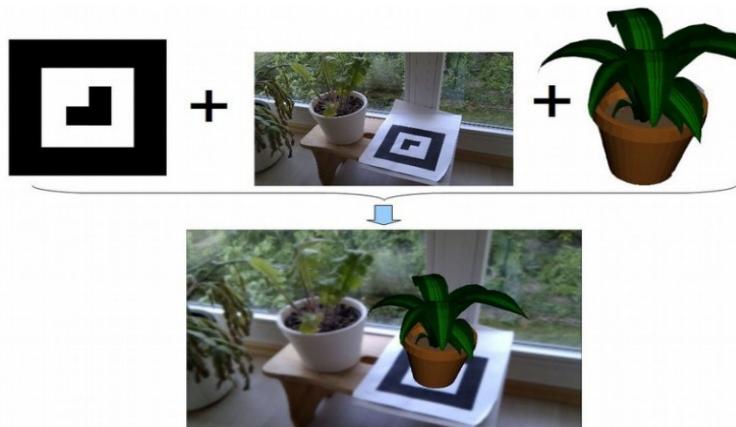
- Core idea: each pixel provides color + *distance*
- Stereo cameras: 2 cams mounted in parallel
  - Replicate (part of) human depth perception
  - Find *stereo correspondences* between 2 images
  - Use camera/lens geometry to calculate distance
- Depth cameras: single camera + emitter
  - ToF – Time-of-flight: measure travel time of IR flash
  - Structured light: shift in projected light pattern
- Both methods require specialized hardware!

# Tracking: vision – marker-based

Image source (FU): <https://code.google.com/p/andar/>

Image source (CC): [https://en.wikipedia.org/.../File:App\\_iSkull,\\_an\\_augmented\\_human\\_skull.jpg](https://en.wikipedia.org/.../File:App_iSkull,_an_augmented_human_skull.jpg)

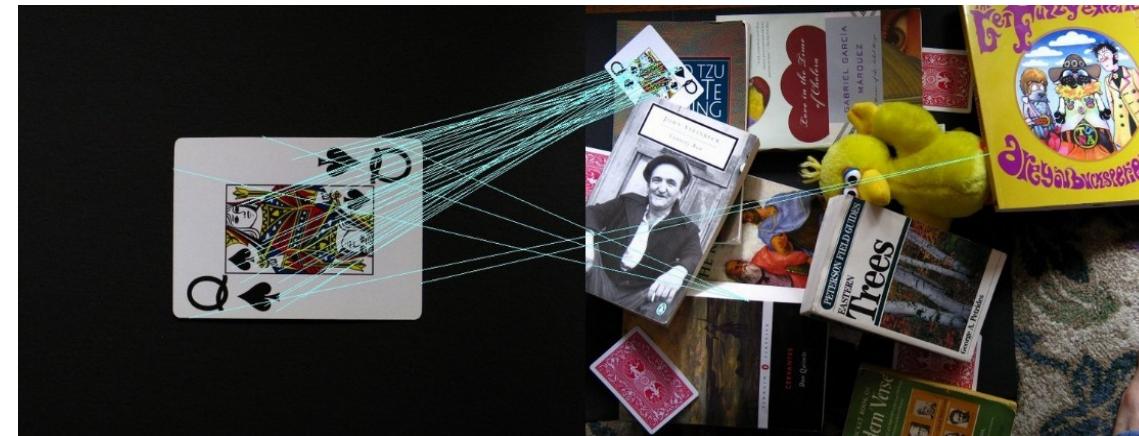
- Core idea: use pre-defined markers/targets
  - “Fiducials”: printed black-and-white patterns
  - Image targets: use (flat) real-world objects
- System detects pose relative to target



# Marker-based tracking: SIFT & Co.

Image source (FU): <https://robwhess.github.io/opensift/>

- SIFT = Scale Invariant Feature Transform
  - Detects key points in images
  - Describes them independent of size, rotation, ...
  - Descriptors can be matches across images  
→ calculate geometric transformation



# Tracking: vision – SLAM (1)

Image source (FU): <https://www.youtube.com/watch?v=F3s3M0mokNc>

- Simultaneous Localisation & Mapping
  - Creates 3D environment map + 6D camera pose
  - Requires only single camera
  - Works on almost any device
  - Creates stereo correspondences from motion
  - (Optionally) uses IMU data to determine motion magnitude



# Tracking: vision – SLAM (2)

Image source (CC): <http://photozou.jp/photo/show/124201/251690045>

- Map generation requires significant processing power
  - Possible on most recent smartphones with ARKit/ARCore frameworks
  - Needs calibration data for camera (distortion), IMU (alignment to camera)
  - Includes plane detection (floor, tables, walls) for object placement + shadows
  - Touchscreen-based interaction

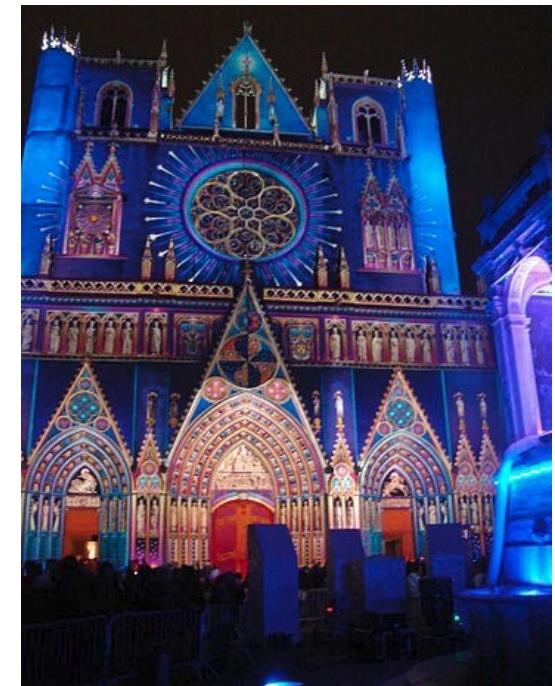


# Spatial AR/Projection Mapping (1)

Image source (CC): [https://en.wikipedia.org/.../File:Cath.\\_St\\_Jean\\_%282%29.JPG](https://en.wikipedia.org/.../File:Cath._St_Jean_%282%29.JPG)

Video source (FU): <https://www.youtube.com/watch?v=KBx4RGoB6XI>

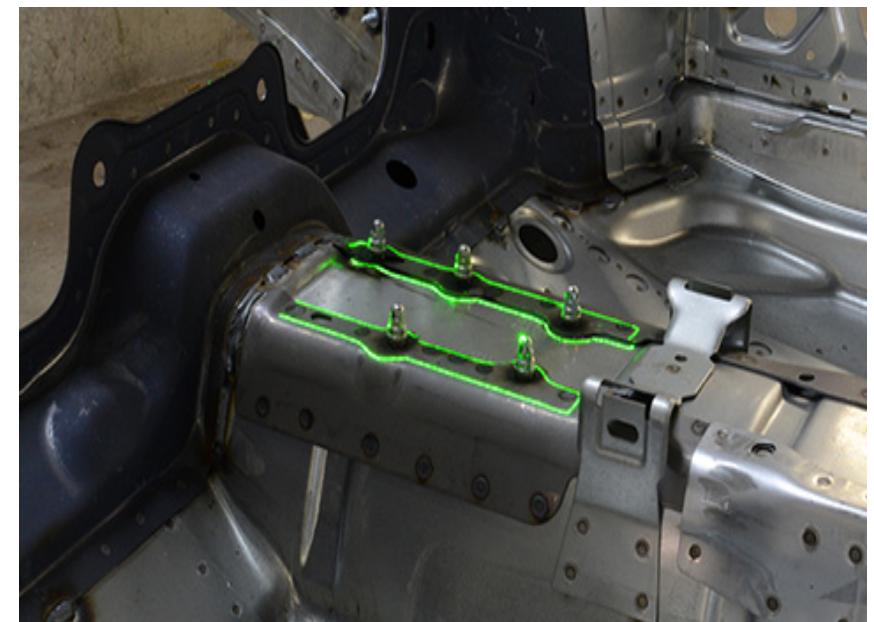
- Project augmentations directly onto real world
  - Mostly static projector/camera setups
    - E.g. for buildings, cars, other large objects
  - Pico projectors → mobile use?
    - Big problem (again): brightness vs. power supply
    - Other issue: focus distance → laser projectors?
    - Requires ...
      - accurate environment maps
      - object tracking



# Spatial AR/Projection Mapping (2)

Image source (FU): <https://www.extend3d.de/>

- Industrial usage scenario: project assembly instructions directly onto workpiece (“Werklicht” by Extend3D)
  - Needs high brightness & focal depth (green outline) → laser projector required
  - Workpiece geometry needs to be known in advance → target for visual tracking (similar to image targets)

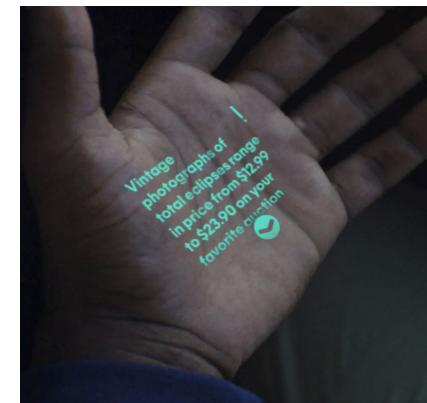
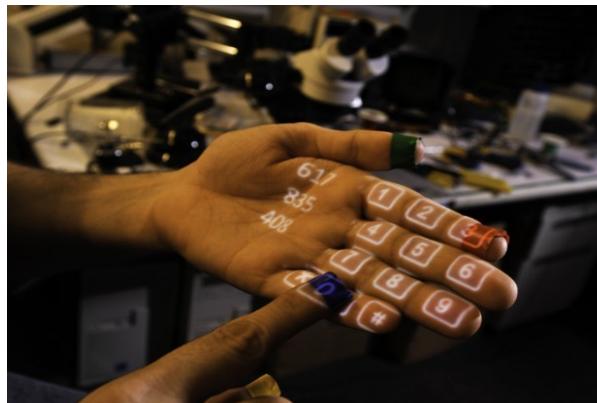


# Interaction with AR

Image source (FU): <http://www.pranavmistry.com/projects/sixthsense/>

Image source (FU): <http://ilab.cs.ucsb.edu/projects/taehee/HandyAR/>

- Touch screen, e.g. “Touch Projector”, **AI Pin**
  - Not feasible with HMDs, only for handheld use
- Individually tracked tools (e.g. Wiimote, gloves)
- Optical recognition/tracking of hands



# AR applications

Image source (FU): <http://www.trylive.com/>

Image source (FU): <http://campar.in.tum.de/Chair/ResearchIssueMedAR>

- AR: still waiting for the “killer app”
  - Advertisements (Ikea, fashion) →
  - Military (sadly): cockpits, weapon sights
  - Education (e.g. iSkull, slide 14)
  - Repair & Maintenance (e.g. see [video](#))
  - Gaming (e.g. Ingress, Pokemon Go)
  - Medical applications (X-ray vision) →
  - Navigation (only prototypes)



# “Mobile” Virtual Reality?

Image source (CC): [https://de.m.wikipedia.org/wiki/Datei:Oculus\\_Quest.jpeg](https://de.m.wikipedia.org/wiki/Datei:Oculus_Quest.jpeg)

Image source (FU): [https://de.m.wikipedia.org/wiki/Datei:Oculus\\_Touch\\_Hand\\_Controller\\_2.jpeg](https://de.m.wikipedia.org/wiki/Datei:Oculus_Touch_Hand_Controller_2.jpeg)

- Meta Quest 1-3: no cables (mobile HW)
- 4 low-res high-speed IR cameras
  - Tracking of hand-held controllers
  - “Room-scale” 6DoF tracking
- No obstacle detection, only pre-defined safety boundaries → needs large space
- Possible workaround: “redirected walking”
- General research topic in VR: locomotion



# The End

