Fundamentals of Virtual Reality

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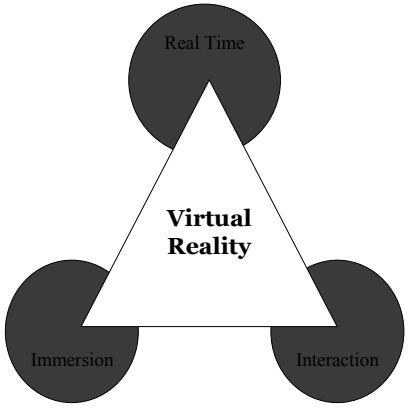
Fundamentals of VR Systems

- **VR one of hottest research and development areas in computer industry today.**
- **VR not new technology, development dates back almost 50 years (first flight simulators during World War II)**
- **Potential applications: from medical imaging and interior design to intercontinental videoconferencing and exploration of future worlds.**
- **VR often thought of as new technology, but development dates back almost 50 years to flight simulators built by aircraft industry and U.S. Air Force during and after World War II.**

Triangle of Virtual Reality



Triangle of Virtual Reality (2)

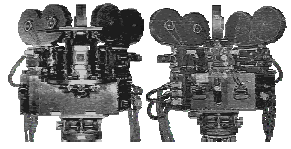
- **Immersion :**
  - ***Feeling to be in the 3D Virtual Space.***
- **Interaction :**
  - ***Possibilty of moving in the 3D space and manipulate objects***
- **Real Time :**
  - ***Actions can immediately modify the state of the space .***

History of Virtual Reality

- **Student pilots learned how to manoeuvre airplanes by manipulating controls in specially built airplane cockpits, removed from airplanes themselves, and mounted on movable platforms that tilted and rolled based on pilot's actions on controls.**
- **VR's future also influenced by film techniques such as stereoscopic, or 3-D cinema, and several wide-screen systems that Hollywood filmmakers were experimenting with during the early 1950's.**

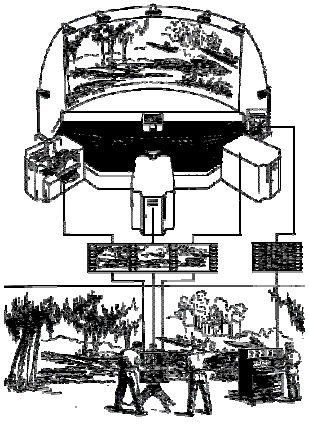
CINERAMA

- **Cinerama, best-known of these technologies, sought to expand movie-going experience by filling a larger portion of audience's visual field.**
- **3 cameras, shooting from slightly different angles, used to film each scene in Cinerama movie.**

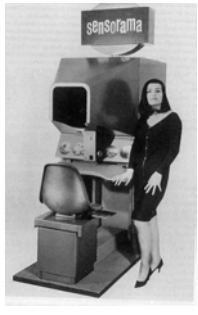


CINERAMA (2)

- **Film then synchronized and projected onto 3 large screens that curved inward, wrapping around audience's peripheral visual field.**
- **Technology proved too costly to be embraced by most commercial theaters, but theory of visual immersion becomes an important VR element ?**



Sensorama



- **in 1962, Sensorama: simulation of sensory experiences of a motorcycle ride by combining 3D movies, stereo sound, wind, and aromas.**
- **Special seat and binocular showing California lanscapes and Brooklyn streets.**

HMD

- **In the 1960s Raymond Goertz at Argonne National Laboratory in Argonne, Illinois demonstrated early versions of HMDs.**
- **Displaying images from remote, closed-circuit cameras, these were used for viewing inside "hot cells" where radioactive materials were handled experimentally or processed in small batches for use in nuclear power and medicine.**

Ivan Sutherland

- **Pioneer in computer graphics, probably contributing more than any other individual to its development.**
- **Sketchpad, program developed by Sutherland (his thesis), used computer technology to create images from abstract ideas.**
- **Using Sketchpad and a penlike device, a computer could create sophisticated images on a display screen resembling a television set.**
- **1965: wrote about 'The ultimate display' which included interactive graphics, force-feedback devices, and mentioned audio, smell and even taste!**

Ivan Sutherland (2)

- **1968: described HMD that tracked viewer and updated graphics display to correctly reflect new viewing position.**
- **used of two displays visible from a pair of half_silvered mirrors => stereoscopic computer graphics images overlaid onto the real world.**
- **In the late 1960's and 1970's, research on a number of fronts formed basis of today VR.**

The Aspen Movie Map

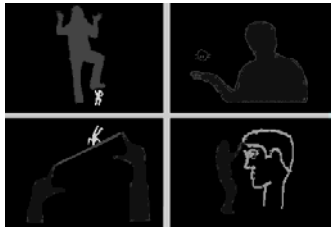
- **developed by group of researchers including Scott Fisher at MIT**
- **showed video images of Aspen, Colorado**
- **visitors could actually navigate by indicating their choices on touch-sensitive display screen**

Movie (web)

Videoplace, 1970

- **one of several experimental artistic environments designed by arts scholar Myron Krueger**
- **Computer responds to gestures of audience by interpreting, and even anticipating actions.**
- **Audience members could "touch" each other's video-generated silhouettes, and animated organisms computers used to create what Krueger called "artificial reality"**






Movie (web)

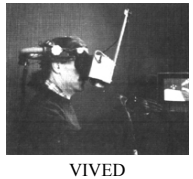
NASA

- **Mid-1980's: different technologies converged to create first true VR system.**
- **Researchers at NASA' s Ames Research Center charged with creating affordable pilot training system for manned space missions.**
- **People involved: Scott Fisher, Stephen Ellis, Michael McGreevy, and Warren Robinett.**
- **efforts led to development of Virtual Interface Environment Workstation.**
- **first system combined such standard VR elements as computer graphics and video imaging, 3-D sound, voice recognition and synthesis, and HMD.**

Scott Fisher

NASA (2)

- **data glove, based on invention designed to play air guitar, completed the system.**
- **1984: Mike McGreevy and Jim Humphries originators of VIVED (VIrtual Visual Environment Display) .**
  - **They evaluated potential of monochrome HMD system for future astronauts.**
  - **Later, VIEW (Virtual Interactive Environment Workstation) project developed general_purpose, multi_sensory, personal simulator and telepresence device.**



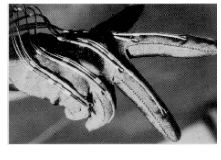
VIVED

VIEW

Movie (web)

VPL

- **Jaron Lanier's company, VPL Research, first company to focus efforts on developing products for infant VR industry, and provided headgear and gloves used in many early VR applications.**
- **Head- tracking helmets and data gloves, wired to a specially programmed computer system, provide traditional entry into virtual worlds.**



Virtual worlds without using immersion devices.

- **PHANTOM: developed at MIT A.I. Lab, creates illusion of touching virtual objects.**
- **Projected systems, often used in museums and for medical displays, take image of user's motions and display it with other images on large screen.**
- **Simulation VR, widely found in VR game arcades and parks, use combination of video monitors and movable platforms to create virtual experiences.**

Virtual worlds without using immersion devices (2)

- **Magic Edge: combination restaurant/bar in Mountain View, California, offers VR flight simulators that let would-be fighter pilots battle each other over fully rendered virtual landscape.**
- **Goertz, and later Michael Noll of Bell Laboratories, also developed prototype force-feedback devices.**

Today

- **In recent years, VR devices have improved dramatically as result of various technological advances.**
- **Computers more powerful, higher memory capacity, smaller, and cost less than in the past.**
- **These developments + advent of small LCD displays that can be used in HMDs, have made it possible for scientists to develop VR simulations.**

Flight simulators

- **Development of flight simulators has made very significant contributions to development of VR.**
- **Much of technology needed for VR developed for military flight simulators (Furness at US Air Force) .**
- **Advanced fighter cockpit where fighter pilot wore HMD that augmented out window view with graphics.**
- **Graphics included friend_or_ foe identification, targeting information, threat information (e.g. ground_based missile sites) and optimal flight path information.**

Flight simulators (2)

- **fighter pilot operating under extremely high stress levels (both cognitive and physical), yet has to assimilate and process masses of data.**

Flight simulators (3)

- **Some of the needs identified to make flight simulators possible include:**
  - ~ ***rapid update rates (i.e. very fast tracking and redisplay, preferably at least 30 frames/second***
  - ~ ***short lag times (no noticeable delay between movement and production of correct visuals)***
  - ~ ***secondary visual cues like shadows and textures; motion feedback and force feedback;***
  - ~ ***techniques for management and efficient display of complex worlds.***
- **Unfortunately, commercial flight simulators cost millions of dollars each.**
- **For VR, we must achieve similar fidelity at a tiny fraction of the cost.**

Virtual Reality (VR) and Virtual Environments (VEs)

- **VE refers to technology capable of shifting a subject into a different environment without physically moving him/her.**
- **To this end inputs into subject's sensory organs are manipulated in such a way, that perceived environment associated with desired VE and not with physical one.**
- **manipulation process controlled by computer model based on physical description of VE.**
- **Consequently, technology able to create almost arbitrarily perceived environments.**

Virtual Reality (VR) and Virtual Environments (VEs)

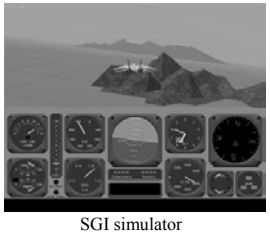
- **VR known as a new dimension in man-machine communication that (up to now) combines real-time (3D) computer graphics and direct (mostly) intuitive interaction in 3D space.**
- **"ultimate illusion" is not achievable at all.**
- **VEs must improve man machine communication**
- **One should be used (like today's telephone) by "everyone" for human (-to-human) communication.**
- **VEs should allow better and faster understanding of even complex applications and provide means for intuitive operations and control.**

- **Acceptance of VEs in industrial application, i.e. for product development, product presentation and process control heavily dependent on key issues like:**
  - ***~quality of presentation;***
  - ***~easiness of interaction and***
  - ***~correctness of behavior.***
- **Two keys concepts: Immersion and Presence**

Immersion

- **key issue in VR systems as central to paradigm where user becomes part of simulated world, rather than simulated world being feature of user's own world**
- **First "immersive VR systems": flight simulators where immersion achieved by subtle mixture of real hardware and virtual imagery.**

- **Cockpits real with their instruments, joysticks, levers, switches, buttons, sliders.**
- **Each instrument possess individual mechanical characteristics.**
- **Pilots constrained to floor-mounted chairs, and during take-off and landing scenarios, restrained by seat belts.**
- **It would be ridiculous to build all instruments and chairs in virtual world.**



SGI simulator

Virtual Take Off simulator

- **Drawback: monitors used and pilot and co-pilot cannot share each other's images, as each pilot looking at individual display**
  - ***~ resolved by using system of projectors and panoramic spherical mirror, as done in Rediffusion Simulation's WIDE system.***
  - ***~ Typically, 3 projectors form seamless coloured image upon back-projection screen, with each projector forming image with 50• horizontal field of view.***

According to Slater, participant "immersed" in VE in two ways.

1. **Through VE system displaying sensory data depicting his surroundings.**
   - ~ ***Part of immediate surroundings consist of representation of participant's body and environment displayed from unique position and orientation defined by place of participant's viewpoint within environment.***
   - ~ ***Body tracking devices, such as electromagnetic sensors enable movements of person's whole body and limbs to become part of dynamic changes to objects in VE under his immediate control.***
2. **second aspect of immersion: proprioceptive signals about disposition and dynamic behaviour of human body and its parts become overlaid with consistent sensory data about representation of human body: "Virtual Body" (VB).**

These VEs are called "Immersive VEs" (IVEs).

- **Term "immersion" description of a technology, which can be achieved to varying degrees.**
- **necessary condition Ellis' notion of VE, maintained in at least one sensory modality (typically visual).**
- **e.g. HMD with wide field of view, and at least head tracking would be essential.**
- **degree of immersion increased by adding additional, and consistent modalities, greater degree of body tracking, richer body representations, decreased lag between body movements and resulting changes in sensory data, and so on.**

- **Astheimer defines immersion as feeling of VR user, that his virtual environment is real.**
- **Analogously to Turing's definition of artificial intelligence: if user cannot tell, which reality is "real", and which one is "virtual" => computer generated one is immersive.**
- **high degree of immersion equivalent to realistic VE.**
- **Several conditions must be met to achieve this: the most important seems to be small feedback lag; second is a wide field-of-view.**

- **Displays should also be stereoscopic, usually the case with HMDs.**
- **A low display resolution seems to be less significant.**
- **We perceive world through continual stream of visual, auditory, tactile, kinesthetic and olfactory sensory data.**
- **rendering of these external sensory data not enough to create immersion.**
- **human body must itself be tracked, so that changes in displays driven by movements of human body.**

Example: turning the head around

- **The perceiver experiences a change in ambient optic array corresponding to turn.**
- **Objects at one side become occluded by head and go out of view, and others come into view.**
- **There is translation of whole, and re-arrangement of object occlusion relationships.**
- **Objects (and parts of body too) now occlude different parts of other surfaces, and become occluded in differ-ent way themselves.**

- **We should also note that the person can voluntarily cause significant changes in the scene.**

  e.g. movement of arm will cause change in occlusion structure.
- **We may say that immersion requires that overall body tracked with movements resulting in changes transmitted to display systems => great immersion.**
- **Of course, head tracking is essential.**

Presence

- **According to Slater, an Immersive Virtual Environment (IVE) may lead to sense of presence for participant taking part in such an experience.**
- **Presence: psychological sense of "being there" in environment based on technologically founded immersive base.**
- **However, any given immersive system does not necessarily always lead presence for all people**
- **Presence so fundamental to our everyday existence that difficult to define.**

- **It does make sense to consider negation of sense of presence as loss of locality, such that "no presence" equated with no locality, sense of where self is as being always in flux.**
- **Link between immersion and presence, but not simple function.**
- **different individuals have differing requirements for sensory data in order to construct models of world.**

The following criteria seem to be crucial:

- **Presence: sense of "being there" in environment specified by displays.**
- **participant likely to momentarily "forget" about external physical world, and treat virtual world as real.**
- **participant would exhibit behaviours same as those they would carry out in similar circumstances in everyday reality.**
- **Flight simulators provide very high degree of presence for users, but, only provide presence in one relatively fixed environment - that of airplane cockpit.**
- **VR systems should be able of providing presence in arbitrary large number of environments, limited only by imagi-nations of environment designers.**

Applications of Virtual Reality

- **VR may offer enormous benefits to many different applications areas.**
- **One main reason why it has attracted so much interest.**
- **VR currently used to explore and manipulate experimental data in ways that were not possible before.**

Vehicle Simulation for Ergonomics

Architecture: visit of buildings and monuments

Virtual Cities

- **Virtual cities in VR are computer based spaces that give the users the sense (mostly visual, and sometimes auditive) of being part of them, usually by moving inside them in real-time.**
- **VR can be expressed with two techniques: panoramic views and 3D-models.**
- **3D-models cities can be re-creation of real cities or imagined cities.**
- **Cities can be interactive, single-user or multi-user interfaces.**

Panoramic Views

- **Users have a 360° (panoramic) view of the city, which gives them a good impression of being there.**
- **The plugin QuickTimeVR is usually needed.**
- **Generally uses real images.**
- **Inconvenient: the users cannot change their view point. They are not able to move but turn their head.**

Example: Helsinki

3D Modeled Cities

- **Very popular and correspond the most closely to the definition of VR.**
- **Real immersion in a virtual environment, sometimes with sound. Can be used for entertainement, business, virtual reality immersive training (fire, police, emergencies etc.), urbanistic or architectural planification, etc.**
- **Visitors can walk virtually in the city, as if they were walking in a real place. They can freely explore streets and buildings from any angles. It is even possible to fly above the city.**

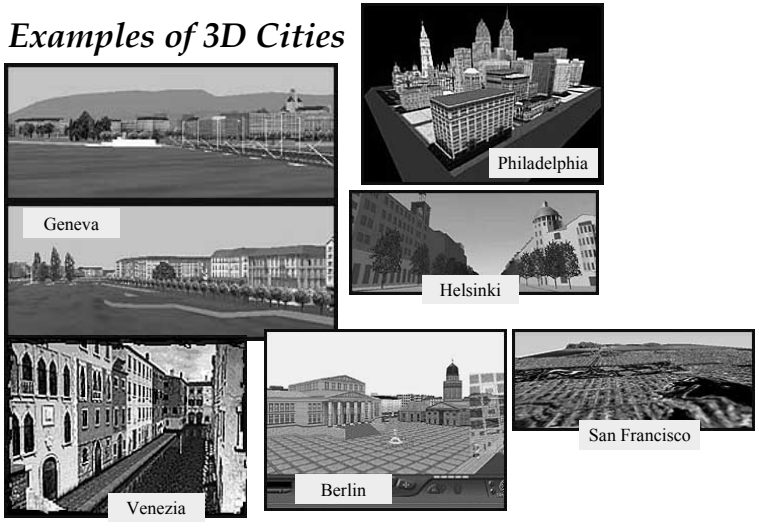
3D Modeled Cities (2)

- **It is to visualize these cities (with a simple browser and an added plugin, or a with flight simulator game).**
- **Lots of models are created in VRML (to visualize them, a VRML plugin, such as Cosmoplayer for Window and MacIntosh, or VRweb for Unix stations, is needed).**
- **For detailed models and ordinary connection, download from the internet can sometimes be long.**
- **There can be lag on slow computers.**
- **Complete realistic models are rarely for free.**

Real Cities

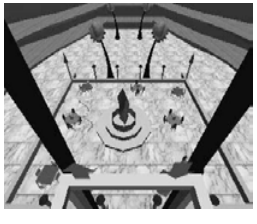
- **Most of the real cities are merely 3D-models in VRML (with little or no interaction facilities).**
- **Usually free but uncomplete models (even though it is sometimes possible to buy good quality models).**
- **In general, uses a single-user interface.**

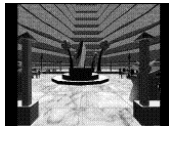
Examples of 3D Cities



Fear of heights (acrophobia)

- **One of the very common phobias is the fear of hefights.**
- **People are having extreme reactions on the very notion of heights.**
- **Psychological treatments for this, as well as for other phobias includes exposure to real anxiety.**
- **Whereas in the real world it is difficult to control the surrounding and the height the patient is exposed to, VR enables a therapist and a patient to achieve the complete control of the virtual world.**





VR for Psychoterapy

•With advent of realistic virtual humans, possible to recreate situations in VE, immersing real patient into virtual scenes,

•e.g., to re-unite patient with deceased parent, or to simulate patient as child allowing him/her to re-live situations with familiar surroundings and people.

Fear of spiders (arachnophobia)

- **created at the University of Washington**
- **After identifying a phobic patient, SpiderWorld was created by placing virtual spiders in the virtual kitchen.**
- **Prior to treatment, the patient had been clinically phobic for nearly 20 years and had acquired a number of spider-related obsessive-compulsive behaviors.**
- **During VR therapy, the patient was sometimes encouraged to pick up the virtual spider and/or web with her cyberhand and place it in orientations that were most anxiety provoking.**

Post-traumatic Stress Disorder Treatment

- **created to treat Vietnam veterans suffering from post traumatic stress disorder**
- **currently under evaluation by psychotherapists at the Atlanta Veterans Administration hospital**
- **users wear a virtual reality helmet and ride (including landing and taking off from an open field) a combat helicopter over various Vietnam terrain like rice paddies, river, jungle**

Virtual Reality in Emergency Situations

- **VR techniques used to create models of the real world which have many potential applications in safety.**
- **Obvious use: training in operation of equipment in simulators.**
- **Errors of trainees do not damage equipment or the people involved.**

Virtual Reality in Emergency Situations (2)

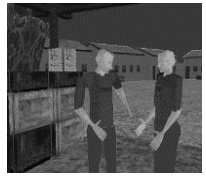
Potential for VR training systems summarized by Denby (1998):

- **Demonstrating correct/incorrect and standard procedures**
- **Advise trainees during simulations**
- **Test competencies and record decisions for review**
- **Demonstrate unusual situations**
- **Train staff for hazardous situations safely**

Virtual Reality in Emergency Situations (3)

- **Emergency management characterized by:**
  - ~ *unexpected combinations of rare events*
  - ~ *emotionally charged environments*
  - ~ *inadequate information on conditions*
  - ~ *potentially significant hazards*
  - ~ *time sensitive action requirements.*
- **Diverse and complex data input, and unusual combination of events => VR tools ideal technique**
- **VR methods can provide tools to:**
  - ~ *manage an emergency*
  - ~ *to assist planning and the development of emergency response plans*
  - ~ *training tools for emergency managers and rescue teams.*

Functions of Emergency Management



- **Emergency management includes many different activities, but breaks down to some basic steps which are:**
- **Collect information on the emergency field**
- **Analyze the significance of the data**
- **Make decisions of appropriate action**
- **Investigate specific activities and task**

Advanced Disaster Management Simulator

- **Train emergency personnel in handling fire & hazardous materials**
- **Can be expanded to include medical emergencies, natural disasters and generally other incidents that require command-and-control skills.**
- **Customization of scenarios, exercises and environments**
- **Evaluation of trainee can be done with computerized scoring**

Virtual Reality In Mine Emergency Management

- **Virtual reality is used to simulate the emergency situations in mines. The aims of these simulations are:**
- **To train rescue teams**
- **To gather the data from emergency area**
- **To prevent emergency situations**

Virtual Reality Earthquake Simulator

- **preparation for the earthquake through the virtual reality experience**
- **simulation utilizes result of the research on the behavior of a collapse of furniture, floor and wall**
- **training of the actions that should be carried out when the earthquake occurres**
- **possible to freely set the existence and the installation sites of fire extinguisher, emergency bag , torch, etc.**
- **scenario (family evacuating from their house):**

Virtual Hostage Rescue

- **VRaptor (Virtual Reality Assault Planning, Training, Or Rehearsal)**
- **virtual reality simulation for two-person law enforcement teams**
- **participant's task**
- **to determine who are the hostages and save them**
- **take prisoner those kidnappers who surrender**
- **shoot those who fire weapons**
- **four virtual reality characters: 2 men, 2 women**
- **sitting, standing, or lying in a room**

Medical Emergency

- **Injuries**
- **Heart attack (JUST project)**

JUST

keyframes

Medical Emergency (2)

Entertainment

- **area which starts to drive development of VR technology.**
- **biggest limiting factor in VR research today: sheer expense of technology because low volumes.**
- **For entertainment, mass production required.**
- **Another alternative: development of "Virtual Worlds" for Lunaparks/casinos.**

Atlantis Cyberspace