



## PA198 Augmented Reality Interfaces

### Lecture 1

Introduction to Virtual and Augmented Reality

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21<sup>st</sup> September 2015

## Fotis Liarokapis

- PhD in Computer Engineering
  - University of Sussex, UK
- MSc in Computer Graphics and Virtual Environments
  - University of Hull, UK
- BSc in Computer Systems Engineering
  - University of Sussex, UK



## My Research

- Research areas:
  - Computer Graphics
  - Virtual Reality
  - Augmented Reality
  - Procedural Modeling
  - Interactive Environments
  - Serious Games
  - User studies



## Contact Details

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- Office Location:
  - C411
- Office Hour:
  - Monday 13:00 to 14:00



## Course Details

- Prerequisites
  - Knowledge of computer graphics fundamentals
- Lectures
  - Every Monday
  - Time: 14:00 to 16:00
  - Location: B411
- Lab/Seminar
  - Every Monday
  - Time: 16:00 to 17:00
  - Location: B311



## Course Objectives

- Demonstrate an understanding of the main mathematical concepts, hardware and software technologies used in augmented reality
- Evaluate different approaches, methodologies and tools focused on augmented reality
- Propose augmented reality environments for both indoor and outdoor environments
- Design multimodal augmented reality interfaces for various application domains



## Syllabus

- Introduction to Virtual and Augmented Reality
- Wearable computing and user interfaces
- Augmented Reality Software (i.e. ARToolKit, etc)
- Camera Models for Augmented Reality
- Visualisation Displays (optical, video-see through, etc)
- 3D and multimodal interaction
- Tracking technology and Haptics
- Mobile Augmented Reality
- Perception Issues in Augmented Reality
- Rendering for Augmented Reality
- Collaborative Augmented Reality
- Spatial Augmented Reality and Holograms
- Application Domains (i.e. archaeology, navigation, education etc).
- Future of Augmented Reality



## Teaching Methods

- Delivery of the material will be based on
  - Expository lectures
  - Reinforced by computer demonstrations of the application of the material
  - Video demonstrations



## Assessment Methods

- One Assignment
  - An essay
  - Practical assignment
- Written exam
  - Time allowed
    - 90 minutes



## Plagiarism and Cheating

- If you use an external resource cite it clearly!
- Don't do things that would be considered dishonest... if in doubt ask
- Cheating earns you:
  - Fail in the class
  - Getting reported to the University
  - No exceptions



## Literature

- Billinghurst, M., Clark, A. Lee, G. A Survey of Augmented Reality, Foundations and Trends in Human-Computer Interaction, Vol. 8, No. 2-3 2014. DOI: 10.1561/1100000049
- Schmalstieg, D., Hollerer, T. Augmented Reality: Theory and Practice (Game Design/Usability), 2015. ISBN-10: 0321883578, ISBN-13: 978-0321883575
- Craig, A.B. Understanding Augmented Reality: Concepts and Applications, Elsevier, 2013. ISBN-10: 0240824083, ISBN-13: 978-0240824086
- Kipper, G., Rampolla, J. Augmented Reality: An Emerging Technologies Guide to AR, Elsevier, 2012. ISBN-10: 1597497339, ISBN-13: 978-1597497336



## Assignment

- Make use of an AR API to create an educational game
  - i.e. ARToolKit
- Implementation in C/C++
- Emphasis will be given on the interaction and visualisation techniques
  - Not on tracking!
- Deadline end of the term



## Details



- The game should be focused on indoor environments
  - Not mobile!
- The topic is focused on designing a game/tool to assist students to learn computer graphics
- Visualisation
  - All types of multimedia information can be superimposed
- Tracking
  - Single or multiple markers



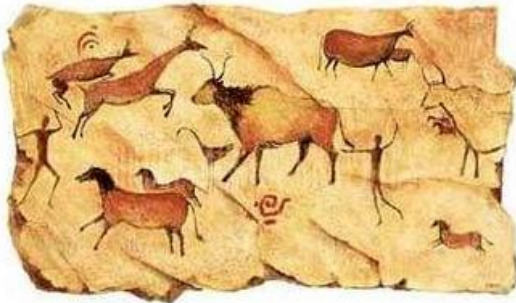
## Report Structure



- Title page
- Contents
- Abstract (or summary)
- Introduction
- Background theory
- Methodology and results
- Conclusions
- References
- Appendices



## First VR Interpretation



## VR History



- In mid 1950s Morton H Eilig built a single user console called Sensorama that included a stereoscopic display, fans, or emitters, stereo speakers and a moving chair
  - This enabled the user watch television in 3D



## VR History .



- In 1961, Philco Corporation engineers developed the first Head-Mounted Display (HMD)
  - Known as the Headsight
- The helmet consisted of a video screen along with a tracking system
  - Also linked to a closed circuit camera system
    - Similar HMD was used later for helicopter pilots



## VR History ..



- In 1965, Ivan Sutherland proposed the 'Ultimate Display'
  - After using this display a person imagines the virtual world very similar to the real world
- During 1966, he built an HMD
  - Was tethered to a computer system



Ultimate Display



HMD



## VR History ...



- In 1967, Brooks developed force feedback GROPE system



## VR History ....



- 1977
  - Sandin and Sayre invent a bend-sensing glove
- 1979
  - Raab et al: Polhemus tracking system
- 1989
  - Jaron Lanier (VPL) coins the term virtual reality
- 1994
  - VR Society formed



## VR History .....



- The first complete VR system was developed by NASA
  - “Virtual Visual Environmental Display”
- Became “Virtual Interface Environment Workstation” (VIEW) 1989



## Current State of VR



- Nowadays VR is moving from the research laboratories to the working environment by replacing ergonomically limited HMD's with
  - Projective displays
    - CAVE and Responsive Workbench
  - Mobile devices
    - PDAs, smartphones, tablets, etc
  - Interaction devices
    - Wii, Kinect, many others



## VR Nowadays



- \$3-5 Billion VR business
  - Around \$150 Billion Graphics Industry
  - Visualization, simulation, gaming, CAD/CAE, multimedia, graphics arts
- Closely aligned with computer games/video games and other apps



## VR Nowadays .



- A number of different expensive devices exist
- Target to get full immersion





## Virtual Reality Definition



- “The computer-generated simulation of a 3D image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors”
- Some popular related terms include:
  - Virtual Environments (VE), Artificial Reality, Telepresence and Cyberspace

<http://www.oxforddictionaries.com/definition/english/virtual-reality>



## Telepresence



- The use of various technologies to produce the effect of placing the user in another location



## Artificial Reality



- Responsive Environment
  - An environment where human behavior is perceived by a computer which interprets what it observes and responds through intelligent visual and auditory displays



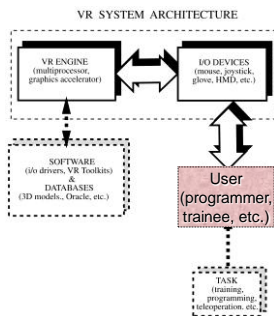
## Burdea’s 3 I’s of VR



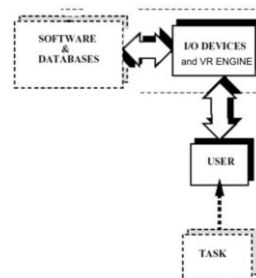
- Interactivity
  - User impacts world
- Immersion
  - Believing you are there
- Imagination
  - User ‘buying’ into the experience



## VR Typical Architecture



## Modern VR Systems





## VR Immersion



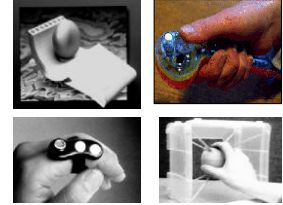
- In a typical VR system the user's natural sensory information is completely replaced with digital information
- The user's experience of a computer-simulated environment is called immersion
- As a result, VR systems can completely immerse a user inside a synthetic environment by blocking all the signals of the real world



## VR Interfaces



- Keyboard, Mouse, Joystick
  - 3D Pointing Devices
  - Spaceball
  - CyberWand
  - Ring Mouse
  - EGG



## VR Interfaces .



- Whole-hand and body input
  - 5<sup>th</sup> glove
  - Handmaster
  - ArmMaster
  - TCAS Dataware



## Auditory Interfaces



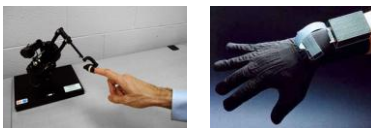
- Auralization
  - 3D simulation of a complex acoustic field
- Sonification
  - Audible display of data
- Speech Recognition



## Haptics



- Haptic, from the Greek ἀφή (Haphe), means pertaining to the sense of touch
- Haptic technology refers to technology which interfaces the user via the sense of touch by applying forces, vibrations and/or motions to the user



## Haptics .

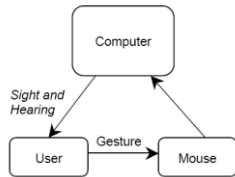


- This mechanical stimulation may be used to assist in the creation of virtual objects for control of such virtual objects, and to enhance the remote control of machines and devices (teleoperators)
- Some low-end haptic devices are already common in the form game controllers
  - i.e. Joysticks and steering wheels



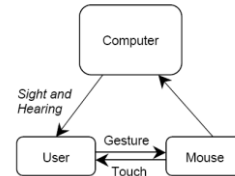
## Why a Haptic Interface?

- Up until now, most human – computer interaction is one way



## Why a Haptic Interface? .

- Haptic devices are input-output devices  
– Bi-directional



## Why a Haptic Interface? ..

- The sense of touch can carry huge amount of information
- To be able to actively interact with an environment, there must be feedback
- It increases sense of presence in a VE application
- It increases human performance
- It can be fun!



## Haptic Interfaces Basic Components

- Motor and transmission to send physical stimulation
- Electronics to control sensors and motor
- Software equations and algorithms for creating real world physics



## Body-based HI

- Force-feedback glove
- 5 degree of freedom
- 16N to each fingertips
- Pneumatic pistons



## 5 DOF

- Each actuator is attached to the base through a spherical joint  
– 2 DOF
- Its cylinder shaft can both translate and rotate  
– 2 DOF
- The fingertip attachment connects to the cylinder shaft through a cylindrical joint  
– 1 DOF





## Exoskeleton Devices



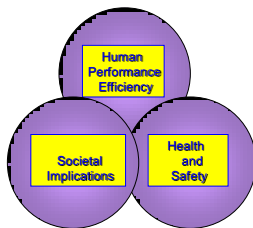
## Ground-based HI



- 2 DOF Haptic Devices
- Provide the feeling of real touch
- High fidelity (400Hz)
- Rehabilitation of visually handicapped persons, micro-gravity experiments



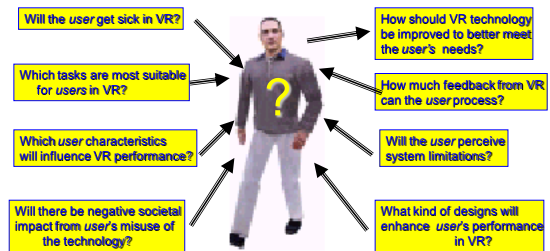
## Human Factors in VR



Stanney et al., 1998



## Human Factors in VR .



Stanney et al., 1998



## Dangers of VR/Video Games



- Excessive game play can be fatal
  - Can be worst with immersive VR!
- In Korea, where 30% of the population subscribes to online multiplayer games, one man died in 2005 after playing 50 hours (almost non-stop) StarCraft
- 3 Chinese died in 2007 after playing more than 50 hours, and 2 died in 2005



## Dangers of VR/Video Games .



- EverQuest is a 3D online game played by more than 400,000 people
- Games can lead to isolation and suicide
- Hudson Wooley, an epileptic who was playing 12-hours per day, eventually committed suicide







## Advantages of VR/Games



- People regularly exposed to video-games have improved:
  - Visual and Spatial attention (C. S. Green, D. Bavelier, Nature, 2003)
  - Memory (J. Feng et al., Psychol. Sci., 2007)
  - Mental rotation abilities
  - Enhanced sensorimotor learning (D. G. Gozli, et al., Hum. Mov. Sci., 2014)
- Extensive video-game practice has also been shown to improve the efficiency of
  - Movement control brain networks
  - Visuomotor skills (J. A. Granek, et al., Nerv. Syst. Behav., 2010)



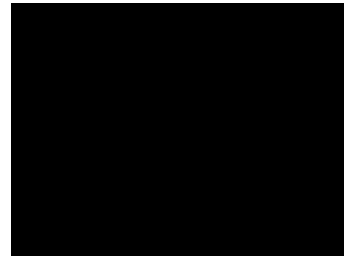
## Cyber Tennis Video



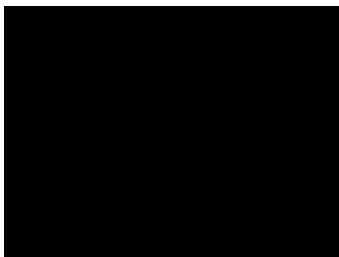
## Virtual Project Video



## Social Phobia Video



## Virtual Guide Video



## Introduction to Augmented Reality



- Augmented Reality
  - Abbreviation (AR)
- Czech Translation...
  - Rozšířená realita





## Some Definitions



- “A technology that superimposes a computer-generated image on a user’s view of the real world, thus providing a composite view.”
- “An enhanced image or environment as viewed on a screen or other display, produced by overlaying computer-generated images, sounds, or other data on a real-world environment.”

<http://www.oxforddictionaries.com/definition/english/augmented-reality>

<http://dictionary.reference.com/browse/augmented+reality>



## Another Definition

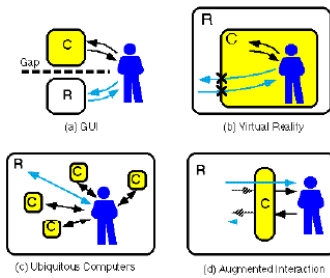


- “... Augmented Reality is a type of **virtual reality** that aims to duplicate the world’s environment in a computer. An **augmented reality** system generates a composite view for the user that is the combination of the real scene viewed by the user and a virtual scene generated by the computer that augments the scene with additional information. The virtual scene generated by the computer is designed to enhance the user’s sensory perception of the virtual world they are seeing or interacting with. The goal of Augmented Reality is to create a system in which the user cannot tell the difference between the real world and the virtual augmentation of it. Today Augmented Reality is used in entertainment, military training, engineering design, robotics, manufacturing and other industries.”

[http://www.webopedia.com/TERM/A/Augmented\\_Reality.html](http://www.webopedia.com/TERM/A/Augmented_Reality.html)



## Invisible Interfaces



## Augmented Reality Concept



- The concept of AR is the opposite of the closed world of virtual spaces since users can perceive both virtual and real information
- Most AR systems use more complex software approaches compared to VR systems
- So, it is harder!



## Augmented Reality Concept .



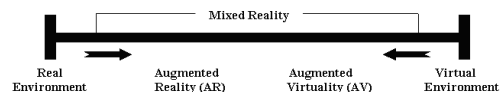
- The basic theoretical principle is to superimpose digital information directly into a user’s sensory perception rather than replacing it with a completely synthetic environment as VR systems do
- In some cases we want it to be very realistic, in some other cases not!



## Milgram’s Reality-Virtuality Continuum



- Milgram 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



Paul Milgram and Fumio Kishino, 1994



## VR and AR Similarities



- Both technologies process and display the same digital information and often make use of the same dedicated hardware
- For example, both an VR and an AR system may be equipped with a head-mounted display (HMD) to visualize the same 3D computer generated model



## VR and AR Differences



- An AR system uses the real world instead of trying to replace it
- On the other hand, in a VR system the whole environment is synthetic
- The user is completely immersed within a virtual world trying to mimic reality
- A VR simulated world does not always have to obey all laws of nature



## VR and AR Differences .



- The most common problems of VR systems are of emotional and psychological nature including motion sickness, nautia, and other symptoms, which are created by the high degree of immersiveness of the users
- Although AR systems are influenced by the same factors the amount of influence is much less than in VR since only a portion of the environment is virtual



## VR and AR Technology Requirements

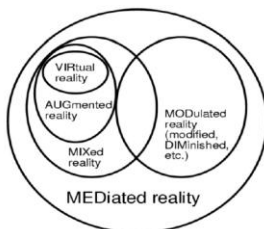


	Virtual Reality Replacing Reality	Augmented Reality Augmenting Reality
Scene Generation	requires realistic images	minimal rendering okay
Display Device	fully immersive, wide FOV	non-immersive, small FOV
Tracking and Sensing	low accuracy is okay	high accuracy needed

Billingshurst, M., Clark, A. Lee, G. A Survey of Augmented Reality, Foundations and Trends in Human-Computer Interaction, Vol. 8, No. 2-3 2014



## Mann's Mediated Reality



Billingshurst, M., Clark, A. Lee, G. A Survey of Augmented Reality, Foundations and Trends in Human-Computer Interaction, Vol. 8, No. 2-3 2014



## Metaverse



- Neal Stephenson's "SnowCrash"
- The Metaverse is the convergence of:
  - virtually enhanced physical reality
  - physically persistent virtual space
- Metaverse Roadmap
  - <http://metaverseroadmap.org/>



## Metaverse Dimensions



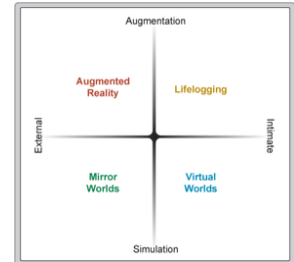
- **Augmentation** technologies that layer information onto our perception of the physical environment.
- **Simulation** refers to technologies that model reality
- **Intimate** technologies are focused inwardly, on the identity and actions of the individual or object
- **External** technologies are focused outwardly, towards the world at large



## Metaverse Components



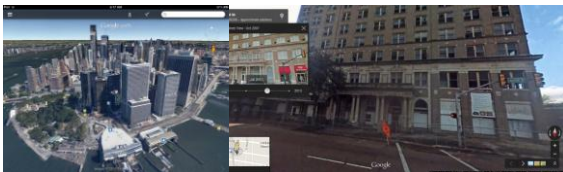
- Four Key Components
  - Virtual Worlds
  - Augmented Reality
  - Mirror Worlds
  - Lifelogging



## Mirror Worlds



- Mirror worlds are informationally-enhanced virtual models of the physical world
  - Google Earth, MS Street View, Google Maps



## LifeLogging



- Technologies record and report the intimate states and life histories of objects and users
  - Nokia LifeBlog, Nike+, FitBits



## AR History



### AR History Overview



- 1960's - 80's: Early Experimentation
- 1980's - 90's: Basic Research
  - Tracking, displays
- 1995 - 2005: Tools/Applications
  - Interaction, usability, theory
- 2005 - Now: Commercial Applications
  - Games, Medical, Archaeology, Navigation, Industry



### AR History 60's to 70's



- 1960 - 70's: US Air Force helmet mounted displays (T. Furness)
- 1970 - 80's: US Air Force Super Cockpit (T. Furness)



AR 60's



AR 70's



### AR History 90's



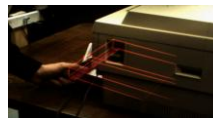
- Early 1990's: Boeing coined the term AR
  - Wire harness assembly application begun (T. Caudell, D. Mizell)



### AR History 90's .



- KARMA (91)
  - Feiner
- Optical see-through HMD
- Knowledge-based assistant for maintenance
- Ultrasound trackers attached to assembly parts



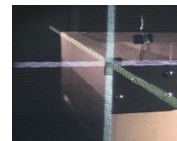
### AR History 90's ..



- 1994: Motion stabilized display [Azuma]
- 1995: Fiducial tracking in video see-through [Bajura / Neumann]
- 1996: UNC hybrid magnetic-vision tracker



State, et al. 1996



### AR History 90's ...



- 1996: MIT Wearable Computing efforts
- 1996: Transvision



- 1996: Studierstube



### AR History 90's ....



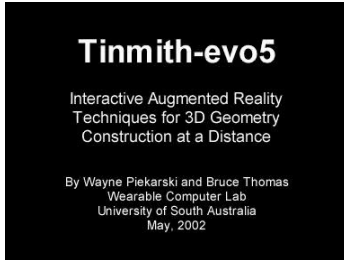
- 1997: Feiner's Touring Machine



- 1998: Dedicated conferences begin
- Late 90's: Collaboration, outdoor, interaction
- Late 90's: Augmented sports broadcasts
- 1998 - 2001: Mixed Reality Systems Lab



## Tinmith Construct Video



## Werable AR



- Thomas and Piekarski's wearable AR systems in 1998, 2002, and 2006



## AR History 20's



- 2003: PDA based AR
- 2004: Mobile phone AR



## Cell Phone AR Video



fakultät medien augmented reality Bauhaus-universität

Video See-Through AR on Consumer Cell-Phones

Mathias Moehring, Christian Lessig, Oliver Bimber

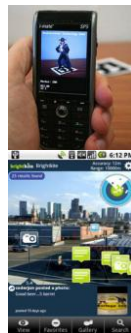
copyright 2004, Bauhaus University



## AR History 20's .



- 2007: AR Reaches Mainstream
- 2008: Location aware Phones – Browser-based AR
- 2009: Outdoor Information Overlay
- Nowadays: Many commercial AR tools



## Some AR Software

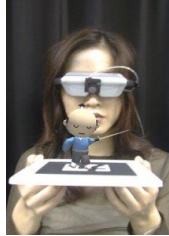




## ARToolKit



- ARToolKit is the first software library for building AR applications
  - Easy to work with
- Uses fiducials for tracking



## Magic Lens Video



## ARToolKitPlus



- Mobile version of ARToolKit
- Succeeded by Studierstube Tracker



## Layar



- Mobile browser called Layar
- Allows users to find various items based upon augmented reality technology



## Some Software SDKs



- ARToolKit
  - <http://artoolkit.sourceforge.net/>
- Metaio
  - <http://www.metaio.com/>
- Vuforia
  - <https://www.vuforia.com/>
- Wikitude
  - <http://www.wikitude.com/>
- Layar
  - <https://www.layar.com/products/creator/?gclid=CLbHu5mJ2cACFVGWtAodOzQACA>



## AR Issues



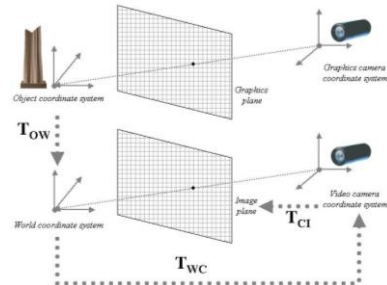
## Important Issues in AR



- Registration
  - Hardware, software, hybrid
- Rendering
  - Photorealistic, parallel
- Interaction
  - Natural, sensors
- Interfaces
  - Tangible, software, hardware, hybrid



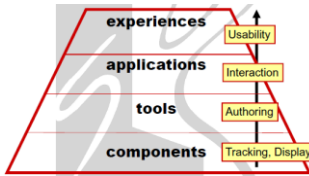
## AR Coordinate Relationships



## AR Experience Design



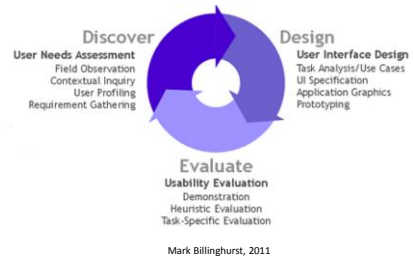
- Building compelling AR experiences



Mark Billinghurst, 2011



## Interaction Design Process



Mark Billinghurst, 2011



## Important Issues for Designing AR



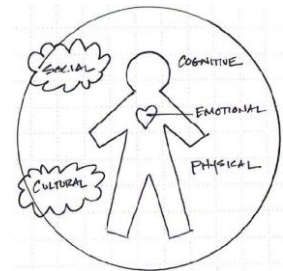
- Designing for everyone
  - Very hard!
- Understanding specific needs
- Users should be involved throughout the design process
- Consider all the needs of the user



## Interaction Design is All About You



- Users should be involved throughout the Design Process
- Consider all the needs of the user







## Gartner's top 10 disruptive technologies 2008-2012

- Multicore and hybrid processors
- Virtualisation and fabric computing
- Social networks and social software
- Cloud computing and cloud/Web platforms
- Web mashups
- User Interface
- Ubiquitous computing
- Contextual computing
- **Augmented reality**
- Semantics



## Google Searches for AR



## AR Economic Expectations

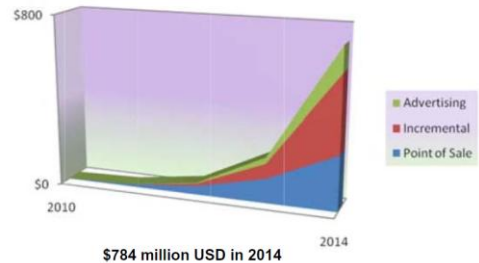
**Wearable Devices Market**  
\$1.4 B 2013 → \$19 B 2018  
(Juniper Research)

**Augmented Reality Apps Market**  
\$692 M 2013 → \$5.2 B 2016  
(Markets and Markets)

**Google Glass**  
87,000 u 2013 → 21 M 2018  
(BI Intelligence)



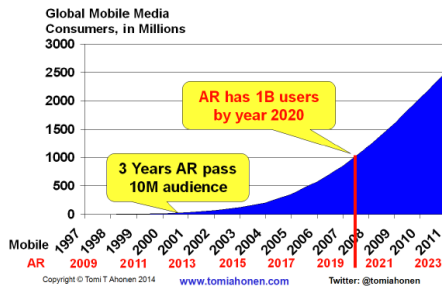
## Mobile AR Market 2010-2014



<http://www.neosentec.com/news/economic-expectation-of-wearable-devices-augmented-reality-and-google-glass/>



## Mobile Media and AR Media



## Gartner's 2014 Hype Cycle for Emerging Technologies





## Some Applications



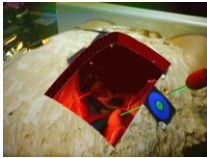
### AR Application Domains

- Health
- Military
- Archaeology
- Manufacturing
- Information overlay
- Navigation
- Gaming
- Many more

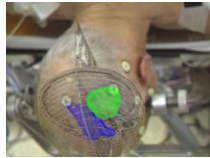


### AR in Health

- Use AR for training and diagnosis
  - ‘X-ray vision’ for surgeons
  - Aid visualization, minimally-invasive operations
  - MRI, CT data



Ultrasound project, UNC Chapel Hill

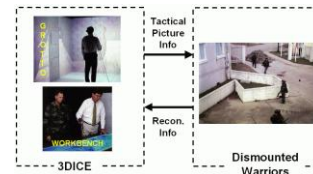


Sauer, et al, 2002



### AR in Military

- The area that AR was firstly applied
  - Military training on aircrafts and helicopters as well as battlefields simulations
  - Secret research!



Julier, S., Baillet, et al, 2000

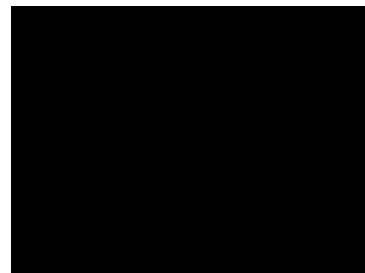


### AR in Archaeology

- Archeoguide (2000-2002)
  - Cultural heritage on-site guide
  - Hybrid tracking
  - Virtual overlay
- ARCO (2001-2004)
  - Museum environment
  - Annotations
  - Educational games



### Cultural Heritage Example

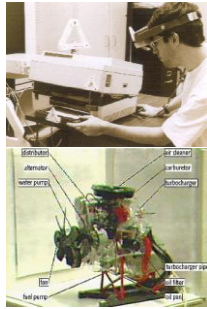
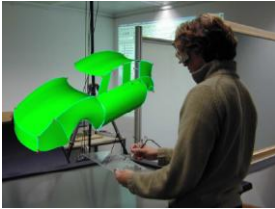




## AR in Manufacturing



- Various applications



## AR in Information Overlay



- Indoor and outdoor environments
- Public and private annotations



## AR in Navigation



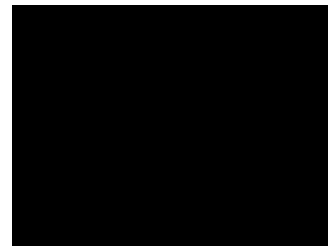
- Initial approaches were very heavy and difficult to use
  - Users had to carry a computer
- Mobile computing solved the problems
  - Other issues still exist!



LOCUS project, 2004-2007



## LOCUS Video



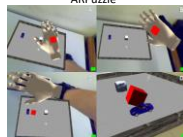
## AR in Games



- AR gaming offers new opportunities to interactive gaming
- Virtual objects can be re-arranged in a tangible manner
- Exciting user interaction



AR Puzzle



AR Car Racing



## Checkers Video





## Summary

- To build AR applications you need to focus on the technology as well as the user experience
- Great user experience is based on
  - Low level AR component technology
  - Authoring tools
  - Application/Interaction design
  - User experience texting



## Questions



## Acknowledgements

- Special Thanks to Prof. Mark Billinghurst