Augmented Realilty: Basics and Applications

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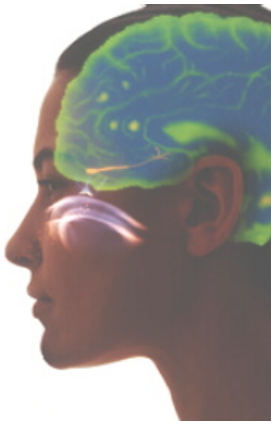

OUTLINE

- What is AR?
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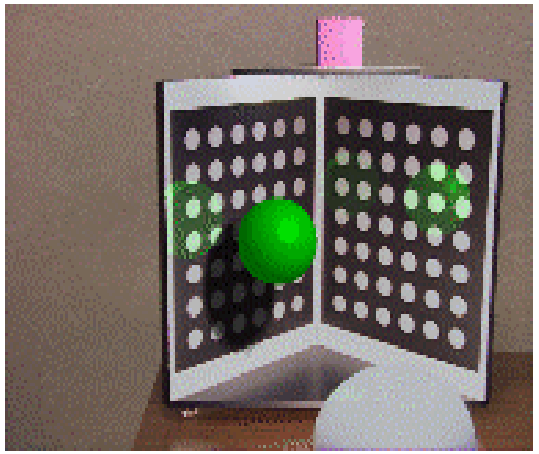
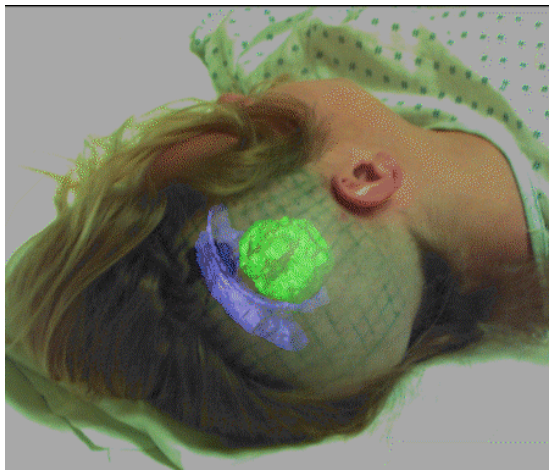




What is AR?

- *Augmented Reality* (AR) is a variation of *VE/VR*.
  - VR technologies completely immerse a user inside a synthetic environment. While immersed, the user cannot see the real world around him.
  - In contrast, AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world.
- AR supplements reality, rather than completely replacing it. It creates the illusion that the virtual and real objects coexisted in the same space.
- AR can be thought of as the "middle ground“ between VE (completely synthetic) and telepresence (completely real)

What is AR?

e.g., Real desk with virtual lamp and two virtual chairs
(ECRC)

What is AR?

- AR systems have the following three characteristics:
  - Combines real and virtual
  - Interactive in real time
  - Registered in 3-D
- This definition allows other technologies besides Head Mounted Displays (HMDs) while retaining the essential components of AR.
- ***Does not include*** film or 2-D overlays like "*Jurassic Park*" featuring photorealistic virtual objects seamlessly blended with a real environment in 3-D, as they are not interactive.
- 2-D virtual overlays on top of live video can be done at interactive rates, but the overlays are not combined with the real world in 3-D. Hence, they are not AR.

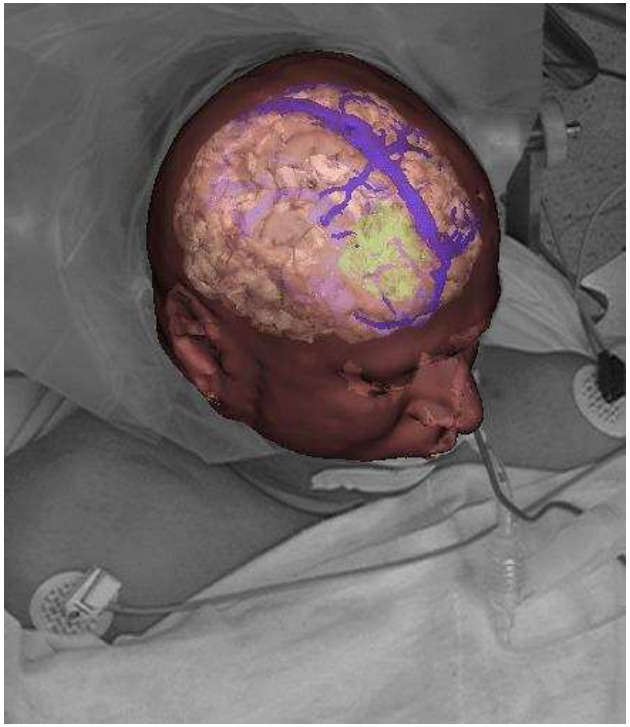
Motivation

- AR enhances a user's perception of interaction with the real world.
- The virtual objects display information that the user cannot directly detect with his own senses.
- The information conveyed by the virtual objects helps a user perform real-world tasks.
- AR is a specific example of what is known as ***Intelligence Amplification (IA):*** using the computer as a tool to make a task easier for a human to perform.

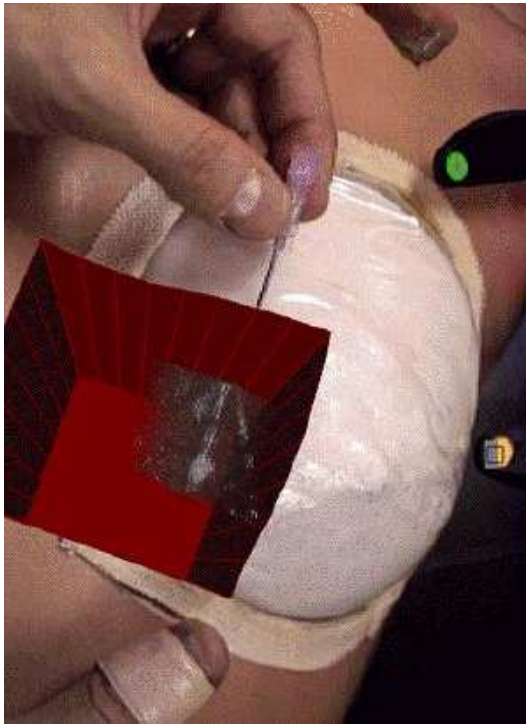
Applications

- Main classes of applications:
  1. Medical
  2. Manufacturing and repair
  3. Annotation and visualization
  4. Robot path planning
  5. Entertainment
  6. Military aircraft
- There are several miscellaneous applications.

Applications: Medical



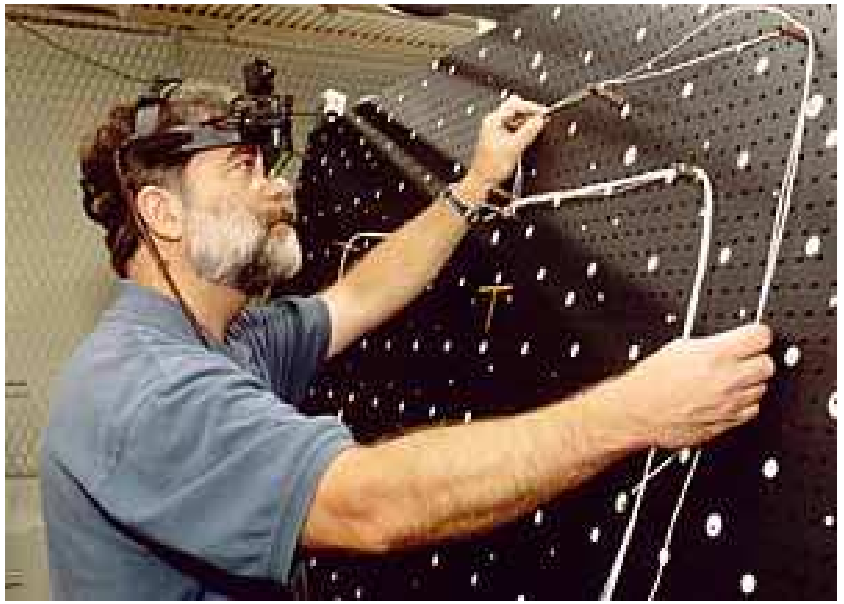
Surgeon X-ray vision: Minimally-invasive brain surgery
(AI Lab, MIT)



Real-time stereo HMD display with ultrasound volume display of needle inserted into the breast
(Andrei State, UNC)

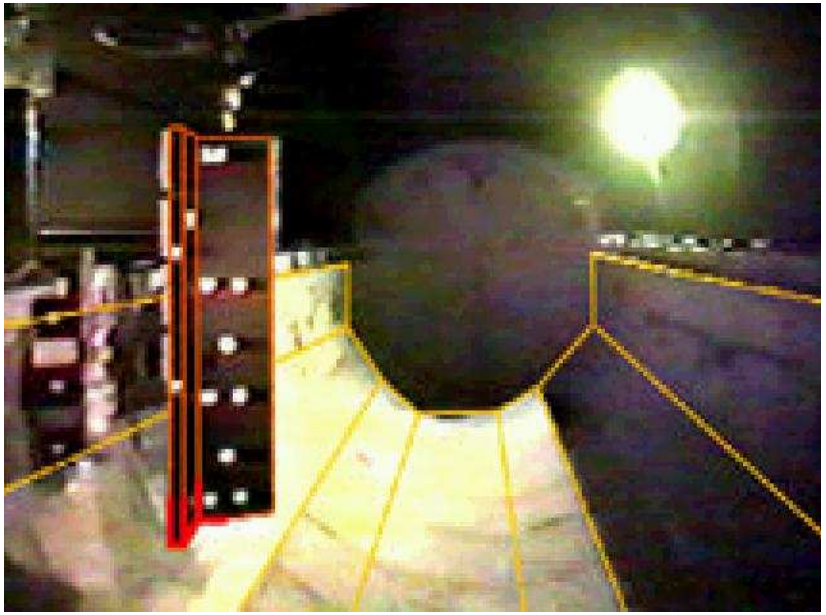
Applications: Manuf & Repair

Augmented view of River Wear in Sunderland, Newcastle (U.K.) with a planned footbridge
(UK)



VR HUDset used in the wire shop to connect the wires by showing an image of the circuit and information about type of wire to be used
(Boeing, US)

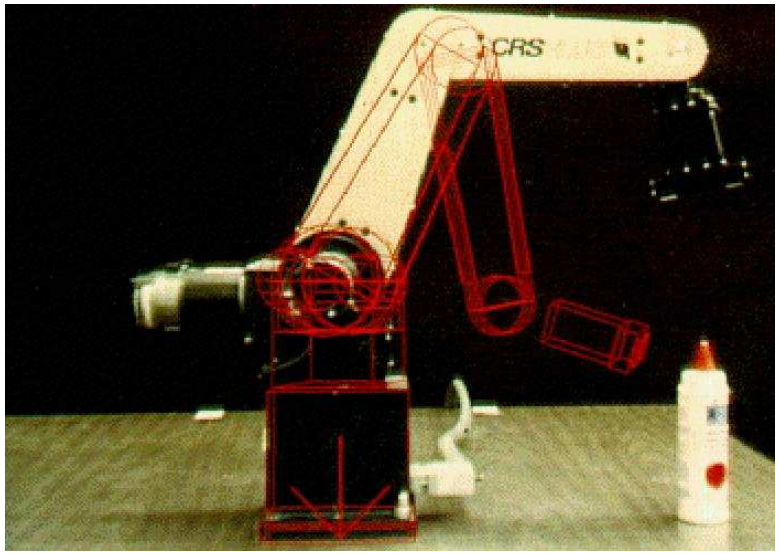
Applications: Annotation

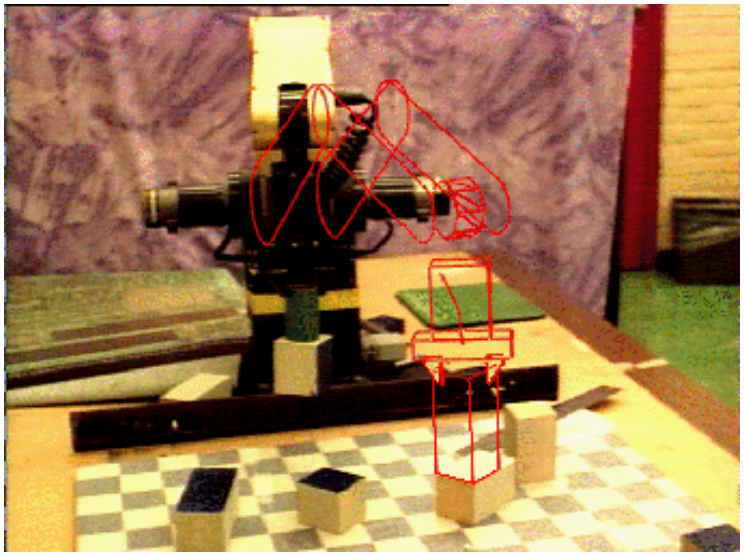


Virtual lines help display geometry of shuttle bay as seen in orbit
(U. Toronto, Canada)

Engine model part labels appear as user points at them
(ECRC)

Applications: Robot path planning





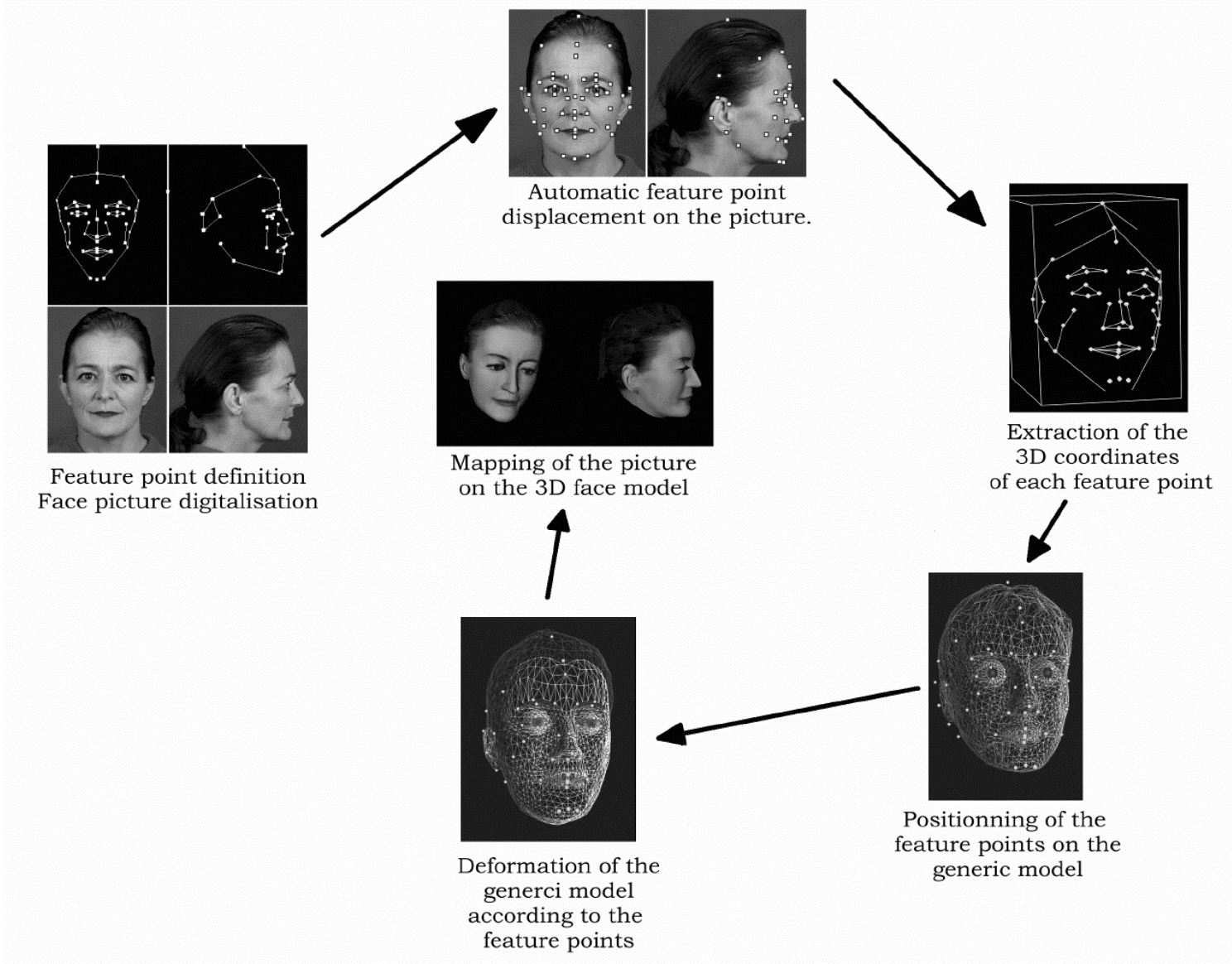
Virtual lines show planned motion of a robot arm

(U. Toronto, Canada)

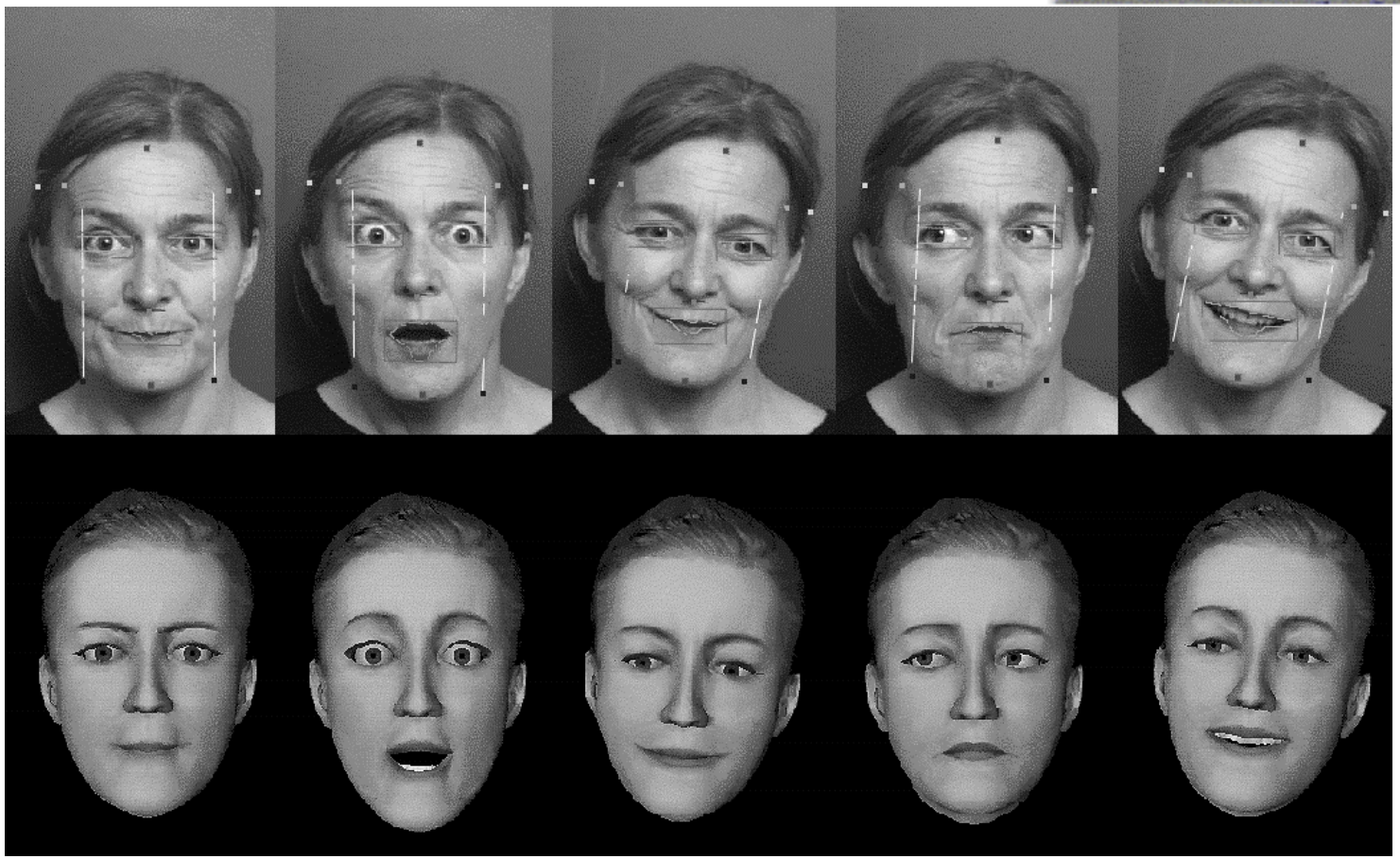
Applications: Entertainment

Screenshot from the movie“Who Framed Roger Rabbit?” blending the real character and background with computer generated cartoon characters

Entertainment: Virtual actors



Entertainment: Virtual actors

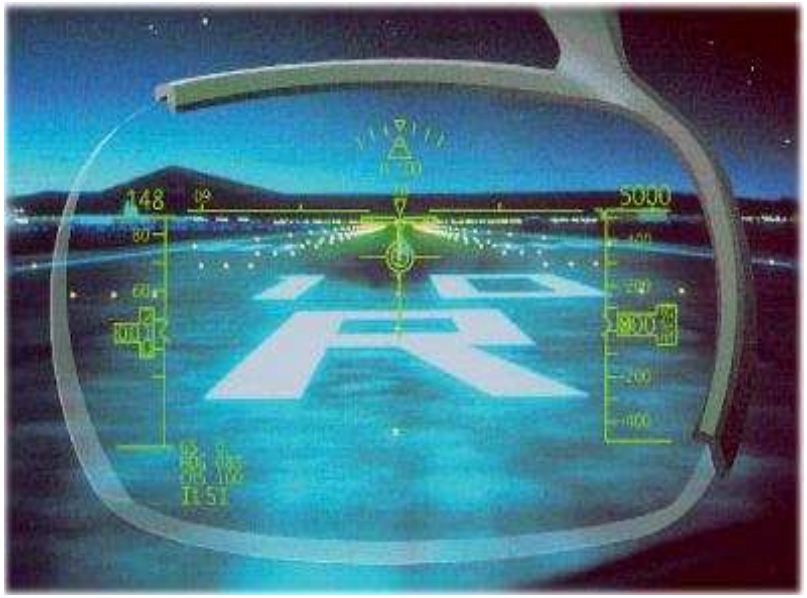


Real-time facial expression recognition and animation of the clone's face

(MIRALab, University of Geneva)

Applications: Aircraft

Boeing 737 cockpit with Head-up Display (HUD)
(Flight Dynamics Inc.)



Head Up Guidance System (HGS)
(Flight Dynamics Inc.)

Applications: Nightvision

Nightvision system in the 2000 Cadillac DeVille

(Cadillac.com.)

AR: Applications

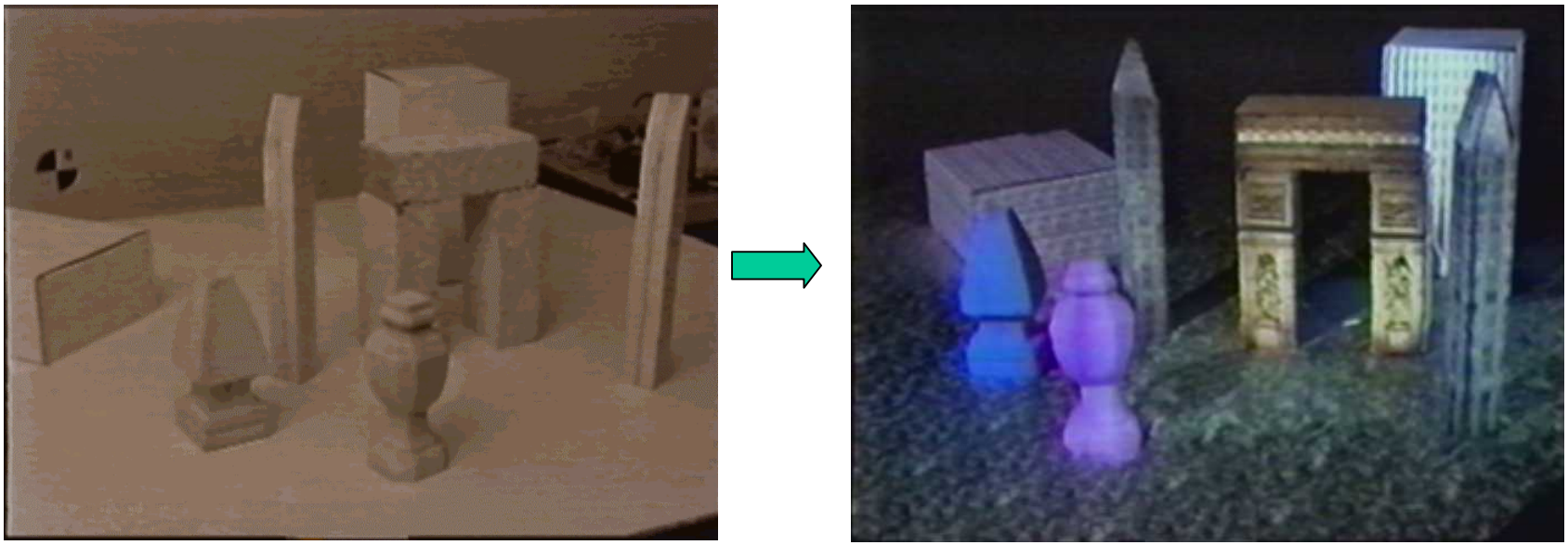


Table-Top Spatially-Augmented Reality: Bringing Physical Models to Life with Projected Imagery

(Ramesh Raskar, UNC)

Characteristics

- Discussion on the characteristics of AR systems and design issues encountered when building an AR system.
- Two ways to accomplish this augmentation: optical or video technologies.
- Blending the real and virtual poses problems with focus and contrast and some applications require portable AR systems to be truly effective.

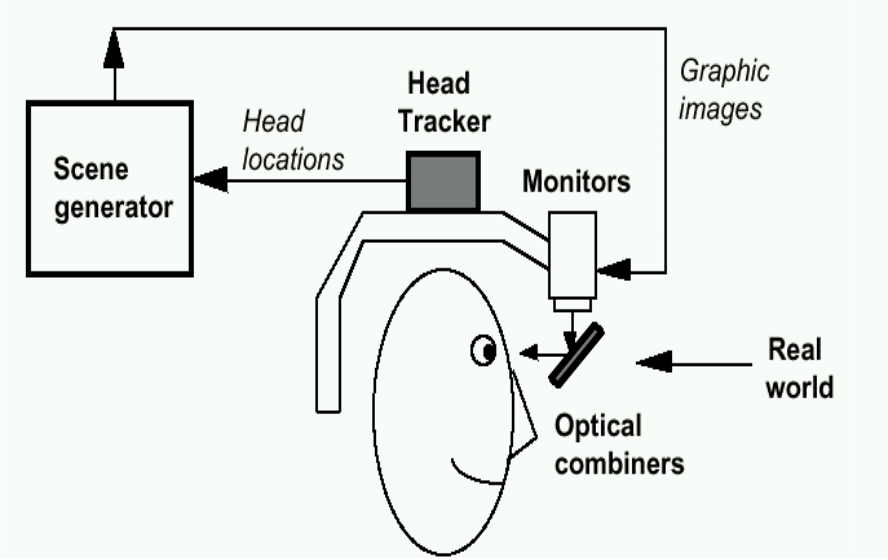
Characteristics: Augmentation

- Besides *adding* objects to a real environment, AR also has the potential to *remove* them.
  - Graphic overlays might be used to remove or hide parts of the real environment from a user. e.g., to remove a desk in the real environment, draw a representation of the real walls and floors behind the desk and "paint" that over the real desk, effectively removing it from the user's sight.
- Has been done in movies. Doing this interactively in an AR system will be much harder, but this removal may not need to be photorealistic to be effective.
- Blending the real and virtual poses problems with focus and contrast and some applications require portable AR systems to be truly effective.

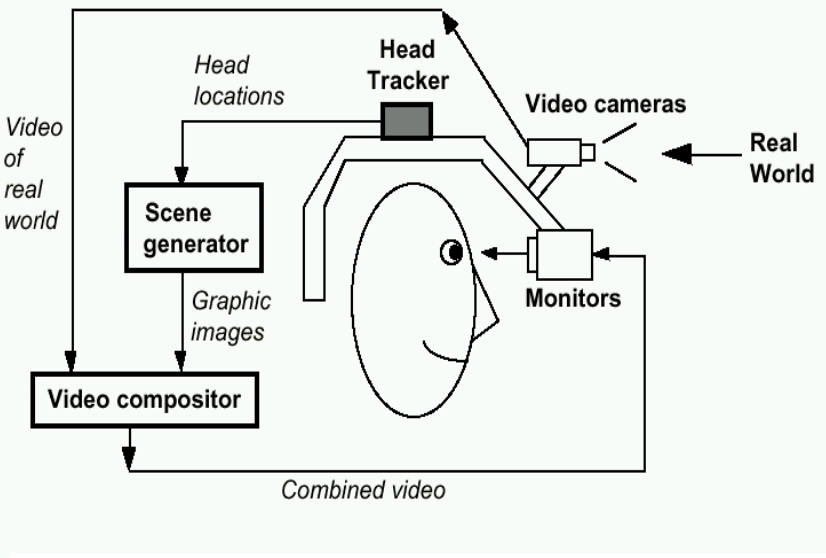
Characteristics: Augmentation

- AR might apply to all senses, not just sight.
- AR could be extended to include sound.
  - The user would wear headphones equipped with microphones on the outside. The headphones would add synthetic, directional 3D sound, while the external microphones would detect incoming sounds from the environment. Thus, one can cancel selected real incoming sounds and add others to the system. This is not easy, but possible.
- Another example is haptics.
  - Gloves with devices that provide tactile feedback might augment real forces in the environment. For example, a user might run his hand over the surface of a real desk which can augment the feel of the desk, perhaps making it feel rough in certain spots.

Characteristics: Optical vs Video



Optical see-through HMD conceptual diagram



Video see-through HMD conceptual diagram

Characteristics: Focus & Contrast

- Focus can be a problem for both optical and video components. Ideally the virtual should match the real.
  - Depending on video camera's depth-of-field (DOF) and focus settings, parts of the real world may not be in focus.
  - In computer graphics, everything is rendered with a pinhole model, so regardless of distance, everything is in focus.
  - To overcome this, graphics can be rendered to simulate a limited DOF, and the video camera can have autofocus lens.
- Contrast is a big issue owing to its large dynamic range in real environments.
  - The eye is a logarithmic detector simultaneously handling contrasts varying by 6 orders! Most display devices do not even come close.
  - Thus optical devices are usually made dark-tinted to reduce this range. For video, everything must be clipped or compressed into the monitor's dynamic range.

Characteristics: Portability

- In most VR systems, the user is not encouraged to walk around much.
  - Instead, the user navigates by "*flying*" through the environment, walking on a treadmill, or driving some mockup of a vehicle, etc.
  - Whatever the technology, the result is that the user stays in one place in the real world.
- Some AR applications, however, need support for a user who will walk around a large environment (usually move to the place where the *task* is to take place).
  - "*Flying*," as performed in a VR system, is no longer an option. If a mechanic needs to go to the other side of a jet engine, she must physically move herself and the display devices she wears.
  - Therefore, AR systems will place a premium on portability, especially the ability to walk around outdoors, away from controlled environments. The scene generator, the HMD, and the tracking system must all be self-contained and capable of surviving exposure to the environment.

Registration

- One of the most basic problems in AR.
- Objects in the real and virtual worlds have to be properly aligned with respect to each other.
- Some applications demand *accurate registration*., e.g., *virtual surgery* where error can be fatal!!
- Registration errors can also cause motion-sickness.
- AR requires much more accurate registration than VR. Even tiny offsets in the real and virtual images is usually easy to detect.
- Errors are difficult to control. *Static* errors are not a big-issue, but *dynamic* errors for devices like the HMD is a major source of problems.

Conclusion

- AR is a relatively new field (since 1993) and is far behind VR in maturity.
  - Several vendors sell complete, turnkey VR systems.
  - No commercial vendor currently (??) sells an HMD-based AR system.
- First deployed HMD-based AR system will probably be in the application of aircraft manufacturing (Boeing is currently exploring this technology extensively).
- A breakthrough is required in real-time HMD tracking in the outdoors at the accuracy required by AR for this technology to move ahead rapidly.
- AR has a great future as it promises better navigation and interaction with real and virtual world in ways which has previously been unimaginable.