UNIVERSITY OF CRETE
FACULTY OF SCIENCES AND ENGINEERING
COMPUTER SCIENCE DEPARTMENT

COURSE CS-564 (OPTIONAL)

ADVANCED TOPICS

IN HUMAN – COMPUTER INTERACTION

Course Convenor: Constantine Stephanidis

AUGMENTED REALITY

Introduction – What is Augmented Reality?

https://www.youtube.com/watch?v=09vxKN1zLNI

Definition

- Augmented Reality (AR) allows computer generated virtual imagery to exactly overlay physical objects in real time
- Unlike virtual reality (VR), where the user is completely immersed in a virtual environment, AR allows the user to interact with the virtual images using real objects in a seamless way
- Azuma (1997) provides a commonly accepted definition of AR as a technology which
  1. combines real and virtual imagery,
  2. is interactive in real time,
  3. registers the virtual imagery with the real world

Issues for providing an effective AR experience

a) Graphics rendering hardware and software that can create the virtual content for overlaying the real world

b) Tracking techniques so that the changes in the viewer's position can be properly reflected in the rendered graphics

c) Interaction techniques specifying how the user can manipulate the AR virtual content

d) Display hardware for merging virtual images with views of the real world

e) Tracker calibration and registration tools for precisely aligning the real and virtual views when the user view is fixed

f) Computer processing hardware for running AR simulation code and for supporting input and output devices

Secondary Issues

- Usability evaluation
- Mobile/wearable systems
- AR authoring tools
- Visualization techniques
- Multimodal AR input
- Novel rendering methods
- Software architecture, etc.

Tracking

Devices & Techniques

Tracking (1/2)

- Tracking devices
  - Digital cameras and/or other optical sensors
  - GPS
  - Accelerometers
  - Solid state compasses
  - Wireless sensors
  - etc.
- Each of these technologies has different levels of accuracy
- Selecting the proper device(s) depends on the type of system being developed

Tracking (2/2)

- General tracking technology for **AR** [by Li et al (2008)]
  - Mechanical
  - Magnetic sensing
  - GPS
  - Ultrasonic
  - Inertia
  - Optics

Tracking techniques

- Sensor-Based Tracking Techniques
  - are based on sensors such as magnetic, acoustic, inertial, optical and/or mechanical
- Vision-Based Tracking Techniques
  - use image processing methods to calculate the camera pose relative to real world objects
  - are analogous to closed loop systems which correct errors dynamically
- Hybrid Tracking Techniques
  - are hybrid methods which combine several sensing technologies with vision-based techniques
    - For example, Azuma et al. (1998) proposed that developing AR systems that work outdoors required a tracking system based on GPS, inertial and computer vision sensing

Interaction techniques and user interfaces

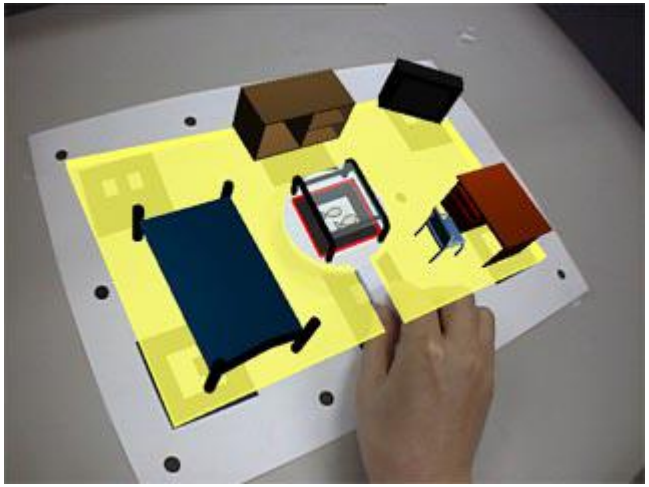
Input Devices for AR systems

- Reitmayr et. al.'s mobile augmented system utilizes gloves
- ReachMedia uses a wireless wristband
- Smart-phones can be used as a pointing device
  - Google Sky Map on Android phone requires the user to point his/her phone in the direction of the stars or planets s/he wishes to know the name of
- The input devices chosen depend greatly upon the type of application the system is being developed for and/or the display chosen

Tangible AR

- AR bridges the real and virtual world
  - objects in the real world can be used as AR interface elements
  - their physical manipulation can provide a very intuitive way to interact with the virtual content
- New interaction paradigm known as Tangible Augmented Reality (TAU)
  - TUI (Tangible UI) paradigm applied to AR interfaces
  - Physical objects have familiar properties, physical constraints, and affordances
  - The intuitiveness of the physical input devices can be combined with the enhanced display possibilities provided by virtual image overlays

Tangible AR: Examples (1/3)



- A person uses a real paddle to select and arrange virtual furniture in an AR living room design application
- Paddle motions are mapped to gesture based commands, such as tilting the paddle to place a virtual model in the scene and hitting a model to delete it

(Kato et al., 2000)

Tangible AR: Examples (2/3)

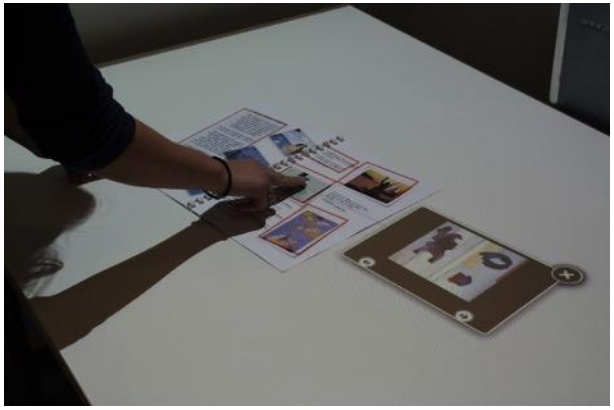
Multimodal Diverse Travel:

http://www.youtube.com/watch?v=ZxqUEYxc5FA

- The system comprises a table, whose surface is covered by a printed map on which the location of various cities and other notable sites is projected
- White paper tablets with a coloured frame are at the visitors' disposal
  - On each tablet a magnifying glass is displayed
  - When the magnifying glass is placed over a city, related images, videos and texts appear on the tablet
- For every city there are multiple information "pages", which can be viewed by touching virtual buttons at the bottom of the tablet

(Grammenos et al., 2011)

Tangible AR: Examples (3/3)



- *Study Table*: An interactive table to augment physical books that are placed upon its surface, with
  - music and digital animation
  - presentation of multimedia related to the content of the book
  - real-time search from popular search engines and videos repositories
  - note-taking through handwriting
- The provided digital content is displayed either within or laterally to the open books
- users interact with the system using infrared light markers or through touch

(Margetis et al., 2013)

Collaborative AR

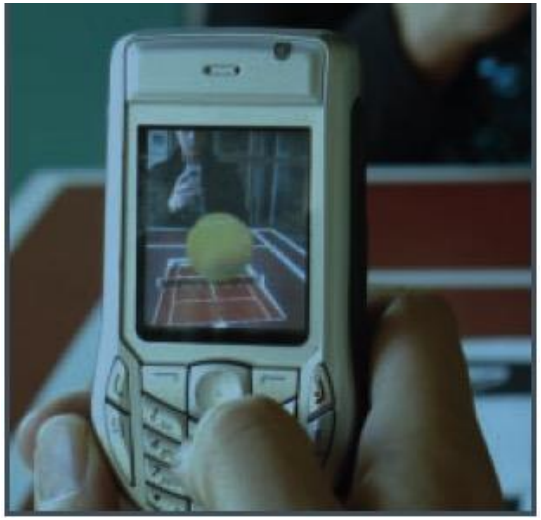
- AR can support remote and co-located activities
- Co-located collaboration
  - AR enhances a shared physical workspace and creates an interface for 3D CSCW (Computer supported collaborative work)
  - Researchers have begun exploring how mobile AR platforms can be used to enhance face-to-face collaboration
- Remote collaboration
  - AR seamlessly integrates multiple users with display devices in multiple contexts, enhancing telepresence

Collaborative AR: Examples (1/2)

- A mobile collaborative Augmented Reality system that
  - supports true stereoscopic 3D graphics
  - a pen and pad interface
  - direct interaction with virtual objects
- Multiple users can naturally collaborate in an augmented shared space
- Instantaneous collaboration can be established as users wearing the system meet
- For demonstration purposes, a chess game application was created and tested

(Reitmayr & Schmalstieg, 2001)

Collaborative AR: Examples (2/2)



- Players sit opposite each other with a set of markers between them
- A virtual tennis court model is superimposed over the real world
- The phone becomes a virtual racket
- Multi-sensory feedback is provided
  - hearing a sound and feeling a vibration when the virtual ball hits the real phone

(Henrysson et al., 2005)

Hybrid AR Interface

- A hybrid user interface combines a variety of different, but complementary interfaces
  - Touch, gestures, surface, tangible, sensing, etc.
- A flexible infrastructure for hybrid user interfaces should automatically accommodate a changing set of input and output devices and the interaction techniques which use them

Hybrid surface (Ericsson studio)

Hybrid AR: Example

User exploring the site in life-size–world mode of VITA

Handheld widget is used on the Diamond-Touch table, acting as a "magic" lense

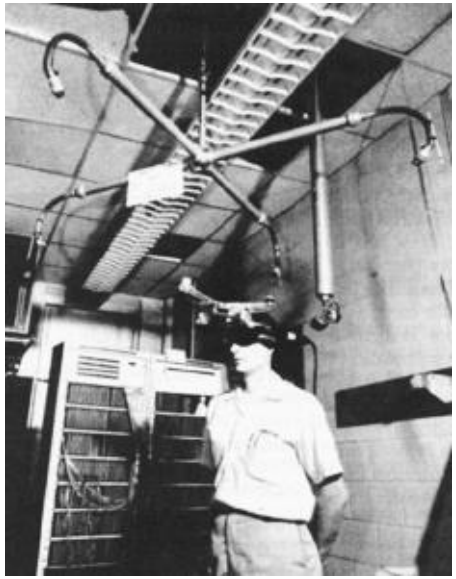
- VITA is a collaborative mixed reality system for archaeological excavation
- see-through HMDs were combined with a multi-user, multi-touch, projected table surface, a large screen display, and a tracked hand-held display
- Users use a tracked glove, speech commands and the multi-touch sensitive surface to interact multimodally with the system and collaborate by jointly navigating, searching, and viewing data

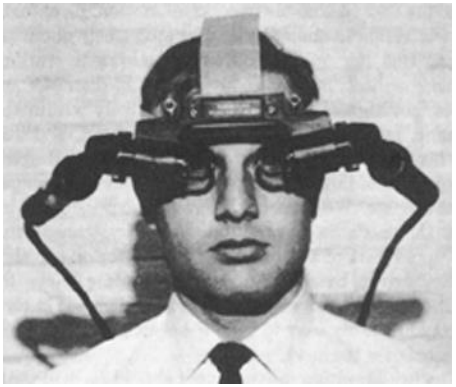
(Benko et al., 2004)

Display Hardware

See-through head-mounted displays (HMDs)

- See-through HMDs allow the user to see the real world with virtual objects superimposed on it by optical or video technologies
- The first HMD system by Ivan Sutherland, the Sword of Damocles (1968), is considered to be the first virtual reality and augmented reality system
- The pre-cursor to all HMDs

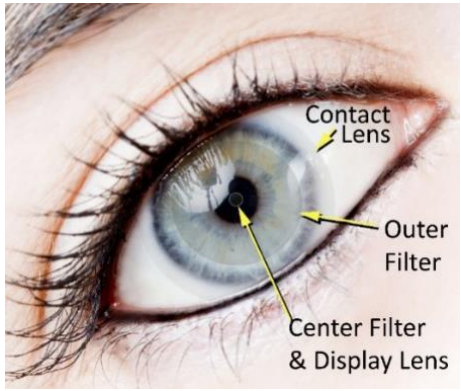




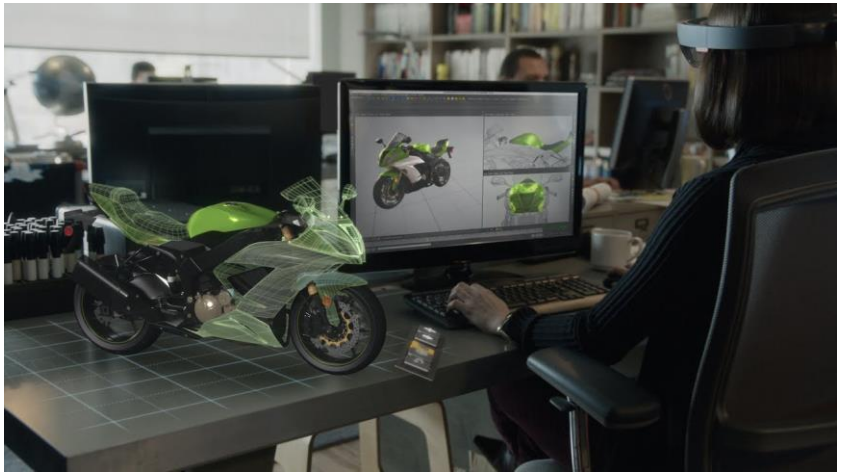
Types of HMDs

- Head-mounted displays are divided into two categories:

1. Optical see-through (OST)
   - They allow the user to see the real world with their natural eyes and which overlay graphics onto the users view by using a holographic optical element, half silvered mirror or similar technology
   - Examples: Google Glass, Innovega iOptik, Microsoft HoloLens
2. Video see-through (VST) HMDs
   - The user has a video view of the real world with graphics overlaid on it
   - Examples: Wikitude (and other handhelds), Oculus Rift, Gear



Microsoft HoloLens



- The Microsoft HoloLens is an optical see-through HMD that will be the premier device for Windows Holographic, an augmented reality platform by Microsoft that can run any standard Windows 10 app
- In addition to a high-end CPU and GPU, HoloLens features a holographic processing unit (HPU), a custom coprocessor by Microsoft which efficiently processes and integrates data from the various sensors, handling tasks such as spatial mapping, gesture recognition, and voice and speech recognition
  - accelerometer, gyroscope, magnetometer
  - photo/video camera, speakers, microphone arrays

Microsoft HoloLens demo BUILD 2015

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

Oculus Rift

Oculus Rift DK2
(On the right is the near infrared CMOS sensor)

- The **Rift** is an upcoming virtual reality head-mounted display developed by Oculus VR
  - Supports Full HD per eye
  - Internal tracking (Gyroscope, accelerometer, magnetometer)
  - Positional tracking
- Oculus SDK
  - The Oculus Rift is paired with the publicly available Oculus SDK which includes source code, documentation, and samples
- The consumer version of the product is expected to become available in early 2016

Projection-Based Displays / Spatial Augmented Reality

- Spatial Augmented Reality (SAR) makes use of:
  - video projectors
  - optical elements
  - holograms
  - radio frequency tags
- …to display graphical information directly onto physical objects without requiring the user to wear or carry the display
- Spatial displays separate most of the technology from the user and integrate it into the environment
  - naturally scales up to groups of users
  - allowing collaboration between users
  - increasing interest for such augmented reality systems in universities, labs, museums, and in the art community

ILLUMIROOM

ILLUMIROOM by Microsoft: https://www.youtube.com/watch?v=sJ4hWa6y710

Handheld Displays

- Handheld displays are a good alternative to HMD and HMPD systems for AR applications
- they are minimally intrusive, socially acceptable, readily available and highly mobile

Wikitude

Layar

Application Domains

Application Domains

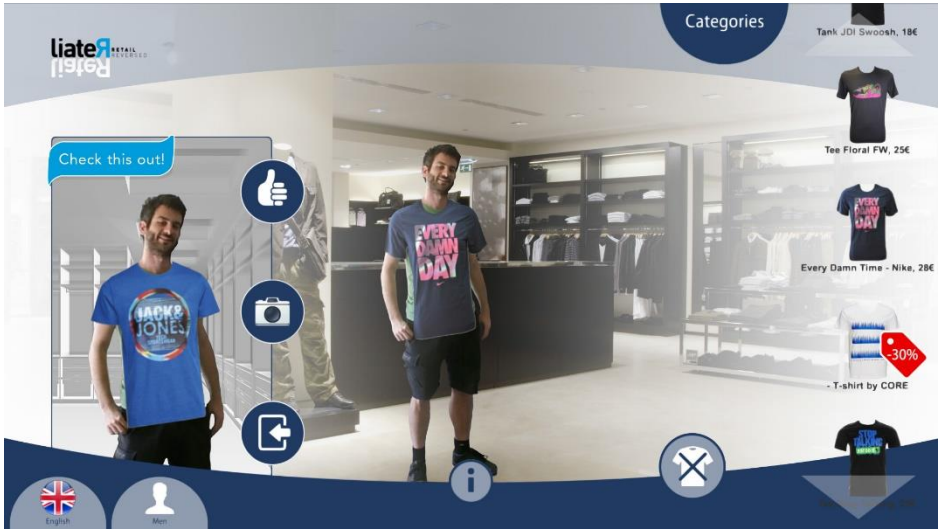
- Four basic types of applications that are most often used for AR research [by Carmigniani et al (2011)]:

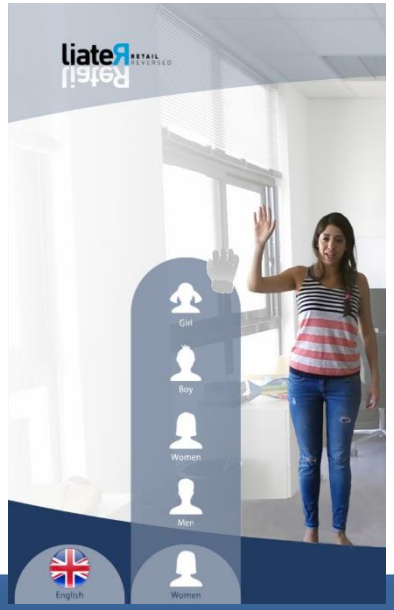
1. Advertising and commercial
2. Entertainment and education
3. Medical
4. Mobile applications

Advertising and commercial

Magic Mirror, where the user tries on virtual shoes

MINI advertisement in German automotive magazines, 2008. The reader simply had to go to the MINI's website, show the ad in front of their webcam, and a 3-D MINI appeared on their screen



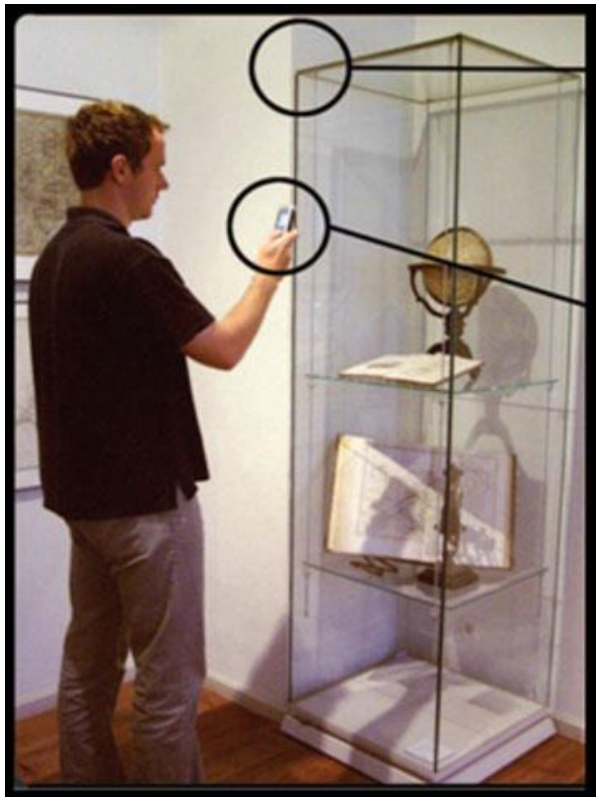


liateR (developed by FORTH-ICS)

- Adapts 3-D virtual clothing on users' bodies, following their movement
- Allows apparel combinations
- Supports gesture-based interaction in front of a large screen, which acts as a virtual mirror

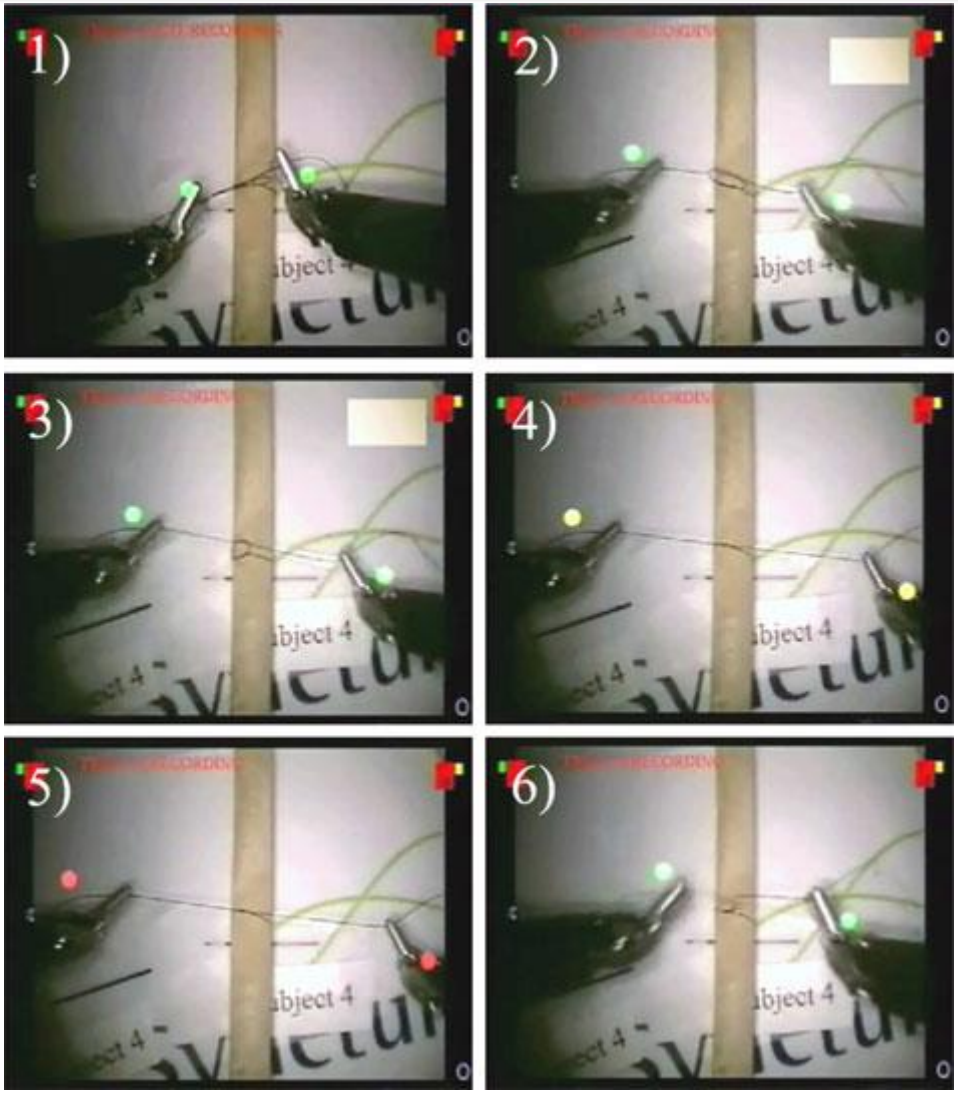
Entertainment and education

- Cultural apps with sightseeing and museum guidance
- gaming apps with traditional games using AR interfaces
- smart-phone apps that make use of AR for an entertainment and/or educational purpose



Mobile phone-enabled guidance in a museum (Bruns et al, 2007)

Medical applications



Bichlmeier et. al. (2007) system for viewing through the skin

Sequential shots of knot tying task from Akinbiyi et al (2006): Dynamic augmented reality for sensory substitution in robot-assisted surgical systems

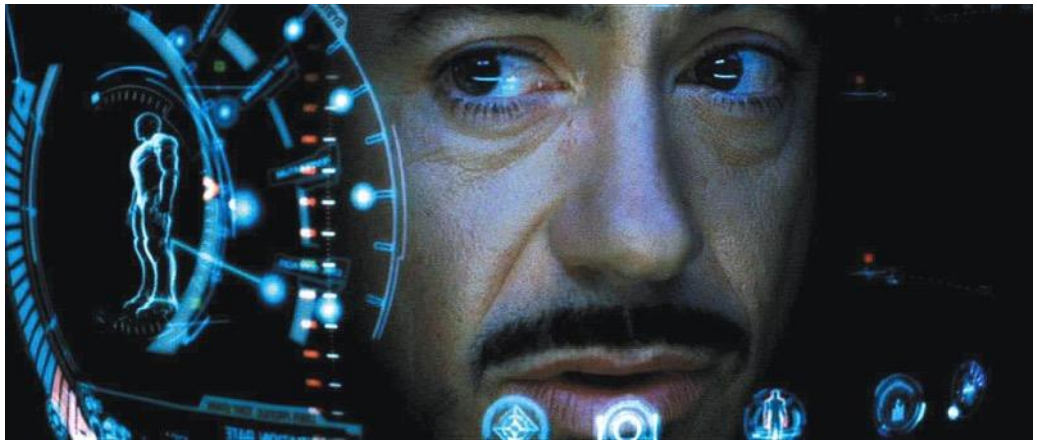
Mobile applications

- Extremely prolific through smartphone apps
- Navigational, Informative, Gaming and commercial / advertising apps are the most common but the area is rapidly expanding

Design Guidelines

Augment the periphery of vision

- AR potentially obscures too much of the user's view
- To avoid getting in the user's way, designers should use visual design that maximizes transparency while maintaining readability
  - Objects should be placed at the edge of the user's view when they are not needed, and adjacent to the locus of attention when they are
  - Because human brains are hardwired to detect motion, data pushed to the periphery risks triggering false positives in the user's peripheral vision. Therefore, movement at the edges of the display should be kept to an absolute minimum



Iron Man (2008)

Place augmentations at the current depth of focus

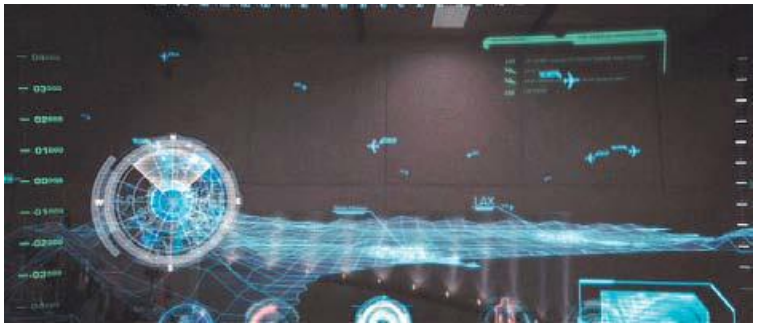
- Challenge regarding AR and HMDs: focal depth difference between
  - augmenting information ←→ real world view being augmented
- Eye strain when changing focus constantly and quickly between the two
- AR systems should have stereoscopic capabilities so that
  - Augmentations seem to be at the same distance as the thing being augmented
  - Users access the information with a simple glance without having to fully refocus

Consider alternative channels for information

- When working with one sensory channel, consider alternative channels for the augmentation
- These other channels might be better suited to the information and have the additional benefit of not obscuring the primary one

Information is empowering, but do not distract the user

- It is possible to augment reality with all sorts of rich, layered information, but the user only has one locus of attention, and their focus is on the task at hand
- To avoid distracting them, limit content to what is either vital or explicitly asked for, relegating cues about access to further information to a distant second level of attention



Tony Stark is in the act of flying his experimental, supersonic, and weaponized suit for the first time. Tempting him to read an encyclopedic entry about the Ferris wheel seems like an irresponsible Distraction (Iron Man, 2008)

Augmented reality is personal

- Augmentations can be coordinated between AR displays such that each viewer sees the same thing as if it were "in reality"
  - this should be kept to high-level or public information, such as street signs or general warnings

Firefly, "Serenity" (Episode 1, 2002)

- Examples
  - The communications officer might be able to see graphics describing whether the communications channels are jammed
  - The weapons officer could see whether the ship's shields were up
  - The science officer might get a readout of any radiation or chemical emissions from the ship

Provide opportunities for the user to intervene

- The results of computer processes have consequences
- The direr those consequences, the more human oversight is needed to safeguard against false negatives and false positives
- Provide a first checkpoint by slowing processes down to the speed at which a human can decide whether intervention and correction are necessary

(Iron Man, 2008)

Iron Man HMD:
Why show the red targets instead of automatically killing the foes (faster)?

Limitations of AR

Tracking techniques

- Real time 3D tracking difficulties:
  - Complexity of the scene
  - Motion of target objects, including the degrees of freedom of individual objects and their representation
    - moving objects may separate and merge due to (partial) occlusion or image noise, and object appearance may also change due to different illuminations
  - Solutions:
    - **mark-based tracking** (uses markers such as LEDS - not suitable for large scale navigation),
    - **model-based methods** (capitalize on the natural features of the environment – often cumbersome and could lead to failure where no distinguishable features are detected)
    - **hybrid tracking systems**
  - how to accurately find distinguishable objects for "markers" outdoors, since they are not always available

Interaction techniques and UIs (1/2)

- AR enables users to manipulate digital objects by tangible physical tools, even directly by hand
- Current limitations :

1. difficult to tell the state of the digital data associated with physical tools
2. the visual cues conveyed by tangible interfaces are also sparse
3. three dimensional imagery in a tangible setting can be problematic as it is dependent on a physical display surface

Interaction techniques and UIs (2/2)

- Human Factors considerations:
  - Physically cumbersome system design, leading to discomfort for the user
    - For example, in a particular wearable system, a whole set of heavy equipment is needed to be carried for a long time
  - Discomfort of wearing interaction devices for an extended period of time
  - Tethered cables often becoming tangled for the VITA collaborative mixed reality system
  - In this sense, AR interfaces based on handheld devices are suitable

AR Displays

- HMDs
  - users have to wear them continuously; might be cumbersome and uncomfortable after a long time
  - HMDs usually have a limited FOV; cannot effectively support collaborative work without non-verbal cues like eye contact
- Projector-based displays
  - they usually lack mobility, because the setups for most projection based displays are fixed
- Handheld
  - The main limitation may be the tracking
  - Currently, most handheld displays based AR systems employ ARToolKit or similar tracking with markers, which limit the work range

Future trends and directions

Research paradigms

- Ubiquitous computing deals with computing in the environment and with activities in the context of the environment
- Tangible User Interfaces augment the real physical world by coupling digital information to everyday physical objects and environments
- Sociological reasoning to problems of interaction: Social, psychological, cultural, organizational, and interactional context can be found in AR systems integrating social computing by making socially produced information available to their users

Ubiquitous computing & Tangible bits (1/2)

- They change the world into an interface
  - Take advantage of natural physical affordances to achieve a heightened legibility and seamlessness of interaction between users and information
  - Whether these physical affordances, constraints, and properties are made perceivable, visible, or actionable, is of great importance

Ubiquitous computing & Tangible bits (2/2)

- In AR, most work makes use of visual cues to enhance usability and user experience
  - haptic, or audio are less obvious
  - some affordances are of no use
    - if a screen is not touch-sensitive, though it still affords touching, it has no result on the computer system
- Ubiquitous computing enables information processing capability to be present in everyday objects
  - it extends AR interfaces to daily objects
  - Currently, various challenges in ubiquitous tracking make this interaction paradigm premature for wider deployment

Sociological reasoning to problems of interaction (1/2)

- Aims to understand the social, cultural and psychological phenomena behind AR
- Historically, human knowledge, experience and emotion are expressed and communicated in words and pictures
- Given the advances in interface and data capturing technology, knowledge, experience and emotion might now be presented in the form of AR content

Sociological reasoning to problems of interaction (2/2)

- Almost no work published is toward affective (emotional) user interface
- Fundamental issues of human-computer interaction (HCI) in the context of interactive digital media (IDM):
  - **Capturing**, **representing** and **processing** human affective (emotional) and cognitive (behavioral) knowledge about the real and virtual space
- How to leverage psychological and social impacts of the virtual and real environments across demographic user profiles?
  - It is expected to shed light on the understanding of the AR development as IDM products

Future Potential

- Currently, to bring AR research from laboratories to industry and widespread use is still challenging
- Both academia and industry believe that there is huge potential for AR technology in a wide range of application areas

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The End

Questions?