Computer Vision and Mixed Reality

Introduction to Augmented Reality
Chapter 1

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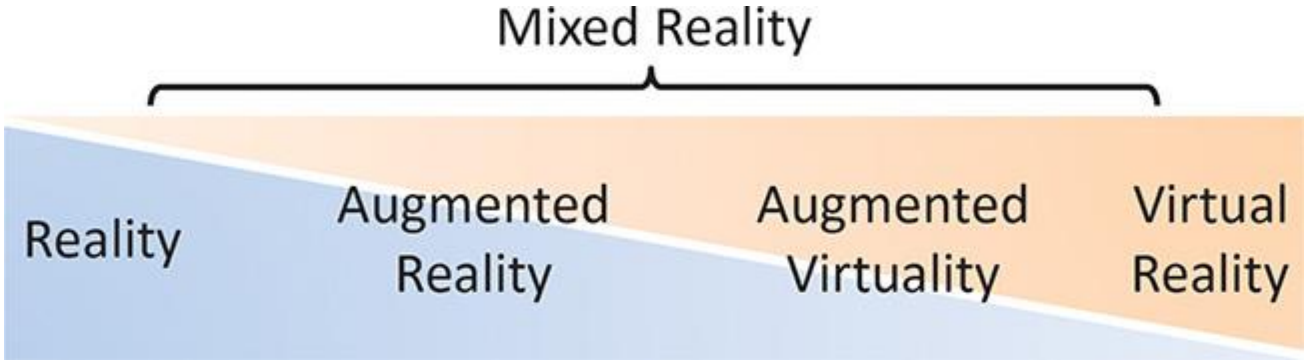
Definition and Scope

The space between reality and virtual reality, which allows real and virtual elements to be combined to varying degrees, is called **Mixed Reality (MR)**



[MR involves the] merging of real and virtual worlds somewhere along the "**virtuality continuum**" which connects completely real environments to completely virtual ones.
Milgram and Kishino [1994]

Definition and Scope

Virtual Reality (VR) *immerses* a user in a completely *computer-generated environment*

A **totally virtual world** is created from computer graphics and audio applications

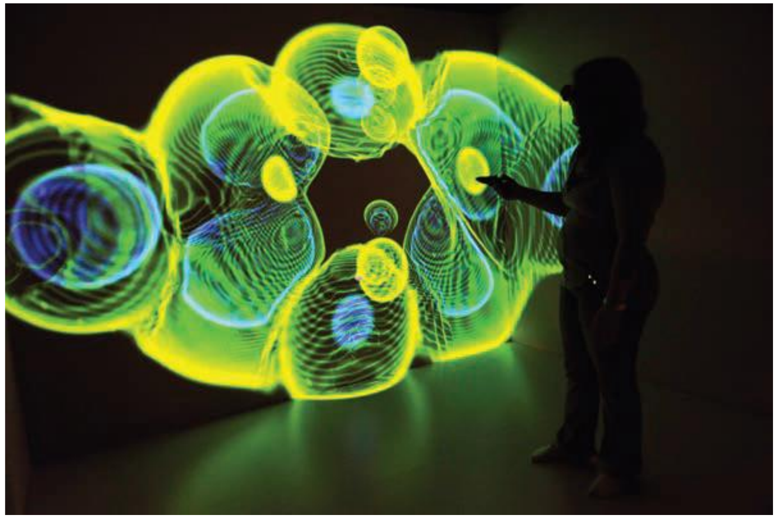
A **totally immersive experience** in which you are no longer in the current environment

Removes any restrictions as to what a user can do or experience

Definition and Scope

Virtual Reality Experiences

Head Monted Display (HMD)



Computer-Assisted
Virtual Environment (CAVE)

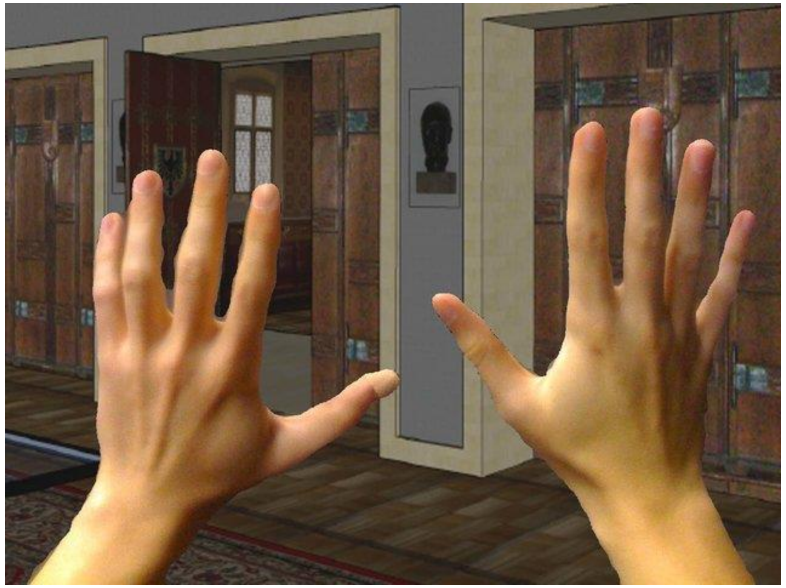
Definition and Scope

Since VR is so immersive, its applications are inherently limited

A fundamental problem with VR is motion to photo latency. When you move your head, the VR image must update quickly, within 11 milliseconds for 90 frames per second, or you risk experiencing motion sickness.

Definition and Scope

Augmented Virtuality (AV) occurs when we start putting some real elements in the virtual world



[Bruder et. al 2009]

AV has not received as much attention as VR and AR

Definition and Scope

Augmented Reality (AR) is the combination of *digital data and real-world human sensory input* in *real-time* that is apparently *attached* (registered) to the physical space.

According to Azuma [1997], AR must have the following three characteristics:

- Combines real and virtual
- Interactive in real time
- Registered in 3D

Definition and Scope

AR doesn't necessarily need to be visual!

Audio, haptics, and even olfactory or gustatory AR are included in its scope, even though they may be difficult to realize

What about bionics, can it be seen as AR for the body?

Definition and Scope

“Interactive in real time”

AR is experienced in real time, not pre-recorded

Interactivity implies a human–computer interface

The user continuously navigates the AR scene and controls the AR experience

Definition and Scope

"Registered in 3D"

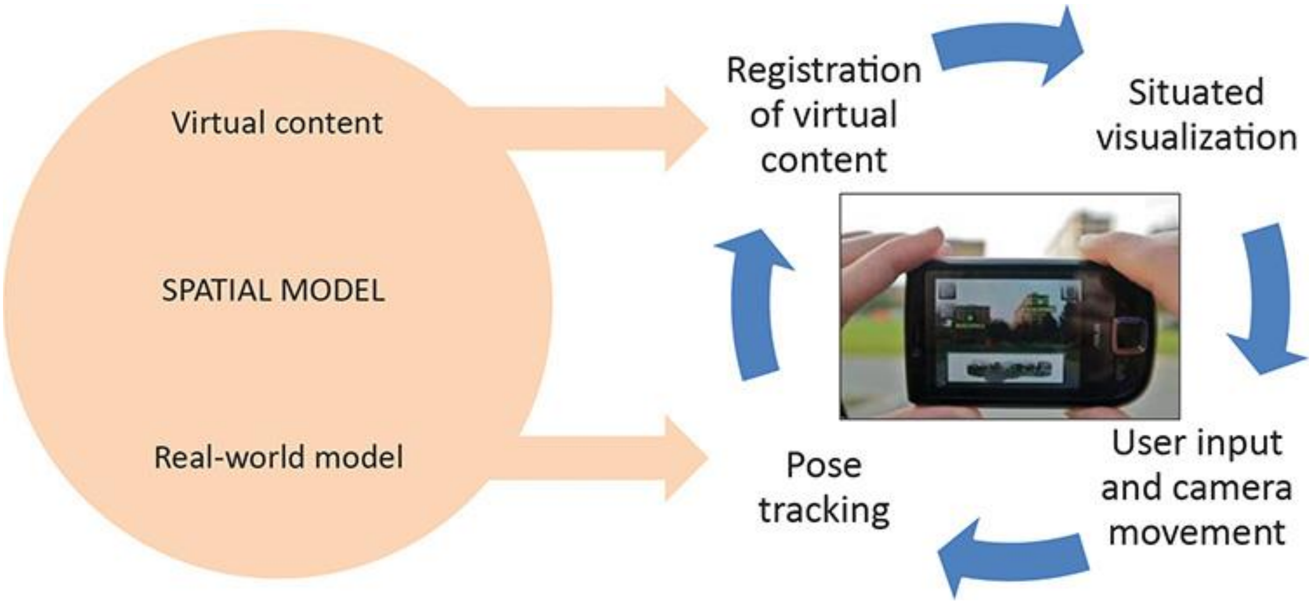
Virtual objects must be aligned and registered with the real 3D world

AR systems must track user's viewpoint or pose and combine the real view with virtual content, presents to the user a *situated visualization* (a visualization that is registered to objects in the real world).

AR uses **Computer Vision** to recognize the real visual and 3D world!

Definition and Scope

A complete AR system requires at least three components: a **tracking component**, a **registration component** and a **visualization component**

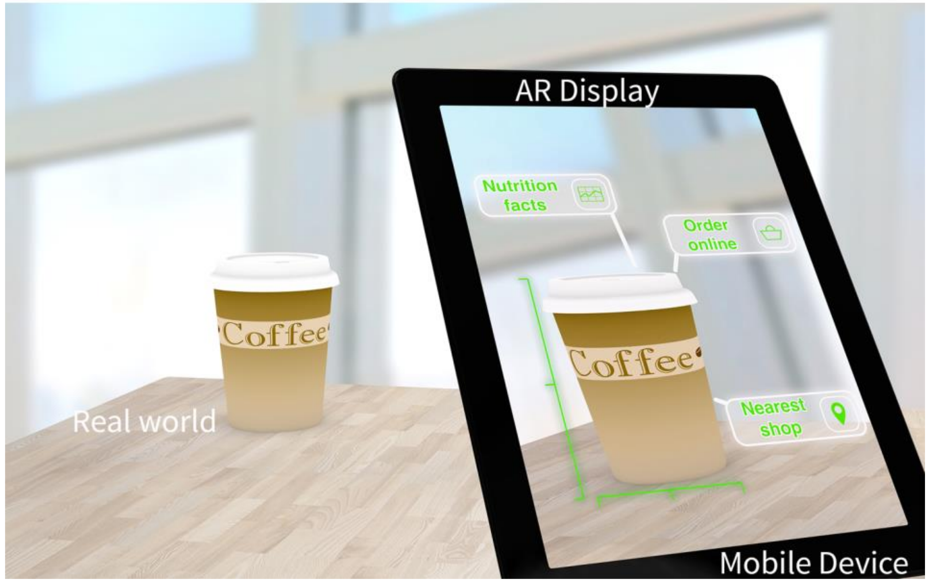


A fourth component — a spatial model (i.e., a database)— stores information about the real world and about the virtual world and both must be registered in the same coordinate system

Definition and Scope

- Examples of AR devices

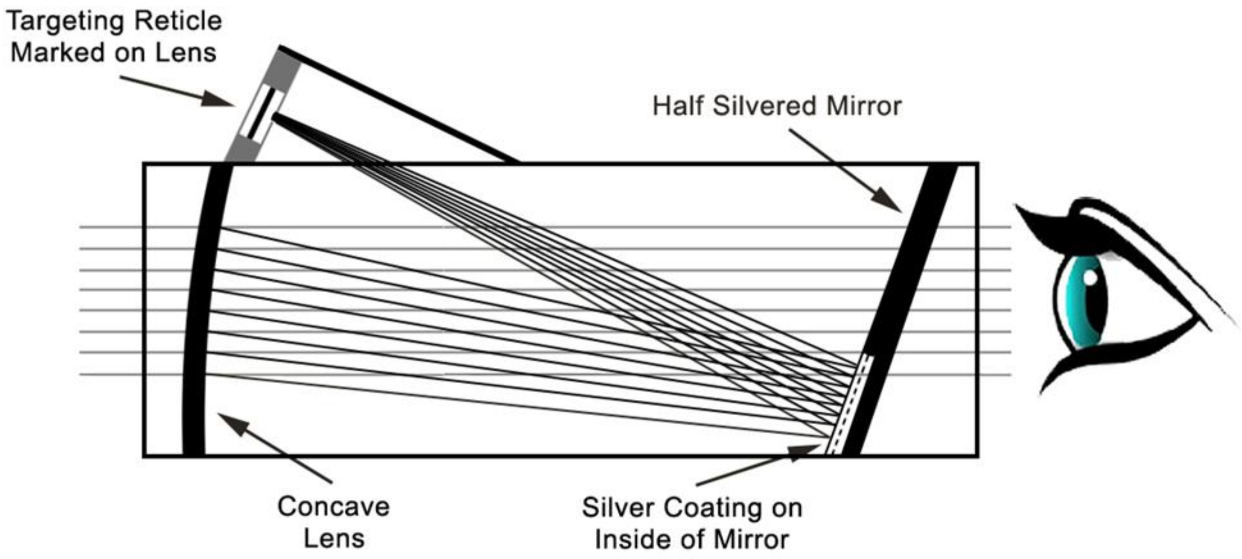
Handheld mobile video see-through
(Monocular)



Wearable near-eye optical see-through

A Brief History of Augmented Reality

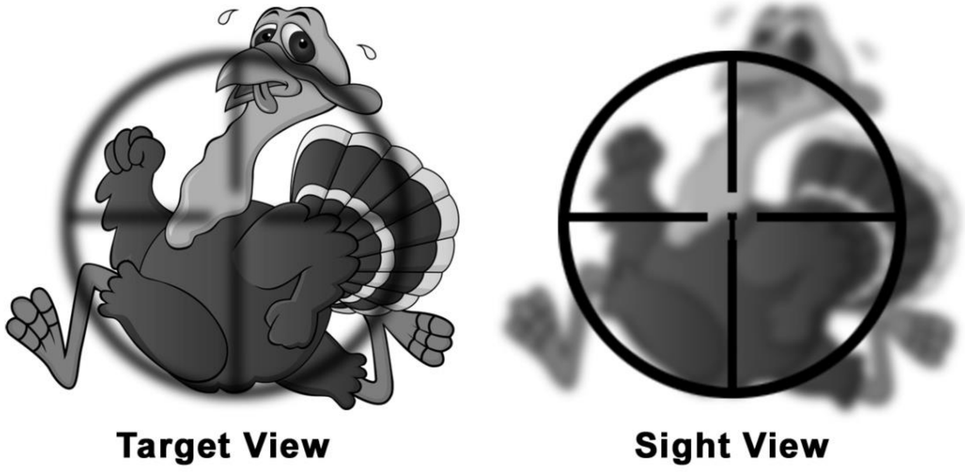
- Early 1900s - Earliest technical foundations traced to Irish telescope maker Sir Howard Grubb for his invention titled "A New Collimating-Telescope Gun-Sight for Large and Small Ordnance."



Grubb's invention was intended for use in helping aim projectile firing weapons.

A Brief History of Augmented Reality

- Grubb's invention solved challenge of human eye only being able to focus on one depth of field at a time by creating reticle at optical infinity.



A Brief History of Augmented Reality

- The basic principles of Grubb's invention can be found in modern head-up displays…

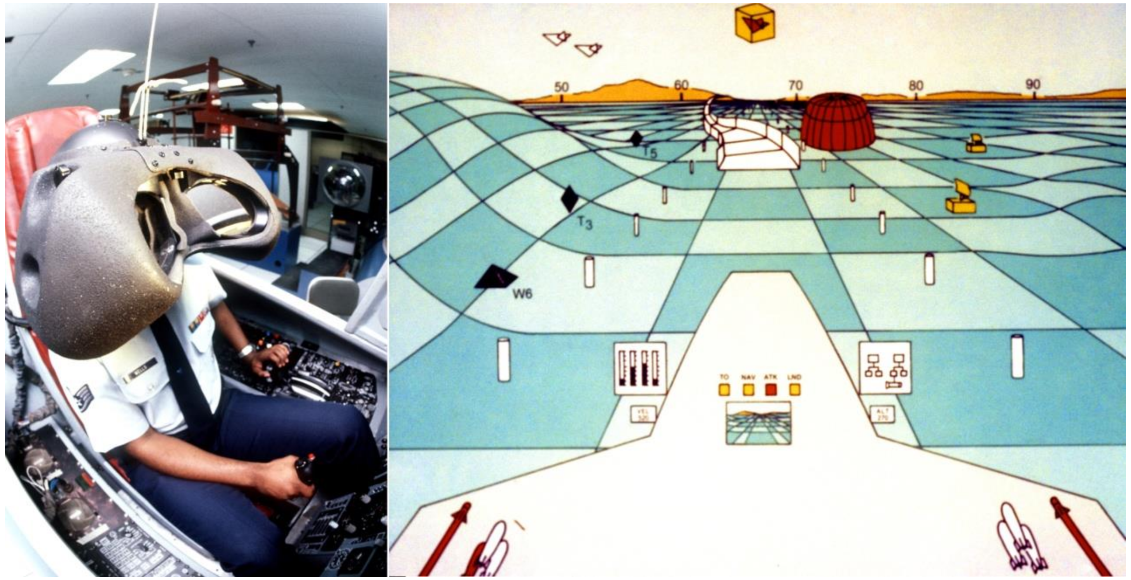
A Brief History of Augmented Reality

- Ivan Sutherland constructed the **first VR system**, the first head-mounted display (HMD) [1968]

- This display already included **head tracking** and used **see-through optics**.

A Brief History of Augmented Reality

- The U.S. Air Force Visually Coupled Airborne Systems Simulator (VCASS) circa 1982.



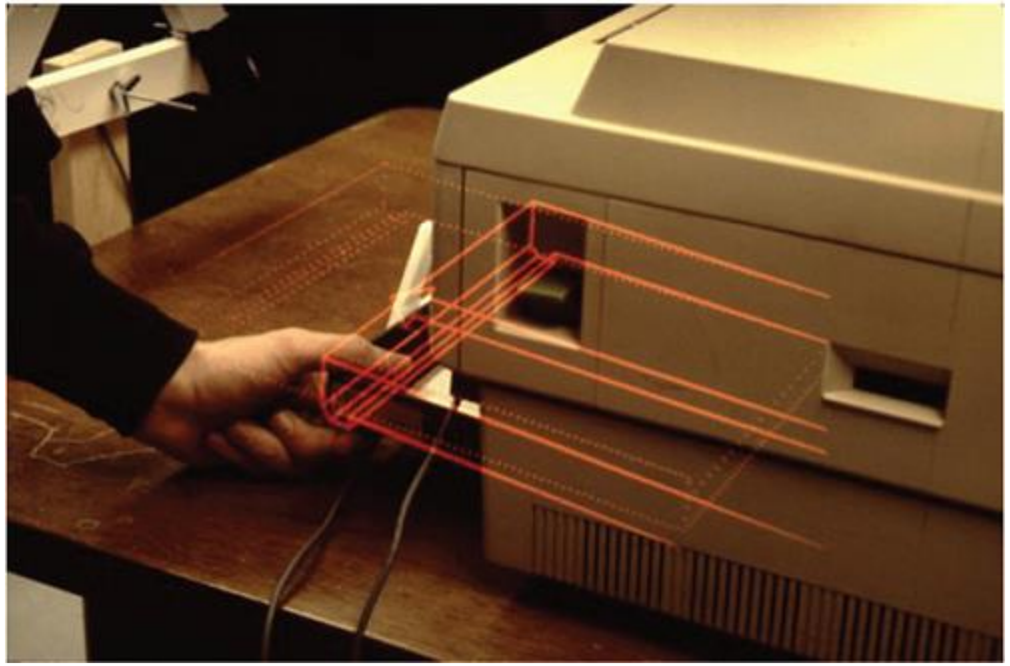
A Brief History of Augmented Reality

- Early 1990s - Phrase "**augmented reality**" coined by Boeing research scientist Tom Caudell.

Researchers at Boing used a see-through HMD to guide the assembly of wire bundles for aircraft. Courtesy of David Mizell.

A Brief History of Augmented Reality

- 1993 KARMA was the first **knowledge-driven AR application**
- Capable of automatically inferring appropriate instruction sequences for repair and maintenance procedures



A Brief History of Augmented Reality

- In 1994, State et al. at the University of North Carolina at Chapel Hill presented a compelling **medical AR application**,

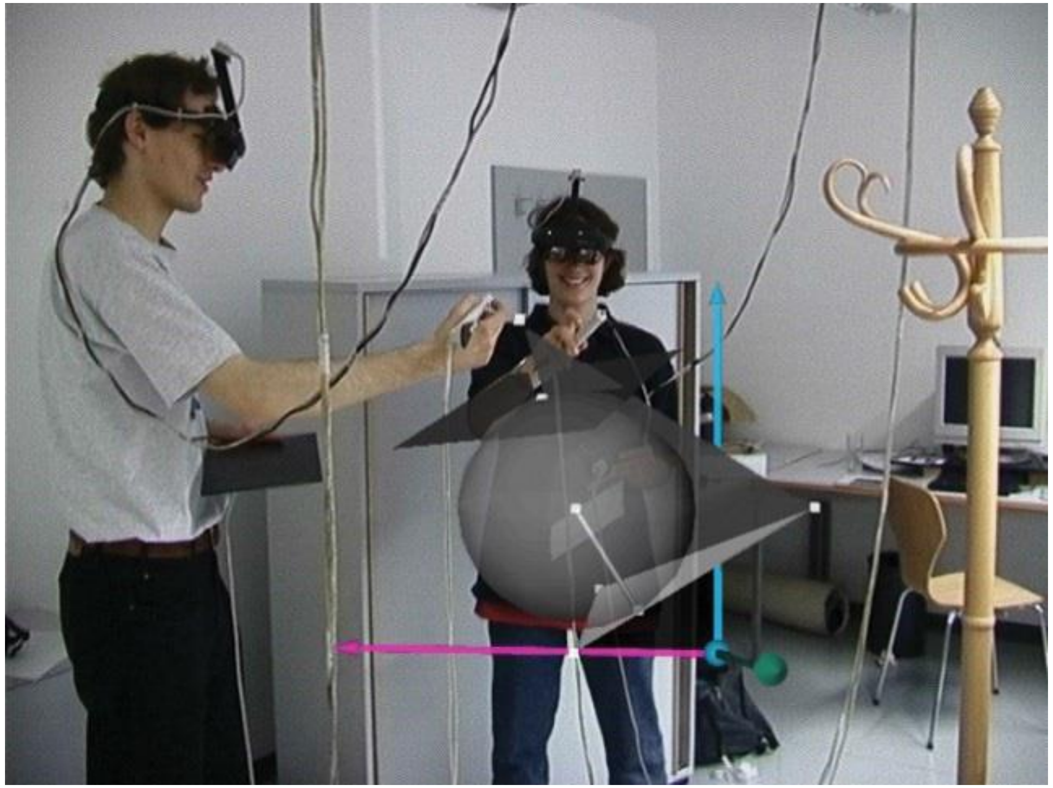
A Brief History of Augmented Reality

- Around the mid-1990s Steve Mann at the MIT Media Lab explored **wearable computing** and mediated reality with the “WearCam” projet [1997] a waist-bag computer with a video see-through HMD

- In 1995, Rekimoto and Nagao created the first true (tethered) **handheld AR display**, “NaviCam”

A Brief History of Augmented Reality

- In 1996, Schmalstieg et al. developed *Studierstube*, the first **collaborative AR system**



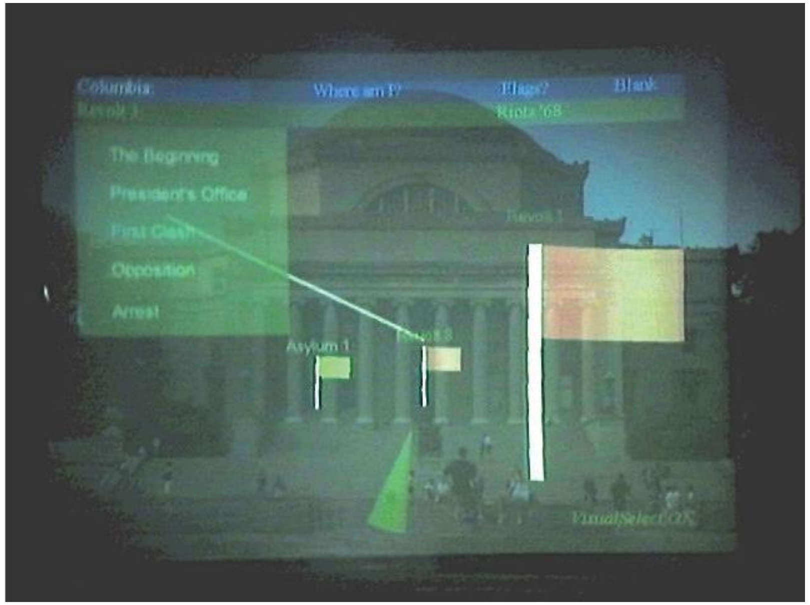
A Brief History of Augmented Reality

- From 1997 to 2001, the Japanese government and Canon Inc. jointly funded the Mixed Reality Systems Laboratory
  - Designed the **first coaxial stereo video see-through HMD**, the "COASTAR"
  - First steps in the **digital entertainment market**

RV-Border Guards was a multiuser shooting game developed in Canon's Mixed Reality Systems Laboratory. Courtesy of Hiroyuki Yamamoto.

A Brief History of Augmented Reality

- In 1997, Feiner et al. developed the **first outdoor AR system**, the “Touring Machine”
  - see-through HMD with GPS and orientation tracking
  - backpack holding a computer (mobile 3D graphics)
  - various sensors and an early tablet computer for input



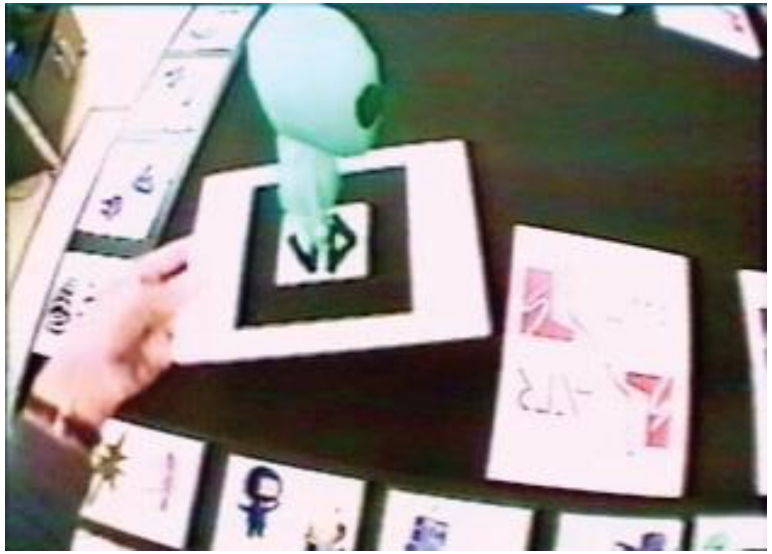
A Brief History of Augmented Reality

- In 1998, Thomas et al. developed an outdoor AR navigation system, the “Map-in-the-Hat” platform
- The successor “Tinmith” platform was used for advanced applications, such as 3D surveying, but is most famous for delivering the **first outdoor AR game**, ARQuake

Screenshot of ARQuake [*Quake* to Tinmith], the first outdoor AR game. Courtesy of Bruce Thomas and Wayne Piekarski.

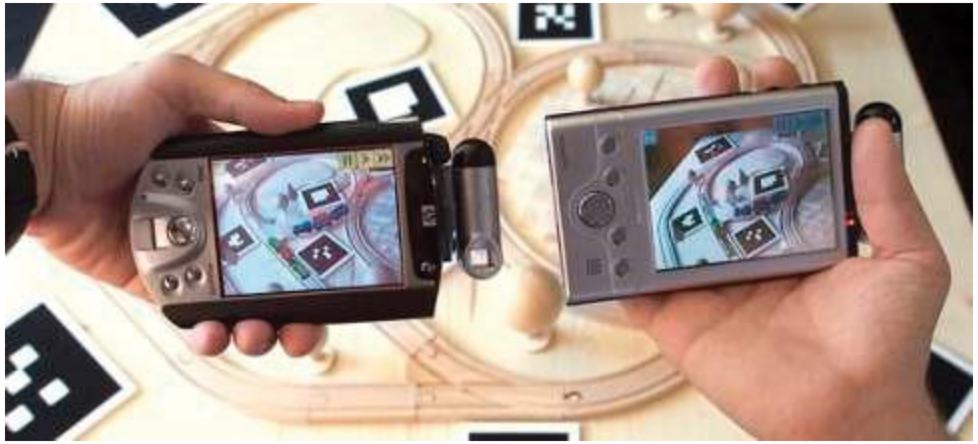
A Brief History of Augmented Reality

- Raskar et al. [1998] presented the "Office of the Future", a **telepresence system** built around the idea of structured light-scanning and projector-camera systems (depth sensors and camera-projection coupling)
- Kato and Billinghurst [1999] released **ARToolKit**, the first open-source software platform for AR



A Brief History of Augmented Reality

- After 2000, cellular phones and mobile computing began evolving rapidly
- In 2003, Wagner and Schmalstieg presented the first **handheld AR system running autonomously** on a “personal digital assistant”— a precursor to today’s smartphones.
- One year later, the “Invisible Train” [Pintaric et al. 2005], a **multiplayer handheld AR game**



A Brief History of Augmented Reality

- In 2008, Wagner et al. introduced the first truly usable **natural feature tracking system** for smartphones, the ancestor of the popular **Vuforia** toolkit for AR developers
- PTAM (parallel tracking and mapping) system of Klein and Murray [2007] approached the area of **tracking** which can track without preparation in unknown environments
- KinectFusion system developed by Newcombe et al. [2011a], which builds detailed **3D models from an inexpensive depth sensor**

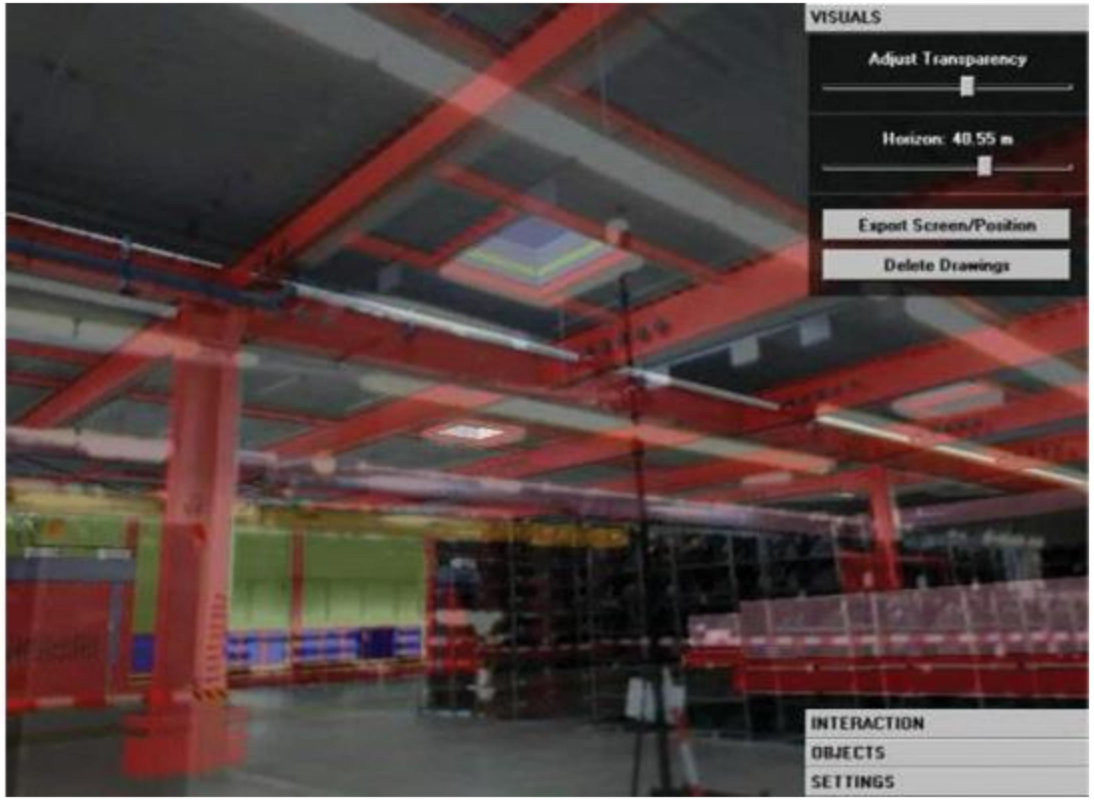
Applications

- Industry and Construction

AR can be used for discrepancy analysis in industrial facilities. These images show still frames overlaid with CAD information. Note how the valve on the right-hand side was mounted on the left side rather than on the right side as in the model. Courtesy of Nassir Navab.

Applications

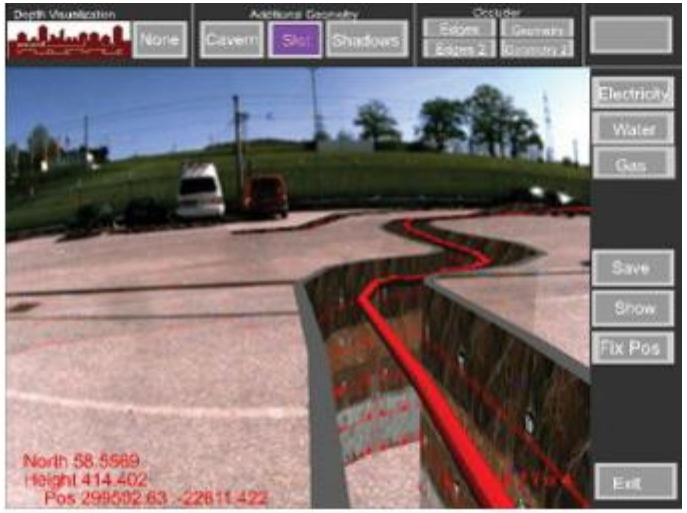
- Industry and Construction



The Planar is a touchscreen display on wheels (left), which can be used for discrepancy analysis directly on the factory floor (right). Courtesy of Ralph Schönfelder.

Applications

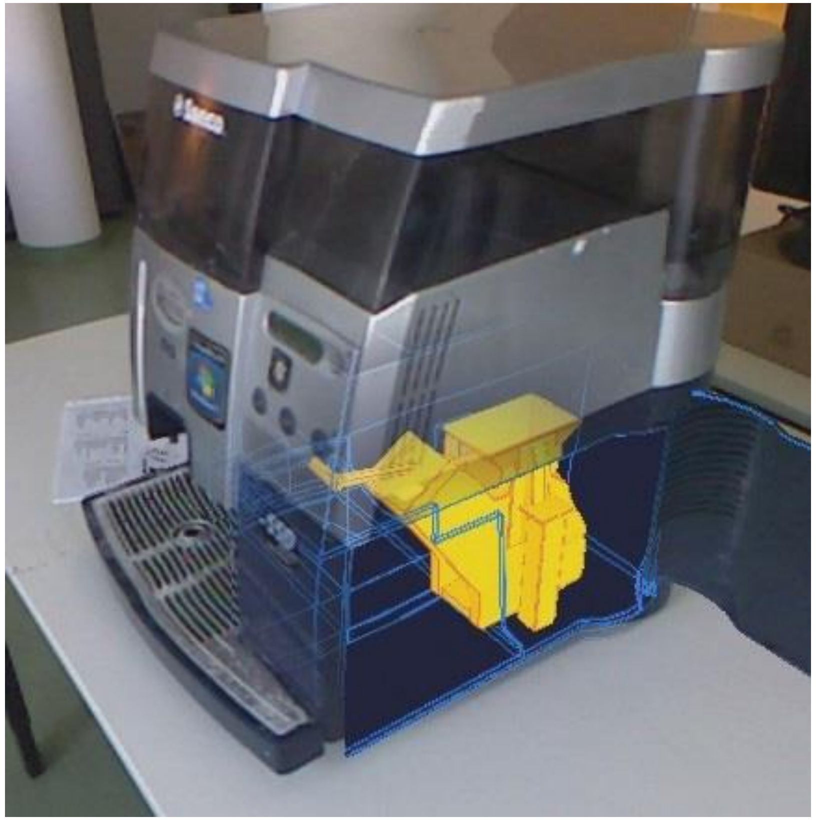
- Industry and Construction



Tablet computer with differential GPS system for outdoor AR (left). Geo-registered view of a virtual excavation revealing a gas pipe (right). Courtesy of Gerhard Schall.

Applications

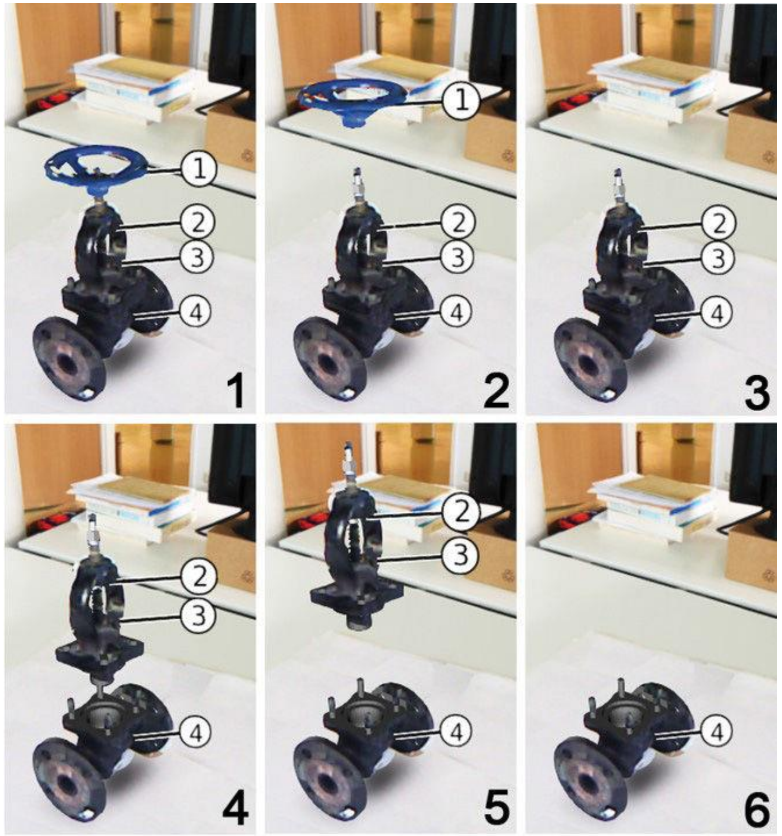
- Maintenance and Training



Ghost visualization revealing the interior of a coffee machine to guide end-user maintenance. Courtesy of Peter Mohr.

Applications

- Maintenance and Training



Automatically generated disassembly sequence of a valve.
Courtesy of Peter Mohr.

Applications

- Maintenance and Training

A car repair scenario assisted by a remote expert via AR telepresence on a tablet computer (left). The remote expert can draw hints directly on the 3D model of the car that is incrementally transmitted from the repair site (right). Courtesy of Steffen Gauglitz.

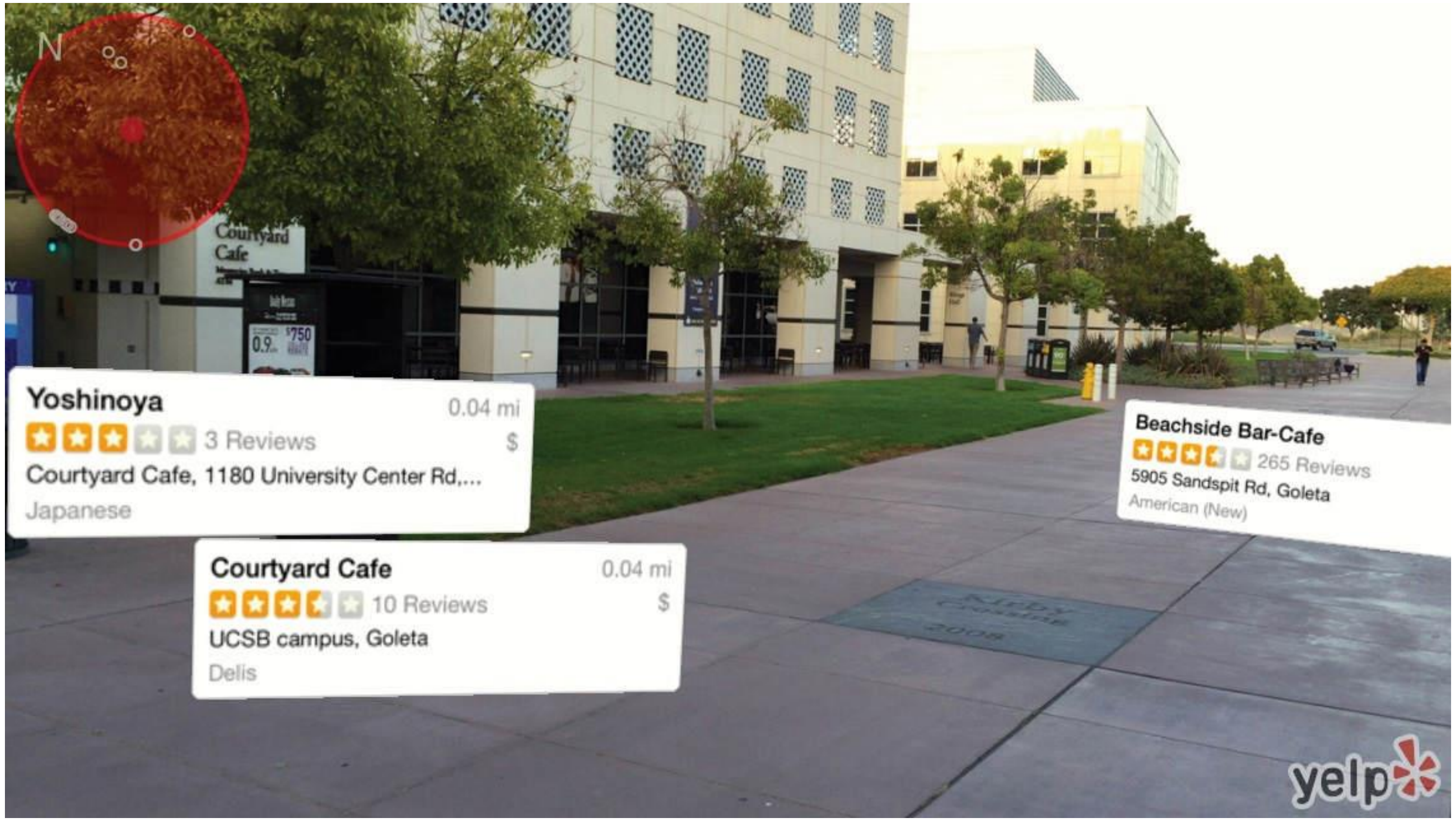
Applications

- Medical

Evena's Eyes-On Glass helps clinicians visualize a patient's veins by using a unique lighting and video system to overlay an enhanced view onto the wearer's real-world view.
[Another example.]

Applications

- Personal Information Display



AR browsers such as Yelp Monocle superimpose points of interest on a live video feed.

Applications

- Personal Information Display

Google Translate superimposes spontaneous translations of text, recognized in real time, over the camera image.

Applications

- Navigation

The parking assistant is a commercially available AR feature in many contemporary cars. Courtesy of Brigitte Ludwig.

Applications

- Television

Augmented TV broadcast of a soccer game. Courtesy of Teleclub and Vizrt, Switzerland (LiberoVision AG).

Applications

- Advertising and Commerce

The lifestyle magazine Red Bulletin was the first print publication to feature dynamic content using AR. Courtesy of Daniel Wagner.

Applications

- Advertising and Commerce

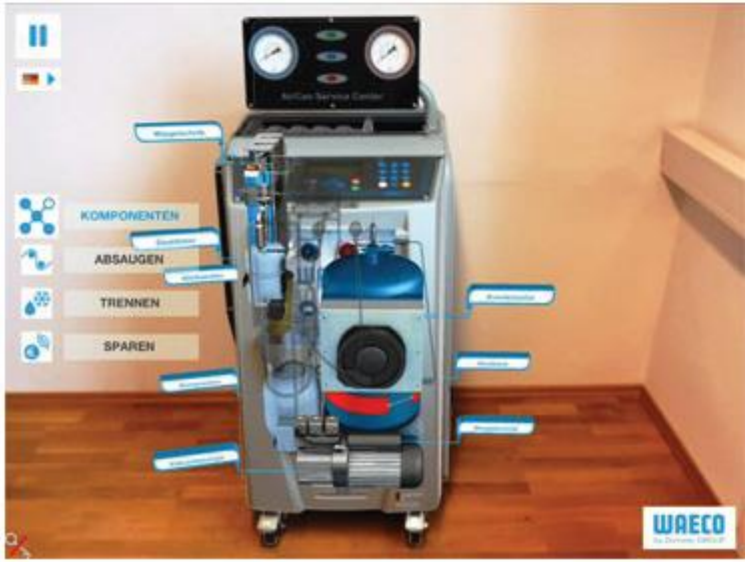
Physical real-world 'marker'

Marker transformed into 'augmented reality' when held in view of a webcam. Output as displayed on a computer screen.

[Mini AR advertising](#)[2008]

Applications

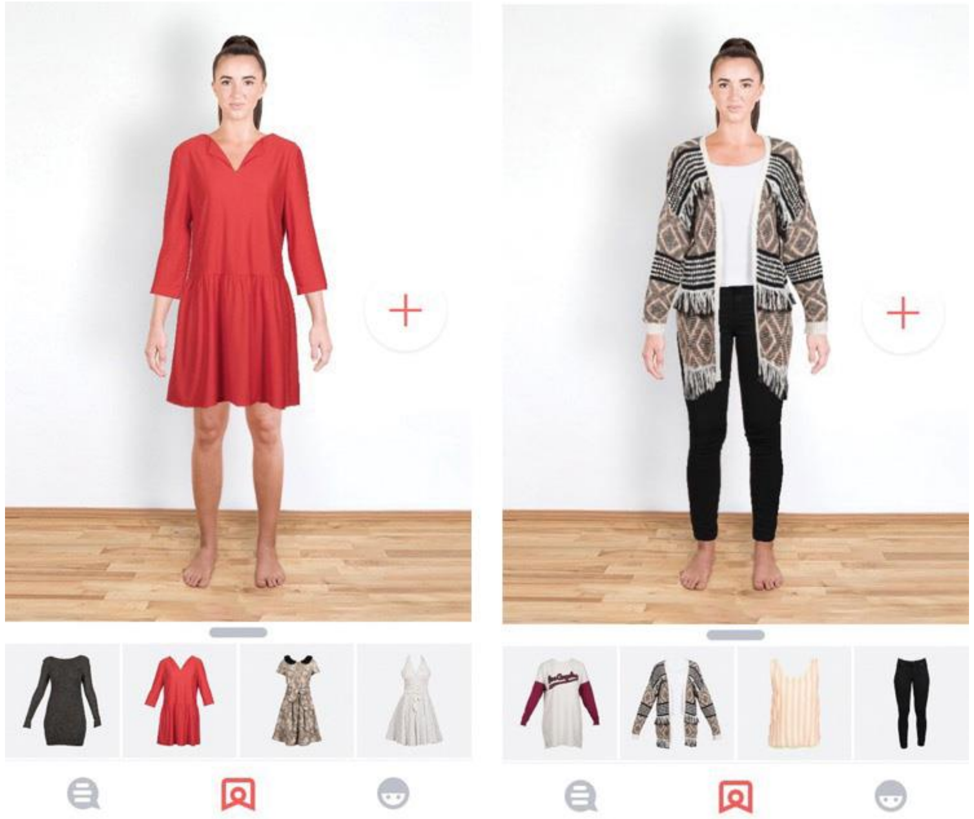
- Advertising and Commerce



Marketing presentation of a Waeco air-conditioning service unit. Courtesy of magiclensapp.com.

Applications

- Advertising and Commerce



Pictofit can extract garment images from online shopping sites and render them to match an image of the customer. Courtesy of Stefan Hauswiesner, ReactiveReality.

Applications

- Advertising and Commerce

IKEA AR App showing virtual furniture placed in the room.

Applications

- Gaming

Vuforia SmartTerrain scans the environment and turns it into a game landscape. © 2013 Qualcomm Connected Experiences, Inc. Used with permission.

Applications

- Gaming

Using a TV-plus-projector setup, the *IllumiRoom* extends the game world beyond the boundaries of the screen. Courtesy of Microsoft Research.

Applications

- Gaming

Microsoft HoloLens demonstration shows off holographic Minecraft

Bibliography

Based on:

[1] - Augmented Reality: Principles and Practice, 1st Edition by Dieter Schmalstieg and Tobias Hollerer, June 2016, Pearson Education