

# Augmented Reality

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# Augmented Reality and Virtual Reality

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## □ Virtual Reality

- Totally immersive environment
- Visual senses are under control of system (sometimes aural and proprioceptive senses too)

## □ Augmented Reality

- System augments the real world scene (supplements reality, instead of completely replacing it)
- User maintains a sense of presence in real world
- Needs a mechanism to combine virtual and real worlds, i.e., registration

## □ Mixed Reality

- Mixed reality includes augmented reality, augmented virtuality, and other mixed configurations

# Augmented Reality

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- ❑ Ronald Azuma (1997)
- ❑ "In contrast with virtual reality, which refers to a situation in which the goal is to immerse a user in a completely synthetic environment, augmented reality refers to a situation in which the goal is to supplement a user's perception of the real world through the addition of virtual objects."
- ❑ Blends real and virtual, real-time interactive, registered in 3D
- ❑ Enhance perception of and interaction with real world
- ❑ Potential for productivity improvements in real-world tasks

# Mixed Reality

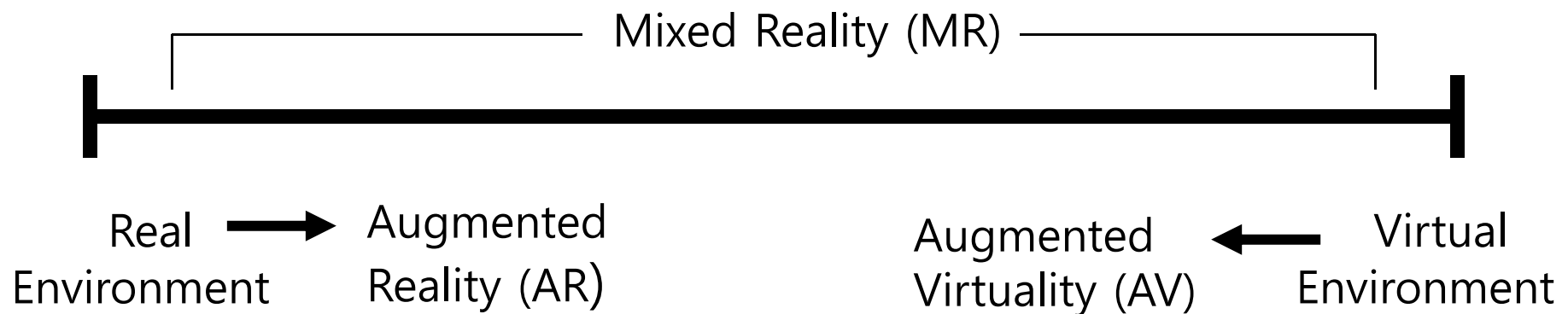
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- Paul Milgram and Fumio Kishino (1994)
- "Mixed reality is a term that has been used to refer to the entire spectrum of situations that span the continuum between virtual reality and actual reality. Mixed reality includes augmented reality, augmented virtuality, and other mixed configurations."

Milgram, Paul; H. Takemura; A. Utsumi; F. Kishino (1994). "Augmented Reality: A class of displays on the reality-virtuality continuum" *Proceedings of Telemanipulator and Telepresence Technologies*. pp. 2351–34.

# Reality-Virtuality Continuum

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Miligram coined the term “Augmented Virtuality” to identify systems which are mostly synthetic with some real world imagery added such as texture mapping video onto virtual objects.

# Augmented Virtuality

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- A system in which real multi-sensory input is provided, which supplements the visually presented virtual environment
- *Directing the smell of coffee grounds to a user* when she/he passes near a coffee maker in the virtual environment
- *Turning on a heat lamp over the user* when she/he approaches a spot in the virtual environment that is exposed to full sun
- *Turning on a fan in front of the user* when she/he approaches a spot in the virtual environment that is exposed to wind

# AR History

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- ❑ 1960s – First See-Through HMD (Ivan Sutherland)
- ❑ 1970-80s – US Air Force Super Cockpit (Thomas Furness)
- ❑ Early 1990s
  - **Boeing** coined the term “**Augmented Reality**”
  - Wire harness assembly application (T. Caudell, D. Mizell).
- ❑ Early to mid 1990s – UNC ultrasound visualization
- ❑ 1994
  - Motion-stabilized AR display (Azuma)
  - First motion-stabilized AR display that works outdoors and achieves tighter registration than any previous outdoor AR system.
- ❑ 1995 – Fiducial tracking in video see-through AR
- ❑ 1996 – UNC hybrid magnetic-vision tracker
- ❑ Late 1990s – Collaboration, Outdoor applications
- ❑ 2000 – Augmented sports broadcasts

# AR History

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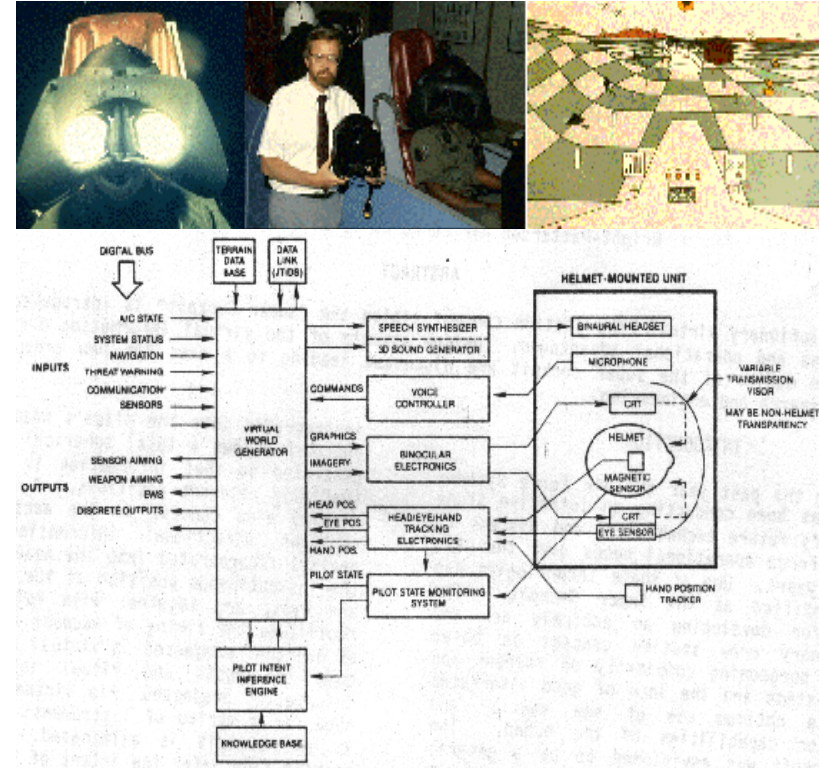
- ❑ 1999 – HIT Lab **ARToolKit** open-source AR SDK
- ❑ 2008 – **Wikitude** AR SDK for iOS, Android, Smart Glasses
- ❑ 2010 – Qualcomm **Vuforia** AR platform
- ❑ 2016 – **Pokémon GO** AR mobile LBS game by Niantic
- ❑ 2017 – Apple **ARKit** (iOS 11) API for developers working on virtual reality and augmented reality applications
- ❑ 2017 – Google **ARCore** SDK for building augmented reality experience
- ❑ 2017 - Microsoft **Mixed Reality Toolkit(also known as HoloToolkit)** for HoloLens and other Windows-based MR headsets
- ❑ 2018 – Magic Leap **Lumin** SDK for Magic Leap One
- ❑ 2019 – **MRTK v2** is not compatible with MRTK v1
- ❑ 2020 – Vuforia 9.5(Oct 22 2020), Apple ARKit4, HoloLens2 MRTK v2.5.1



# AR History



Surtherland's "Ultimate Display"



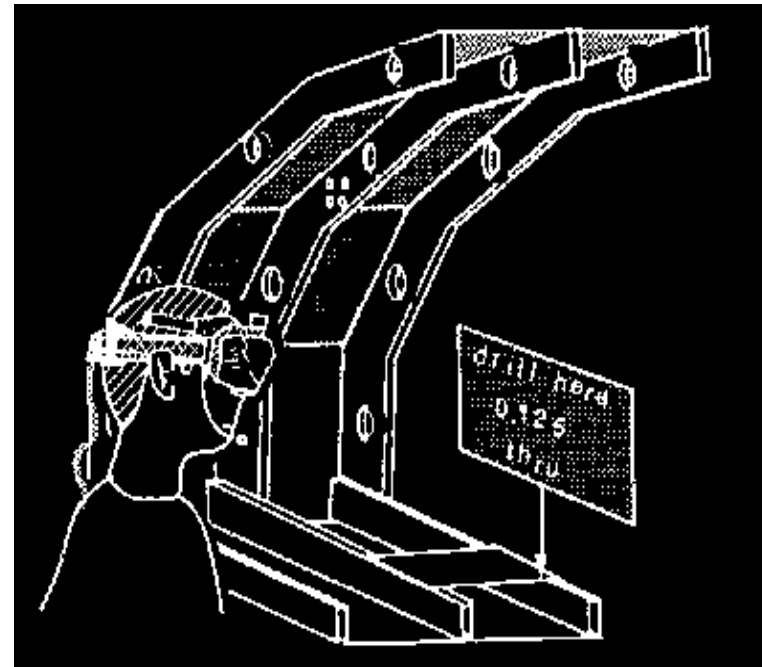
Furness' "Super Cockpit", a simulated virtual cockpit

# AR History – Assembly and Maintenance

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Layout Diagrams for the wire bundles appear "superimposed" on the layout board



Boeing HUDSET (Heads-up Display See-through head-mounted display)

# AR History – Assembly and Maintenance

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Assembly, maintenance, and repair of printer @ Columbia University

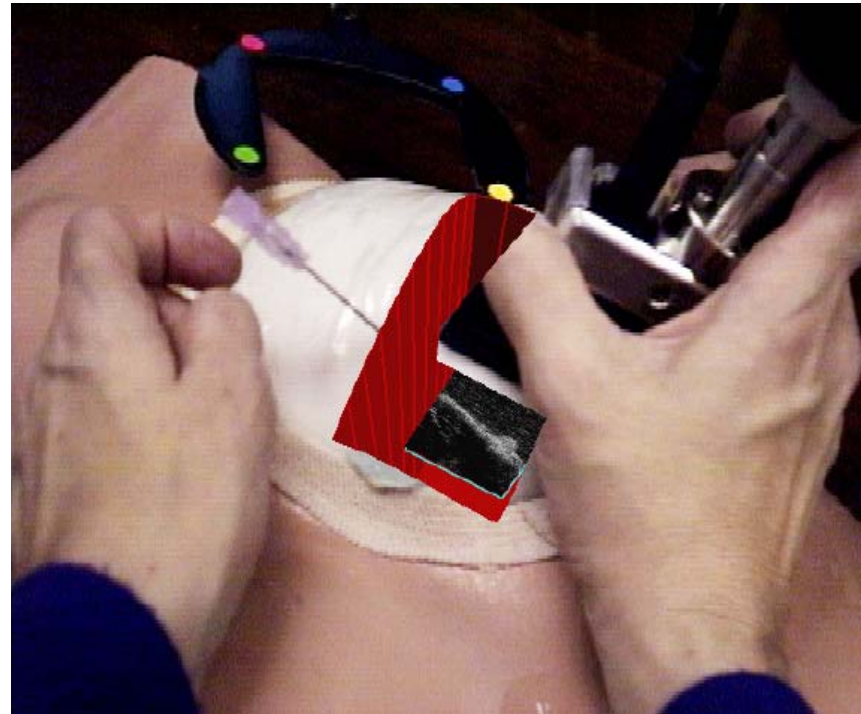


# AR History – Medical training

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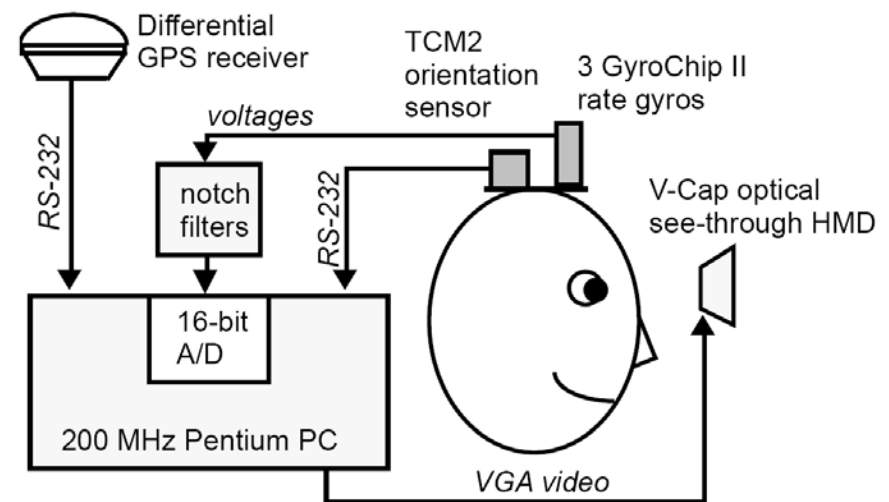


Video See-through Augmented Reality HMD built on the basis of a Sony Glasstron LDI-D100 device



HMD point of view image from a 1996 AR guidance experiment @ UNC, Ultrasound project

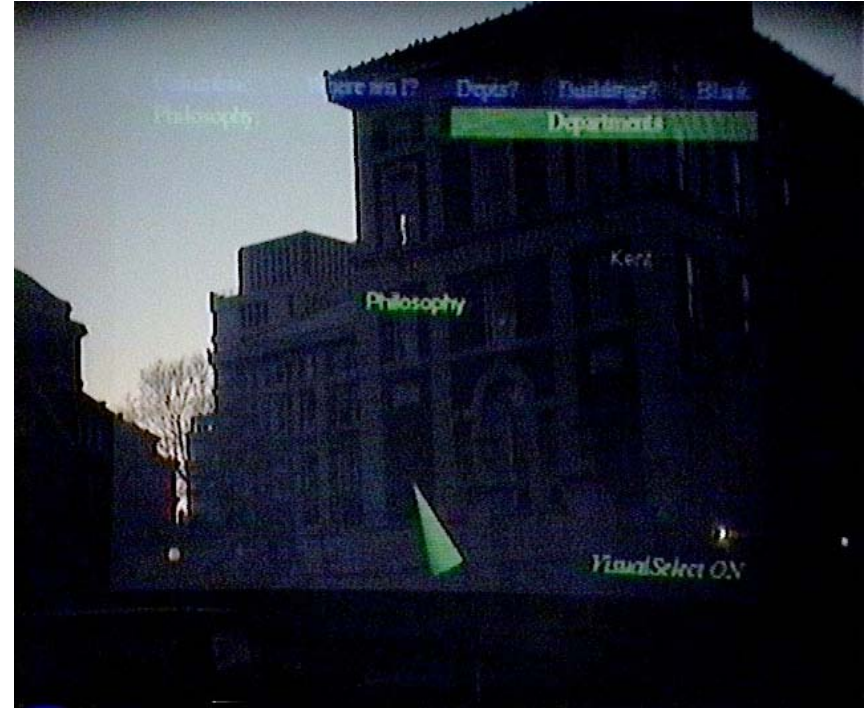
# AR History – Annotating environment





# AR History – Annotating environment

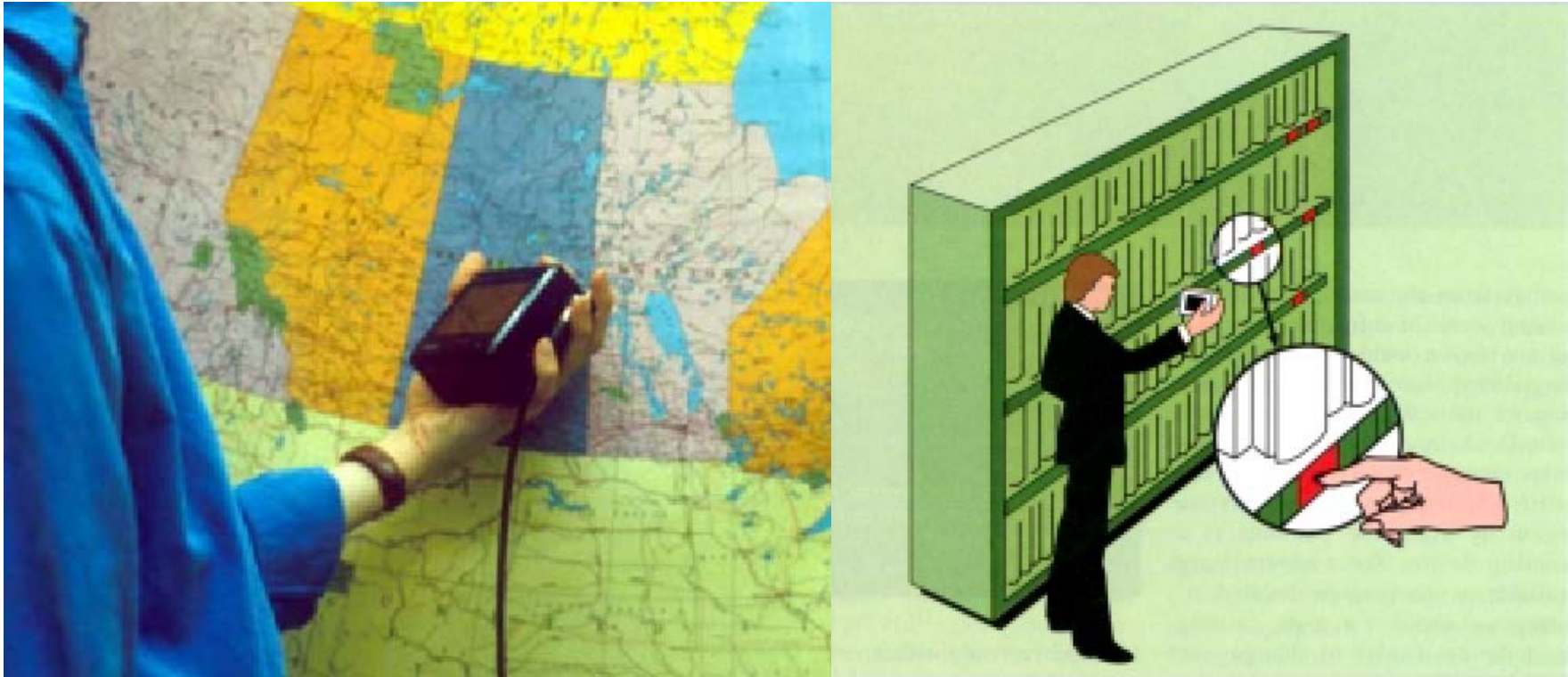
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Touring Machine, a Mobile Augmented Reality Systems project - Campus information system @ Columbia University [Feiner et al 1997]

# AR History – Annotating environment

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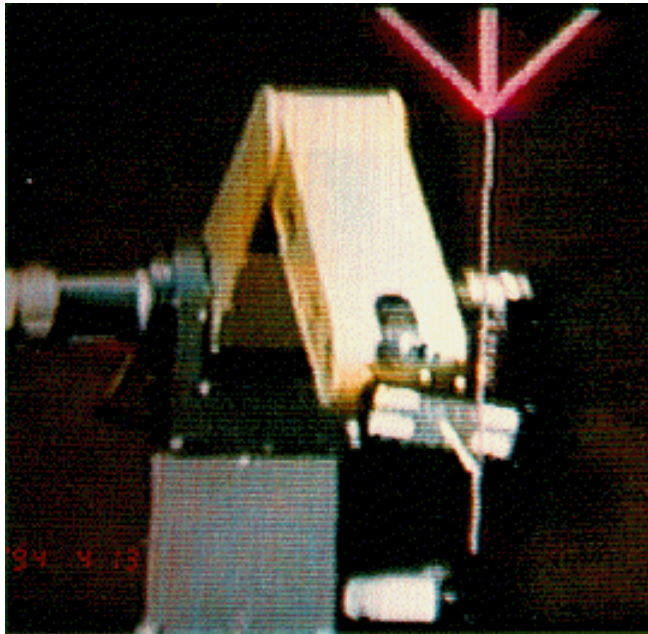


Augmenting maps, libraries, etc - Chameleon @ U of Toronto  
[Fitzmaurice 1993]

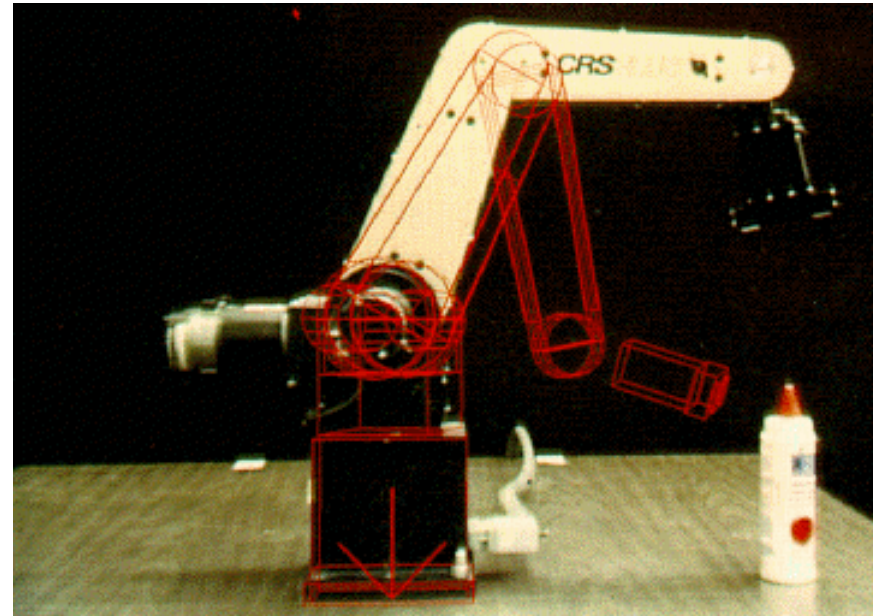


# AR History – Robot control

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Robotic path planning,  
previewing - Virtual Pointer in  
space for the robot to follow

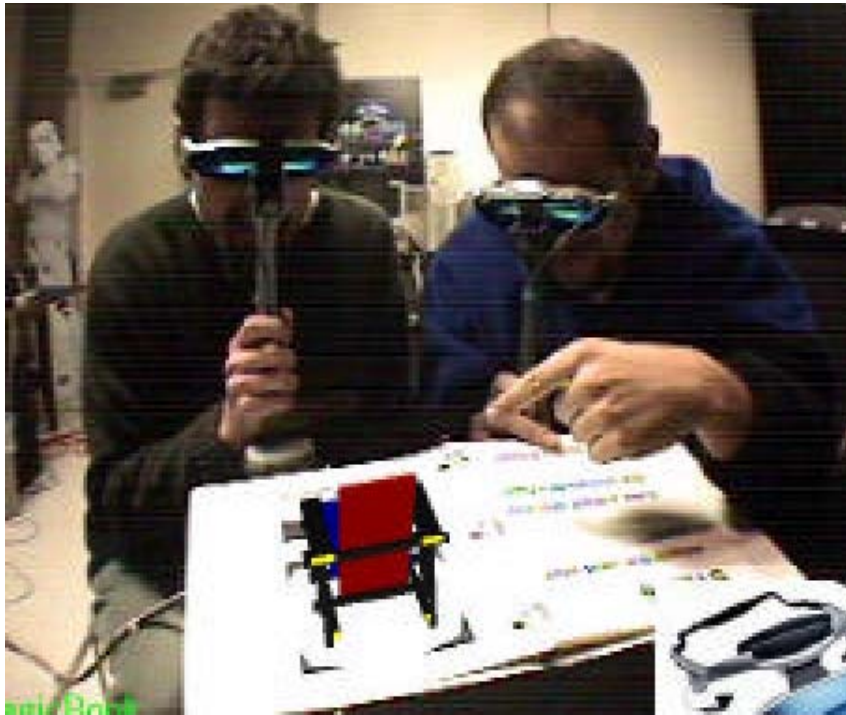


Remote manipulation  
ARGOS (Augmented Reality  
through Graphic Overlays on  
Stereovideo) @ U. of Toronto  
[Drascic et al 1993]



# AR History – Collaboration

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Use AR to allow users to collaborate inside the same real environment, in the Magic Book Project [Billingshurst 2001]

# AR History – Broadcast augmentation

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Adding virtual content to live sports broadcasts

- First down line in American football
- Hockey puck trails
- Virtual advertisements
- National Flags in swimming lanes in 2000 Olympics Commercial application
- Princeton Video Image

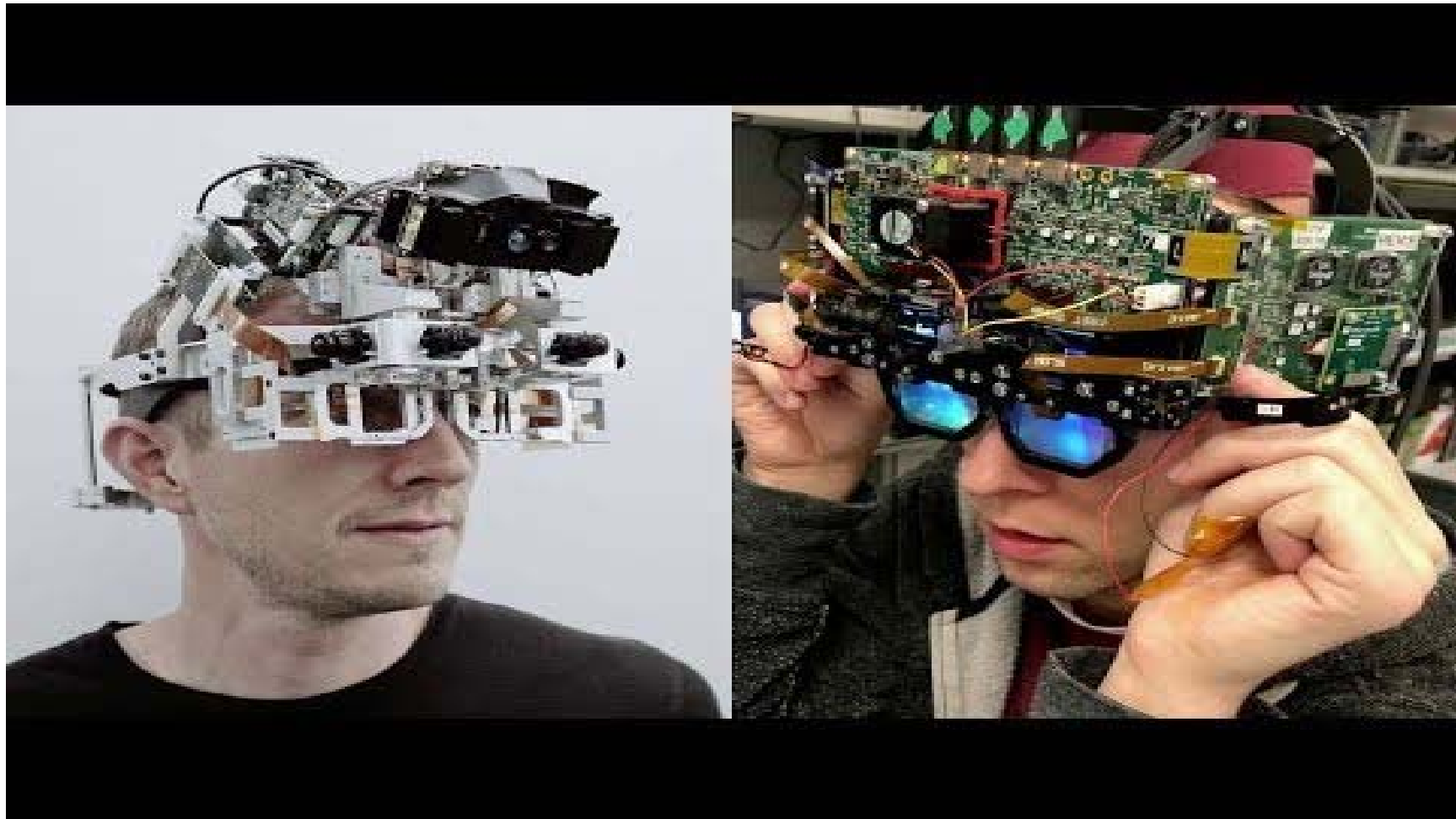
# Pokemon GO



2016 AR mobile Location Based System game by Niantic

# HoloLens & HoloLens2

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HoloLens2 : Unpacked, explained by HoloLens inventor, Alex Kipman  
<https://youtu.be/S0fEh4UdtT8>



# Magic Leap AR Display

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Magic Leap One Augmented Reality Review  
<https://youtu.be/Vrq2akzdFq8>

# Combining the Real and Virtual Worlds

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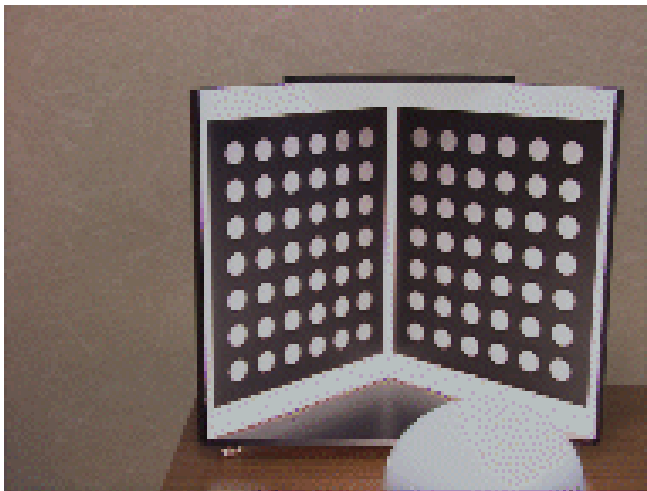
To combine real and virtual world, we need:

- ❑ Precise models
- ❑ Locations and optical properties of the viewer (or camera) and the display
- ❑ Calibration of all devices
- ❑ To combine all local coordinate systems centered on the devices and the objects in the scene in a global coordinate system

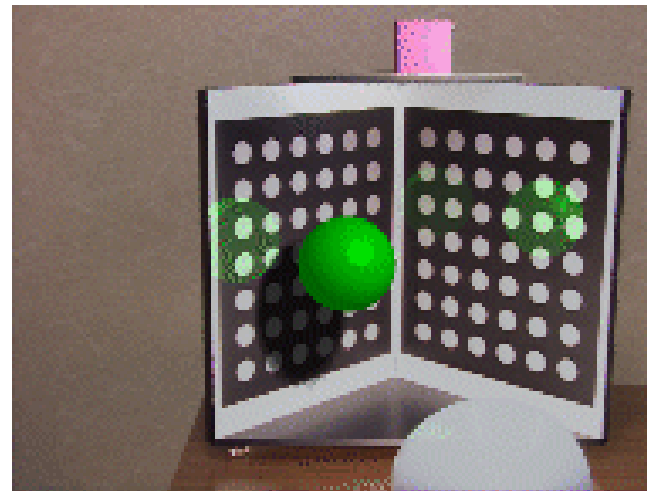
# Combining the Real and Virtual Worlds

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- ❑ Register models of all 3D objects of interest with their counterparts in the scene
- ❑ Track the objects over time when the user moves and interacts with the scene



Real world



Real world with virtual objects and inter-reflections and virtual shading

# Realistic Merging

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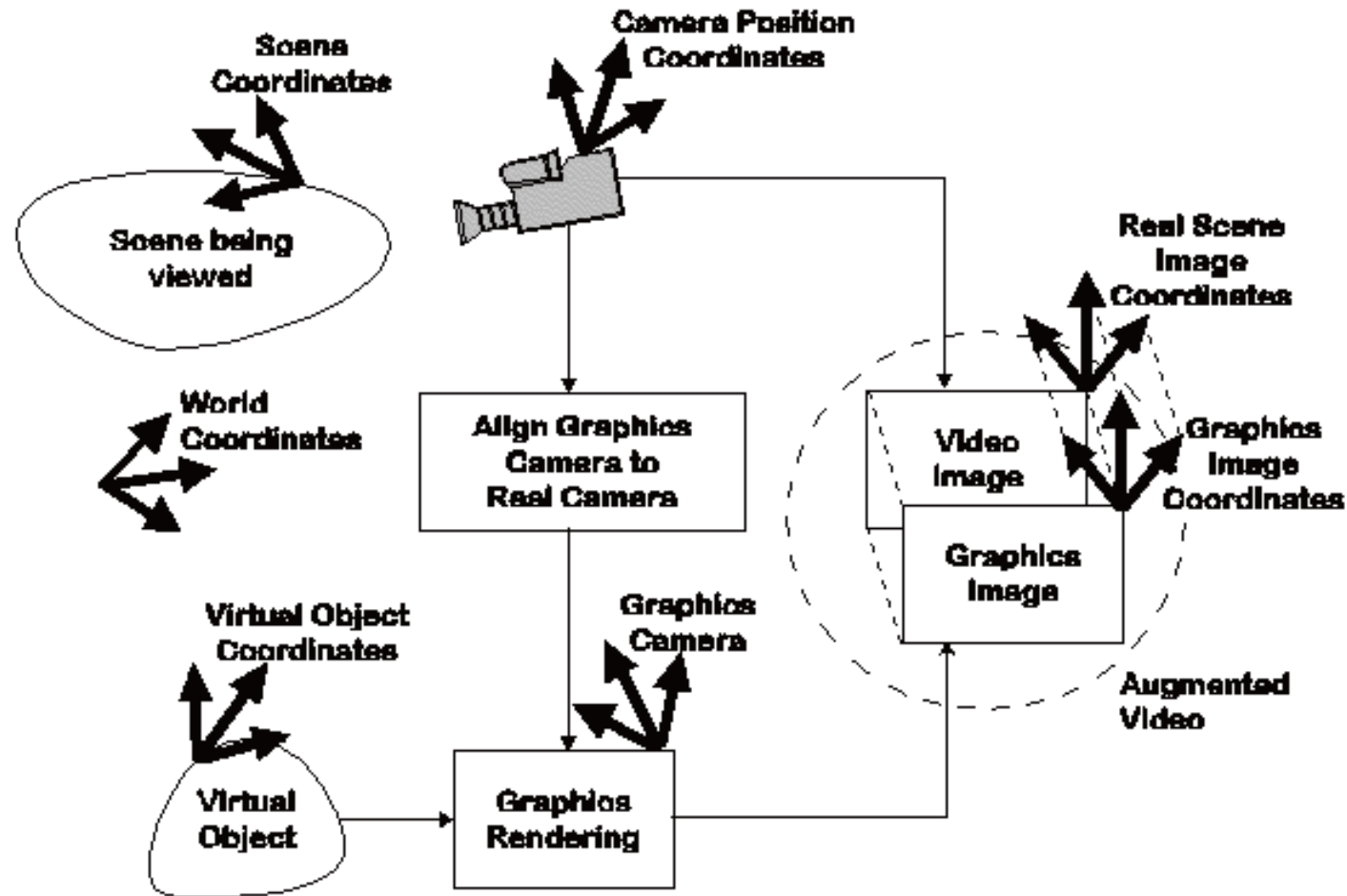
To create realistic merging, we need:

- ▣ Objects to behave in physically plausible manners when manipulated
  - ▣ Occlusion
  - ▣ Collision detection
  - ▣ Shadows
- 
- ▣ All of this requires a very detailed description of the physical scene



# Components of an AR System

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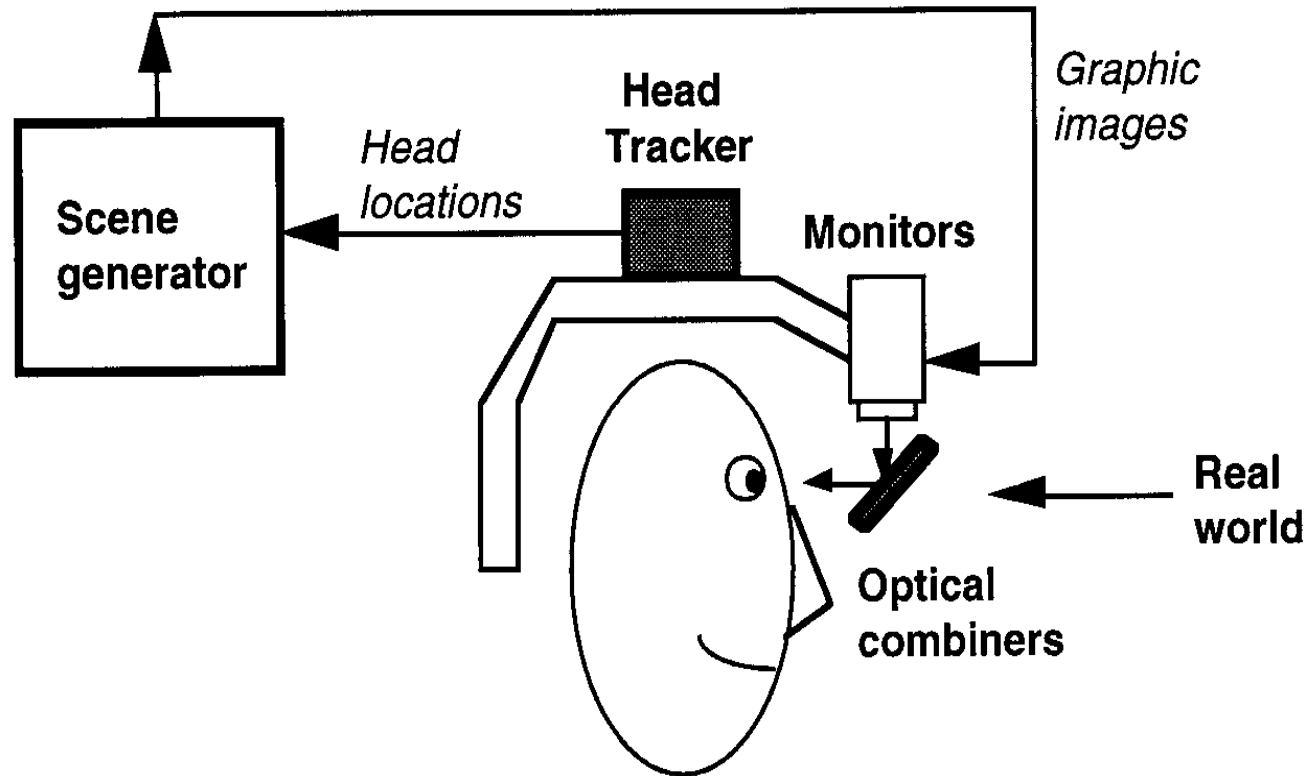
# Augmented Reality Technology

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- ❑ Augmented reality systems often involve the use of head mounted displays
- ❑ There are two main categories of HMD-based AR systems
  - Optical See-Through
  - Video See-Through
- ❑ However, some augmented reality systems involve the use of projectors or other display devices instead of HMDs.
  - Monitor-based
  - Projection-based
  - Head-Mounted Projective Display (HMPD)
  - Hand-held Augmented Reality

# Optical See-Through Display

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# Optical See-Through Display

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Kaiser Electro-Optics Sim Eye XL 100A



AddVisor 150™

# Optical See-Through Display

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- ❑ An optical see-through head mounted display works by placing optical combiners in front of the user's eyes
- ❑ These combiners are partly **transmissive** allowing the user to see through them, and partly **reflective**, allowing the user to see in them the reflection of virtual images portrayed on miniature displays in their line of sight

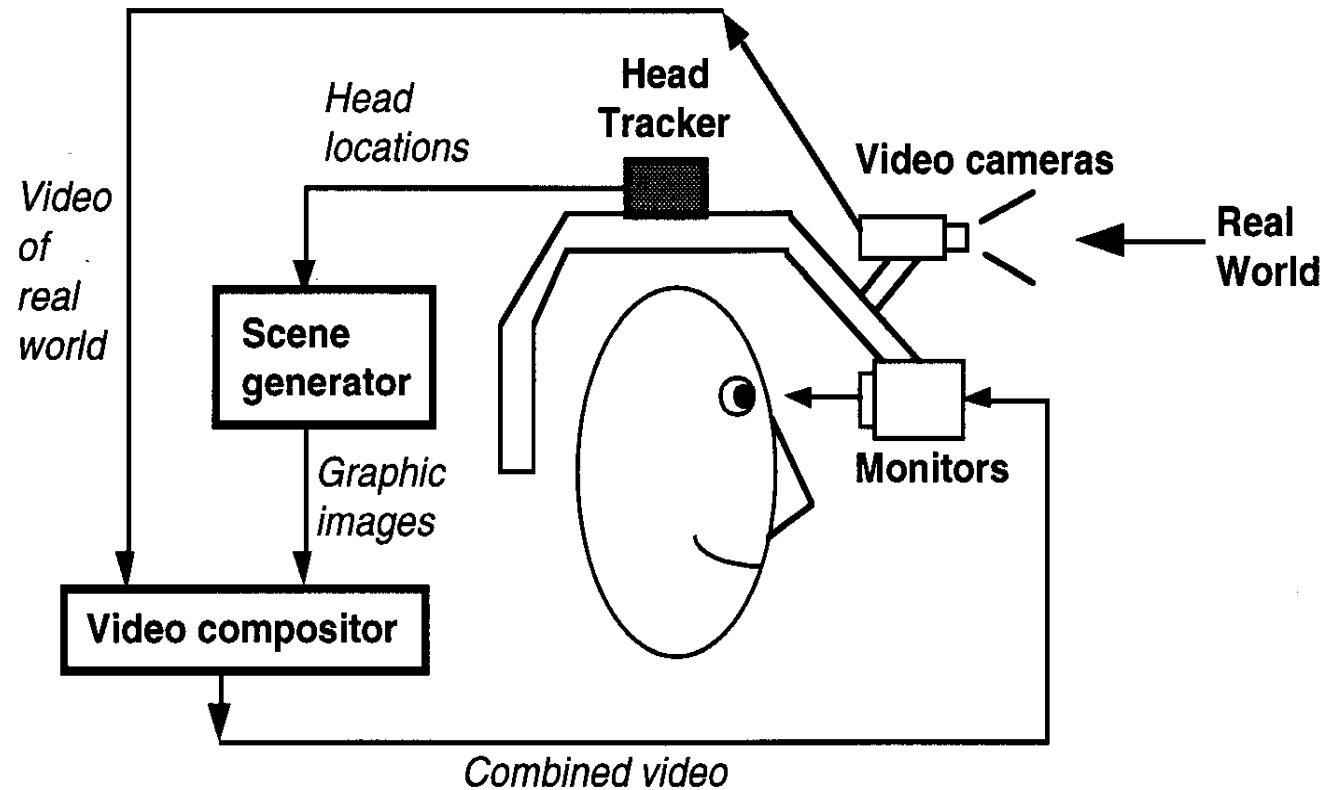
# Advantages of Optical See-through HMD

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- Simpler & cheaper
- Direct view of real world
  - Full resolution
  - No time delay (for real world)
  - Safety
  - Lower distortion
- No eye displacement
  - Video see-through HMD creates an offset between cameras and real eyes
  - But, COASTAR video see-through display avoids this problem

# Video See-Through Display

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# Video See-Through Display

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Work done by Jannick Roland, Frank Biocca @ UNC



# Video See-Through Display

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Samsung Windows Mixed Reality Headset Odyssey+ (<\$1K)

# Video See-Through Display

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- ❑ A video see-through head mounted display uses miniature cameras to capture the view of the world that would be seen by each eye
- ❑ The video images of the real world are then combined with the computer-generated images of the virtual world, to create augmented-reality images that can be displayed on a traditional (non see-through) HMD

# Advantages of Video See-Through HMD

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- True occlusion
  - But, ELMO optical display that supports occlusion
- Digitized image of real world
  - Flexibility in composition
  - Real and virtual view delays can be matched
  - More registration, calibration strategies
- Wide field of view is easier

# Video Composition for Video See-Through Display

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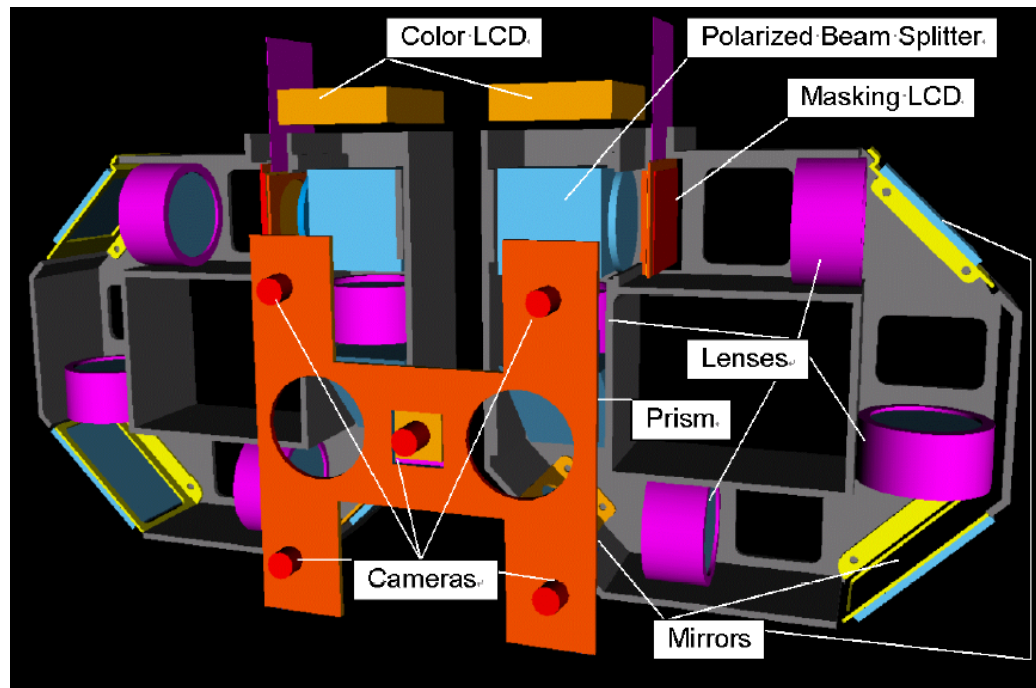
- ❑ The real and virtual images can be combined using a **chroma key (blue screen)** approach:
  - The background in the virtual images is defined to be a particular color that doesn't appear in the virtual objects
  - Pixels in the background color are replaced by pixels from the registered real world images
  - Used for special effects
- ❑ This results in the virtual objects being superimposed over the real world images (regardless of depth)

# Video Composition for Video See-Through Display

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- ❑ A better approach is to perform a **depth-composite** of the real and virtual images, allowing closer objects to occlude farther objects regardless of their provenance (real world or virtual world)
- ❑ Combine real and virtual images by a pixel-by-pixel depth comparison
- ❑ This requires having information about the depth at each pixel in the real world image

# ELMO Occlusion-Capable Optical See-Through HMD



Kiyokawa, Billinghurst, Campbell, Woods, ISMAR 2003

# COASTAR (Co-Optical Axis See-Through Augmented Reality) Video See-Through HMD

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MR Laboratory & Canon





# Optical vs. Video See-Through HMD

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A view from a Optical See-Through HMD

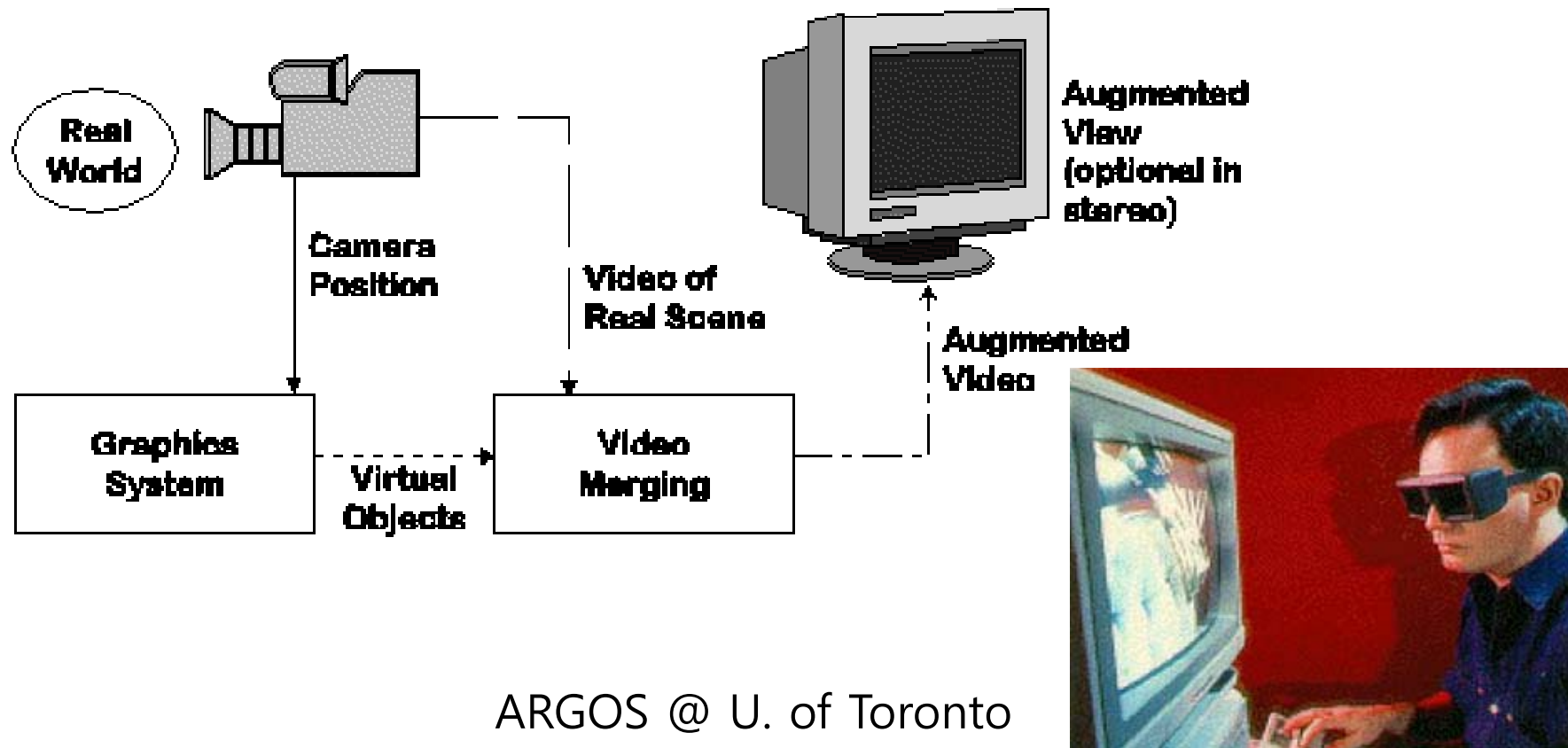


A view from a Video See-Through HMD



# Monitor-based Augmented Reality

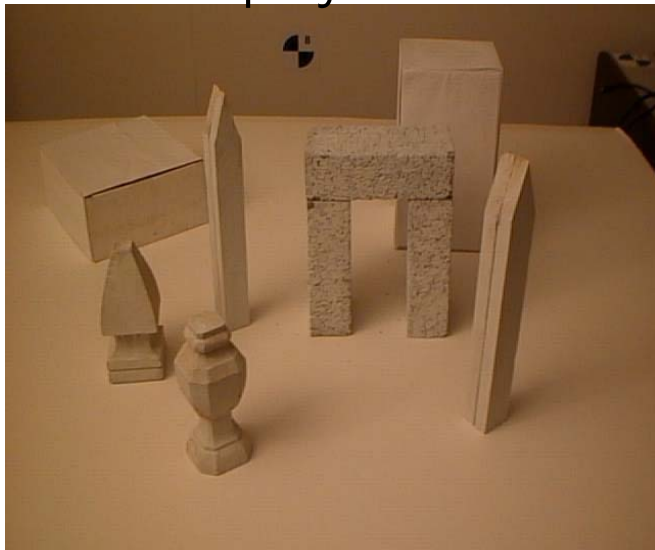
- Simplest available
- Less feeling of being immersed in the environment



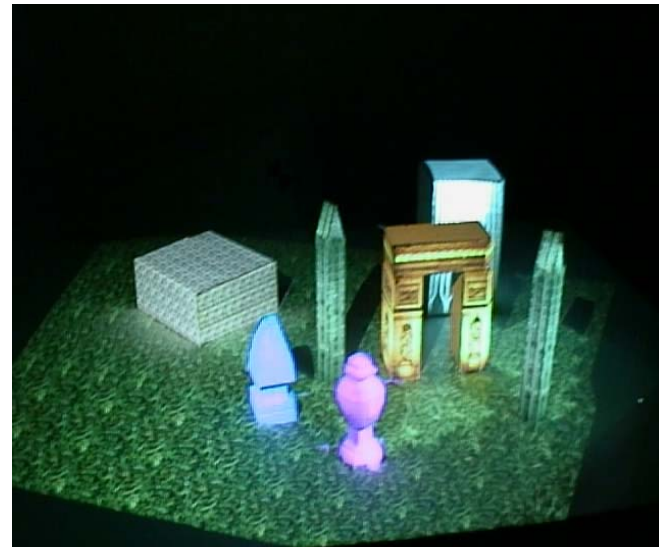
# Projector-based Augmented Reality

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- Shader Lamps: Table-Top **Spatially Augmented Reality**  
[Raskar @UNC 1999]
  - The architectures are white bricks and wooden/paper blocks with textures projected from two DLP projectors mounted on the ceiling



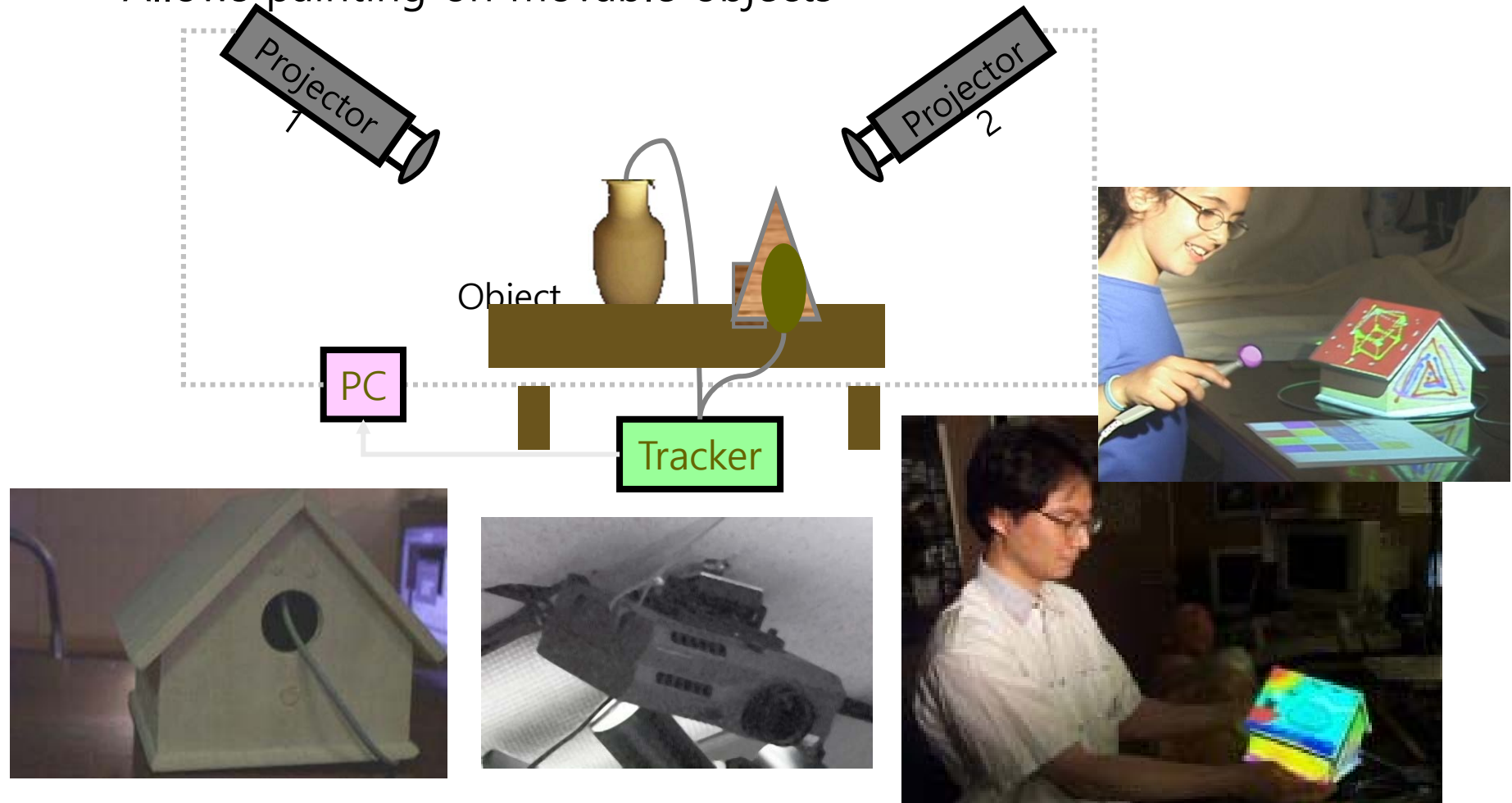
A photograph of the simple physical model, made up of white diffuse surfaces



The physical model illuminated to create an illusion of a tabletop with colorful objects

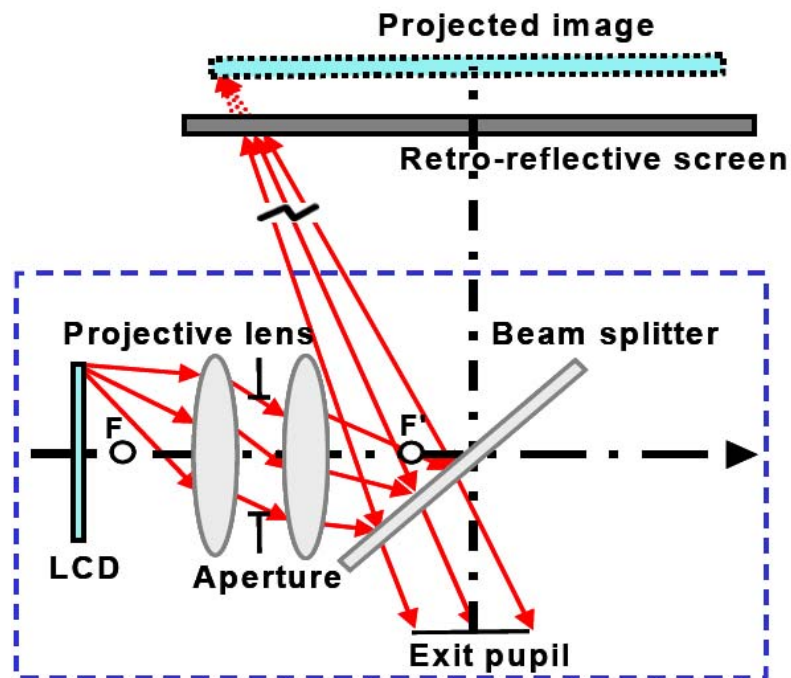
# Projector-based Augmented Reality

- Dynamic Shader Lamps [Raskar @UNC 2001]
  - Allows painting on movable objects



# Head-Mounted Projective Display

- SCAPE (Stereoscopic Collaboration in Augmented and Projective Environments) [UIUC 2004]
  - a hybrid environment involving both projective and optical see-through head-mounted displays



# Hand-held Augmented Reality Display

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- Augmented Reality using consumer Cell Phones or PDA
  - PhoneGuide: Museum guidance supported by on-device object recognition on mobile phones
  - Video See-Through AR and Optical Tracking with cell phones



# AR Tracking

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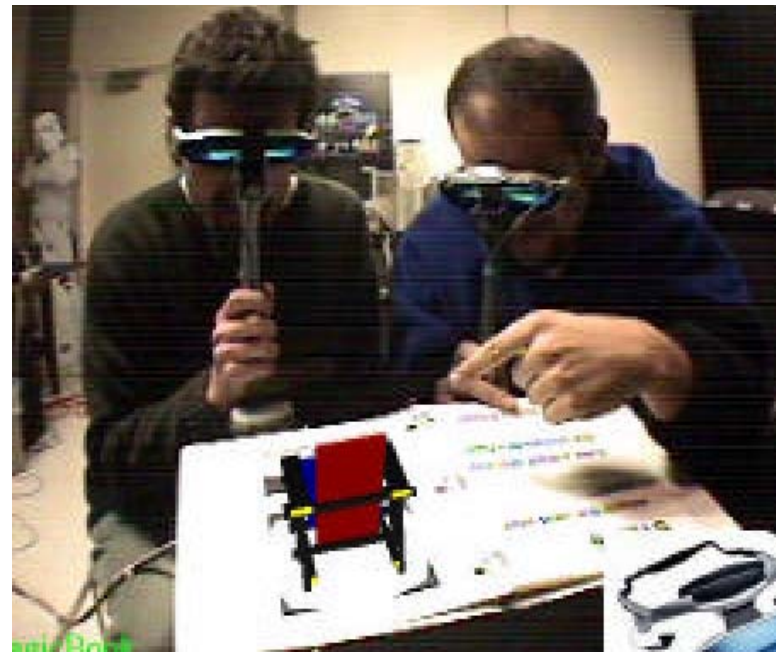
- ❑ Tracking is significantly more difficult in AR than VR
- ❑ Indoor AR tracking:
  - Inertial trackers, such as Intersense IS-300
  - UNC Hi-Ball optical tracker using multiple IR sensors to track IR sources mounted on the ceiling
- ❑ Outdoor AR tracking:
  - Global Positioning Satellites (GPS),
  - Hybrid tracking using vision and inertial gyroscope sensors
- ❑ Improving tracking using estimation and prediction



# AR Tracking

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- ❑ Shared Space project @ HITLab, UW
  - Vision-based (**fiducial**) tracking for collaborative applications
  - Targets are placed on square tiles and virtual images appear over the tiles in a see-through HMD
  - **AR Toolkit**



# AR Tracking

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## □ Marker AR

- A marker is usually designed as a rectangle image holding black and white areas inside it.

## □ Markerless AR

- Marker-less AR can use real images and objects to position the camera in 3D space and present eye-catching effects on top of the real picture.
- The heart of the marker-less AR are image recognition and object detection algorithms.

Markerless AR using SURF(SIFT) <https://youtu.be/caFHvamMUTw>



# Registration Problem

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- ❑ Virtual and Real must stay properly aligned
- ❑ If not, compromises illusion that the two coexist & prevents acceptance of many serious applications
- ❑ Accurate registration is difficult
  - Sensitivity of visual system
  - Many sources of error
- ❑ Augmented reality information display
  - Head-stabilized
  - Body-stabilized
  - World-stabilized



Increasing Registration  
& Tracking  
requirements

# Sources of Registration Errors

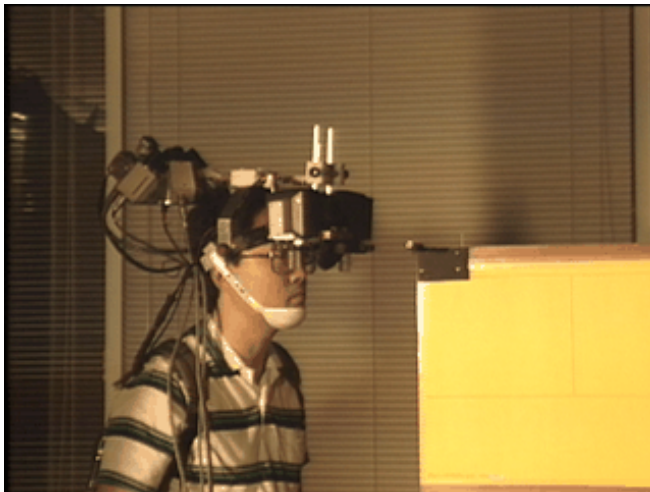
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- ❑ Static errors
  - Optical distortions
  - Mechanical misalignments
  - Tracker errors
  - Incorrect viewing parameters (e.g. COP, distance between head tracking and user eye position, FOV)
- ❑ Dynamic errors
  - System delays (largest source of error)

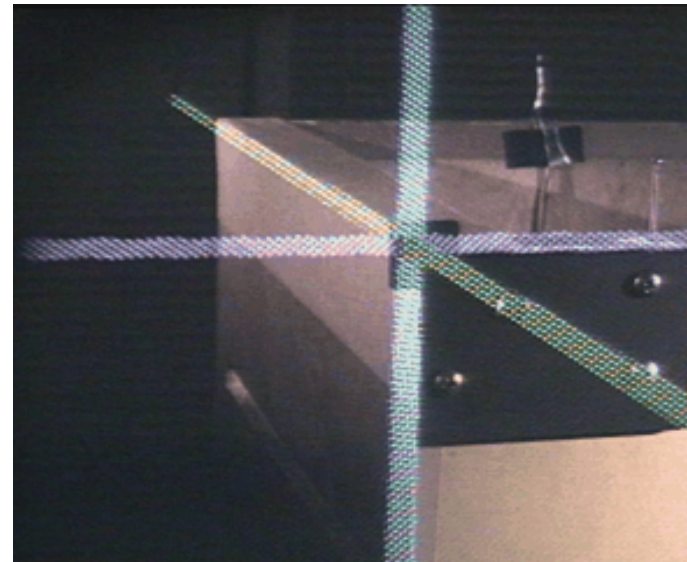
# Reducing Static Errors

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- ❑ Distortion compensation
- ❑ Manual adjustments
- ❑ View-based or direct measurements
- ❑ Camera calibration



View-based calibration [Azuma 94]



# Reducing Dynamic Errors

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- ❑ Dynamic errors (i.e., delay in application loops)
  - Tracking, e.g. 20 Hz = 50 ms
  - Calculate viewpoint simulation, e.g. 500 Hz = 2 ms
  - render scene, e.g. 30 Hz = 33 ms
  - draw to display, e.g. 60 Hz = 17 ms
  - Total delay = 102 ms (i.e., 1 ms delay = 33 ms error)
- ❑ Reduce system lag
  - Faster tracker, faster CPU, Faster GPU, Faster display
- ❑ Reduce apparent lag
  - Image deflection
  - Image warping
- ❑ Match input streams
  - Delay video of real world to match system lag
- ❑ Predictive tracking

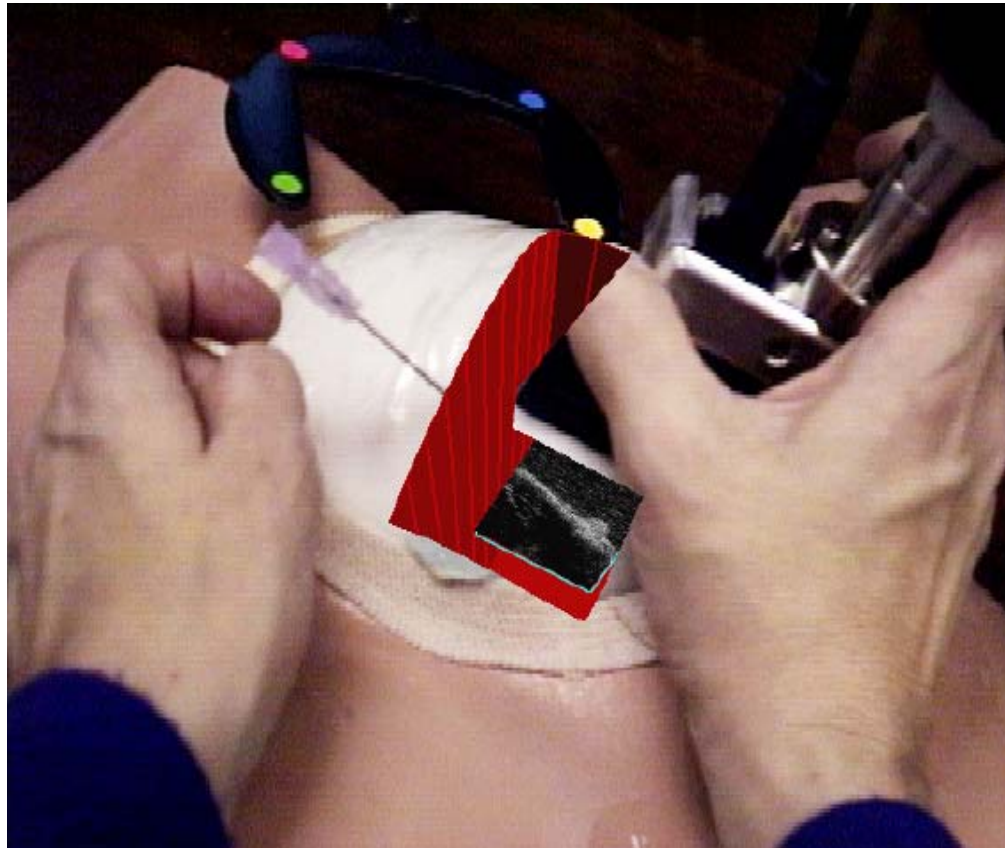
# AR Interaction

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- AR Interfaces as 3D data browsers
  - 3D virtual objects are registered in 3D
  - 3D virtual viewpoint control interaction
- AR interfaces as context-based information browsers
  - Information is registered to real-world context
  - Manipulation of a window into information space
  - But, difficult to modify or author virtual contents
- AR 3D interfaces
  - Virtual objects displayed in 3D real world and can be freely manipulated
  - Use can interact with 3D virtual object everywhere in space
  - But, usually no tactile feedback & lack of seamless interaction for virtual and physical objects
- Augmented surfaces
  - Images are projected on a surface
  - Physical objects can be used as controls for virtual objects

# AR Interfaces as 3D data browsers

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UNC Ultrasound Project

# AR Interfaces as 3D data browsers



Digilog Book – Temple Bell @ GIST

Figure marker design

Virtual button for control

Pointing & Hitting using tangible object

Digilog Book - Unjusa @ GIST

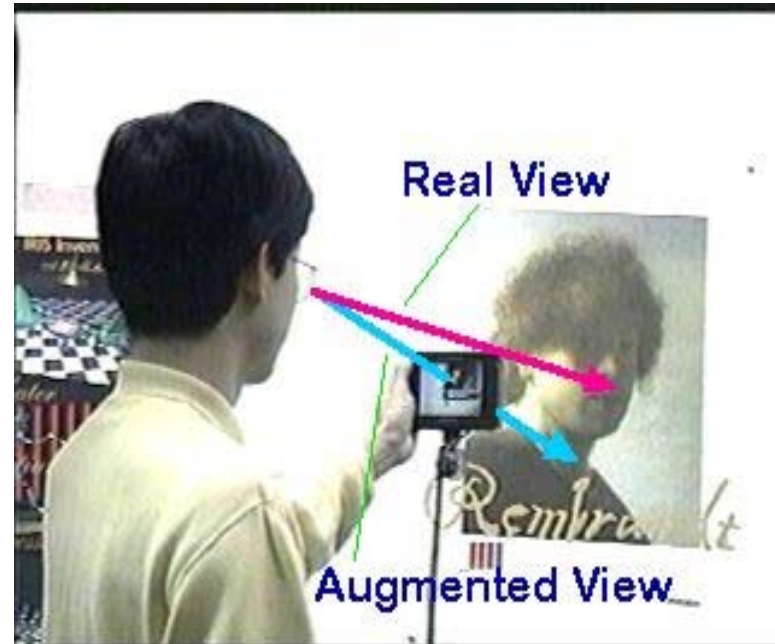


Digilog Book provides **additional information and interactivity** to readers by converging **[paper book]** and multimedia content which stimulate human's visual, auditory, and haptic senses with AR technology



# AR Interfaces as context-based information browsers

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NaviCam [Rekimoto95] <https://youtu.be/S6XKPEexRbU>

# Collaborative 3D AR Interfaces

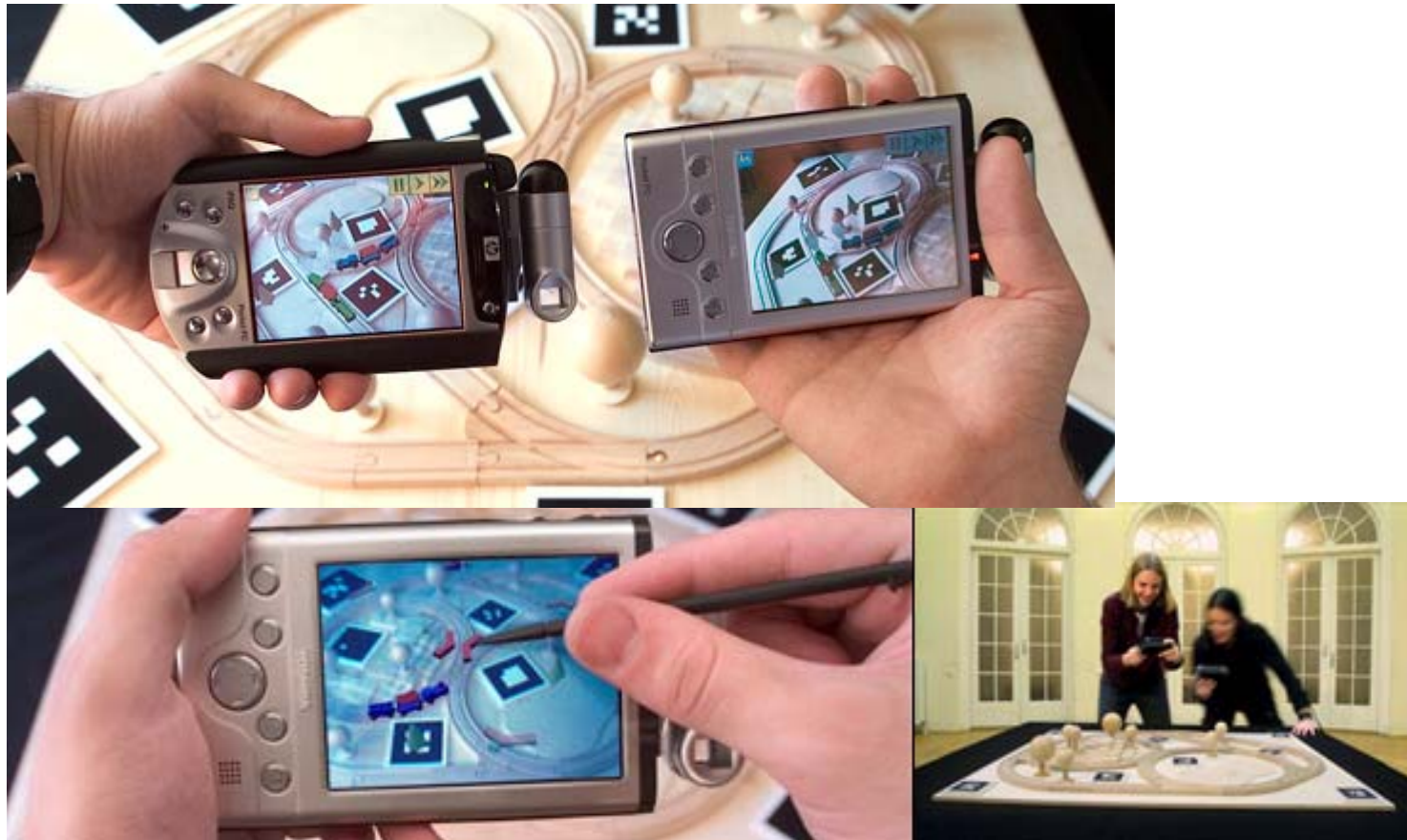
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AR Hockey interface @ MR System Laboratory [Kiyokawa 2000]  
allows two users to play a game of air hockey using a virtual puck.

# Collaborative 3D AR Interfaces

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The Invisible Train @ Vienna University of Technology,  
Real-time multi-user augmented reality application for handheld  
devices (2004)



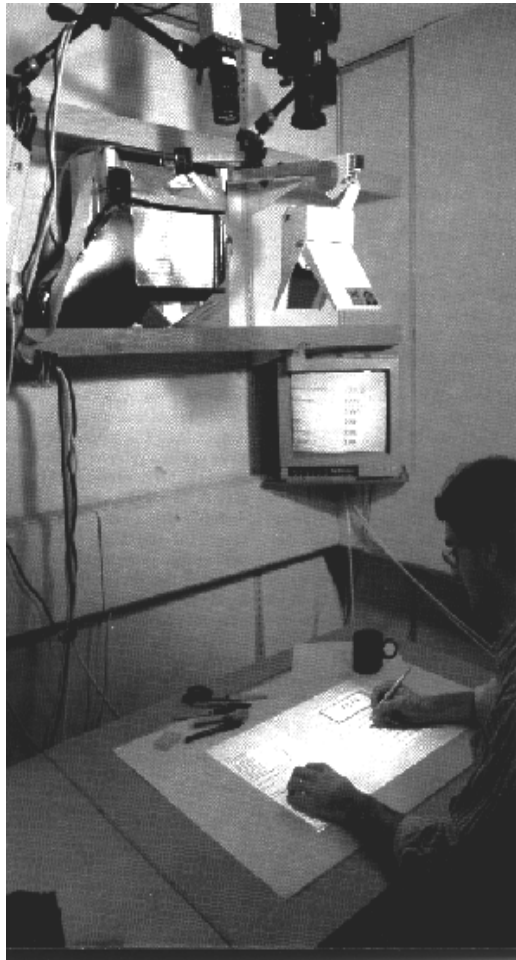
# Collaborative 3D AR Interfaces



AR-based Remote Collaboration System with Empathy Interface [2016]  
Local user wearing OST(Optical See Through)-HMD, eye-tracker, facial expression detector, heart rate and GSR sensor & Remote user on the desktop

# Augmented Surfaces

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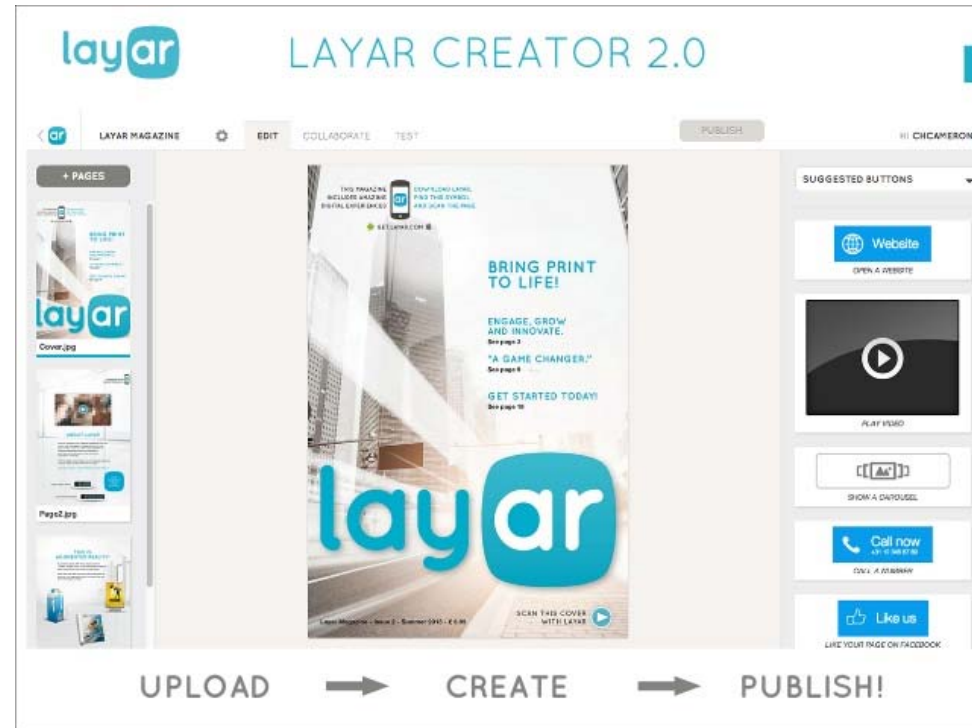


DigitalDesk @ Georgia Tech



Augmented Reality Kitchen @ MIT Media Lab  
[Ted Selker]

# Mobile AR Browser



**Layar** AR (2009)

[https://youtu.be/b64\\_16K2e08](https://youtu.be/b64_16K2e08)

<https://www.slideshare.net/layarmobile/layar-february-20th-webinar-get-started-with-the-layar-creator>



# Mobile AR Browser

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Creating a **Wikitude** AR World with Google Maps

<https://youtu.be/8EA8xlicmT8>

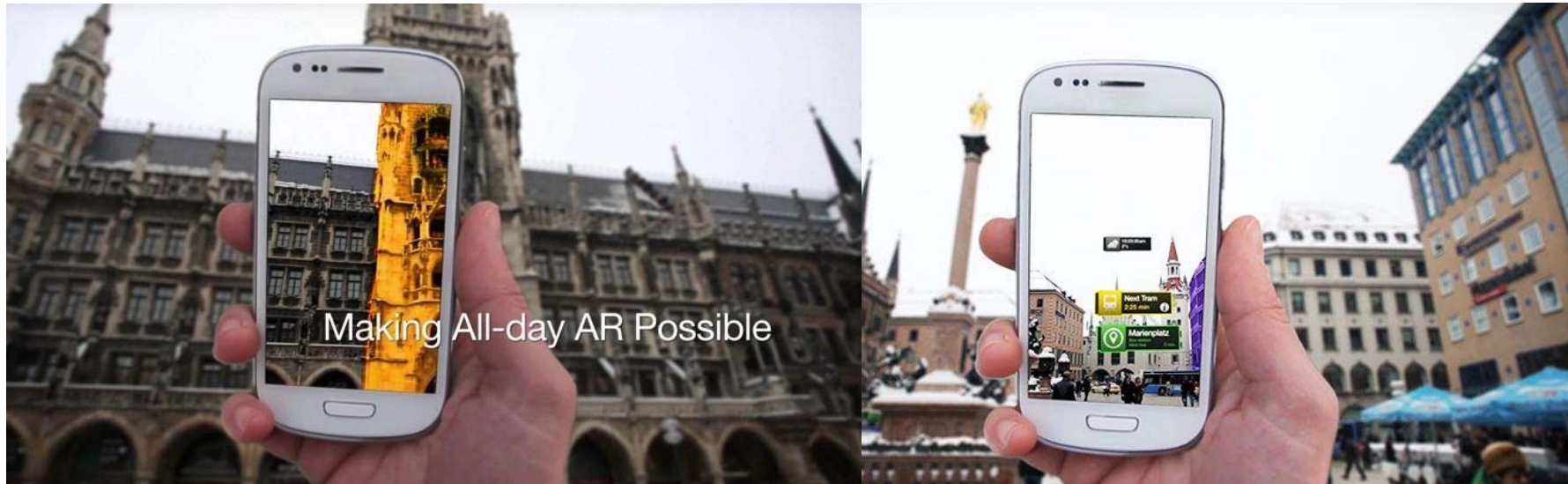
<https://youtu.be/Ot5HKJvIST4>

<https://www.cnet.com/news/wikitude-for-lg-optimus-3d-is-the-first-3d-augmented-reality-browser/>



# Mobile AR Browser

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**Metaio**, a German company whose technology has been used by Macy's, BMW and furniture retailer Ikea.

<https://venturebeat.com/2009/08/04/metaio-launches-augmented-reality-platform-for-mobile-sharing-marketing/>

# Mobile AR Browser



**Sekai Camera** is a social AR (augmented reality) application that offers a brand new experience, enabling users to interact in social communication through digital contents attached to the real world.

<https://youtu.be/oxnKOQkWwF8>

# Mobile AR Browser

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The advertisement features a bright blue background. At the top center is a large white butterfly logo. Below it, the word "iButterfly" is written in a large, white, sans-serif font. To the left of the text is a small image of an iPhone displaying the app's interface. To the right is a larger image of an iPhone showing a close-up of the app's interface, which includes two cartoon characters and a "You got iButterfly!" message. Below the main title, there is a list of features and instructions in white text.

**AR x Motion Sensor x GPS x Coupon**  
"iButterfly" is a free iPhone Apps, utilizing AR & GPS function, which enables users to obtain marketers' message, such as information, coupons, etc. Not only coupons but information linked to the locations and entertaining contents can be also given out with iButterfly.

\* Available on iPhone3G/OS3.1 & above

**Catch them!**  
Various kinds of "butterflies" fly in the AR sky in real cities. Enjoy the realistic catching feeling by using motion sensor.

**Get lucky!**  
Various information, contents, coupons can be given out!

**Collect them!**  
Collect several kinds of butterflies flying in different locations. Distribute information about new kind "butterfly" linked with Twitter and ranking function.

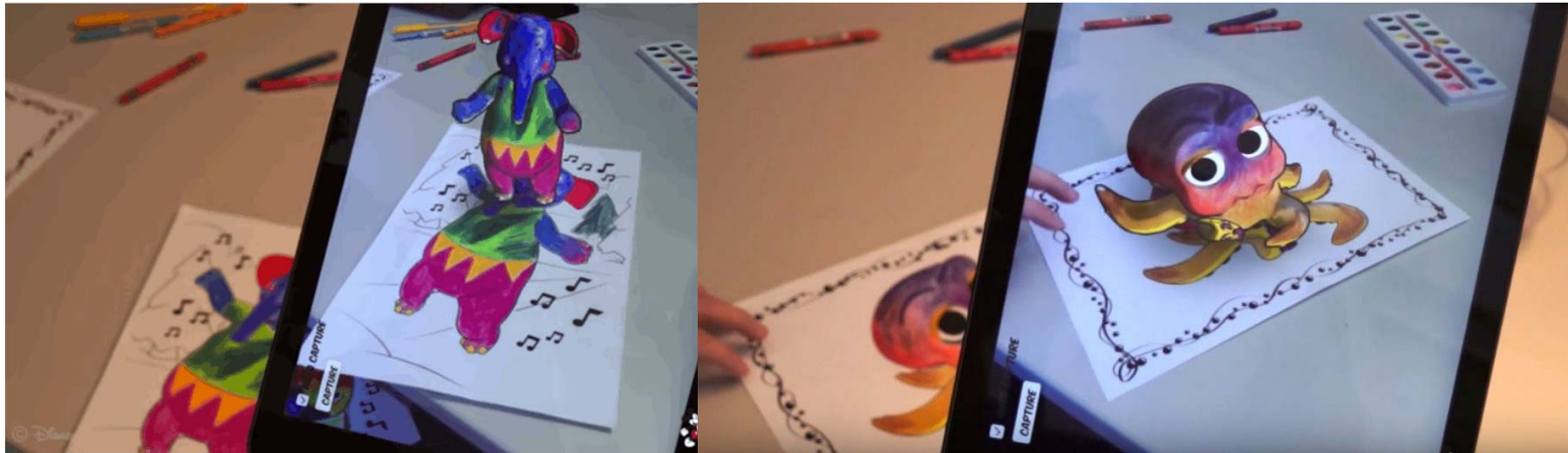
**Share them!**  
Share / exchange butterflies among friends by using Bluetooth

For enquiries about iButterfly, email us at [contact@ibutterfly-asia.com](mailto:contact@ibutterfly-asia.com)

iButterfly AR x Motion Sensor x GPS x Coupon  
[https://youtu.be/HAQh-\\_nFH-s](https://youtu.be/HAQh-_nFH-s)  
<http://ibutterfly.hk/>

# AR Coloring Book

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3D AR Coloring Book by Disney

<https://thenextweb.com/shareables/2015/10/03/researchers-use-ar-to-bring-your-coloring-book-to-3d/>

1. Image tracking using Vuforia SDK
2. Color area extraction & Image warping
3. Texture Mapping



# Chicago Riverwalk AR

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The Chicago 0,0 Riverwalk AR experience provides a novel way for users to explore historical photographs sourced from museum archives. (ISMAR2016)  
<https://youtu.be/79hziCOpLH4>

# MS HoloLens Applications

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HoloLens Apps! Fall 2017 <https://youtu.be/tZQU5HUXisY>

Wheel Replacement Training <https://www.microsoft.com/en-us/store/p/wheel-replacement-training/9nhsszrqht1n>

WhiteCane <https://www.microsoft.com/en-us/store/p/white-cane/9p96g5q8sqgc>

HoloFlight <https://www.microsoft.com/en-us/store/p/holoflight-beta/9nblggh51384>

# AR Ghost

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AR Yokai - A Situated Augmented Reality Ghost Story, using Hololens  
<http://imd.naist.jp/~damien-r/aryoukai/index.html>

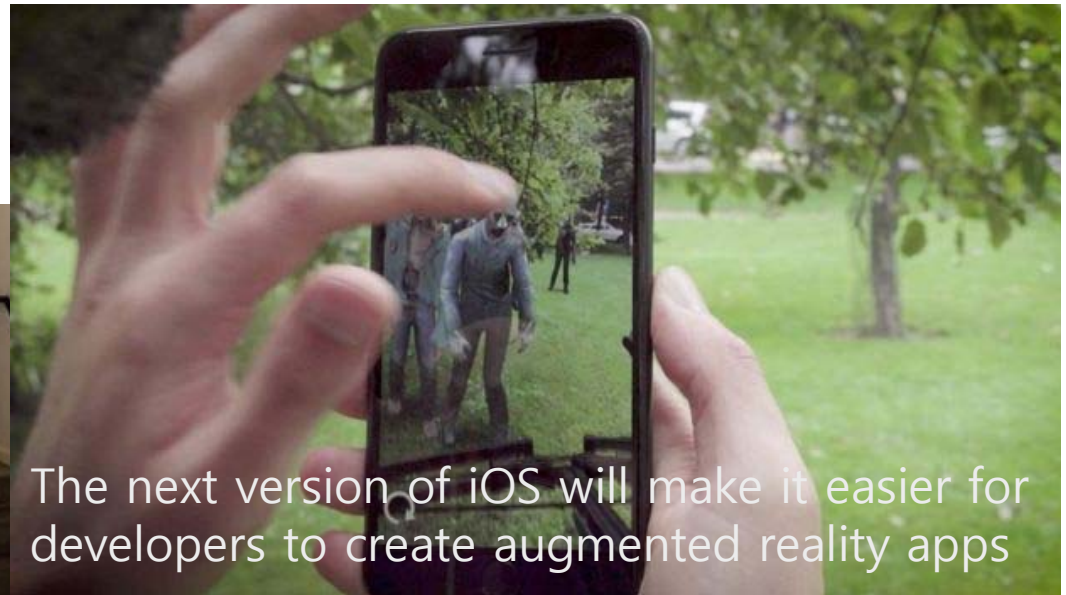


# BBC What future for augmented reality

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Google's ARCore demo shows an animated lion interacting with a dog



The next version of iOS will make it easier for developers to create augmented reality apps

Apple and Google show off rival augmented-reality tech  
<http://www.bbc.com/news/av/technology-41419109/what-future-for-augmented-reality>  
<http://www.bbc.com/news/technology-41098622>

# AR Downsides and Evil Applications

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**BurglAR**

<https://www.wired.com/2010/01/augmented-reality-downsides-and-evil-applications/>

# Reference

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- ❑ <http://www.cs.unc.edu/~raskar/Tabletop/images.html>
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- ❑ <http://www.uni-weimar.de/~bimber/research.php>
- ❑ [http://www.vrlogic.com/html/keo/sim\\_eye\\_xl100a.html](http://www.vrlogic.com/html/keo/sim_eye_xl100a.html)
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