CMSC 498W
Introduction to Virtual and Augmented Reality

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Virtual Reality

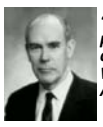
- Right from the time we are born, our senses map the world around us to a set of signals
- What if we were to redefine that mapping through simulated means?
  - Could we do this well enough to have our nervous system treat the synthetic signals as real?

Recent Virtual and Augmented Reality Activity

- Facebook acquisition of OculusVR
- Google investment in MagicLeap
- Microsoft HoloLens
- ODG/Qualcomm
- Intel acquisition of Composyt Light Labs
- Samsung Gear VR
- Sony Morpheus
- HTC/Valve Headset
- Vuzix, metaio, and several other startups …

The Ultimate Display

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



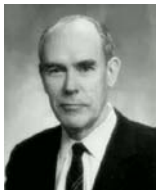
"With appropriate programming such a display could literally be the Wonderland into which Alice walked!"

Ivan Sutherland, May 1965

Guildford Castle

The Ultimate Display

A chair displayed … would be good enough to sit in, and a bullet displayed … would be fatal.



Ivan Sutherland, Proceedings of the IFIP Congress, 1965

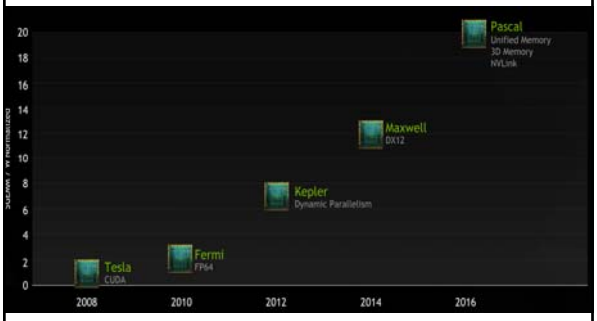
Key Ingredients of Mixed Reality

- Interactive 3D Graphics: Image Generation
- High-Fidelity Displays: Image Delivery
- Real-time Update: Head/body Tracking

Mixed Reality Continuum

Milgram and Kishino, 1994

Image Generation



NVIDIA Roadmap

Key Ingredients of Reality

Our sensory signals change with changes in:

- Head motion
  - At least 4 of the 5 senses: sight, sound, smell, taste
- Limb movement
  - Primarily touch

Changes are all time-critical!

- Visual latency: initially 30-60Hz but now we believe 200 Hz or greater
- Aural latency: >100Hz
- Haptic latency: 1 to 10 kHz

Inertial Tracking

- Accelerometer: Motion sensors, tilt sensing
- Gyroscope: Angular velocity (unaffected by gravity)

Image Delivery: Head-Mounted Displays

Visual Challenges in AR

- Thin, Lightweight, High resolution, wide field of view displays
- Registration of real and virtual worlds
- Rendering of virtual worlds mixed with real worlds
- Perception management for AR

Tracking

- Ultrasonic
- Electromagnetic
- Inertial
- Optical/IR

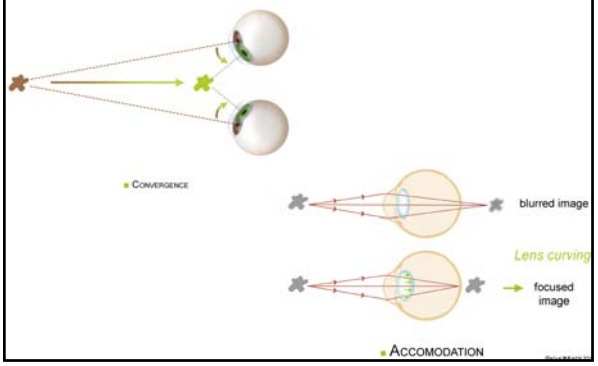
Is all this any good?

- What can VR/AR do?
- Is it any better than a desktop?
- What are the promises and pitfalls?
- Where next?

Pitfalls/Challenges

- Latency
- Resolution
- Vergence-Accommodation
- Registration
- Tracking Range

Vergence Accommodation Conflict



Latency leads to Motion Sickness

Vergence Accommodation Conflict

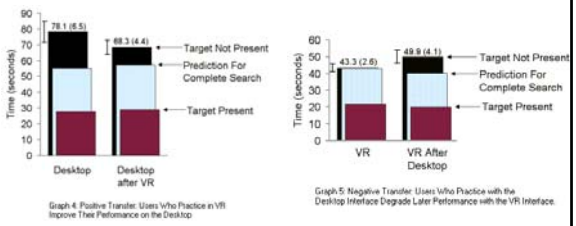
Resolution

Stony Brook 1.5 Gigapixel Reality Deck

Registration: Static and Dynamic Errors

Tracking: Range vs Accuracy

The Hope: Immersion



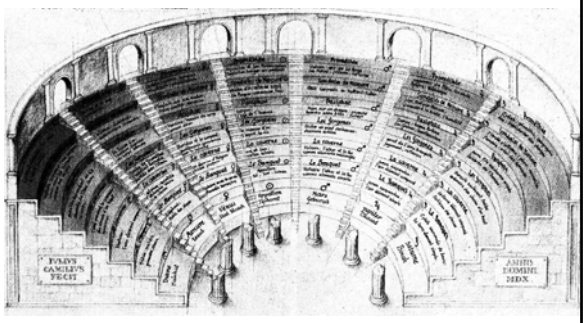
Graph 4: Positive Transfer. Users Who Practice in VR Improve Their Performance on the Desktop

Graph 5: Negative Transfer. Users Who Practice with the Desktop Interface Degrade Later Performance with the VR Interface.

Pausch, Proffitt, Williams, SIGGRAPH 1997

So is there any hope?

A Historical Aside: Ars Memoria



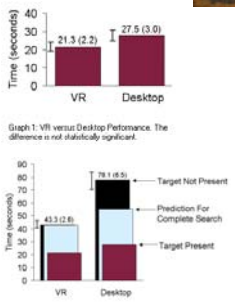
An example of a memory palace, from Giulo Camillo, *L'idea del Theatro*, 1550

The Hope: Immersion

Quantifying Immersion in Virtual Reality

Randy Pausch[1], Dennis Proffitt, George Williams[2]
University of Virginia
pausch@cmu.edu, drp@virginia.edu, gcw@best.com

Figure 1: *Users Stood in the Center of This Room and Looked For Target Letters*



Graph 1: VR versus Desktop Performance. The difference is not statistically significant.

Graph 3: Observed Times To Search the Entire Room and Determine that No Letter is Present.

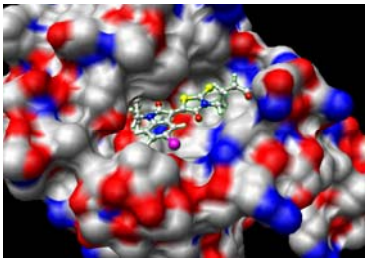
SIGGRAPH 1997

The Hope: Presence
Walking over the Ledge (2001)

Physiological Measures of Presence in Virtual Environments

Michael Meehan Brent Insko Mary Whitton Dr. Frederick P. Brooks, Jr.

The Hope: Direct Manipulation Molecular Docking



13 fold speedup with direct 6DOF manipulator

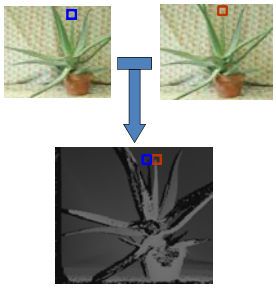
Brooks, Ouh-Young, Batter, Kilpatrick, SIGGRAPH 1990

Visual Attention in Virtual Reality

- Attention Management API:
  - Color
  - Texture
  - Geometry
  - Lighting
- Influence visual attention in HMDs
  - Validate through user studies

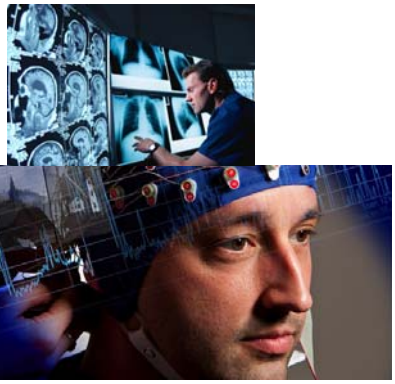
Vision-based Tracking

- Depth from stereo
- Compute how far each point in right image is from the same point in left image
- OpenCV 3.0 alpha routines for CUDA and OpenCL:
  - Block matching
  - Belief propagation

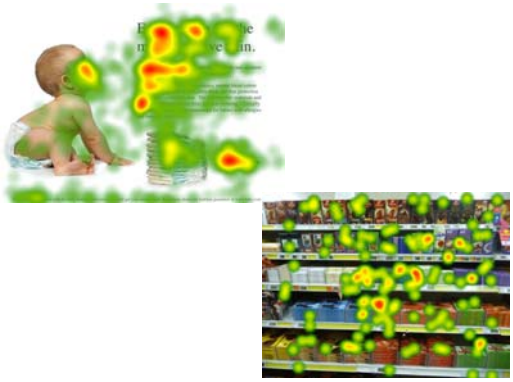


Top graphic adapted from "Computer Vision Acceleration Using GPUs" by Shahroad Qureshi

Neuro Education: Learning and Training



What Controls Visual Attention?



Curing Phobias through Augmented Reality

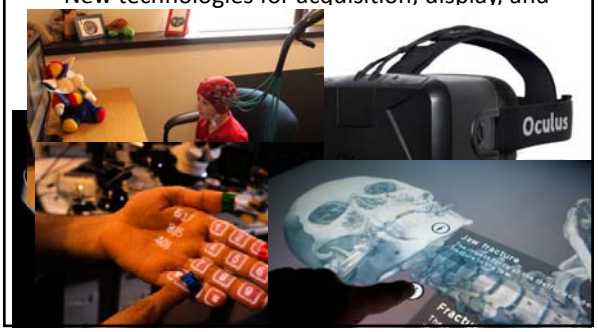
Botella et al. 2010

Maintenance, Assembly, Repair using Augmented Reality

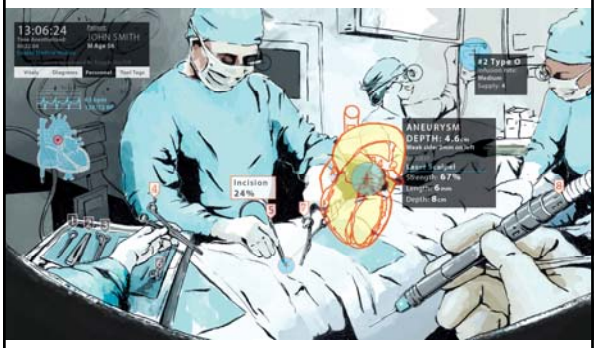
Mixing Real and Virtual Environments

Technology as a Catalyst

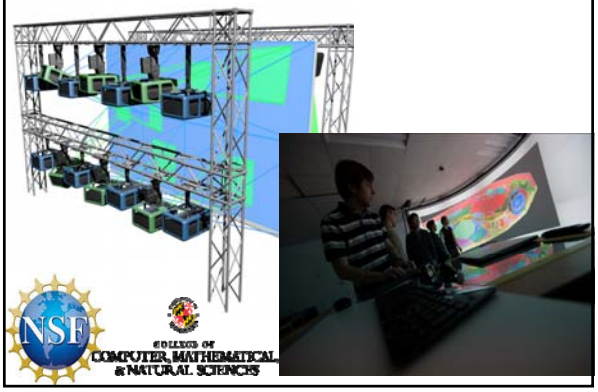
- New technologies for acquisition, display, and



Mixing Real and Virtual Environments



Next steps: Augmentarium



Mixing Real and Virtual Environments

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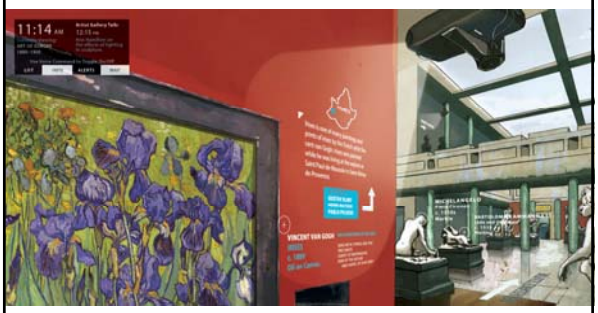

Course Motivation

These are just the first glimpses into a new kind of human augmentation that leverages advances in

Graphics, Wearables, Sensors, HPC, and Perception that amplifies human capabilities