SE3VR11 Virtual Reality
Prof Richard Mitchell

Perception and Technology

In Virtual Reality we create an imaginary world to inhabit

- Important to understand how humans perceive 'worlds'
- Covers Visual, Auditory and Haptic senses

The notes for this course have been developed over many years by many people. My thanks to

Max Parfitt, Faustina Hwang, Andrew Dunk, and Adrian Haffegee

Introduction

PMS has defined VR, introduced some terminology, covered some of the history and applications

He has listed the 4 key elements (Sherman & Craig, 2003)

- A Virtual Environment (world)
- Immersion
- Sensory feedback
- Interactivity

And the Components of a VR System.

- Input and Output Devices
- VR Engines
- Databases

Virtual Reality and Games

Many are interested in computer games …

Often these games portray a world visually and auditory

They have controllers which allow exploration of the world and interaction with the world and others there

To an extent they are Virtual Reality, but

- A flight simulator game at home is ok,
- But not the same as using a real flight simulator
  - (with hydraulically operated mockup of a cockpit)

But Headsets are increasingly available for video games

Games driving VR

In 2016, $5.1billion will be spent on VR gaming

http://fortune.com/2016/01/05/virtual-reality-game-industry-to-generate-billions/

Not surprising therefore that the games industry has helped considerably re VR development

As such, for the individual part of the coursework, you will all use the Unity software https://unity3d.com/5

Good for making simple worlds, with inbuilt physical modelling, interaction, movement and exploration

For more detailed models, other software is better

So in Groups make more complex worlds – individuals in groups can focus on other packages.

Focus of My Lectures

I shall focus on how a VR world can be produced

Note Technology provides only a model of the world

Sufficient to 'fool' our senses

This requires an understanding of how we perceive

Hence I look at the senses first then the technology

First, however, how can we quantify VR?

- This relates to some of the four key elements..

Then I justify why we need to know of 'Human Factors'

Quantifying VR

What makes one VR experience better than another?

- Graphical realism? Frame rate? A good storyline?

How can you describe what's good or bad about VR to someone?

Common terms are: Presence and Immersion.

Used to describe physiological and psychological integration of a subject when using a virtual reality system.

But…

Immersion and Presence

As loosely defined as "Virtual Reality"

Most common definitions are:

- Immersion refers to technological sophistication
  - e.g.: 'a measure of … the [VR] system's capacity to reproduce the physical sensation of the real world' (S. Bouchard 2009)
- Presence refers to a mental state
  - e.g.: 'the physical feeling of being in a place other than the physical location that the user finds him/herself in.' (T. Sheridan 1996)

Determinants of Immersion

How well the VR technology delivers aspects of the VE to the user; measurable and comparable between systems

Determinant of Immersion	Description
Sensory Channels	No. different kinds of sensory stimuli produced by the system
Field of Regard	Directions in 3D from which a stimulus can originate (sound could come from any direction; touch could occur anywhere on body)
Fidelity	The quality of the displays, resolution etc.
Correspondance	How closely user's movements match corresponding environment changes, view position, hand movements etc

Determinants of Presence

How well user feels as though they are a participant within the environment

Determinant of Presence	Description
Interaction	The ease and extent of available interaction
Duration	The length of exposure to a simulation
Self representation	The user's ability to see their own body and actions
Consistency	The uniformity of sensory information. The position something is seen should match the position it is felt
Behaviour	The realism of objects' behaviour in the environment

Distracters and Breaks in Presence

What reduces presence and immersion …

Distracters are stimuli which seem out of place and remind the user they are not really part of the simulation

A 'Break in Presence' according to Mel Slater* occurs when the user stops responding to virtual stimuli and starts noticing real stimuli.

Examples:

- Screen flicker, unrealistic/unexpected VE behaviour, sickness, loud noise etc.

(Interesting psychological research on haptics in VR)

*M. Slater, "Presence and the Sixth Sense,," Presence: Teleoperators & Virtual Environments, vol. 11, pp. 435-440, 2002.

Faithfulness and Believability

An alternative way of classifying VR experience.

More appropriate for describing design of VR systems

Faithfulness:

- Refers to how accurately a simulator recreates real world stimuli.
- Similar to the definition of immersion as technological sophistication

Believability:

- Refers to user experience and psychological state. A Believable VR simulator is not necessarily "faithful"
- Similar to most definitions of Presence.

Why Study Human Factors?

"To adequately create the illusion of reality we must understand both the sensory process and the inference process"

- S. Aukstakalnis

"Designing or selecting a graphics display cannot be done meaningfully without first understanding the human visual system. An effective graphics display needs to match its image characteristics to those of the user's ability to view the synthetic scene."

– Burdea & Coiffet

Why Study Human Factors?

i.e. Virtual Reality is about working out where you can cheat.

To create a believable Virtual Reality you must first understand how the senses perceive reality.

This sets minimum technological requirements

Also sets upper thresholds which need not be exceeded

We will look at what actual happens

Then consider the technology that is suitable

Sensory Perception – Some Jargon

Cue Theory:

A theory [there are others] of how complex concepts are inferred from sensory stimuli

In summary, cue theory states: 'Humans learn to make connections between key events in the sensory information streams (cues) and real world phenomena'

You will hear VR people using the term 'cues' a lot

Useful way of thinking about what form feedback should take in VR

More Jargon

Primary and Secondary Qualities:

Primary Qualities can be perceived by many senses.
 Position is visual, audible and tactile

Secondary Qualities are unique to a single sense
 Red is unique to vision as bitterness is unique to taste

Primary qualities can be more difficult as different sensory displays must agree or conflict can arise

Physiology of the Visual System

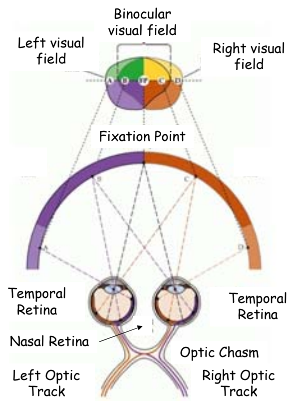
We are visually aware of objects in the world by the way in which they absorb, reflect and scatter different wavelengths of light

The eye converts light in the visible spectrum of frequencies (380-750nm) into neural impulses which can then be processed by the brain

The pattern of light which falls on the retina is called the retinal image.

The photoreceptors convert the retinal image into what is known as a neural image which is then sent on to be converted into edges, textures and objects.

Projection



Of binocular field of view onto two retinas and onto optic tracks

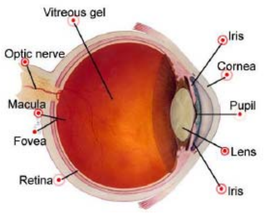
National Center for Biotechnology Information: NCBI » Bookshelf » Neuroscience » Sensation and Sensory Processing » Central Visual Pathways » The Retinotopic Representation of the Visual Field

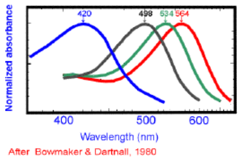
Two Photoreceptors – Rods & Cones

Rods:
- Most sensitive to lower light levels
- More numerous – 120million Vs 6.5m cones
- Only one "Colour"
- Best at motion detection (great flicker sensitivity) mainly in peripheral vision, no rods in foveal region

Cones:
- Three kinds (usually) VERY roughly most sensitive to one of red, green and blue wavelengths
- Get much higher priority on the neural image (more of the optic nerve)
- Concentrated at the fovea

The Eye and Response

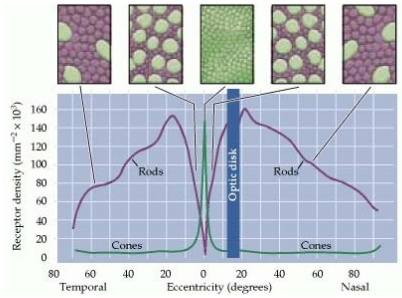




420, 534 and 564nm = Cones
564 = Rods

Eye has Two kinds of photoreceptors: Rods & Cones

The Human Visual System



Distribution of Rods and Cones In the retina

NCBI » Bookshelf » Neuroscience » Sensation and Sensory Processing » Vision: The Eye »

Visual Performance Characteristics

Smallest resolvable separation in a pattern is approx 0.0083° of visual angle (about 167dpi at 1m)

Field of view:

- for one eye = 150° horizontally and 120 ° vertically;
- for two eyes = 180° horizontally and 120 ° vertically

Flicker fusion occurs around 60Hz for most people, maximum sensitivity at 10Hz

The perfect visual display will at least exceed these.

Limitations

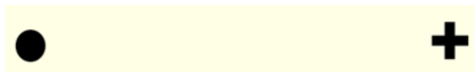
Blind spot –

Cover your right eye. Hold the paper at arm's length.

With your left eye, keep looking at the + while you slowly bring the image closer.

At a certain distance, the dot will disappear – the dot is on the blind spot of your retina.

Try with the left eye



What do you really see?

The one thing we don't see is what's actually there

We interpret the world via very limited sensory organs

Approx a colour by summing narrow bandwidth 'notches'

Miss a huge part of the electromagnetic spectrum

Merge discrete images into continuous motion

Almost no absolute measurement of depth (more later)

Use many assumptions based on expected/learnt phenomena

Optical illusions show where these assumption break down:
http://www.georgemather.com/MotionDemos/BreathingQT.html

But, this turns out to be useful to exploit in VR design

Psychology of the Visual System

Visual perception includes: colour, form, pattern recognition, motion and depth

Depth and motion are more difficult

- there are no (almost) specific receptors for depth so it must be inferred (prone to error)

Depth and motion closely linked

Psychology of the Visual System

Position of an object is found from:
- Relative direction from observer (egocentric direction)
- Distance from observer

Direction is easy, retina is a topographical map of the scene so brain simply maps 2D retinal coordinates to 2D angular coordinates

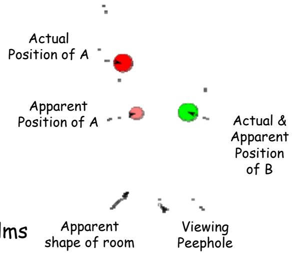
Depth is harder, no absolute method – have to guess

Whole books written about the psychology of vision,
- we'll concentrate on one very small part, very relevant to VR and computer graphics – depth perception

Depth Perception – The Ames Room

How it Works

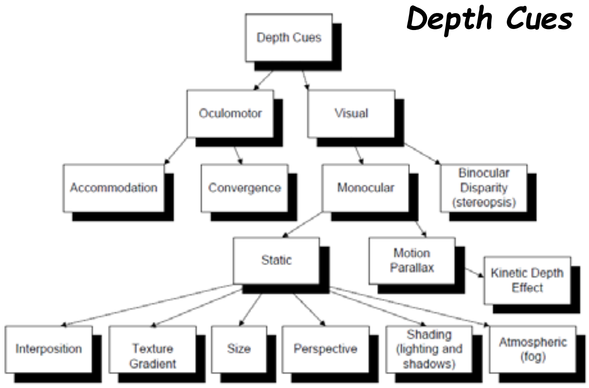
https://en.wikipedia.org/wiki/Ames_room



Used in Lord of the Rings films

Good explanation/demonstration:
http://www.youtube.com/watch?v=Ttd0YjXF0no

Depth Cues



Depth Cues - Oculomotor

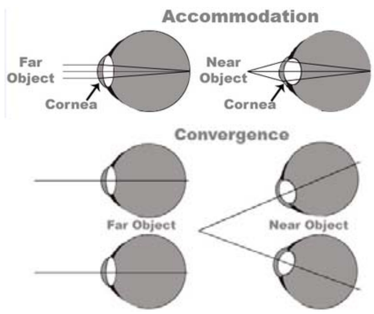
The closest to an absolute measure of depth

Kinaesthetic in origin,
- We move our eyes, using muscles
- Information from muscles to brain give depth cues

Accommodation: how much the ciliary muscles are pulling on the crystalline lens to focus the image
- (almost useless as a depth cue)

Convergence: the orientation of the eyes,
- i.e. the closer an object the more the eyes rotate towards each other.

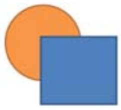
Figures



http://ucalgary.ca/pip369/mod4/depthperception/oculomotor

Depth Cues – Static, Monocular

Interposition:
- When one object partially obscures another
- Simple but strong, will override most others

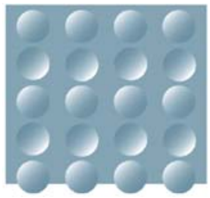


Size:
- Expected depth can also affect perceived size

Linear perspective/Texture Gradient
- Both closely linked
- Parallel lines converge as they get farther away
- Horizontal lines get closer

Depth Cues – Static, Monocular

Shading:
- Includes Lighting and Shadowing



Atmospheric
- Distant objects become less clear
- - air pollution, fog etc.
- (also bluer – used by artists)

Shadows - give relative position between objects

Depth Cues – Stereopsis (seeing solid)

Retinal Disparity
- Each eye gets a slightly different view
- Brain fuses images together to create 'solid' objects
- Less effective with distance

http://cmp.felk.cvut.cz/demos/Stereo/New/Matching/cedar-right.png

Depth Cues – Dynamic

Motion Parallax
- When objects or the viewer are in motion, closer objects move faster across the retina than those farther away
- When a single eye moves approx the distance between the eyes (60-70mm) the depth cue is equivalent to binocular disparity
- This effect is quickly lost when scene stops moving

Kinetic Depth

Kinetic Depth effect (Similar to parallax)
- Objects can seem 3D when moving and 2D when stationary.
- Think of a glass sphere with dots painted on it.
- http://www.youtube.com/watch?v=XGfMB76U5ts
- http://www.georgemather.com/MotionDemos/KDEQT.html

These are examples of the human mind attempting to make sense of the world from limited and incomplete sensory input

Motion Perception

Motion is a very Primary quality* – it can be perceived visually, audibly, tactilely, through smell and even balance

In the real world objects move smoothly and continuously.

In the virtual world (and cinema, TV etc) they 'jump'

For all the senses a threshold exists where two successive stimuli are perceived as one continuous stimulus
- For vision this is known as flicker fusion ~17ms*
- For audition this is know as flutter fusion ~10ms*
- For touch this is known as vibration and is around 5ms*

* Fraisse, P., Time And Rhythm Perception, in Handbook Of Perception. 1978, Academic Press. p. 203-247.

Motion Perception – Apparent Motion

BUT fusion is not necessary for motion to occur,
- it is preferable though

Apparent Motion occurs when the time delay between successive stimuli is lower than the fusion threshold but the brain still perceives motion

Lots of varieties: Short range, long range, transformational, biological

Some of theses effects work for touch and sound too.

Examples here:
- http://www.georgemather.com/MotionMP4.html

Summary Questions

1. A VR interface is to be designed to train jet fighter pilots. There is some debate as to whether the interface should have stereoscopic 3D vision. What are some of the arguments for and against in terms of depth perception and the pilots actions?
2. Many TVs are now being sold as '3D Ready'. Why might it be said that all TVs are 3D?

IMPORTANT: These questions are NOT compulsory and are NOT part of the course mark. They are for you to test your understanding of the lecture material.

Visual Display Technologies

Most displays can be categorised as:
- Desktop
- Wearable
- Projection

Most of the 3D cues from last lecture are part of the 2D image, stereoscopy needs dedicated hardware
- Generating most good 3D cues therefore a software/rendering problem
- Why We might refer to any TV or monitor as "3D ready"

Common stereo techniques discussed next, others exist

Stereoscopic Display Techniques

A different image must be presented to each eye

If both eyes viewing same display surface need to selectively block or transmit light

Most single surface displays have some ghosting (crosstalk)
- when one eye sees parts of image intended for other
- Can cause discomfort, loss of presence / stereo fusion
- In practice single display systems are rarely completely free from ghosting

Three main varieties: active, passive and autosteroscopic

Active Stereo

Left/Right image are alternated on display surface. LCD 'shutter' glasses block each eye alternately


CrystalEyes 3, StereoGraphics


3D Vision
Nvidia

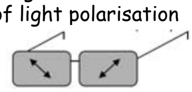
Ghosting affected by:
- Display fade time
- Light blocked by LCD
- Synchronisation of glasses and display

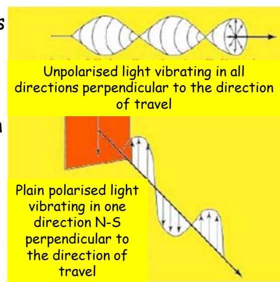
Passive Stereo - Polarisation

Many passive stereo techniques
- Polarisation and Frequency Multiplexing most common

Viewer wears glasses : each lens allows only one direction of polarised light to pass

Display transmits each L/R image with diff orientation of light polarisation





http://www.mineralatlas.com/Optical%20crystallography/properties%20of%20light.htm

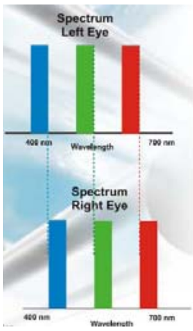
On Polarisation

Linear polarisation:
- Cheaper/easier to manufacture with high % light absorption/transmission
- User can't rotate head

Circular Polarisation
- Often more ghosting
- Invariant of viewer orientation
- Display surface must preserve polarisation (usually requires special coating)

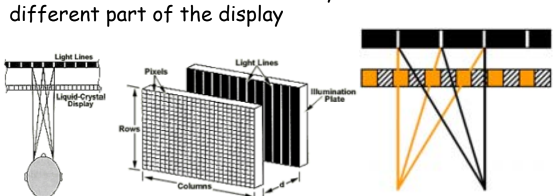
Passive Stereo–Frequency Multiplexing

Frequency Multiplexing –
Old style Anaglyph, newer Infitec.
Block diff parts of spectrum
Invariant of head rotation.
- Anaglyph loses colour info.
- Infitec can preserve colour if intensities correctly adjusted
- Any display surface can be used

Autostereoscopic Displays

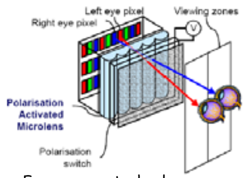
Don't use glasses
lenses/barriers make sure each eye sees a different part of the display



http://dti3d.com/About/dti_technology.htm

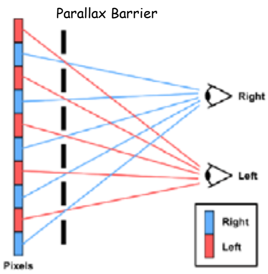
Autostereoscopic – Fixed Barriers

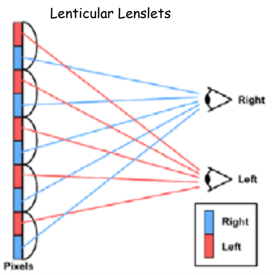
Have a limited viewing angle and 'sweet spots'
- Can sometimes allow multiple viewing positions (look around) by trading off resolution
- Don't scale well, better for small displays

From www.vrtechnology.org

AS – fixed lenses/barriers

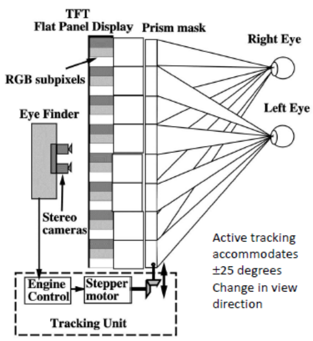




From www.3dforums.com

AS - Movable Barriers

To increase viewing angle : track user's eye position and adjust barrier to match
- Get 'look around' effect
- Only one viewer at a time



Comparing Visual Displays

Lots of criteria for selecting/comparing performance:

Technological:

- Field of View/Field of Regard
- Resolution
- Update Rate
- Interface with tracking methods
- Associability with other sense displays - i.e. integration with audio and haptic displays

continued

Continued

Ergonomic:

- User mobility
- Environment requirements
- Throughput - the number of people who can experience the VE in a given time
- Safety
- time.
- Encumbrance

Lots of others:

- Portability
- Cost

Desktop displays

Cheap, common, accessible

- Small FoV/FoR
- Use all the stereo techniques discussed

http://www.panoramtech.com

Linear Polarised:

http://www.planar3d.com/

Shutter Glasses:

http://www.nvidia.com

Autostereoscopic:

http://www.seereal.com/

Circular Polarised (Row Interlaced):

http://www.zalman.co.kr

Wearable Displays

Just considering head mounted. Also have boom mounted and hand held.

- More expensive than desktop, especially for high quality (£10k++)
  - OculusRift may change this!
- Separate display for each eye
- Optics magnify image and change focal length (1-5m)
- Resolution generally low
- Usually limited field of view <60°
- Trade off FoV <-> Resolution
- Excellent (complete?) Field of Regard

Visette 45, Cybermind

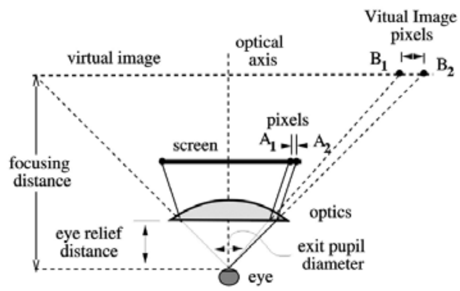
Wearable Displays

Real world normally blocked from view

- Weight & comfort a big issue
- Low latency tracking essential.
- Can't see own body
- Balance and movement affected
- Unnatural body positions often adopted
- Distance travelled often underestimated by up to 25%, unclear why

Head Mounted Display

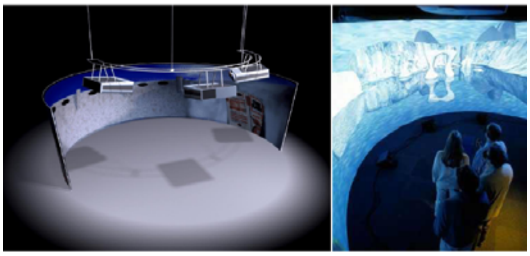
A simplified model of the optics (from www.vrtechnology.org)



Projection Displays

One or more projectors or screens
- Large area – good field of View
- 2D or Stereo (Linear, Circular or Infitec most common)
- Usually rear projected to prevent users' shadows
- Can see own body – good for presence and natural movement/interaction
- Multiple users can share environment (configurations can affect this i.e. head tracking)
- Different configurations in use:
  - Panoramic, Vision Domes, Spheres, Power Walls

Panoramic Displays



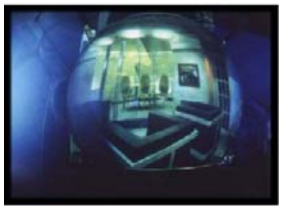
i-Cone, Fraunhofer IMK

Vision Domes

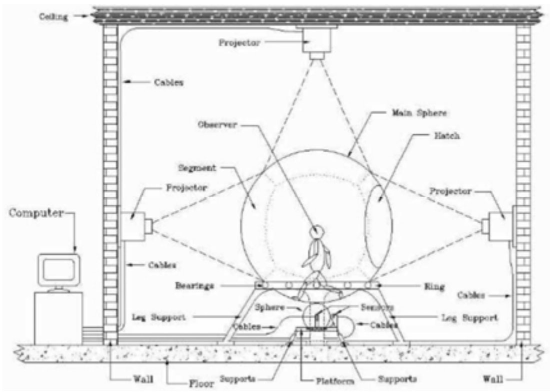
http://www.avrrc.lboro.ac.uk

http://www.cg.tuwien.ac.at

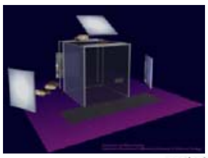
Spheres

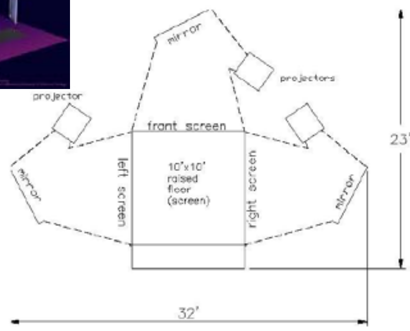


Cybersphere
http://www.vr-systems.ndtilda.co.uk/sphere1.htm



Cubic Displays





Computer Assisted Virtual Environment

Or CAVE Assisted Virtual Environment
Has 3 to 6 large screens
Puts user in a room for visual immersion
Usually driven by a one or more powerful graphics engines
Can put equipment into room to aid realism
    Eg shopping trolley in model of supermarket
Can have multiple people

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Advantages of CAVE

Provides high resolution and large FOV
Uses peripheral vision
Use pair of light weight shutter glasses for stereo viewing
User has freedom to move about the device
Has space to place props (cockpit etc.)
Environment is not evasive
Real and virtual objects can be mixed
A group of people can inhabit the space

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Disadvantages

Very expensive (approximately 1 million dollars)
Requires a large amount of physical space
Projector calibration must be maintained
Only 1-2 users can be head tracked
Stereo viewing can be problematic
Physical objects can get in the way of graphical objects

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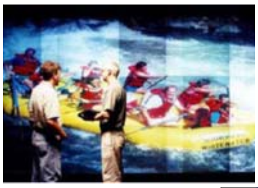
Projection Displays - Issues

Multiple projectors must have:
    Geometric continuity
        (correct alignment)
    Photometric continuity
        (consistent brightness and colour)



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Wall Displays

To keep resolution high, multiple projectors usually tiled
    Continuity particularly important
    Where images overlap, need to adjust brightness
        Can adjust brightness in software or hardware
        (blend plates)

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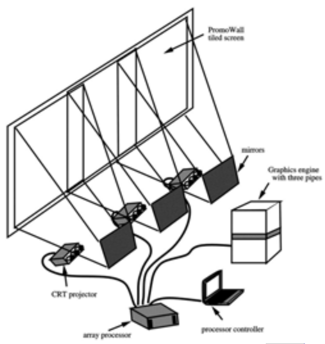

From www.vrtechnology.org

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Wall Displays – Tiling and Blending

Summary

Providing a good visual representation of a virtual world is important

There are numerous technological solutions

It is an active area of work

As is shown by the 2016 Consumer Electronics Show, where VR features – see

http://www.bbc.co.uk/news/technology-35192737

Next week we start to consider hearing virtual worlds

Auditory Perception

We have explored the ways in which virtual worlds can be displayed

Now we consider how they can be heard

Again we look at how we perceive the real world
this time hearing it

And then look at the technologies to allow us to hear virtually.

Transmission of sound

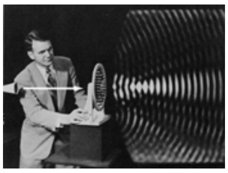
Sound travels as a pressure wave through any medium dense enough to sustain it.

Speed related to medium's density (340m/s in air at sea level)

Intensity drops off with distance (Inverse Square Law)

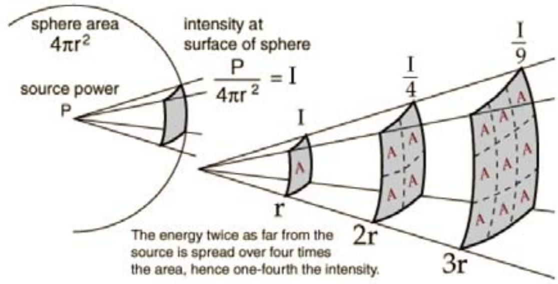
Intensity loss related frequency^2

High Freq attenuate more



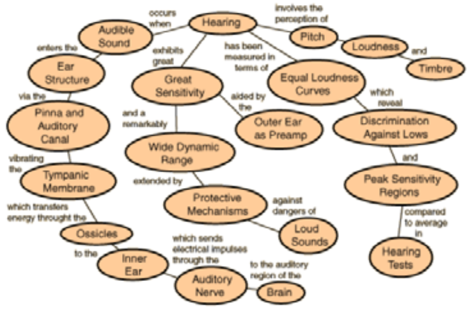
Like light, sound is 'coloured' when reflected, absorbed or passed through objects

Transmission of sound



See http://hyperphysics.phy-astr.gsu.edu/

The Ear



http://hyperphysics.phy-astr.gsu.edu/hbase/sound/hearcon.html

Human Auditory System

Converts mechanical sound energy into neural impulses

Outer ear (Pinna) acts like a radar dish, focusing energy from large area to a small point (auditory canal)

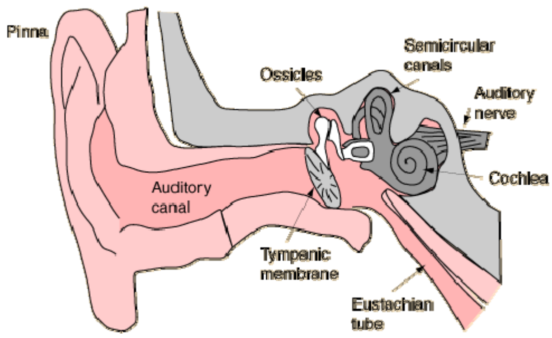
The auditory canal acts as a closed tube resonator: selective freq amplification (~2-5Khz, speaking range)

The middle ear transmits pressure waves to the Cochlea

Inside the Cochlea is the Basilar Membrane
Covered in 15000+ tiny hairs, bent by soundwaves
These trigger electrochemical impulses

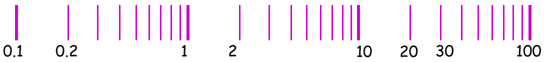
Somehow brain actually converts these to meaningful info
(various theories)

The Ear



Logarithms and Sound

We hear sound over wide ranges of freq : 20Hz to 20kHz
Info from 20..200Hz as important as that 200..Hz
So use log scale … same space when go from f to f*fac



Just like piano keyboard … octave is from f to 2*f

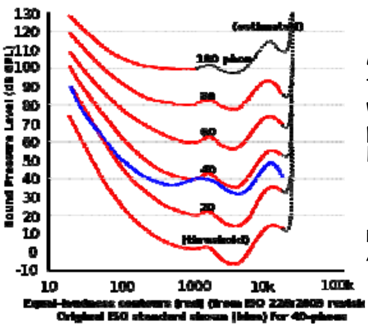
http://www.reading.ac.uk/~shsmchlr/jsfreqresp/AudioSignals.html

Sound power also large range .. 20log10(V) is V in dB

Auditory Performance

Typical young humans perceive signals 20Hz-20KHz
The band 500Hz-2KHz is particularly sensitive
Human hearing has continuous & complete Field of Regard
(sound can be heard from any direction)
Building blocks of sound perception : pitch and loudness
Perception of Pitch ~ logarithmic with frequency
Loudness also logarithmic with amplitude
but affected by other factors including:
duration, previous stimuli, attention and frequency
(equal loudness contours)

Equal-loudness_contour



Measure of sound for diff freqs where listener perceives constant loudness (unit phon)

http://en.wikipedia.org/wiki/Equal-loudness_contour

Auditory Perception

Eye has a 2D array (retina), but ears have two points
Yet we distinguish and separate many different simultaneous sounds
'Cocktail Party Effect' – can focus on partic sound even when many other noises
The most powerful cues for this come from grouping sounds by location
Localisation : judging position of sound source in 3D
Requires both direction and distance information.

Spatial Hearing

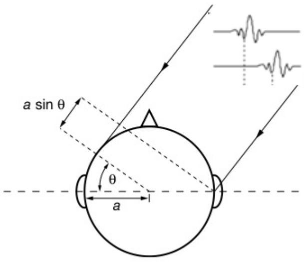
We locate sound sources based on:
- azimuth cues - position left right
- elevation cues - position up down
- range cues - distance away
- reverberation and echoes
- (and knowledge of the world)

Broad spectrum sounds (many freqs) much easier
carry more info and relate to more auditory cues
Often v. diff to identify direction of single, const freq

Localisation –Time Cues

Sound travels at a constant speed.
If not equidistant to both ears, reach one ear first.

Called Inter-aural Time Difference (ITD)
A sound arriving from the side will be delayed by 600-800μs
A human can perceive delays down to 10-20μs



Localisation –Time Cues

For a continuous, non-varying sound the time of arrival at each ear loses meaning

A less powerful cue is Inter-aural Phase Difference (IPD)

The time delay causes a phase change.

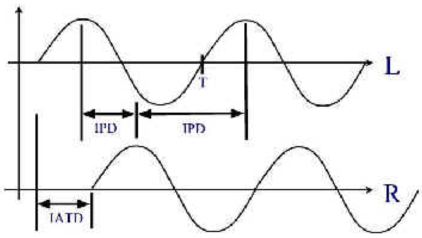
IPD is not consistent, certain angle/frequency combinations will result in no phase shift

At low freq (<1-1.5KHz) , wave length larger than the head

- Then neither ITD or IPD work

Hence need one subwoofer in your surround sound system

Showing Phase Difference



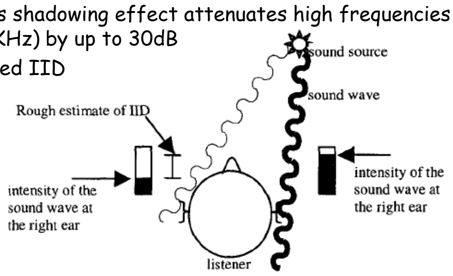
IPD = IATD = T - IATD

Interaural Intensity Difference (IID)

Sounds originating off to one side of the head must pass through the head to reach the far side

This shadowing effect attenuates high frequencies (>4KHz) by up to 30dB

Called IID



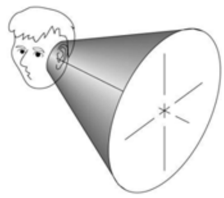
Localisation – Frequency Cues

ITD, IID and IPD do not completely explain the human's sound direction capability

For any point in space there exists a conical set of points equidistant from both ears.

This is the Cone of Confusion

Can be worth tilting your head



Localisation – Frequency Cues

Cone of Confusion : ITD gives azimuth not elevation info

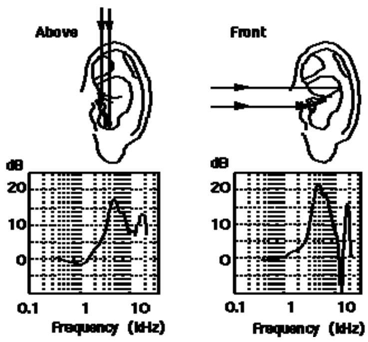
The pinna (outer ear) has non uniform shape

- Makes judgment of elevation possible
- Depending on the direction, different frequencies are attenuated or amplified
- For a sufficiently complex sound this 'colouring' produces strong elevation cues

The interaural distance, head shape and pinna shape make up the Head Related Transfer Function (HRTF)

- Unique to any person
- {Can use shape of pinna for id instead of fingerprints}

Ear better at sounds from side



Localisation – Motion Cues

As with vision, motion parallax v. strong positional cue
If sound of long enough duration
  Listener move head (intentionally or unintentionally)
  Then ITD and IID info change
  Can reduce/remove any ambiguity
In ideal circumstances all these direction cues combine
  for an accuracy of about 1° in azimuth (horizontally) and around 17° in elevation

Localisation – Range Cues

Like vision, depth perception of sound more difficult
Sound intensity reduces with distance
  due to spreading and attenuation in air
  but is not a reliable cue
    (need lot of knowledge about the source)
Experience of the frequency components of a familiar sound gives an indication of its distance
Again, motion parallax important
  When head position changes nearby sound sources will change interaural cues more than distant ones

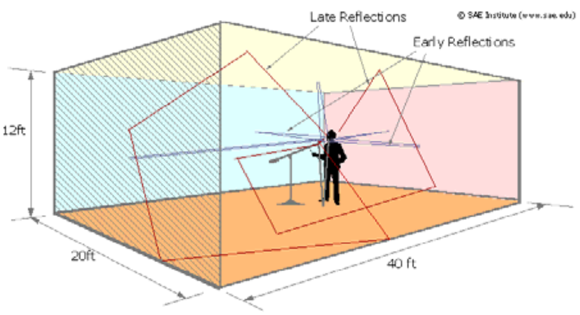
Localisation – Environmental Cues

A human can tell by listening
  Whether in a small room or a large auditorium
  Whether a sound is coming from round a corner or behind a closed door
How? Brain picks up how sound's freq and time characteristics are modified by the environment
This is primarily due to reflection and occlusion

Localisation – Environmental Cues

Reflections (reverberation) are a function of time
The complete audio picture heard by a listener comprises
  The direct path sound
  First/early reflections bounced off a obstacle
  Secondary/Late reflections travelled further
Reflections also affected by absorption and diffusion characteristics of the materials they encounter
  These alter the frequency spectrum

Image



http://www.sae.edu/reference_material/audio/pages/Reverb.htm

Localisation – Environmental Cues

Occlusions are primarily a function of frequency
When an obstacle blocks a direct sound path or one of its reflections higher freq components are attenuated

Exclusions
Direct Path clear
Reflections muffled

Occlusions
Direct Path muffled
Reflections muffled

Obstructions
Direct Path muffled
Reflections clear

Spatial Hearing – Knowledge of World

Expectation and familiarity
- we perceive sounds to come from places where we expect sounds to come from

Visual cues
- we perceive sounds to come from sources that look like they're making sounds

(exploited by ventriloquists)

Given what we have heard, we now can consider how to produce sound for virtual worlds..

Audio Systems

Sounds are transformed by environment and listener (HRTF) before reaching inner ear
- Former tells listener about position of source in environment and some properties of the environment
- From HRTF the listener receives info about the sound source's position relative to their head

For VR, 3D audio processing techniques needed so sound
- appears in both correct position and environment type

How these transforms are implemented
- closely related to the display type,
- two categories: headphones and loudspeakers

Stereophonic Headphones &HRTFs

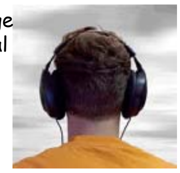
The perfect 3D audio system can make a sound appear to originate from any direction

Need manipulation of cues humans have learnt for location

One method : provide unique audio image to each ear as close as poss to ear canal
- headphones

Then immediate environmental effects are removed

Easy to create an artificial soundscape



But, also removed are the cues produced by the HRTF

Stereophonic Headphones and HRTFs

Recreating interaural time differences is not difficult
- a sound is played in each ear at different times

Recreating the effects of the pinna is much more difficult
- Due to the required complexity and high quality of the real time frequency transforms
- And the fact that everyone's ears are different

An unrealistic HRTF can result in
- high front-back confusion and internalisation
  - (sounds appear very close to or inside the head)

Making an HRTF

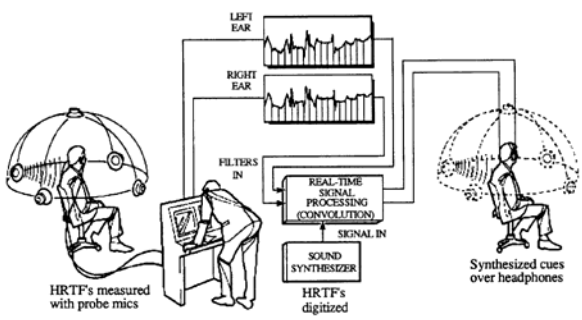
A HRTF can be found in two ways:
- Placing small microphones in the ear canal and recording the transformation between a tone played at a known location and the recording from within the ear
- Taking measurements of the pinnae and calculating acoustic models

Even though the HRTF should be personalised to get good results, this is not practical for general purpose VR

Instead, averaged transforms from multiple humans or dummy heads are used

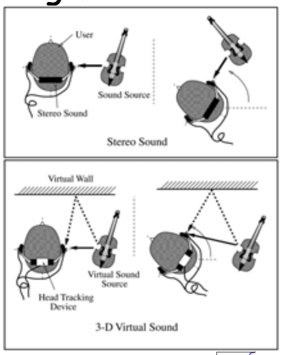
Full HRTFs can also result in distorted sound so simplified versions are often used, even less realism

Measuring the HRTF



On Head tracking for VR

Parallax effect very strong cue for auditory localisation.
Head tracking and updating of listener's position important
For desktop displays need less: user's head in same direction
For HMDs and immersive environments, any absence of head tracking
- very noticeable,
- reducing presence
- may cause disorientation.



Loudspeaker & Multichannel Displays

Alternative to headphones for recreating the full HRTF
- Place a number of loudspeakers around the user, utilising at least some of the natural direction cues

Creating a sound which appears to originate from the direction of a physical speaker is very easy
More diff. to create a sound which moves around user
- does not originate exactly at a physical speaker,
- a so called 'Phantom Source'

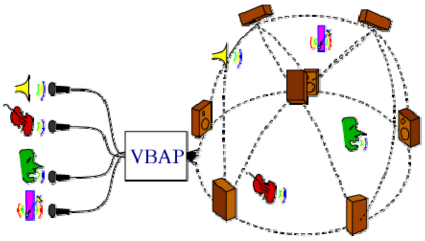
Many techniques for loudspeakers recreating spatial cues
- Cross-talk cancellation, Vector Base Amplitude Panning, Ambisonics and Wave Field Synthesis

Vector Based Amplitude Panning

Virtual source shares the gain between the nearest speakers to the direction of actual source of user
- If a source lies in exactly the same direction as a speaker all the gain will be channelled through it
- If the source lies evenly between two speakers half the gain will go to each

Signal well defined as minimum number of speakers used
It is difficult to generate a virtual sound which is perceived very far from a real speaker
Effectiveness related to density /direction of loudspeakers

Figure



http://legacy.spa.aalto.fi/research/cat/vbap/

V. Pulkki "Compensating displacement of amplitude-panned virtual sources." Audio Engineering Society 22th Int. Conf. on Virtual, Synthetic and Entertainment Audio pp. 186-195. 2002 Espoo, Finland

Cross-Talk Cancellation

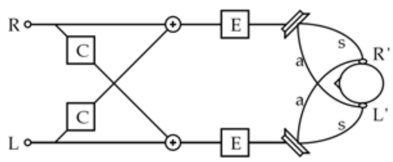
With VBAP, Virtual sources appear close to real speakers
- Because there are many cues, (ITD and pinna)
- These indicate to the listener the sound's origin

Difficult to recreate these cues as both ears receive the output of every speaker - known as cross-talk
If know approx position of listener relative to speakers
- Can do cross-talk cancellation

To remove the unwanted signal from one speaker,
- add signal 180^0 out of phase to that of diff speaker
- delayed so both signals arrive at ear at same time

Cancellation sets parts of each speaker's output ear gets

Cross-Talk Cancellation



To create a virtual source, still need artificial HRTF, so limitations described for headphones apply equally here.
Many consumer 3D audio systems use cross-talk cancellation with HRTFs for two speaker configurations but something more like VBAP for rear speakers

Ambisonics

Ambisonics encodes what the user should hear as
- a sound pressure (W) and
- a set of direction vectors (X, Y, Z) of particle velocity

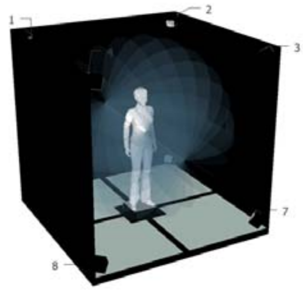
In simplest decoding scheme the output of each speaker is linear combination of the four channels dependant on the position of the speaker in relation to the user

Most implementations use 8 speakers at corners of a cube

Generally all speakers are used to localise a sound in any direction

As such spatial definition can be quite low in some cases

Eight Speakers



Ambisonics

Unusually the signal is the same irrespective of the number of speakers or where they are

Has picked up some support in computer games (see wikipedia for a list)

Good BBC interview here: http://www.ambisonic.net/

University of Reading link: Professor Peter Fellgett was part of the group who originally developed the theoretical framework for Ambisonics

Wave Field Synthesis, WFS

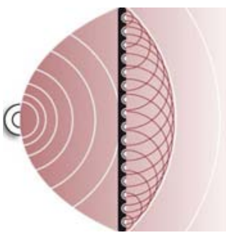
WFS based on principle that any wave-front can be regarded as a superposition of elementary spherical waves

The ideal implementation is an anechoic room covered with a large number of individually driven speakers

Each speaker reproduces the portion of a wave front that, if originating from a specific source, would be passing through it at any point in time

Theoretically a highly realistic sound field could be created, but a number of practical restrictions exist:
- Reflection free (anechoic) surfaces
- The density of speakers

Synthesising a wave front



Multiple speakers synthesising a wave front
http://www.iosono-sound.com/technology/wave-field-synthesis

Loudspeakers Vs Headphones

Headphones:
- Eliminate actual environmental effects
- Lose actual HRTFs
- Custom HRTFs are inaccurate and can distort sound
- Difficult to get generic HTRFs but time consuming/awkward to generate specific
- Sounds seem closer (internalised)
- Directionality is good

Loudspeakers Vs Headphones

Loudspeakers:

- Have to deal with actual environment
- Get real HRTF up to a point
- Directionality from physical speakers is very good, i.e. sounds from behind very realistic
- Really need speakers from every direction
- If want true phantom sources need to isolate with CC filters
- Important part of localisation is parallax, get this well

Some links

Virtual Barber Shop:
http://www.youtube.com/watch?v=IUDTlvagjJA

http://www.noogenesis.com/binaural/binaural.html

http://www.ambisonic.net/

http://ixbtlabs.com/articles2/sound-technology/

http://www.soundonsound.com/sos/oct01/articles/surroundsound3.asp

Next time we consider feeling a virtual world …

Haptic Perception

What is Haptics?

- Pronunciation: \hap-tik\
- Function: adjective
- Etymology: International Scientific Vocabulary, from Greek *haptesthai* to touch
- 1 : relating to or based on the sense of touch
- 2 : characterized by a predilection for the sense of touch <a *haptic* person>
- www.merriam-webster.com

What is Haptics

"Haptics is now commonly viewed as a perceptual system, mediated by two afferent subsystems, cutaneous and kinesthetic, that most typically involves active manual exploration. Whereas vision and audition are recognized for providing highly precise spatial and temporal information, respectively, the haptic system is especially effective at processing the material characteristics of surfaces and objects."

The haptic system uses sensory information derived from mechanoreceptors and thermoreceptors embedded in the skin ("cutaneous" inputs) together with mechanoreceptors embedded in muscles, tendons, and joints ("kinesthetic" inputs). (Lederman & Klatzky, 2009).

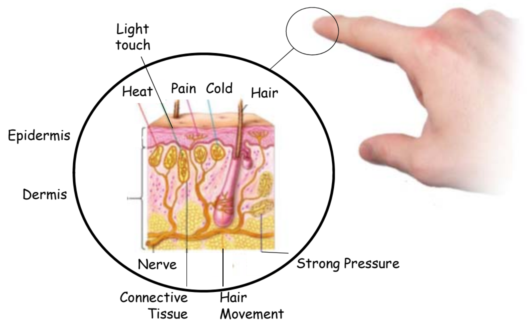
Touch & Haptics

Touch describes sensations produced when objects come into physical contact with the body.

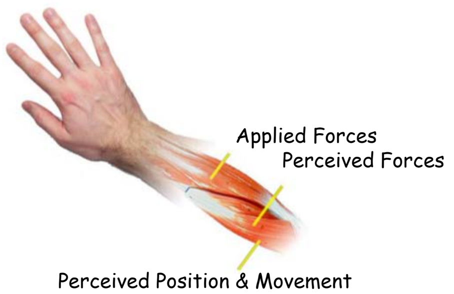
Tactile sensation originates in the skin
  Small scale surface geometry, pressure, texture, vibration, temperature

Kinaesthetic/Proprioceptive sensation occurs in the muscles, joints and tendons
  Weight, force, stiffness, large scale shape

Tactile Sensation



Kinaesthetic …



What is Haptics?

Haptics includes tactile and kinaesthetic sensation

In Psychology & VR haptics usually refers to Active Touch

For Active Touch to occur changes in touch sensation must correlate with purposeful movement
  Using a mouse isn't usually considered haptics even though you can feel it and sense its position
  This is because there is no feedback

A haptic device gives touch feedback based on input

Physiology of Haptics - Tactile

Relies on sensors in and close to the skin

Three types:

- Thermoreceptor (Temperature)
  - Measure RATE at which skin temperature changes.
  - Two kinds, warm and cold.
- Nociceptor (Pain)
  - Don't generally include pain sensation in haptics as is a subjective experience (not referenced to world)
  - Usually better to know how to avoid than recreate!
- Mechanoreceptor (Deformation and Vibration)

Physiology of Haptics - Tactile

Average person has approximately 2m^2 of skin which contains a variety of different receptors

As with the retina in the eye, distribution of receptors is not even.

Denser populations occur where high touch acuity is required (finger tips, lips)

The Sensory Hommunculus represents the proportion of brain area devoted to different parts of the skin

Types of Mechanoreceptor

Glabrous (non-hairy) area of the hand (palm and finger tips) contains four types of mechanoreceptor

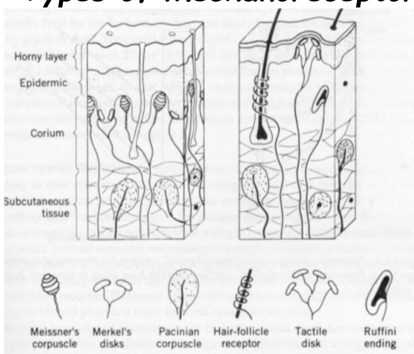
40% are Meissner's corpuscles – detect movement across the skin; light touch

25% are Merkel's disks – sustained touch and pressure

13% are Pacinian corpuscles – deeper in skin (dermis); acceleration sensors; most sensitive to vibrations of about 250 Hz

19% are Ruffini corpuscles – detect pressure, skin shear, lateral skin stretch

Types of Mechanoreceptor



Properties of Mechanoreceptors

Sensorial Adaption : decrease in electrical response from a receptor over time (for a constant stimulus)

- Slowly Adapting (SA) receptors keep firing for a while
- Rapidly Adapting (RA) quickly forget and output rapidly decreases

Comparison of Mechanoreceptors

Table 3.3 Comparison of various skin mechanoreceptorss

Receptor Type	Rate of Adaptation	Stimulus frequency (Hz)	Receptive Field	Function
Merkel Disks	SA-I	0–10	Small, well defined	Edges, intensity
Ruffini Corpuscles	SA-II	0–10	Large, indistinct	Static force, skin stretch
Meissner Corpuscles	FA-I	20–50	Small, well defined	Velocity, edges
Pacinian Corpuscles	FA-II	100–300	Large, indistinct	Acceleration, vibration

Based on Seow [1988], Cholewiak and Collins [1991], and Kalawsky [1993]

Spatial Resolution

Density and receptive field size affects spatial resolution

Receptive field size : area of skin which can excite a receptor

If the sensor has a large receptive field – it has low spatial resolution

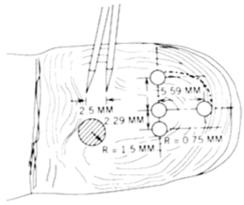
If the receptive field is small, has high spatial resolution

Varies depending on receptor type and location on the body

Spatial Resolution

Acuity is measured using the two-point threshold test

- Minimum separation between two points of contact that can be achieved before they are perceived as one
- From 2mm on the finger pad, 1mm on the palm to 30mm on the forearm and up to 70mm on the back.



Localisation : ability to judge distance between two temporarily separate stimuli … accuracy up to 0.17mm

Proprioception & Kinaesthesia

Proprioception is (unconscious) awareness of positions and movements of the body and the amount of force being applied by the muscles from internal mechanisms

Kinaesthesia is often used interchangeably with proprioception but places a stronger emphasis on motion and force and is not purely internal (includes vision)

No distinct line between Proprioception and tactile cues:

Judgment of properties such as stiffness come from both.

Without knowledge of limb position and velocity, the output of the mechanoreceptors becomes a jumble of disconnected sensations.

Proprioception & Kinaesthesia

The sensors for proprioception are in the muscles, tendons and joints

Many of the receptors are the same as those found in the skin such as Ruffini Endings and Pacinian Corpuscles

Give information about joint angles and velocities

Also stretch sensitive receptors connected between tendons and muscles called Golgi Organs

Gogli Organs also activate a 'cut-out' system which protects the muscles from applying excessive damaging force.

Proprioception & Kinaesthesia

Proprioception has open-loop elements and includes commanded forces in internal model

Measurement of positions, forces and angles is not absolute and can drift. (Floating arms illusion)

Accuracy of angular position decreases with joint size and limb length - about 0.2° at the hip to 0.7° in the metatarsophalangeal joint

The open-loop nature of proprioception can be exploited in touch interface design

Psychology of Haptics

'The frequently made suggestions that vision is "more accurate than" or "dominates" touch seem to miss the point. Suggestions of this kind derive from the notion that touch exists only to do what vision can do better. Touch is not simply an inferior form of vision, nor hearing. Touch, as touch, has its own capabilities and limitations.'

- S. J. Lederman

Psychology of Haptics

Touch is uniquely different from vision and hearing
- Many secondary qualities unique to touch (rough, heavy, cold etc.)
- Perception of sight and sound occurs at a distance, touch requires direct contact
- Touch is a two way process, touch can alter the environment as well as receiving information about it

Form Perception

As with visual shape perception, touch based shape perception is predominantly concerned with finding boundaries
- but language is in terms of forces and positions.

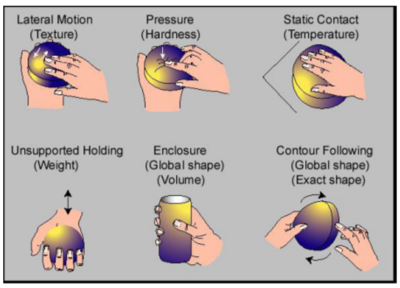
The mechanoreceptors give small scale shape information in terms of lines, edges, and corners etc. which occur as a result of forces deforming certain areas of the skin.

The proprioceptive system gives shape on a larger scale by measuring force direction on joints and mapping them to positions in space

Exploratory Procedures

Humans use consistent and predictable movements when haptically investigating an object

The so called Exploratory procedures (EPs)



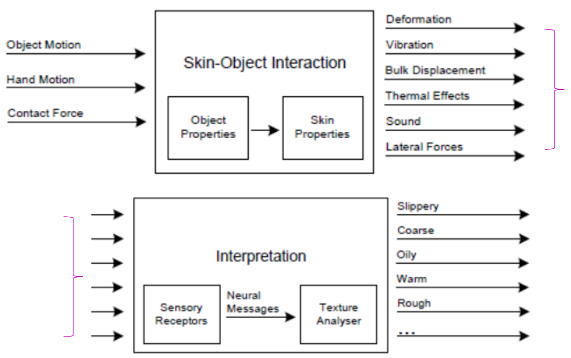
Texture Perception

Highly complex process, driven by tactile sensors

Different sensory channels are fused together to create the experience of texture

The complex nature of the process gives rise to a diverse set of perceptual experiences:
- rough, sharp, cold, sticky, slippery, rubbery, oily and grainy etc.

Not only the object's properties affect the output, skin properties such as dryness also have an effect.
- For example, cold skin makes surfaces seem smoother as the skin's elasticity is reduced



Haptic Display Technologies

We have explored aspects of touch
- How humans feel the real world

Next we consider the technology available
- for feeling virtual worlds

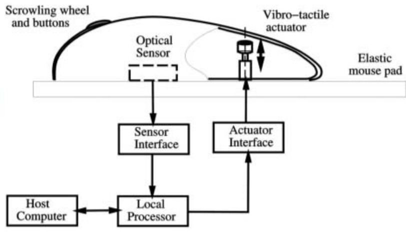
Haptic Displays - Tactile

Temperature, vibration and skin deformation

Most widely used devices generate vibration (known as vibro-tactile)

Range from very simple such as mobile phones, to gloves with multiple embedded vibrating units

Haptic Displays - Tactile



The iFeel Mouse (0-125 Hz).

Glove

CyberTouch Glove (Virtex): 6 individually controlled vibrotactile actuators
0-125 Hz frequency,
1.2 N amplitude at 125 Hz

Haptic Displays - Tactile

Devices that work by causing small deformations in the skin are usually based on arrays of mechanical pins which can be moved as required

Challenging – from earlier we know that we need an array with 1mm between pins and bandwidth >300Hz

Pins are usually actuated by electromagnetic methods: solenoids, voice coils etc. due to the high performance they are capable of (speed and force)

Very difficult to make portable. Generally big and heavy

Tactile Pin Array - Actuation

Principle	Description	Comments
Thermo-electric stim-ulators	Use shape memory alloys which rapidly change shape on change of temperature	Can exert high forces at large displacements but thermal capacity of material limits frequencies to 10Hz
Electro-Magnetic	Use solenoids or small motors	Such mechanical devices lose performance as their size drops resulting in small forces and low refresh rates.
Pneumatic	Use air pockets or plungers controlled by air valves	Can be made small, light weight and flexible (as air source elsewhere). Though compressibility of air limits frequencies to around 10Hz
Piezo-electric	Piezoelectric actuators move lever mechanisms	Can display high forces at a wide range of frequencies but lever mechanisms at required density result in large devices.

Haptic displays – Tactile pin arrays

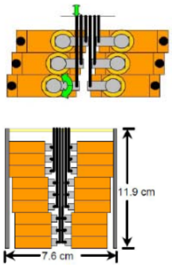
Full display

6*6 display showing sinewave

Servo Arrangement

Servos tightly packed for 2mm pin spacing
Servo rotates translating to vertical movement

Vertical layout of servos
Six blocks of six servos rigidly attached to aluminium chassis



Haptic Displays - Tactile

See laterotactile.com

Stimulator of Tactile Receptors by Skin Stretch (STReSS)

Lateral skin deformation (now laterotactile stimulation) was first described in (Hayward and Cruz-Hernandez, 2000).

Travelling wave of lateral skin deformation induces sensation of moving feature under finger tip.

STReSS is a 2D laterotacltile display … stimulates finger tip with matrix of piezoelectric actuators

Haptic Displays – Force Feedback

Devices which provide force back as well as touch

Used in research since the 60's and available commercially for 20 years.

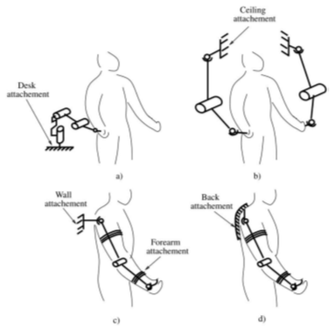
Until recently, prohibitively expensive and experimental

Haptic Displays – Force Feedback

Generally need mechanical grounding to resist user motion

- Exceptions: using gyroscopic forces or air jets
- But limited applications

Can be grounded on desk, wall, or on user body;



Haptic Displays – Force Feedback

Different ways to compare performance, some are:

- Apparent Mass: How much inertia the device has (not just weight)
- Workspace: How large the interactive area is
- Stiffness: How rigid a virtual surface can be displayed

Generally speaking can divide force displays into back-drivable and admittance controlled

FF - Back-drivable devices

Moved by the user

When in "free space" the motors are turned off.

When a virtual surface is contacted the motors turn on and resist movement

Designed to be as lightweight as possible

Trade-off is low force and low stiffness

FF : Admittance Controlled Devices

Use a force sensor to measure user input and move themselves out of the way.

When in "free space" the motors are running and responding as quickly as possible

When a virtual surface is contacted the motors turn off/resist movement

Designed to be as rigid and high force as possible

Trade-off is high apparent mass and low bandwidth.

Force Feedback Examples - Gloves

Pros:
- Many points of contact
- Lightweight so quick to move
- Very large workspace

Cons:
- Limited force direction per contact
- Slow force response
- Low stiffness
- Only basic geometry displayed, no weight or lateral forces (friction)


Serial Linkage Admittance Controlled

Pros:
- High forces
- Low mass and friction for smooth (low bandwidth) movements
- Large workspace
- High stiffness (can exceed human perception of stiffness)

Cons:
- Difficult to have multiple points of contact
- Can't make quick (high bandwidth) movements

Serial Linkage Back-drivable


Pros:
- Usually light/low mass
- Moved very quickly
- Simpler to build & control
- Can have multiple contacts each with multiple DoF

Cons:
- Small motors and light linkages mean low forces and low stiffness.
- Usually small workspaces


Parallel Linkage Back-drivable


Pros:
- More rigid structure than serial linkage, so higher achievable stiffness
- Also higher force output

Cons:
- Small workspaces
- Difficult to have multiple points of contact


Magnetic levitation

Pros:
- High force and high stiffness
- Very low friction

Cons:
- Very small workspace
- Difficult to construct and control

Parallel String/Cable drive (SPIDAR)

Pros:
- Low mass and good workspace
- Cheap/Simple

Cons:
- Low force output
- Can't move too quickly or string gets tangled
- High maintenance

Degrees of Freedom

The Degrees of Freedom of a robotic device are: "The number of independent linear or rotational movements that completely specify the position and orientation of the whole mechanism"

In a haptic device:
- Active DoF can be controlled by the device itself (usually by motors)
- Passive DOF can be tracked, moved by the user but no forces felt

Degrees of Freedom

- The Human arm has ~ 7 DoF
- A free floating object in space has 6 DoF
- When controllable DOF of a robot = movable DOF it is known as holonomic
- A 6 DOF haptic interface is significantly more mechanically complex and hence expensive
- When are 6 DOF devices necessary?

Haptic Presentation Properties

- Cues provided
- Grounding
- Number of display channels
- Degrees of freedom
- Form
- Fidelity
- Spatial and temporal resolution
- Latency tolerance
- Size/available workspace

Logistic Properties

- user mobility
- interface with tracking methods
- environment requirements
- associability with other sense displays
- portability
- throughput
- encumbrance
- safety
- cost

Summary Questions

1. A touch screen interface is not usually considered haptic. Why not and what might be added to make it into a haptic device?
2. It is required to design a full body tactile feedback suit. What aspects of the tactile sensory system can be exploited to make the design simpler?
3. A training simulator is to be built to teach astronauts to assemble equipment in zero gravity. A body grounded force feedback glove system is being considered, what are the pros and cons of using this type of device.

Interaction and Input Devices

Interaction and VR

" Interaction with a virtual world is a key ingredient of a VR experience.

Indeed, if the display of a virtual world does not respond at least to a user's physical movement, then it is not considered virtual reality."

Sherman and Craig, 2003

Interaction Methods

Should be easy and intuitive

Are often unnatural (but humans adapt)

May or may not mimic real life

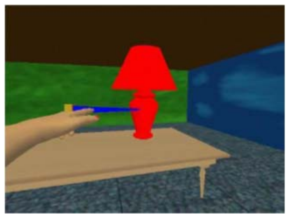
Often rely on metaphors and people's familiarity with them

Interaction Tasks

1. Manipulation
2. Navigation
3. Interacting with others
4. System controls

1. Manipulation

Comprises:
- Selection
- Action
- (and confirmation)



Sometimes selection and action can be rolled into one

Selection

Selection Technique
- Indication of object (methods)
- Confirmation of selection
- Feedback

Some Methods
- Virtual hand
- Ray Casting
- Occlusion Techniques
- Extensions

Selection – Virtual Hands

Method
- Users hand maps directly to virtual environment
- Very intuitive as it directly relate to the real world

Limits
- Can not reach objects that are far away without moving

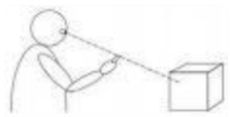
Selection – Ray Casting

Method
- Laser pointer
- Can be attached directly to the hand
- Collision on nearest object
- Allows selection of distant objects

Limits
- Far away objects can be difficult to select
- Occluded objects can not be selected
  - Possibility of traversing all possible selections

Selection – Occlusion

Selection is based on occlusion of an object from a users viewpoint
- Vector drawn between eye position and pointing device
- Selection based on collision of vector and object
- Simplifies selection by only using 2 DOF



Selection – Extensions

Improves the virtual hand technique
- Allows the user to select objects past their physical reach
- Linear scaling
- Non-linear scaling

Action

Actions you might want to perform on a virtual object include moving, scaling, rotating, changing colour…

Some Methods
- Virtual hand
- H.O.M.E.R
- Scaled world grab

Manipulation – Virtual hand

- Direct mapping between users hand and virtual object
- Intuitive object manipulation because it mimics what we do in the real world

Manipulation - H.O.M.E.R

Stands for
- Hand centered
- Object
- Manipulation
- Extending
- Ray-casting

"Normal" ray-casting – a light ray extends from the users' hand and the object attaches to the ray

With HOMER, the virtual hand attaches to the object

Manipulation - Scaled World

The world is scaled to the user instead of hand to object

Any object – no matter size and distance – can be manipulated using real-world metaphor

Allows a basic virtual hand manipulation

Manipulation – World in Miniature WIM

Replica of environment produced in miniature

Miniature is manipulated and the changes are replicated in the environment

Allows manipulation of objects out of users physical reach

2. Navigation

Movement/Travel
- Moving from one place to another

Way finding
- Acquiring and using spatial knowledge
- Knowing where you are relative to where you want to go

Navigation – Movement

Types of Movement
- Exploring – no end goal
- Searching – end goal known
- Manoeuvring – precise movement to position viewpoint

•Methods of Movement
- Target Selection – Pointing, gaze selection
- Steering – joystick control
- World grab and pull
- Physical locomotion

Navigation – Way Finding

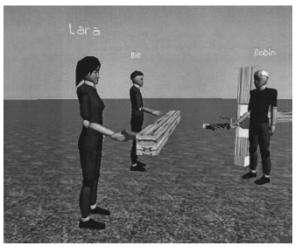
Route generation
- "Move to location"
- Teleportation

Map generation
- Target selection
- World in miniature (WIM)
- Zoom back technique

Things to consider
- Lack of spatial knowledge can make way finding difficult

3. Interacting with others

Consider the types of interactions in
- Shared versus collaborative environments
- Co-located versus distributed environments



4. System Control

Control over the system running the application is often needed
- Opening / Saving files
- Changing sound volume
- Selecting devices to be used
- Setting visual options
  - Eye separation
  - Draw distances
  - Size of text and objects

System Control – Menus

In 2D environments it is common to see WIMP
- Buttons
- Drop down boxes
- Text Boxes
- Tabs
- etc....

2D menus can be adapted for 3D environments
- Advantages as they are recognisable
- Function the same way as on the desktop
- Adapted to run on a tablet

System Control – Menus

3D menus or widgets where more exotic looks are created
- Taking advantage of the third dimension
- Menu cubes and ray cast selection
- Created at hand position
- Heads up display

1D Menu
- Dial based selection
- Normally hand rotation

System Control – Tool Selectors

Similar to menus
- Enables quick access to specific options
- Options related to current task
- Options used regularly
- Tool belt
- Tool chest or box

System Control – Task Tools

Possible tools in an application
- Undo / redo
- Quick save
- Spell check

Related to 3D environments
- Limit motion for manipulation X / Y / Z
- Flashlight
- Shaping / moulding

Input Devices

Desktop Devices	Data Gloves	Direct Human Input
Tracking Systems	Custom Devices	Mechanical and Haptic Devices

Characteristics

Degrees of Freedom (DOF)	Technology	Output	Values
• X, Y, Z • α, β, γ	• Digital • Analogue	• Discrete • Continuous	• Boolean • Integer • Float

Method	Reference	Type
• Active • Passive	• Relative • Absolute	• Position • Motion • Force

Desktop Devices

- Mice
- Spaceballs
- Keyboards
- Joysticks

Desktop Devices - Mice

The standard mouse or trackball:
- Normally 2 DOF
- Active output
- Relative positioning
- Common and recognisable

3D mice or Spaceballs:
- 3 to 6 DOF
- Passive outputs
- Not as commonly known
- Maps well to 3D environments

Desktop Devices – Force Balls

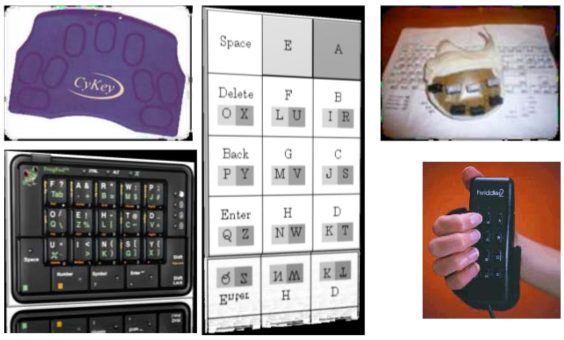
Desktop Devices - Joysticks

Continuous Output
Return to a default positions
2 DOF – but can be more

Desktop Devices - Keyboards

Text input is still needed in VR
Keyboards are Active
Requires a surface
Chord keyboard can free keyboard from a surface.

Chord Keyboards



Data Gloves

Pinch Sensing Gloves

Bend Sensing Gloves

Pinch Sensing Gloves

Made with conductive cloth strips over sections of the gloves

Offers many combinations and gestures

Gestures that do not touch will not work

No accurate representation of the hand position

Bend Sensing Gloves

Strain gauges

Light based sensors

Multiple sensors on each glove

More accurate representation of hand posture

Gestures possible without touching

Wired Gloves

PinchGlove

CyberGlove

CyberGrasp

DataGlove

Direct Human Input

Brain Computer Interfacing (BCI)

Biosignals

Eye Tracking

Speech

Brain Computer Interfacing

EEG is a technique for recording brain activity

- Record brain activity related to the task
- Carry out filtering on the results
- Match the results to activates using probabilities
- Decide on an outcome

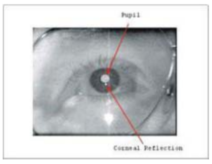
Other Biosignals

Technology is used in some modern prosthetics and VR flight simulators

- Uses dry electrode arrays
- Sensing muscle nerve signals
- Mapping movements to actions

Eye/Gaze Tracking

Cameras used to record eyes
Track pupil location
Contact lenses have been used
Results are converted to coordinates and mapped to the environment



Speech

Speak your intended actions

- Natural way of interacting
- Can interact when hands are occupied

Compromise needed

- Quiet surroundings
- Press to speak
- Key word scheme

Other Devices

Tablets

PDAs

Custom Made Devices

Tablets & PDAs

High resolution displays
Easier to read text
More detail available
Touch surface and stylus
Accurate handwriting or drawing
Gives a physical object to interact with

Custom Devices

Art application

- Paint brush used for detail
- Bucket used for throwing paint
- (not particularly useful in other applications?)

Tracking Systems

Magnetic	Inertial	Acoustic
Optic	Mechanical	Combinations

Tracking Tech. – Performance Criteria

See criteria from Kalawsky, but consider also:

Degrees of freedom per target

- Normally a 3 DoF tracker will measure EITHER position x,y,z OR orientation roll, pitch, yaw (but not both)
- –A 6 DoF tracker will measure position and orientation

Number of simultaneous targets

- Some tracking system can't track many targets at once
- Others must reduce performance for every additional target due to limited bandwidth or similar

Workspace

- Some trackers have a fixed maximum workspace, others may lose performance as workspace increases

Kalawsky – Science of Virtual Reality

Static accuracy: The ability of the tracker to determine the coordinates of a position in space. This is the value without averaging or similar filters applied

Dynamic Accuracy: The accuracy of the system as the sensor is moved. Highly dependant on the integration period of samples, if a long integration period is used then the dynamic accuracy may be very high

Latency: The latency is the time taken to get new data from the sensors including how quickly the sensors respond to changes in position.

continued

Update rate: The time taken to process the data from the sensors and calculate a position. If running faster than the capture (latency part) it may reuse old data (static accuracy may be high). A high update rate alone isn't necessarily an advantage.

Phase Lag: The total time delay of the tracker system, i.e. latency + update rate or the true age of an atom of data as it leaves the tracker system.

Registration: The correspondence between actual position and reported position. Basically calibration both initial and over time, drift.

Signal to noise ratio: signal relative to background noise.

Magnetic Tracking

Method

- Two types: AC and DC
- Low frequency magnetic field induces currents in the receiver coils
- Strength of the signal gives an indication of location and orientation relative to the transmitter

Information

- 3 to 6 DOF
- Affected by metal in the environment
- Normally wired
- 0.1 inch position accuracy
- 0.1 degree rotation accuracy

Magnetic Tracking

Pros:

- Very responsive, low latency
- Can track multiple targets though update rate drops (probably up to ~ 10 at once for real time)

Cons:

- Lose accuracy and registration rapidly as working volume increases (S/N ratio drops)

Inertial Tracking

Method
- Use multiple inertial sensors
  - Gyroscopes (angular measurements)
  - Linear accelerometers (linear measurements, angle wrt. gravity)

Information
- Normally only used for orientation not location because of severe error accumulation from noise and drift
- Compass used to compensate gyroscopic drift
- Can be wired and wireless

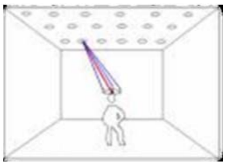
Inertial Tracking

Pros:
- Unlimited working volume
- No line-of-sight issues
- Tilt sensing very accurate
- Highly responsive

Cons:
- Yaw and position has measurement drift. Errors accumulate quickly over time.
- e.g. error of 0.0098m/s^2 (1 milli-g). error is double-integrated: $0.0098\ t^2/2 = 4.5$ m after 30 s

Acoustic Tracking

Method
- High frequency sound emitters
- Microphone receivers
- Distance worked out based on time of flight



Information
- 3 to 6 DOF
- Acoustic reflections or noise can reduce accuracy
- Relatively light and inexpensive
- Can be wired and wireless

Acoustic Tracking

Pros:
- Good accuracy, responsiveness, robustness and registration (if workspace kept small)
- Can have multiple targets (but at a reduction in update rate)

Cons:
- Occluded sensors have a big impact on performance
- Acoustic properties affected by environment (humidity, temperature, pressure)
- Position accuracy better than orientation

Optical Tracking

Method
- Optical sensors
- Measurement of active (LEDs) or passive markers (fiducials, retroreflective markers, natural markers in the environment)

Optical Tracking

Can be inside-out or outside-in (i.e. receivers are fixed or mobile)
- Outside-in has the advantage that a number of cameras can be used to track a single target which increases accuracy and improves line-of-sight
- Inside-out has the advantage of being maximally sensitive to orientation

Image processing systems require controlled light conditions

Wireless

Optical Tracking

Pros:
- High data rates (much faster than sound), great for real time
- Can be made simply, easy access to technology
- Passive systems very scalable (many targets)

Cons:
- Line of sight
- Ambient noise (even for IR)
- Non-uniform performance across axes, often depth less accurate (same reason as humans)

Mechanical Tracking

Includes joystick and mouse (older),

More usually cables and kinematic links with sensorised joints

Pros:
- Good accuracy, responsiveness, registration and robustness.
- Very low latency

Cons:
- Tend to have a limited range of operation.
- Physical links have a fixed length, cables get tangled if rotated
- Low transparency.

Sensor Fusion in Trackers

Rarely actually use one technology in isolation

More common to get information from multiple sources and fuse the data to get a better estimate

Inertial sensors for orientation are usually combined with a 3 axis magnetometer to adjust for yaw drift

Inertial sensors for position are very often combined with optical or acoustic sensors to account for drift

Other sensing technologies are used such as force sensors, bend sensors, capacitance and GPS but normally in combination with the main ones already discussed

Sensor Fusion in Trackers

e.g. Intersense wand
- Inertial orientation
- Acoustic positioning
- Wired and wireless options
- Integrated joystick
- 4 Buttons

Tracking/Input Devices : Wii Remote

Most real trackers like the Wii Remote combine multiple sensing technologies

Has inertial components
- (3-axis accelerometer and 3-axis gyro)

Optical components. High speed cmos camera on the remote (inside looking out) with an IR pass filter detects 4 IR LEDs on the sensor bar

http://www.youtube.com/watch?v=Jd3-eiid-Uw

MS Kinect

Wide variety of input types:

gesture, face and speech recognition

Normal camera plus 2 cameras for depth sensing and 4 microphones

Depth sensing works by projecting a pattern on the scene (presumably in IR). Two cameras for depth are sensitive to pattern. Pattern is denser the further away it is

Normal camera + depth sensing used together to isolate individual users and find facial characteristics and gestures

Speech recognition can isolate separate voice commands and select which person is talking

Simulating a virtual world

This lecture considers two related topics

Physics Engines

- Which allows realistic motion of virtual objects
- Applies to VR and to Games
- We consider kinematic and dynamic motion
- We consider timings of the motion

Interaction with Objects

- Realistic interaction with bodies
- How handle Collision detection and collision response

On Virtual / Game Physics

Game physics

- computing motion of objects in virtual scene
  - – including player avatars, NPC's, inanimate objects
- computing mechanical interactions of objects
  - – interaction usually involves contact (collision)
- simulation must be real-time (versus high precision simulation for CAD/CAM, etc.)
- simulation may be very realistic, approximate, or intentionally distorted (for effect)

Why it is important

Can improve immersion

Can support new game play elements

Becoming increasingly prominent (expected) part of high-end games

Like AI and graphics, facilitated by hardware developments (multi-core, GPU)

Physics engine market is becoming more mature

Physics Engines

Like games engines, can build your own or use/buy another

If build own

- Choose what features you want
- Can make application specific optimisations
- Can be innovative
- But expensive in time to develop

If buy

- Have (nominally) a complete solution
- Have (hopefully) proven robust code
- Features are already defined
- Could be expensive – though some are free

Why Discuss Concepts

To use a Physics engine effectively,

- Best to understand what it is doing
- Especially if you need to implement some features
- Like owning a car – better if know how works

Topics to be covered

- Kinematics and Dynamics
- Projectile motion
- Collision detection and response

Kinematics

How objects move without considering mass/force

Basic quantities

- acceleration a, velocity v, initial velocity u, distance d, and time t

Standard equations

- $d = v\,t$
- $v = u + at$
- $d = ut + \frac{1}{2}\,a\,t^2$
- $v^2 = u^2 + 2\,a\,d$

Example

How high will a ball go if you throw it vertically with initial velocity 5 m/s

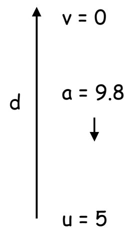
$v^2 = u^2 + 2\ a\ d$

At top v = 0, so ...

$0 = 25 + 2 * -9.8\ * d$

So d = 1.28 m

Answer independent of mass of ball



Computing Kinematics in Real Time

```
start = getTime()                // start time
   p = 0                         // initial position
   u = 10                        // initial velocity
   a = -9.8
function update () {             // in render loop
   simulate(getTime() - start);
}
function simulate (t) {
   d = u * t + 0.5 * a * t * t
   move object to p + d
}
```


Issue

Number of calls and time values used in simulate depend on the frame rate – which may change

For simple problem not too much of an issue

But complex numerical simulations can be sensitive to time steps

(Can get truncation errors and other numerical effects)

Results should be repeatable regardless of host machine

Helps with debugging and better experience of VW

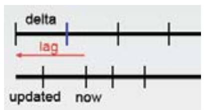
So better to control simulation interval separately

Frame Rate Independence

```
delta = 0.02              // physics simulation interval (sec)
lag = 0                   // physics lag
updated = 0               // time of last update
function update () {      // in render loop
   now = getTime()
   t = (updated - start) - lag
   lag = lag + (now - updated)
   while ( lag > delta )
      simulate(t)
      t = t + delta
      lag = lag - delta
   updated = now
}
```

Simulation ticks

Frame updates



For 3D

Consider all quantities involving positions to be vectors

Then use normal equations

$\mathbf{d} = \mathbf{v}\ t$

$\mathbf{v} = \mathbf{u} + \mathbf{a}\ t$

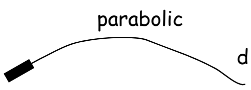
$\mathbf{d} = \mathbf{u}t + \frac{1}{2}\ \mathbf{a}\ t^2$

eg Projectile ..

u = [0, 5, 2]; a = [0, 0, -9.8]

Uses scalar products

$(x_1,y_1,z_1).(x_2,y_2,z_2) = x_1\ x_2\ + y_1\ y_2 + z_1\ z_2$



Dynamics

Kinematics does not consider why an object accelerates or why acceleration may change

Proper simulation needs to also include force and mass

Newton's Laws of motion

- Body remain at rest, or travel in straight line at a constant speed unless acted on by a force
- Acceleration is proportional to resultant force, and in same direction as that force ....
- For every action there is an equal and opposite reaction

Continued

From 2nd law: force = mass * acceleration (f, a vectors)

Force→acceleration→change velocity →change position

Key point

- Dont get instantaneous changes in speed and direction
- Early Pac-Man / Mario style games did

Hence in my robot simulations

- User determines the desired speed
- New speed = function (current speed, desired speed)

How are Forces Applied

Without contact

- Gravity
- Wind
- 'magic'

Usually though involves contact

- Collision ... Rebound
- Includes spring type effects
- Friction .. Rolling or sliding

But detecting when collisions occur is not trivial

- We will return to that later

Physics in VR – Diff Eq

Define relationship between a variable and its differential

Force = mass *Acceleration

$$F(x(t)) = m\,\frac{d^2x(t)}{dt^2}$$

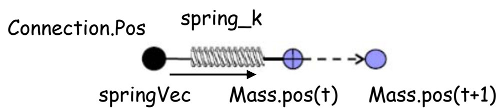
Force on object at Pos x at time t

Acc = change of Vel
Vel = change of Pos

Once have expression for acceleration, can integrate to get velocity and then again for position

Standard methods available for 'numerical' integration

Example - Spring



springVec = Mass.pos – Connection.pos

Mass.pos = mass.applyForce(-springVec*spring_k)

Physics Engines

Integrate laws of physics into a game / virtual world

- Laws are represented by ODE's
- Physics Engines contain "solvers"

Independent of "gameplay"

- Analogous to how a Game Engine supplies independent "renderers"
- Usable for a wide number of genres
  - Race simulation, Robotics
  - People jumping, etc

Primary Physics Engine Classes

World – also called Physics Space

- Container for Bodies, Constraints, Collisionshapes, CollisionHandlers and Solvers

Body

- Representing a single body – rigid or soft
  - A character game object usually has multiply body objects

Constraint

- Representing a connection between two bodies

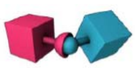
Rigid Bodies

Have Fixed Attributes
- Mass, Mass distribution

And Dynamic Attributes
- Position, Linear/Angular velocity, Orientation

Constraints / Joints

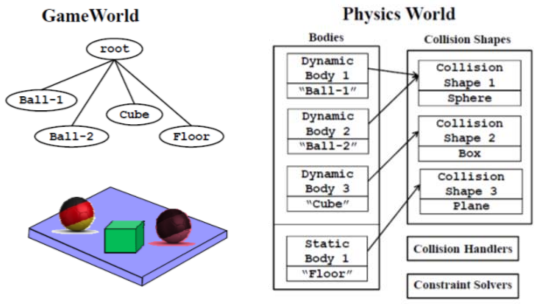
Enforced relationships between bodies, eg


Ball and Socket


Hinge


Slider / Piston

Physics Space



Adapted from John Clevenger, CSUS

On Collisions ..

- Re haptics, we interact with a world that pushes back.
- Like the real world, our virtual world can (should?) contain objects which move.
- Applies to physically based simulation so virtual objects must move under influence of forces
- These objects should never occupy the same space.
- To prevent interpenetration the simulation must:
  - Detect when or if interpenetration is about to occur (Collision Detection)
  - And take the appropriate action to prevent interpenetration (Collision Response)

Collision Detection

Has been defined as:
- "To Automatically report a geometric contact when it is about to occur or has actually occurred"
- – M. Lin & S Gottschalk

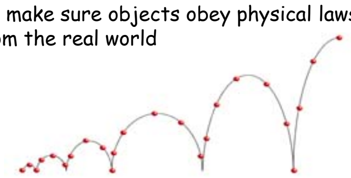
Only part of the problem, to take the correct action we may also need to know:
- What has collided
- When it first happened
- Where it happened
- How much intersection there is

Simulationoral Coherence – Continuous Collision Detection

- In the real world time is continuous, in VR time is discrete
- So if a collision is found it almost definitely occurred prior to finding it – Time of Impact problem (TOI)
- Worse, very fast objects may pass through each other in a single time step – i.e. no collision will be found
- Different ways of solving the problem, none are perfect:
  - Reduce the simulation time step so objects don't move father than their own size in a single step
  - Use Ray-Casts or Swept-Volumes to see if the space traversed by objects overlaps

Collision Response

- We've found a collision so now what?
- When two objects are detected as colliding or about to collide we must take action
  - Can't just arbitrarily reposition – would be unrealistic and difficult to interact with
  - Must make sure objects obey physical laws we expect from the real world



Collision Response – Rigid Bodies?

When objects collide they might
- Bounce (Rigid-body mechanics)
- Deform (soft-body mechanics)
- Break (fracture mechanics)

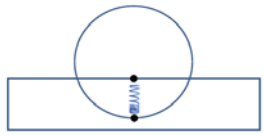
We will look at rigid bodies, most common and simplest

For rigid bodies we calculate forces and impulses to adjust velocities so objects don't violate physical laws

Will look at some common techniques and approaches

Collision Response – Penalty Methods

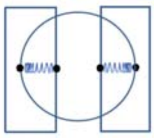
Don't prevent objects overlapping but try to minimise it
- The 'penalty' is how far into a non-allowable situation we have moved and the response is proportional
- Simple version - when objects collide a virtual spring is inserted at each contact point to push objects apart
- Nice/simple in theory, in practice difficult to get stable



Penalty Methods – What's the Problem?

Part of the problem comes from treating all the contact points separately
- Systems with more points of contact will be stiffer than those with less
- Multiple springs can cancel each other out or setup oscillations

Unexpected situations:
There is no net force on the sphere



Penalty Methods –Discrete Time Problem

Biggest problem due to nature of discrete time simulation

Consider a ball hitting the ground:
- Ball's collision detected at time step AFTER it has hit
- Then we apply a force to it which slows it down
- As ball goes further below floor spring force increases
- Until the velocity reaches zero and is then reversed
- On way out force applied to ball gradually reduces
- We detect ball has left the ground AFTER it has occurred yet we were still applying a force to it
- So – ball leaves with more velocity than when it landed!

Discrete Time Problem

Extra energy added to collisions creates unstable sims

More energy is added if the spring force is stiffer or if the simulation time step is longer

i.e. Harder Surface = Stiffer Spring = Bigger error

Can have soft squishy interaction with low error or more rigid contact but more likely to be unstable

If spring stiffness is low objects can be seen to overlap

Can get rid of excess energy with friction in the springs but more damping creates unrealistic motion

Simulations need to be 'tuned' to achieve a good response – not good for general purpose interaction

Constraint Methods

So if want no overlap we need an infinitely stiff spring which can produce an instantaneous change in velocity

Such an Impulse creates a change in momentum as a force creates a change in acceleration

To recreate this we calc exact velocity that should occur after a collision based on the velocity before

Using the simple law of elastic collisions we know the RELATIVE velocity:
- $Vel_{after} = e*Vel_{before}$
  - 'e' is the coefficient of restitution ($-1 < e < 0$)

Continued

We must then apply an equal and opposite amount of impulse 'j' to each object

To find this we can setup two simultaneous equations relating the velocity of each object A and B before and after, their masses and applied impulse 'j':

$Va^{+} = Va^{-} + j/Ma$; $Vb^{+} = Vb^{-} - j/Mb$

Two equations and two unknowns we can solve them and our objects will separate at the correct speed

This was just linear momentum but angular (rotational) momentum can be calculated in the same way

Constraint Methods - Problems

What happens if we have resting contact?

- Use force and acceleration not impulse and momentum

What if many simultaneous contacts?

- To solve more than one point of contact, form a system of non-linear equations that cannot be found analytically
- Even small stacks of objects creates very large systems of equations which are extremely complex to solve
- Solutions out of scope of this course

Impacts on VR Design

The more objects that can be put on top of each other the slower the simulation will get

Some solutions are highly accurate

- but get exponentially slower with number of contacts

Some solutions are ~linear with the number of contacts

- but not so accurate,
- things may fall over,
- heavy objects can't be put on light objects, etc.

Impacts on VR Design

For purely graphical realism the quicker solution may be fine, you can't tell if a box is heavy just by looking (primary & secondary qualities)

For a haptic simulation, a more accurate solution is usually required

- Limits the number of moving objects you can have

A physics engine for graphics can run at 60Hz

But a physics engine for haptics need to run at 500Hz

Some Links

Search youtube for 'physics engine'

More on basic game physics:

- http://www.myphysicslab.com/collision.html
- http://www.myphysicslab.com/contact.html
- http://chrishecker.com/Rigid_Body_Dynamics

Opensource Physics Libraries:

- http://bulletphysics.org/
- http://www.ode.org/
- http://www.box2d.org/

Virtual Reality and Artificial Life

It is possible to develop models for a Virtual World
Buildings are straightforward, for instance
Living objects less so
Then we need to consider behaviour of such objects
Techniques from artificial life can be relevant
See for instance Demetri Terzopoulos' 1999 paper
    Artificial Life for Computer Graphics
Also
    AI and Artificial Life in Video Games
    by Guy W Lecky-Thompson

Terzopoulos' abstract

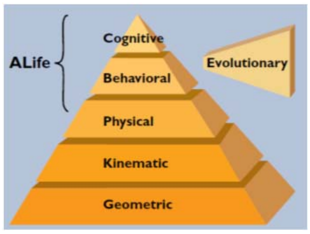
"Computer graphics modeling for image synthesis, animation, and virtual reality has advanced dramatically over the past decade, revolutionizing the motion picture, interactive game, and multimedia industries. The field has advanced from First-generation, purely geometric models to more elaborate physics based models. We can now simulate and animate a variety of realworld, physical objects with stunning realism. What's next?"

Lecky-Thompson

AI, or artificial intelligence, builds better games by directing behaviors inside the games that make them more difficult, while artificial life, or A-Life, adds unpredictability of play and a more lifelike environment to games.

AI can be built up in a game by layering behavioral models on static data to produce behavior that is both intelligent and unpredictable.

Animation Modelling Hierarchy



Early breakthrough model geometric and kinematics

1980s add Physical models

Now add behaviour / ALife

Finally add 'intelligent' / AI

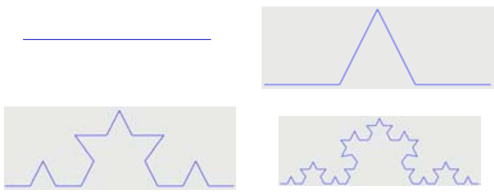
Some Concepts

Design of Living Objects
    Fractals, L-systems etc
Artificial Evolution
    Complex virtual entities created to do tasks
Behaviour of Objects
    Flocking and Boids
    MASSIVE

Fractals

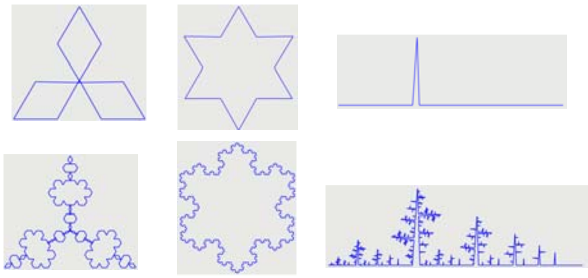
Complex objects defined by systematically and recursively replacing parts of a simple start object with another, using a simple rule

Simplest : Have initiator and generator, both many lines.
    Replace each line in the initiator with the generator shape.
    Makes more lines, so replace all these lines with generator

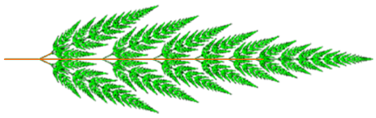


RJM's Page

http://www.reading.ac.uk/~shsmchlr/jsrobotstyle/demoFractal.html



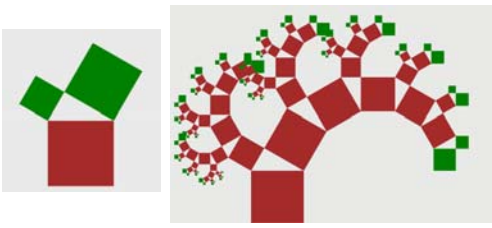
Some Natural Examples



Barnsley Fern

Series of dots each calculated relative to previous ones

Pythagoras Tree



Can also include randomness..

For more sophisticated shapes have formal rules …

Lindenmayer System (L-Systems)

Mathematical formalism proposed by biologist Aristid Lindenmayer in 1968 : foundation for axiomatic theory of biological development

A Lindenmayer system is a variant of a formal grammar (a set of rules and symbols), acting as a parallel rewriting system

It models the growth processes of plants, organisms and self-similar fractals – due to the recursive nature of the rules.

Examples

Useful: http://algorithmicbotany.org/papers/#abop

Details

L-systems are defined as a tuple

$G = \{V, S, \omega, P\}$

V (the alphabet) is a set of symbols containing elements that can be replaced (variables)

S is a set of symbols containing elements that remain fixed (constants)

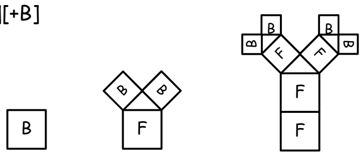
ω (start, axiom or initiator) is a string of symbols from V defining the initial state of the system

P is a set of production rules defining the way variables can be replaced (inc constants, variables)

Example

An L-system is an ordered triplet

- *G = <V, w, P>*
- *V = alphabet of the symbols in the system;* V = {F, B}
- *w = nonempty word , the axiom:* B
- *P = finite set of production rules (productions)*
- B := F[-B][+B]
- F := FF



Production Rules for Artificial Plants

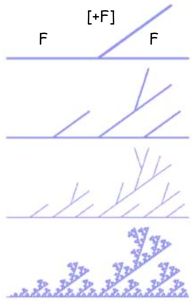
Add branching symbols [ ]
- simple example
- Main trunk shoots off one side branch
  - Angle 45
  - Axiom: F
  - Seed Cell
  - Rule: F=F[+F]F
  - Angle

Gen 1

Gen 2

Gen 3

Gen 8



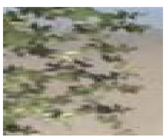
Example

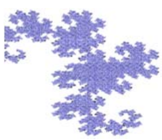
variables : X F
- constants : + − [ ]
- start : X
- rules : (X → F−[[X]+X]+F[+FX]−X), (F → FF)
- angle : 25°

Here, F means "draw forward", − means "turn left 25°", and + means "turn right 25°".
X not drawing action : controls curves' evolution
[means save current values which are restored by]

Results

More Example L - Systems





Colin McRae Dirt : pre-generated and preloaded!

Artificial Evolution

Aim to find a solution to a particular problem:
- Create a population of individuals to represent potential solutions
- Evaluate the individuals
- Introduce some selective pressure to promote better individuals (or eliminate lesser quality individuals)
- Apply some variation operators to generate new solutions
- Repeat

Karl Sims

Evolution of physically realistic agents

Have populations comprising different components …

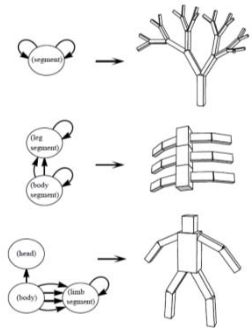
They evolve for doing different tasks

Eg For swimming, Walking, Jumping

Archive video

https://archive.org/details/sims_evolved_virtual_creatures_1994

Creature Morphology

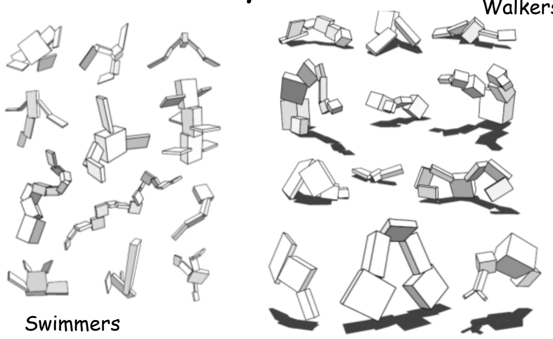


Genotype –
- directed graph

Phenotype –
- hierarchy of 3D parts
- the creatures generated

Example Results

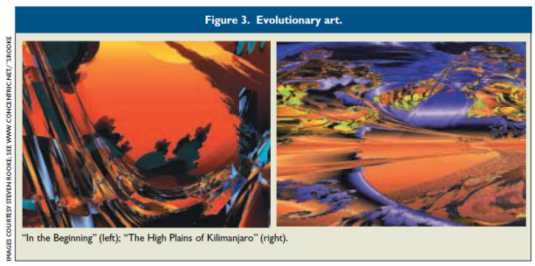
Walkers



Swimmers

Jumpers

Resultant Art – by Steven Rooke



Making Life Realistic

Fractals etc can help make realistic looking images

But 'life' tends to move and interact

So want artificial life to also behave realistically

Need appropriate behaviour, dependent on surroundings

Of interest is having situations with multiple entities

Applications
- Film and TV
- Games
- Simulations : engineering, architecture and transport…

Flocking - Motion

Collective motion:
- Fish in schools, sheep in herds, birds in flocks, lobsters in lines

Characteristics of animal aggregations:
- Distinctive edges
- Freedom to move within own volume
- Coordinated movement

Benefits of Flocking
- Predator protection
- group foraging
- Social advantages – mating

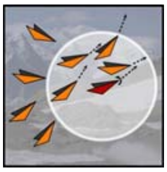
Craig Reynolds and Boids

http://cmol.nbi.dk/models/boids/boids.html 3 rules

Separation
Steer to avoid crowding with local flock mates.

Alignment
Steer toward the average heading of local flock mates.

Cohesion
Steer to move toward average position of local flock mates.

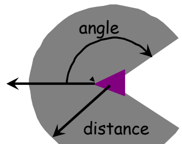




Craig Reynolds & "boids"

Each boid has direct access to whole scene's geometric description

For Flocking react only to flockmates within its small neighborhood.

Neighbourhood = model of limited perception / region where flockmates influence steering



distance, measured from the center of the boid

angle, measured from boid's direction of flight

Flockmates outside local neighborhood ignored

http://www.red3d.com/cwr/boids/

http://dynamicnotions.blogspot.com/2008/12/flocking-boids-c.html

MASSIVE

Software package by Stephen Regelous for visual effects

Key feature : can create 1000s …1000000s of agents

Fuzzy logic used so each agent react individually to surroundings

Used to control prerecorded animation clips
(say from motion capture or hand animation)

Creates characters that move, act and react realistically

Developed initially for Lord of the Rings …

Used in Avatar, King Kong, Narnia, I Robot, Doctor Who

http://www.massivesoftware.com/

Some Images

Summary

Artificial Life / Intelligence have their place in Virtual Worlds/ computer games

Plenty of techniques available – an overview given here of some of the concepts.

Where will VR take you

3 april 1016 issue of the IET's E&T Magazine

http://eandt.theiet.org/magazine/2016/03/virtual-reality-introduction.cfm?origin=EtOtherStories

2016 may be the year that virtual reality (VR) technology breaks into the mainstream. Hardware manufacturers like Oculus are gearing up, with the first Rift headsets reaching customers at the end of March and many people lining up to experience different 'realities'

Topics

More

Happy Reading /// End of Course