Animação e Ambientes Virtuais
2018/2019

Mestrado em Engenharia Informática
Mestrado em Informática
outros mestrados

DI- FCUL

Augmented Reality
(Realidade Aumentada)

Beatriz Carmo

Augmented Reality

enables users to visualize synthetic information overlaid on top of real imagery

"Making Life Easier with Augmented Reality"
https://www.youtube.com/watch?v=Xj2z1MnkYEs

Azuma's definition of Augmented Reality

in *A Survey of Augmented Reality.* Presence: Teleoperators and Virtual Environments 6, 4 (August 1997), pp. 355 - 385:

"AR as systems that have the following three characteristics:
1) Combines real and virtual
2) Interactive in real time
3) Registered in 3-D"

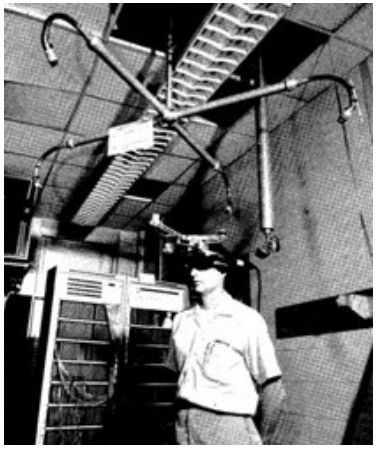
The most referenced publication in the field of AR
http://www.ronaldazuma.com/publications.html

Ivan Sutherland (1968) has created the **first augmented reality system**, which is also the first virtual reality system.

It uses an optical see-through head-mounted display that is tracked by one of two different 6DOF trackers: a mechanical tracker and an ultrasonic tracker.

Due to the limited processing power of computers at that time, only very simple wireframe drawings could be displayed in real time.

Ivan Sutherland (1968)



Half-silvered mirrors in the prisms through which the user looks allow him to see both

• the images from the cathode ray tubes

• and objects in the room simultaneously

[Sutherland68]

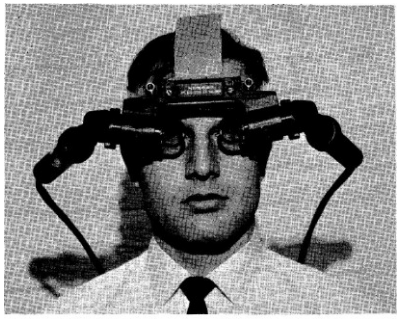


FIGURE 2—The head-mounted display optics with miniature CRT's

Optical vs video

A basic design decision in building an AR system is **how to accomplish the combining of real and virtual**.

Two basic choices are available:

– optical (real objects are seen directly)

– and video technologies (real objects are seen in video images)

[Azuma97]

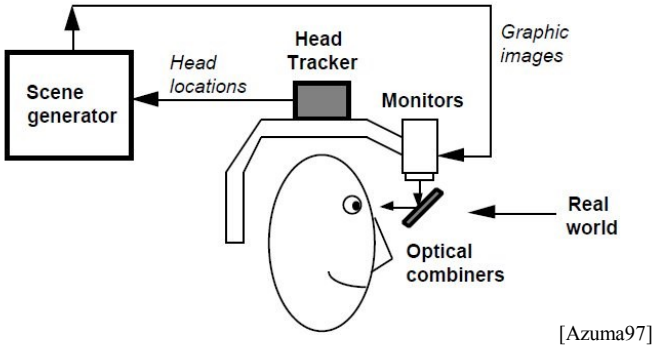
Optical see-through HMD (head-mounted display) or AR glasses

They work by placing optical combiners in front of the user's eyes:

These combiners are partially transmissive, so that the user can look directly through them to see the real world.

[Azuma97]

Optical see-through HMD



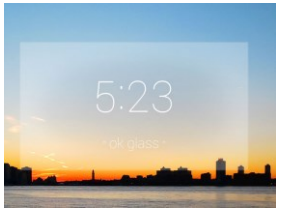
[Azuma97]

Google-glasses

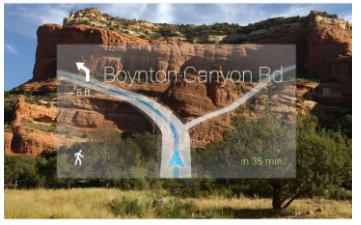
https://www.youtube.com/user/googleglass (since 2013)

- Camera
- One screen
- Voice commands

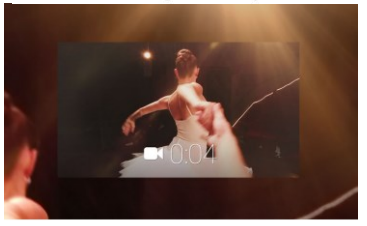
Google-glasses



Say "take a picture" to take a picture.



Directions right in front of you.



Record what you see. Hands-free.

Epson Moverio Smart Glasses

18 March 2014, BBC news http://www.bbc.com/news/technology-26624465

"Epson Moverio 'rivals' Google Glass at technology show

The Japanese imaging giant Epson is one of a number of technology firms looking to create an innovative visual experience through an interactive head-mounted display.

The Moverio augmented-reality glasses are **wired to a controller using the Android mobile operating system**.

They were first released a couple of years ago but a new version is shortly due for release - aimed at workers and "early adopter" consumers."

Mar 2019 – price **$1,099.00** Moverio-BT-350-Smart-Glasses
https://epson.com/For-Work/Wearables/Smart-Glasses/Moverio-BT-350-Smart-Glasses/p/V11H837020

Moverio BT-350 Smart Glasses

Control unit, touch pad

- Adjustable design made to fit multiple sizes
- Si-OLED display for more natural color and images
- **Motion-tracking sensors**
- High-resolution **camera** make it ideal for 360-degree apps
- The binocular display **enables stereoscopic** content too.
- With wireless and Bluetooth® Smart (BLE) connectivity supports multiple accessories.
- Built on the Android™ platform, suitable for developing AR apps

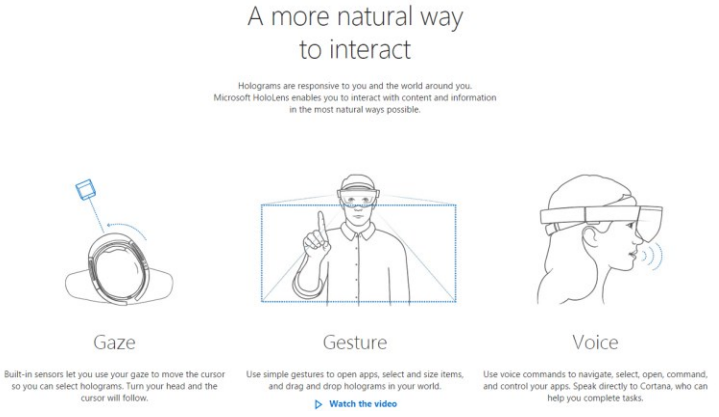
Microsoft Hololens

March 2017 - development edition $3000, commercial suite $5000

March 2019 - HoloLens 2 offers the most comfortable and immersive mixed reality experience available—enhanced by the reliability, security, and scalability of cloud and AI services from Microsoft. $3,500 per device. (HoloLens 2 preorders -https://www.microsoft.com/en-us/hololens/buy)

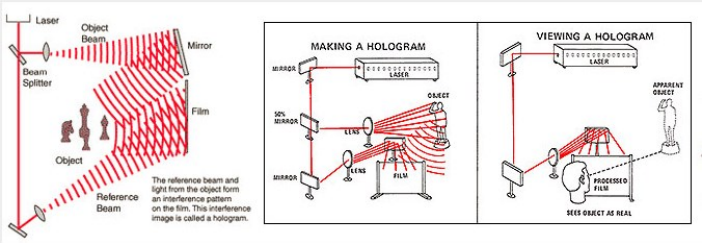
- Mixed reality **blends 3D holographic content into your physical world**, giving your holograms real-world context and scale, allowing you to interact with both digital content and the world around you.
- By understanding your environment, mixed reality enables holograms to look and sound like they're part of your world.

https://www.microsoft.com/microsoft-hololens/en-us/why-hololens (March 2018)



https://www.microsoft.com/microsoft-hololens/en-us/why-hololens (March 2018)

Holograms



Holography is based on the principle of interference. A hologram captures the interference pattern between two or more beams of coherent light (i.e. laser light). One beam is shown directly on the recording medium and acts as a reference to the light scattered from the illuminated scene.

http://holocenter.org/what-is-holography

Video see-through HMD

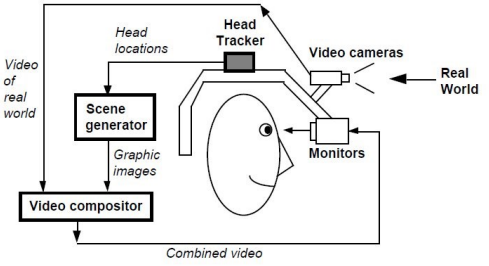
Old solution

They work by combining a closed-view HMD with one or two head-mounted video cameras

- The video cameras provide the user's view of the real world.
- Video from these cameras is combined with the graphic images created by the scene generator, blending the real and virtual.
- The result is sent to the monitors in front of the user's eyes in the closed-view HMD.

[Azuma97]

Video see-through HMD



[Azuma97]

Video see-through

Durovis Dive is a smartphone holder

It allows the smartphone' camera to capture real images.

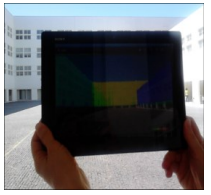
The alignment of virtual and real objects is difficult because there is only **one camera for both eyes** and **without trackers**

Video see-through

Monitor-based/mobile devices configurations

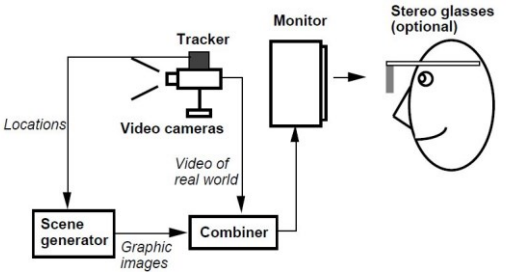
AR systems can also be built using monitor-based/mobile devices configurations, instead of see-through HMD:

- One or two video cameras view the environment (the cameras may be static or mobile)
- The video of the real world and the graphic images generated by a scene generator are combined
- and displayed in a monitor in front of the user



- Stereo glasses can be used for stereoscopic images [Azuma97]

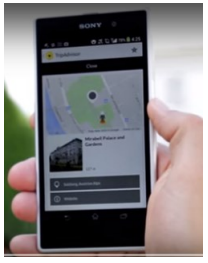
Monitor-based configurations



[Azuma97]

Most promising AR Device today: the Mobile Phone

- Commercial off-the-shelf hardware
  - Low cost
  - Socially accepted
  - Well known
  - Discrete
  - Wide spread
  - Intuitive to use

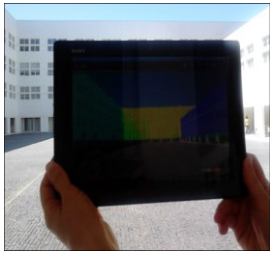


- All in one solution
  - Display
  - Camera
  - CPU

http://www.raeng.org.uk/publications/other/enabling-techniques-for-ar-on-mobile-phones

Magic Lens vs Magic Mirror

In the **Magic Lens** approach the user is able to see through to an image of the real word with added AR elements



http://www.artag.net/videos.html

Magic Mirror vs Magic Lens

The **Magic Mirror** technique involves putting a computer monitor (a screen) behind the area that is being captured by na AR video. The display is the mirror.

http://www.artag.net/

Magic Mirror

http://www.artag.net/

Magic Mirror

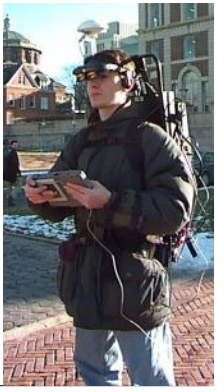
Museu do dinheiro, Lisboa

Each face of the ticket has a marker.

Mobile Augmented Reality Systems

- It uses a see-through head-worn display
- with integral orientation tracker;
- a backpack holding a computer,
- differential GPS, and digital radio for wireless web access;
- and a hand-held computer with stylus and touchpad interface.

(Feiner 1997)



Mobile Augmented Reality Systems

"Map-in-the-hat",
•a backpack-based wearable computer that includes
• GPS,
• electronic compass(*)
• and a head-mounted display
At this stage the system was utilized for navigation guidance
(Thomas1998)

(*) bússola

Camera Phone

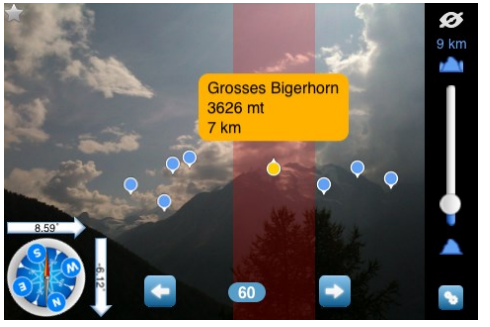
Sharp corporation releases the **first commercial camera phone** to public. The official name of the phone is J-SH04. The phones' camera has a resolution of 0.1 megapixels.
(**2000**, http://k-tai.impress.co.jp/cda/article/showcase_top/3913.html)

Mobile Augmented Reality Systems

[Tokusho2009]

How to combine graphics and real world objects?

- Which graphics?
- Which objects?



SwissPeaks [Karpischek2009]

Tracking

AR requires tracking the position of the real objects
to identify in which position the virtual elements should be placed to be superimposed on the objects of the real world

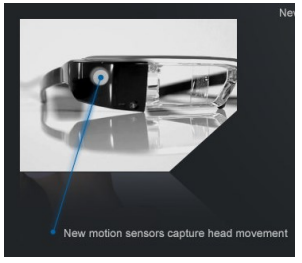
How to translate tracking into portuguese?
(Dicionário da Porto Editora)

- **Tracking** – **localização**, perseguição de pegadas/rasto, rastreio, **rastreamento**
- Rastreio / rastreamento - ato ou efeito de rastrear
- Rastrear (verbo transitivo) 1) seguir o rasto de; ir na pista de; 2) procurar, buscar; 3) investigar, inquirir ;
  (verbo intransitivo) **seguir** rasto ou pista

Tracking

- Head Mounted Display (inertial trackers)
- GPS, digital compass, accelerometer, inclinometer, gyroscope
  (vide VR slides - inertial trackers)
- Sensor fusion
- Visual markers ← Image analysis
  - fiducial markers
  - "natural" markers
- Assisted alignment with images (*Alinhamento assistido com imagens*)

Tracking with Head Mounted Display



MOVERIO-BT-200

Tracking with GPS and digital compass "early days"

Queries based on location and orientation
[DI-FCUL2009]

Lego digital compass and NXT attached to mobile device with GPS

GPS and digital compass

Application system components. Top to bottom:

- UMPC with Bluetooth adapter,
- Android Dev Phone 1,
- Inertia-Cube3 external orientation sensor

[Tokusho2009]

[2009] [1997]

Accelerometers, inclinometers and gyroscopes

Data collected from other sensors, such as, **accelerometers**, **inclinometers** and **gyroscopes** can be also used to determine the position and orientation of the device

Acceleration, angular velocity and rotations can be used to calculate changes in position and orientation.

Data collected with **sensors** usually accumulates errors over time which leads to **lack of accuracy**

Sensor fusion

Sensor fusion is a process by which data from several different sensors are "fused" to compute something more than could be determined by any one sensor alone

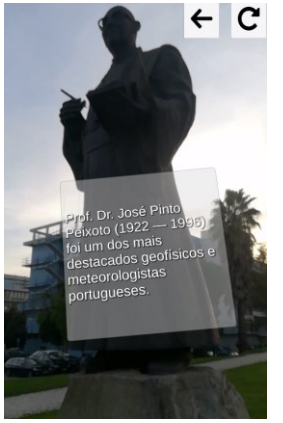
Example: computing the position and orientation of a device in 3D space

Google Play Services -This component provides core functionality like authentication to your Google services, synchronized contacts, access to all the latest user privacy settings, and higher quality, **lower-powered location based services**

AR example with sensors' tracking

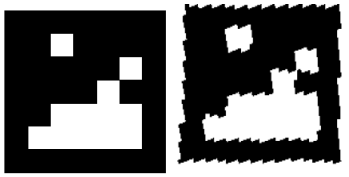
A textbox is superimposed on the image taking into account

- the location of the point of interest
- and the location and orientation of the device



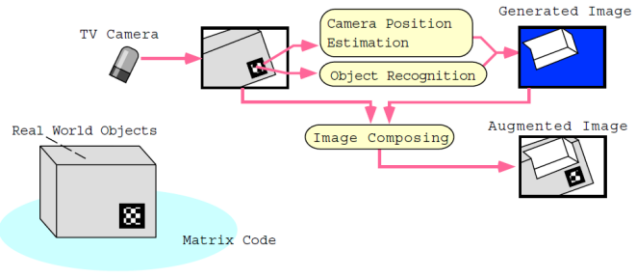
Visual markers

Rekimoto (1998) proposed a method to identify real world objects and estimates their position and orientation using a combination of **visual markers** and a video camera.



2D matrix code examples (left:original, right:restored from video)

Visual markers



Overview of the vision-based information registration method [Rekimoto1998]

Visual markers

- The simple form of marker is a unique **pattern** that is visible to the AR camera and can be identified in the AR system software
- These patterns are **physically added to the real world**
- The marker tags are used to **determine the viewpoint of the real camera** so that the virtual object can be rendered appropriately
- The markers are called **fiducial markers** because they are used as a trusted reference [Cawood2007]

ARToolKit
Fiducial markers

Tracking fiducial markers [Kato99]

• Hirokazu Kato and Mark Billinghurst presented **ARToolKit**, a pose tracking library with six degrees of freedom, using square fiducials and a template-based approach for recognition.

• ARToolKit is available as open source under the GPL license and is still very popular in the AR community.

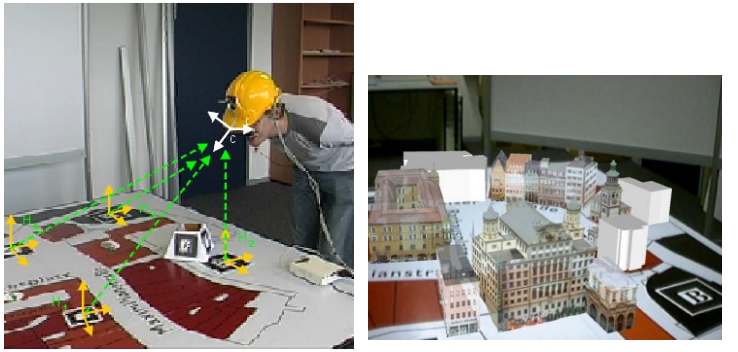
Problems with AR based on fiducial markers

Markers are unaesthetic

and have to be placed over the real world objects,

so they can only be used in controlled environemts and not in general purposed applications

Example of tracking with visual markers



Markerless AR Natural features

- Markerless AR corresponds to create an AR effect without using markers
- It does not require adding markers to a scene in advance
- The main goal is to **recognize "natural" features** such as the corner of a window or a distinctive painting on a wall.
- This requires computer vision algorithms [Cawood2007]

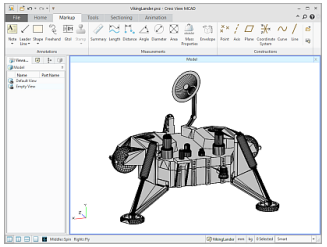
Markers and Markerless AR in Vuforia

Vuforia AR platform (https://www.vuforia.com)

- Developers can easily add advanced computer vision functionality to **Android**, **iOS** and **UWP** apps, to create AR experiences that realistically interact with objects and the environment.
- The Vuforia Engine is natively integrated with Unity

Markers and Markerless AR in Vuforia

Model Targets support the recognition and tracking of object by their shape, using a specially prepared database that is generated by processing a digital 3D representation of the object



https://library.vuforia.com/articles/Solution/model-targets-user-guide.html

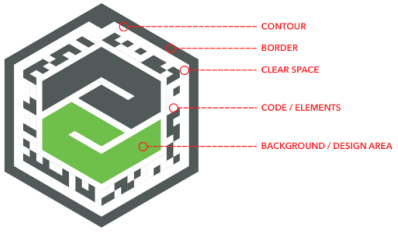
Markers and Markerless AR in Vuforia

VuMarks are customized markers that can encode a range of data formats. They support both unique identification and tracking for AR applications

Markers and Markerless AR in Vuforia

VuMark designs can be created in Adobe Illustrator using the VuMark Designer tool, and then uploaded to the Target Manager as SVG files (Scalable Vector Graphics).

VuMarks have five primary design components that contribute to their uniqueness, detectability, and data encoding capabilities.



Markers and Markerless AR in Vuforia

Image Targets are flat images, such as print media and product packaging.

Image targets can be created with the Vuforia Target Manager

- using JPG or PNG images in RGB or grayscale
- the input images must 2 MB or less

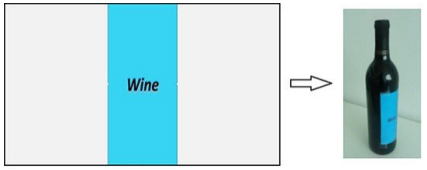
Markers and Markerless AR in Vuforia

Cylinder Targets are images wrapped onto objects that are approximately cylindrical in shape (e.g. beverage bottles, coffee cups, soda cans)

Markers and Markerless AR in Vuforia

Cylinder Targets

You may use the original imagery or design your own label image



https://library.vuforia.com/articles/Solution/Cylinder-Targets-Guide.html

Markers and Markerless AR in Vuforia

Vuforia Ground Plane supports the **detection and tracking of horizontal surfaces**. It enables digital content to be placed on horizontal surfaces in your environment, such as floors and tabletops.

https://library.vuforia.com/articles/Training/ground-plane-guide.html

EasyAR platform

- API for Android and iOS
- Support for Unity
- Free and commercial SDK

https://www.easyar.com/

EasyAR Markers

Marker

Image superimposed on the marker

Marker

Several photos as markers

Previously several photos are taken with the statue from different points of view.

In the image captured with the smartphone, the statue is recognized and a text box is superimposed.

Other SDK for AR

- AR Core (google)

https://developers.google.com/ar/discover/

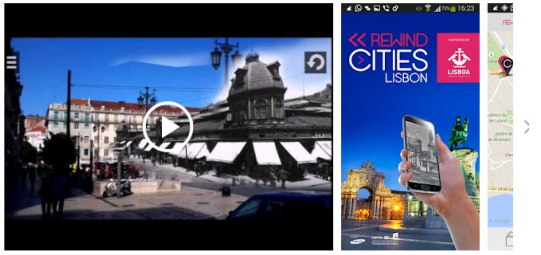
"allows the phone to detect the size and location of all type of surfaces: horizontal, vertical and angled surfaces like the ground, a coffee table or walls"

- Wikitude

https://www.wikitude.com/

Assisted alignment with images (*Alinhamento assistido com imagens*)

Example: Rewind Cities



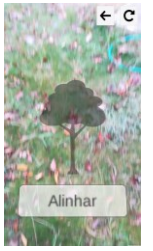
https://play.google.com/store/apps/details?id=pt.itpeople.rewindcitieslisbon&hl=en

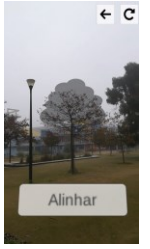
Assisted alignment with images

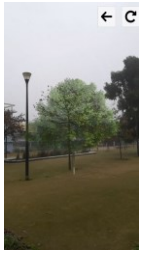
video

Assisted alignment with images

Move the smartphone till the virtual object (1) be aligned with the real object in the image (2) and then click on the screen to init AR experience (3)







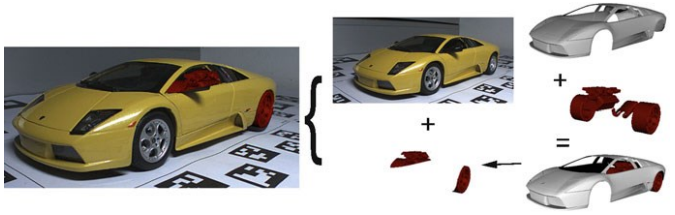
Problems to solve in AR

- Oclusion of virtual objects
- Depth perception
- Perception of symbols
- Interaction

Oclusion of virtual objects

[Kalkofen09]

Phantom objects



[Kalkofen11]

Phantom objects

Algorithm
Occlusion handling using phantom objects (using **z-buffer**)

1. Draw Video
2. Disable writing to color buffer
3. Render virtual representations of real objects (Phantoms)
4. Enable writing to color buffer
5. Draw virtual objects

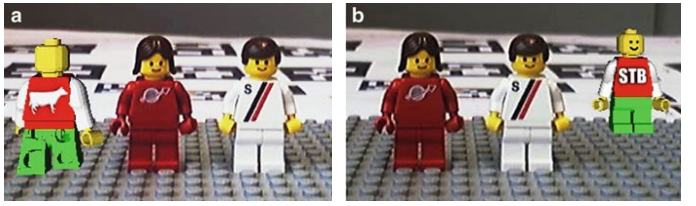
In [Kalkofen11] based on [Breen96]

Virtual representations of real objects are not drawn, they are only used to perform z-buffer calculations

Depth perception

Indiscriminately overlaying hidden information on top of visible real-world entities introduces depth perception problems.[Schall08]

Depth cues



[Kalkofen11]

Depth cues

- **Synchronizing the parameters** of the **virtual** and the **real camera** allows to align real and virtual pictorial depth cues.
- The virtual Lego figure in (**a**) is correctly perceived next to the real figures, whereas the virtual one in (**b**) is correctly perceived behind both.
- This effect is achieved by aligning depth cues such as **perspective distortion** and **relative size**.

[Kalkofen11]

Where are the symbols?

Adaptive simbology

Adaptive simbology

Proposed adaptations

- **Adding a border around the symbol (BW or BB)**
- **Adjusting the colour luminosity (C1 or C2)**
- **Enlarging the symbol (EN with factor 1.5)**
- **Changing the colour of the letters or digits inside the symbol (LW)**

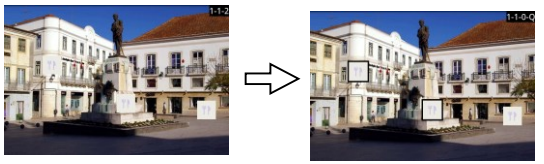
Conclusions of the user study

- The adapted symbols were preferred to base symbols
- Adding a border and adjusting colour luminosity were the most preferred adaptations
- Enlarging the symbol and changing the colour of the letters or digits inside the symbol were never selected when they were showed with other adaptations

[master thesis 2010/2011- Raúl Simplício; GRAPP 2013]

Adapt all the symbols or only those that are not perceptible?

Adapt only symbols that are hard to detect (PA – **partial adaptation**)



- In this case, the symbols in the image may not be all equal

Adapt all symbols (**total adaptation**)

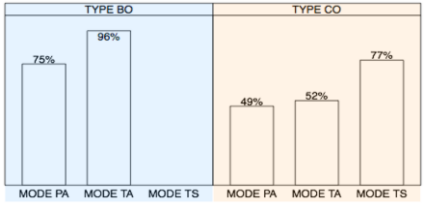
- Case 1: all symbols become easy to distinguish from the background (mode TA)

- Case 2: some symbols become undistinguishable after the adaptation (mode TS)

Results of a user study

- With adding a border around symbols adaptation (type BO)
  - Adaptation of all symbols (mode TA) had the most favourable opinions
  - No influences from background image, genre, order of tests, ambient light

- With adjusting the colour luminosity of symbols (type CO)
  - Adaptation of all symbols (TS mode) had the most favourable opinions



[master thesis 2011/2012 – Edgar Montez; GRAPP2014]

How to interact with AR visualizations?

[Nóbrega2015]

- **Holding position** – point camera devices forward and hold them with arms strectched ➡ Fatigue

Solution
Use a map to help the user approach a certain destination and bring the AR interface only when the user is closer enough or presses an AR button

- **Touch the screen while pointing the device**

Solution
– Design interfaces that rely on thumb interaction
– **Freeze images** and interact with them in a confortable position

AR applications

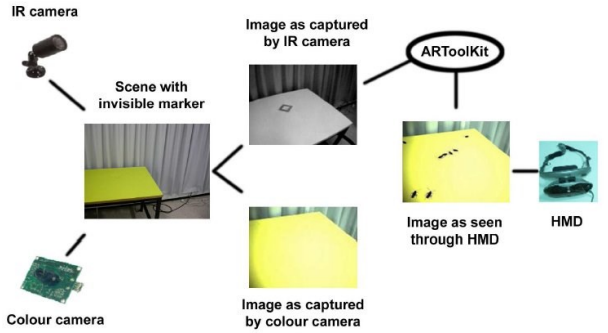
- Treatment of phobias
- Entertainment
- Points of interest
  - Belvederes
  - Mobile devices
- Cultural heritage
- Museums
- Marketing
- Location of infrastructures
- Support to the maintenance of equipments
- Scientific data visualization
- Guided tours in parks

And so on…

Treatment of phobia towards small animals

Which is the tracking technology used here?

Treatment of phobia towards small animals



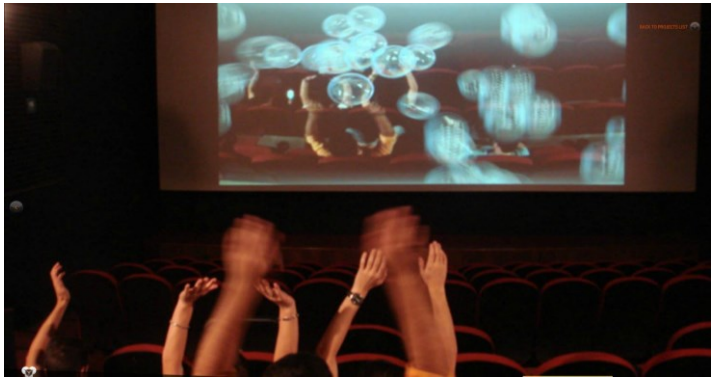
[Juan2011]

Treatment of phobia towards small animals

- Markers are invisible because they are drawn with a special ink
- The invisible marker-tracking AR system (IMARS) "reads" the markers captured using an IR camera

Magic Mirror

http://www.youtube.com/watch?feature=player_embedded&v=TL62txWNFMY



http://www.ydreams.com/index.php#/en/projects/publicurbanexperiences/interactiveaudienceadvergamesDove/

Belvederes
Ponta do Sal, S. Pedro do Estoril

Belvedere of Ponta do Sal

http://www.ydreams.com/index.php#/en/projects/museumslearning/virtualsightseeingcascais/

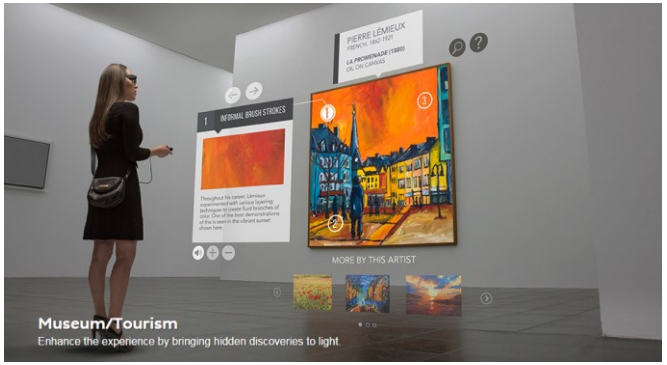
Points of interest

[Pombinho2012]

Cultural Heritage

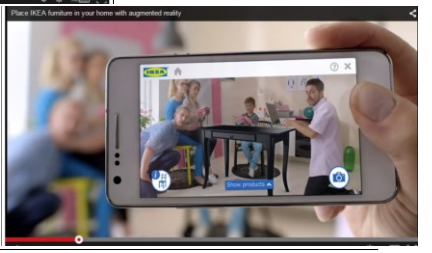
Virtual buildings displayed over captured images [Pletinckx2000]

Museums

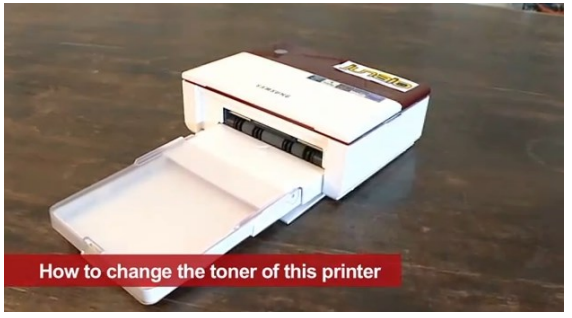


https://www.epson.com/cgi-bin/Store/jsp/Landing/moverio-augmented-reality-experiences.do?UseCookie=yes#lightbox/0/

Catálogo IKEA

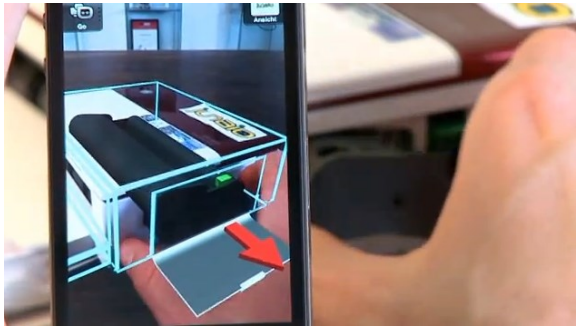


Support to the maintenance of equipments



https://www.youtube.com/watch?v=Xj2z1MnkYEs

Support to the maintenance of equipments

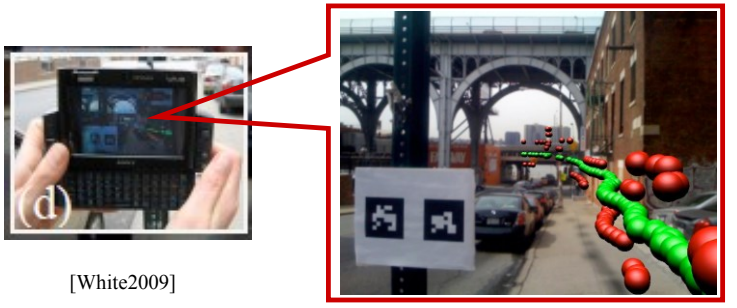


Location of infrastructures

[Schall2008]

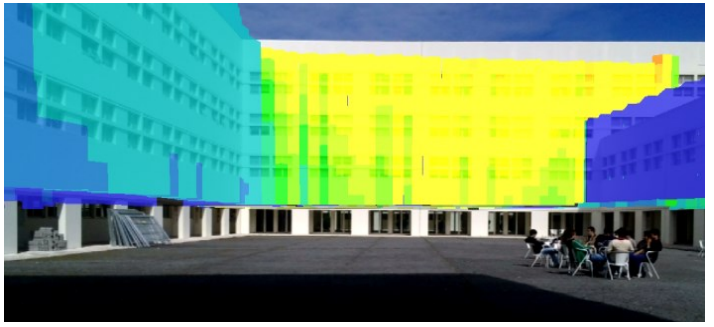
Vesp'R with UMPC (Ultra-Mobile PC) http://www.vidente.at/

Scientific data visualization



[White2009]

Scientific data visualization

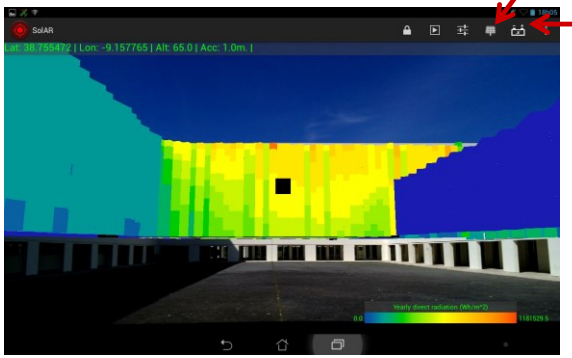


[mestrado 2012/2013 – José Pedrosa; colaboração com o DEGGE]

Scientific data visualization

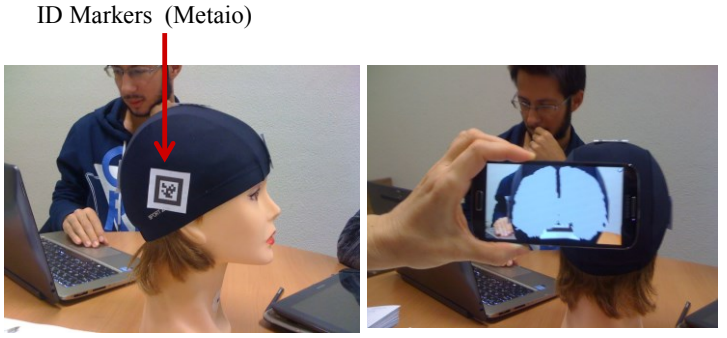
- Data about solar radiation on facades
- Visualization using
  - Colour mapping (surfaces coloured according to values of the variable)
  - Glyphs
  - Animation
- Material: tablet with GPS, accelerometer, gyroscope; uses sensor fusion

Scientific data visualization

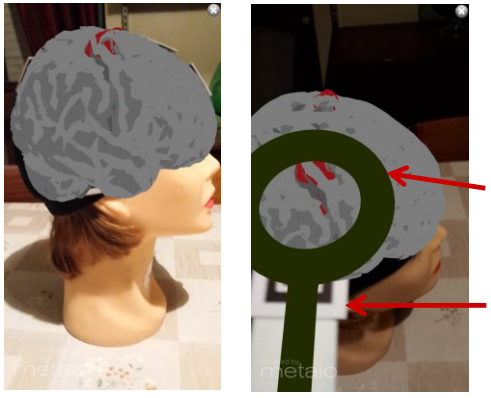


Silvana Silva 13/14, Carolina Meireles 14/15

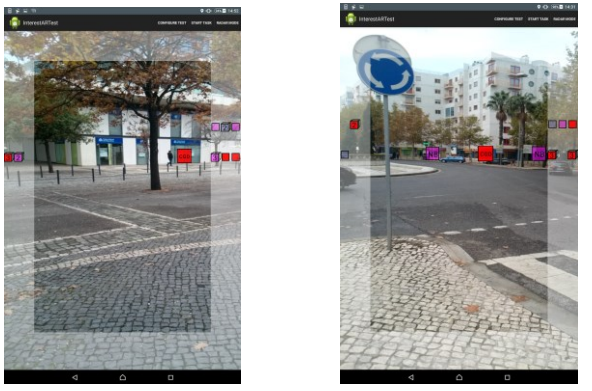
Medical Data
Transcranial Magnetic Stimulation



José Soeiro 14/15; colaboração com IBEB (Instituto de Biofísica e Engª Biomédica)



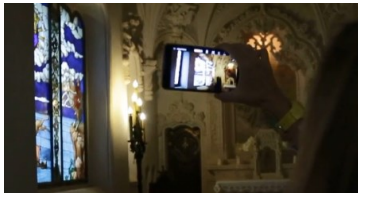
Off-screen objects (points of interest)

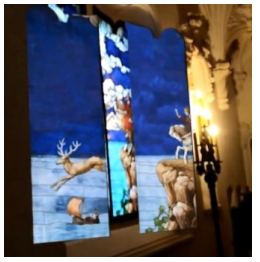


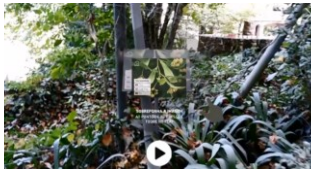
Gonçalo Silva 14/15

Guided tours in parks -
Quinta da Regaleira

http://videos.sapo.pt/132NuucZ6AVVlg2gi5aF







New Project Jardim Botânico Tropical

And so on…