An Introduction to Virtual (and other) Realities
• What is?

• Timeline

• Issues

• Applications

• Challenges
Ivan Sutherland’s 1965 Vision

“Don’t think of that thing as a screen, think of it as a window, a window through which one looks into a virtual world.

The challenge to computer graphics is to make that virtual world look real, sound real, move and respond to interaction in real time, and even feel real.”
Ivan Sutherland’s 1965 Vision

“Display as a window into a virtual world

Improve image generation until the picture looks real

Computer maintains world model in real time

User directly manipulates virtual objects

Manipulated objects move realistically

Immersion in virtual world via head-mounted display

Virtual world also sounds real, feels real”

https://www.youtube.com/watch?v=NtwZXGprxag
What is VR?

“For better or worse, the label virtual reality stuck to this particular branch of computer graphics.
I define a virtual reality experience as any in which the user is effectively immersed in a responsive virtual world. This implies user dynamic control of viewpoint.” (Fred Brooks, 1999)

“A high-end user-computer interface that involves real-time simulation and interaction through multiple sensorial channels (vision, sound, touch, smell, taste)”. (Burdea et al., 2004)

VR almost worked in 1994

VR barely worked in 1999

and now?
VR Timeline

Adapted from [http://www.timetoast.com/timelines/32116](http://www.timetoast.com/timelines/32116)
Sensorama
(Morton Heilig, 1962)

• 3D, wide vision, motion, color, stereo sound, aromas, wind, vibrations

http://en.wikipedia.org/wiki/Sensorama
NASA was pioneer:

“Virtual Visual Environmental Display” (VIVED early 80s)

“Virtual Interface Environment Workstation” (VIEW) 1989
Early VR Demo by Sense8

http://www.youtube.com/watch?v=yQgn6u60290
Applications

- Education and training (e.g. military, medical, hazardous industries...)
- Ergonomics evaluation, project review (automotive industry, architecture...)
- Medicine (physical and psychic therapy, surgery planning, pain relief ...)
- Culture, entertainment (museums, games, ...)
- Data visualization (e.g. science, oil industry)
- Sales and marketing
- ...
Applications in Medicine

• Application areas that went beyond the prototype phase:
  – Radiation Treatment, Planning and Control
  – Interactive 3D Diagnostic Imaging
  – Rehabilitation and Sports Medicine
  – Psychiatric and Behavioral Healthcare
  – Neurological Evaluation
  – Pre-Surgical Planning
  – Pain Mitigation
  – Medical Education
  – Surgical Training
  – ...

![Image of medical equipment and monitor]
Surgical training

- Surgeons may practice the temporal bone preparation to access the middle ear
- High visual realism and haptic feedback

http://www.voxel-man.de/simulator/tempo/video.html
A stroke patient interacts with a virtual reality environment using an electronic glove to "pour tea" during a therapy session

Automotive industry

- VR makes possible to:
  - multiply the number of innovative hypotheses studied
  - limit the number of physical mock-ups
  - cut development time and cost

http://www.youtube.com/watch?v=umD01emkXLC&feature=related

New models can be analysed even before any physical prototype exists
Automotive industry (BMW)

- The “walk-in” cockpit: Test persons assess various new design alternatives
- The control unit is at the front right

http://www.bmweducation.co.uk/downloads/online-resources/BMWVirtual%20Realit%20inCarProduction.pdf
Automotive industry
(Jaguar Land Rover)

- State-of-the-art virtual and high-end visualization technologies

- Increasing efficiency of the product development:
  - faster time to market
  - less investment in physical prototypes
  - helps achieving more robust results

- Virtual Reality Ergonomics laboratory optimize vehicle interior ergonomics and manufacturing or dealer servicing processes.

- Driving simulator (driving dynamics, noise, vibration)

http://www.jaguarlandrover.com/media/23076/jlr_company_information.pdf
Automotive industry (Ford)

Has been using virtual reality technology to various degrees to develop its designs since 2000

“What we’re looking for is the perceived quality of vehicles, as a customer would see them,”

“We want to be able to see the cars and our designs, and experience them before we have actually produced them.”

http://www.forbes.com/sites/leoking/2014/05/03/ford-where-virtual-reality-is-already-manufacturing-reality/
Planning/Training: Assembly/ disassembly

http://www.3ds.com/fileadmin/PRODUCTS/3DVIA/3DVIAVirtools/demoshowcase/html/demo.html?br=1&rub=2&srub=8&de=151#
Training: Coal mining industry

http://www.3ds.com/fileadmin/PRODUCTS/3DVIA/3DVIAVirtools/demoshowcase/html/demo.html?br=1&rub=2&srub=8&de=245#
Several degrees of immersion

- Desktop VR
- Semi-immersive VR
- Fully immersive VR

Potential benefits of Immersion

• Immersion can offer benefits beyond a realistic experience:

• Spatial understanding can result in greater effectiveness in:
  – scientific visualization,
  – design review,
  – virtual prototyping

• Decrease in information clutter and increase the environment’s comprehensibility (increased FOV, FOR, and display resolution)

(Bowman and McMahan, 2007)
Crucial technologies for VR

• Visual displays that immerse the user in the virtual world and block out from the real world

• Graphics rendering system that generates images (20+ frames/s)

• Tracking system that continually reports user’s position and orientation

• Database construction and maintenance system for building and maintaining models of the virtual world
Important Auxiliary technologies

- Synthesized sound including directional sound and simulated sound fields
- Display of synthesized forces and other haptic sensations
- Interaction devices allowing users to interact with virtual objects
- Interaction techniques that substitute for the real interactions possible with the physical world
VR System

• I/O devices:
  - trackers, interaction devices, ...
  - displays (visual, sound, haptics,...)

• Virtual Reality engine (architecture)

• Software for virtual object modeling:
  - geometry, texture,
  - intelligent behavior
  - physical modeling (inertia, hardness,...)

• Users and their tasks (human factors)

(Burdea et al., 2004)
Input devices

- Trackers:
  - Mechanical
  - Magnetic (AC, DC)
  - Optical
  - Ultrasonic
  - Hybrid inertial

- Navigation and manipulation interfaces:
  - Tracker-based
  - Trackballs
  - 3D probes

- Gesture interfaces:
  - Didjiglove
  - Cyberglove
  - ...
• Navigation and manipulation devices:
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• Gesture interfaces:
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  – Cyberglove

http://www.inition.co.uk/
CyberTouch Glove

http://www.cyberglovesystems.com/
And other input devices you know from other contexts:

- Wiimote

- Kinect


Output devices

• Graphics displays:
  – Personal
    (HMDs, HSD, DSD, ...)
  – Large volume displays
    (monitor-based, projector-based)

• Sound displays:
  – Convolvotron
  – Speaker-based 3D sound

• Haptic feedback:
  – Tactile feedback interfaces
    (mouses, gloves, ...)
  – Force feedback interfaces
    (force-feedback joysticks, haptic arms, ...)

Speech and brain interfaces?
Graphics Displays

- HMDs
  - single user; very immersive
  - small field-of-view
  - poor ergonomics
    (weight, cables)

https://www.inition.co.uk/extraordinary-technology/head-mounted-displays/
Graphics Displays

- Projection systems (CAVE like systems)
  - wide, surrounding field of view
  - shared experience to a small group

  - cost of multiple image-generation
  - space requirements
  - reduced contrast and color saturation
  - brightness limitations
  - corner and edge effects

Sound

• In addition to the visual and tactile displays, sound:

  – enhances the presence

  – enhances the display of spatial information

  – can convey simulated properties of elements of the environment (e.g. mass, force of impact...)

  – can be useful in designing systems where users monitor several communication channels (selective attention)
Haptic interfaces

- From Greek *Hapthai* meaning the sense of touch

- Disadvantages:
  - high cost
  - take workspace of desktop
  - large weight
  - safety concerns
  - high bandwidth requirements
Haptic devices

– Tactile feedback interfaces (mouses, gloves, ...)

– Force feedback interfaces (force-feedback joysticks, PHANTOM, CyberGrasp...)

https://www.inition.co.uk/product/haption-virtuose/?%3E
http://www.sensible.com/haptic-phantom-omni.htm
http://www.cyberglovesystems.com/cybergrasp/
Tactile feedback mouse

- Vibrations occur in z, minimizing the negative effect on the x, y mouse accuracy
- The host s/w detects contact between the cursor and haptically enabled borders, icons...
- Haptic commands indicating the onset and type feedback are sent to the mouse processor
- The processor converts commands into vibration and drives the actuator

Gamming mouse; 100USD

I/O evolves

- Every year new devices appear

Some quite “weird”!
I/O evolves

- Every year new devices appear

Some quite “weird”!

Sensics Smart Goggles
Epson Moverio, Hololens...
Meta Glasses

3D Input/3D Output eyewear:
- 3D stereoscopic display
- IMU (Inertia Measurement Unit)
- Depth camera
- RGB camera
- Microphone
- 3D stereo sound

~1000USD

https://www.spaceglasses.com/
Augmented *versus* Virtual Reality

- AR is a natural evolution from VR technology

- The major limitation of VR is that it is not easy to fully and accurately model the actual environment

- Does not need to model the entire real world

- AR enhances an existing environment rather than replacing, reduces the high cost of fully immersive VR environments and avoids time-consuming remodeling of complex real objects
Reality Virtuality “Continuum”

“Augmenting natural feedback to the operator with simulated cues”

(Milgram et al., 1994)

Mixed Reality (MR)

Real Environment          Augmented Reality         Augmented Virtuality           Virtual Reality

http://www.youtube.com/watch?feature=endscreen&v=UgQfo7eNFdw&NR=1

(Steinicke et al., 2009)
Augmented Reality

• “Augmented reality (AR) is a live, direct or indirect, view of a physical, real-world environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data.” (Wikipedia)

• “Augmented Reality (AR) is a variation Virtual Reality ... VR completely immerse a user inside a synthetic environment, ... While immersed, the user cannot see the real world around him.

  ... AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world.

  ...AR supplements reality, rather than completely replacing it. “

  (Azuma, 1997)
Azuma (1997) defines AR as systems that has the following three characteristics:

- 1) Combines real and virtual
- 2) Interactive in real time
- 3) Registered in 3-D
Pertinent issues in AR

- Registry
- Latency
- Calibration
- Human factors

(Ong et al., 2008)
VR/AR popularity

- Google searches for:
  - Virtual Reality
  - Augmented reality

since 2004

- AR became more “popular” around June 2009 (Google insight)

- VR had peak in April 2014 (Oculus Rift and Facebook)
• Looking closer: 2009

• The news near the cross point
The Gartner Hype cycle

- 1. A new technology creates expectations; it is investigated and its potential explained

- 2. Expectations peak; the technology becomes overestimated

- 3. Failures and high cost lead to disappointment

- 4. Technology is consolidated and expectations rise again

- 5. Mainstream productivity is attained
Other Realities: Altered Reality (Augmented + Diminished)

Commerce: Ray Ban Virtual Mirror

http://www.youtube.com/watch?v=Ag7H4YScqZs
Maintenance/ repairing

BMW's working to create augmented reality maintenance tutorials for service technicians seen through a pair of AR goggles - with narration (2009)

http://www.youtube.com/watch?v=Y5ywMb6SeGc
Audi uses AR: Google Glass Metaio Project - Augmented reality turns drivers into a car mechanic

https://www.youtube.com/watch?v=nx-dqZ21NIU
Applications in manufacturing

AR-assisted assembly layout planning and assembly operations  (Ong et al., 2008)
Prettify yourself in Panasonic's AR mirror

http://www.wired.co.uk/news/archive/2014-09/05/panasonic-augmented-reality-mirror
Google Glass Project (2012)

http://www.youtube.com/watch?v=9c6W4CCU9M4
Google glass (2015)

http://www.pcadvisor.co.uk/feature/gadget/google-glass-release-date-uk-price-specs-3436249/

OPTIMIZED FOR GOOGLE GLASS
The Wikitude SDK is fully optimized to take advantage of the unique user-interface of Google Glass.

http://www.wikitude.com/products/eyewear/google-glass-augmented-reality-sdk/
Hololens will be used to help repairing Thyssenkrupp elevators

What future for AR?

• A successful AR application should ideally:
  
  – be accurate, small, light, fast and cheap
  
  – have efficient and suitable UIs allowing users easily operate the virtual and real objects in the 3D environments, such as using their hands to freely interact with the things in their daily life
  
• Fast and stable Internet-based collaborative AR systems will be ideal for some scenarios (e.g. manufacturing)
To keep up with the latest developments: Conferences

- IEEE Virtual Reality (VR) (since 1993)
- ACM Symposium on Virtual Reality Software and Technology (VRST) (since 1994)
- Eurographics Workshop on Virtual Environments (since 1995)
- IEEE International Symposium on Mixed and Augmented Reality (ISMAR) (since 2002)
- IEEE World Haptics Conference (WHC) (since 2005)
- IEEE 3D User Interfaces (3DUI) (since 2006)
- IS&T/SPIE Electronic Imaging
- SIGGRAPH Emerging Technologies
- ...
- http://vgtc.org/wpmu/conferences/
- http://www.vrst.org
- http://spie.org/x16218.xml
“VR almost worked in 1994 barely worked in 1999”  
(Fred Brooks, 1999)

and now?

In my opinion:
• There is a continuum of realities
• It is more consolidated and **much more affordable**
• It has passed the “hype and disappointment phases”
• There is a range of VR settings with very different costs
• **It works and is useful in specific applications**
• It is still not easy to integrate a complete solution
• It still has **human factors challenges**

Don’t forget AR!
Paper presentation schedule (tentative)

5 (11/10/16) – Jorge Ferreira

6 (18/10/16) - Francisco Alves, José Duarte

8 (8/11/16) - Robert Ignasiak, + Szymon Koper

9 (15/11/16) - Miguel Campos, Fábio Pires

10 (29/11/16) - Raphael Carvalho + Francisco Martins

12 (06/12/16) – Diogo Carneiro + Manuel Gaspar

14 (20/12/16) - Paper presentation
Low cost platform and usability in Virtual and Augmented Reality
Other senses – example applications

Other senses – example applications

• Miyaura, M., Narumi, T., Nishimura, K., Tanikawa, T., Hirose, M., "Olfactory feedback system to improve the concentration level based on biological information," *IEEE Virtual Reality Conference, 2011*, pp.139-142
Other senses – example applications

Bibliography - Books


Bibliography - papers


