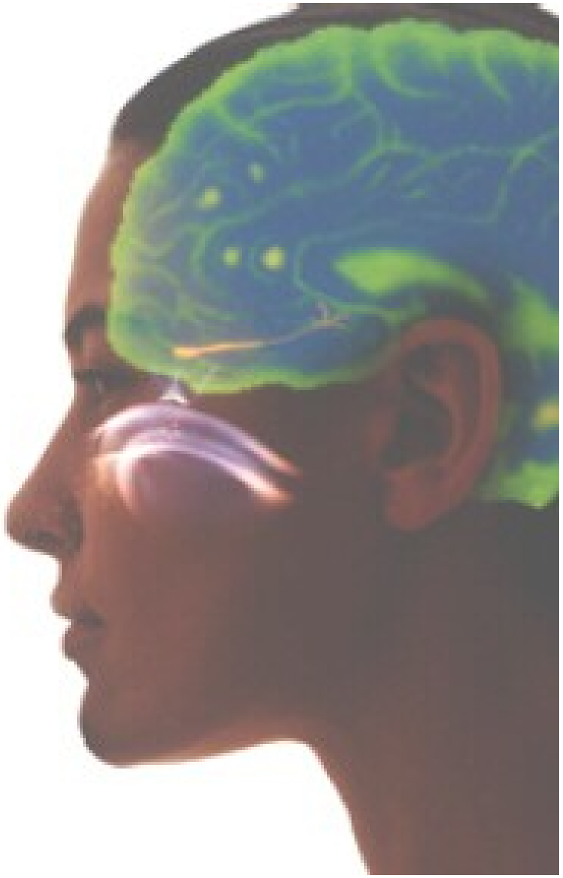
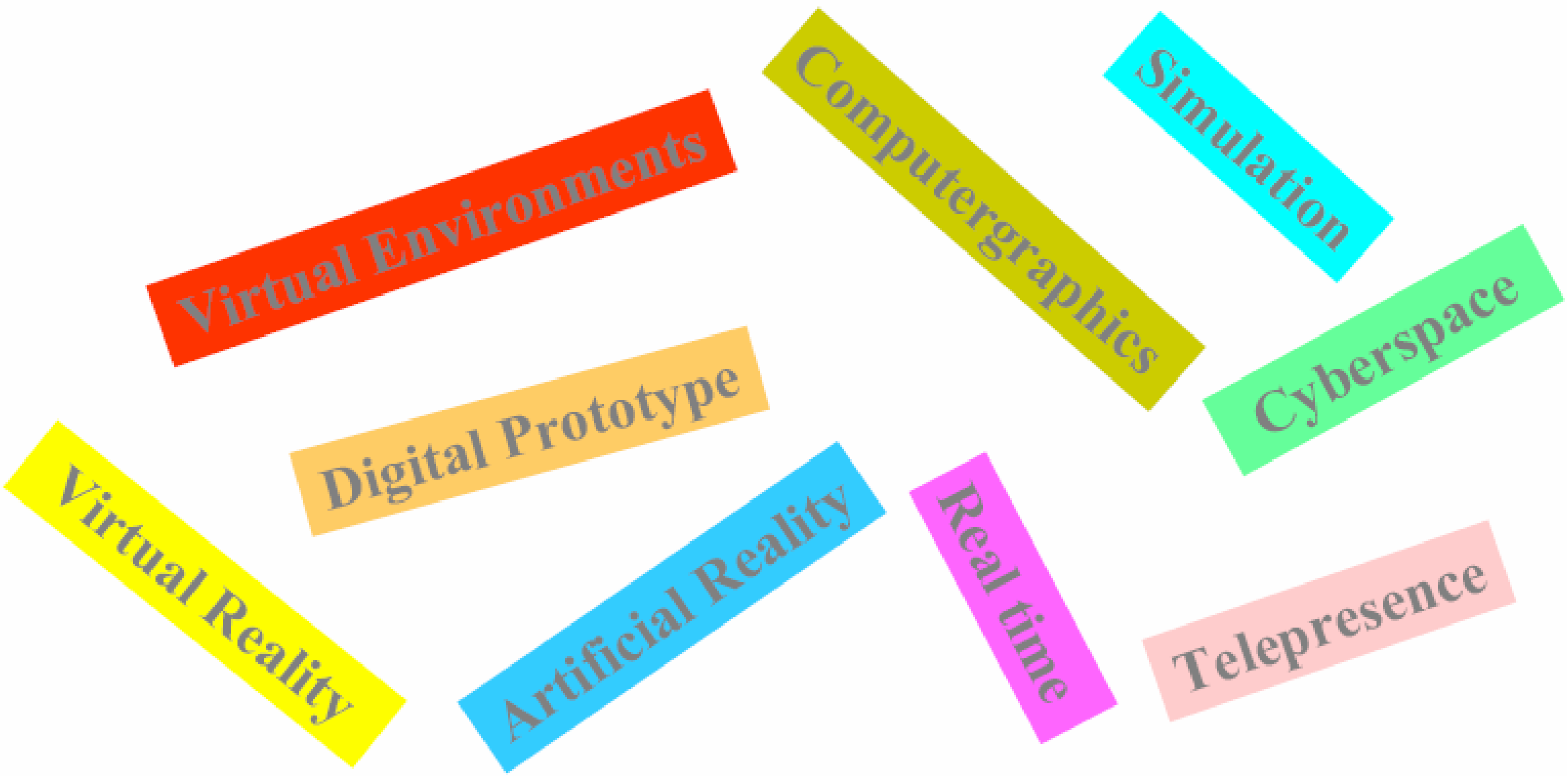
Obogatena resničnost

Kaj je obogatena resničnost?



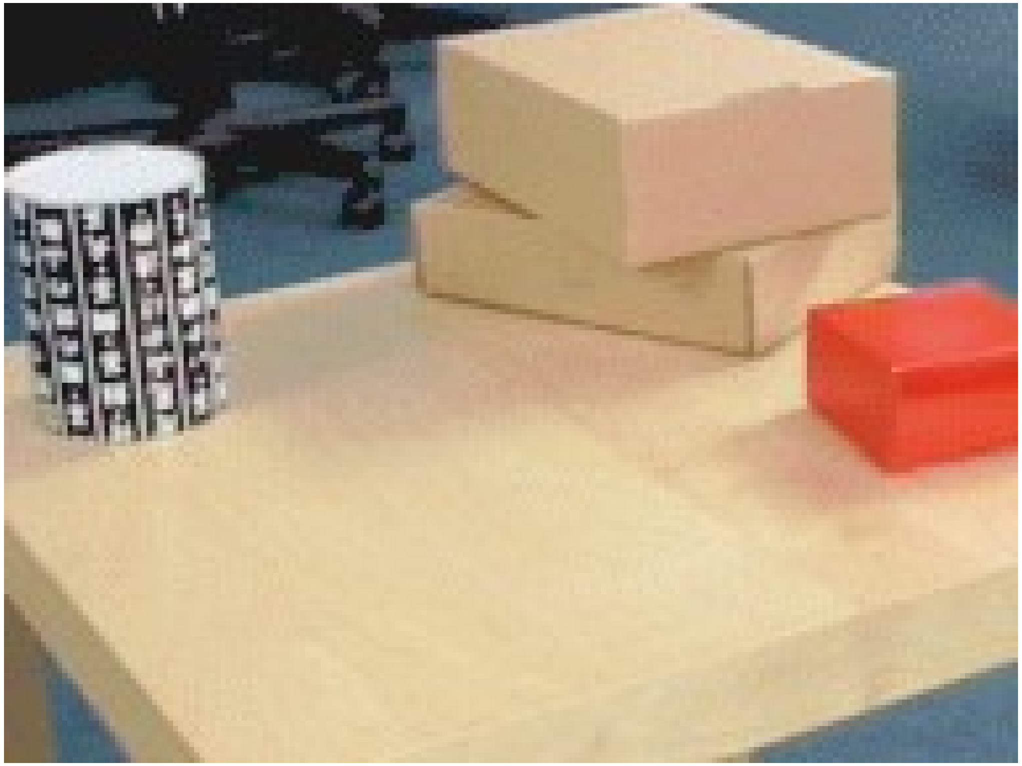
- A combination of a real scene viewed by a user and a virtual scene generated by a computer that augments the scene with additional information.

Kaj je obogatena resničnost?



Definicija obogatene resničnosti

- Virtual Environments (VE): Completely replaces real world
- Augmented Reality (AR): Combines virtual with real Supplements reality, instead of completely replacing it



Definicija obogatene resničnosti

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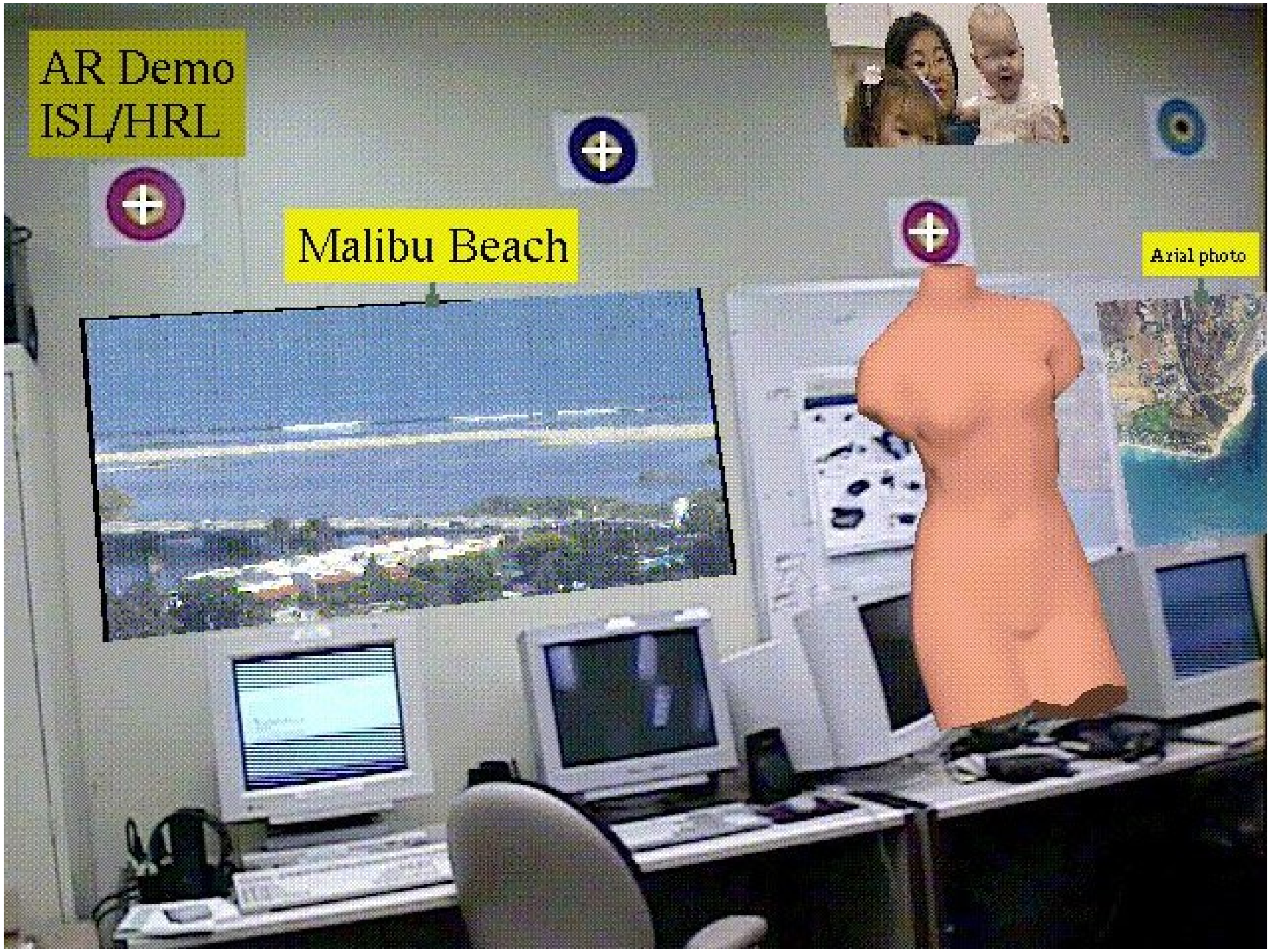
Demonstracija

Definicija obogatene resničnosti

1) Blends real and virtual
2) Real-time interactive
3) Registered in 3-D

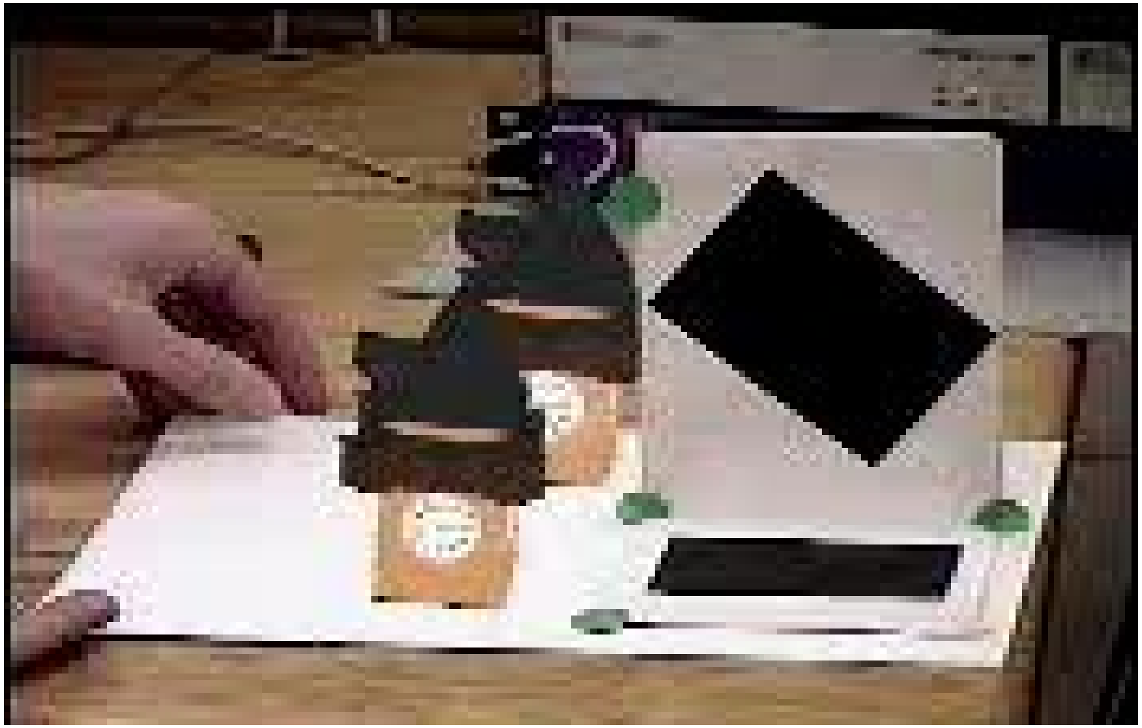
Note: need not be HMD-based!

Example AR image



Youngkwan Cho, STAR system

Vzajemno prekrivanje realnih in sintetičnih objektov



Zakaj bi to raziskovali?

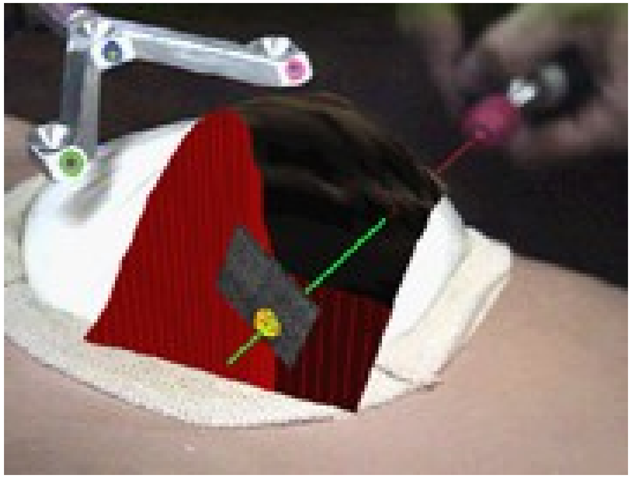
- Enhance perception of and interaction with real world
- Potential for productivity improvements in real-world tasks
- Relatively new field; many problems to be solved

Aplikacije

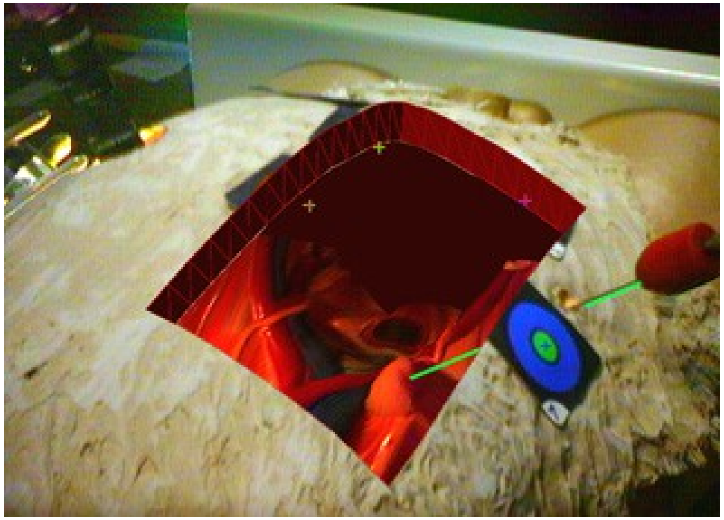
- **Medical**
- **Entertainment**
- **Military Training**
- **Engineering Design**
- **Robotics and Telerobotics**
- **Manufacturing, Maintenance, and Repair**
- **Consumer Design**
- **Hazard Detection**
- **Audio**

Medicina

- “X-ray vision” for surgeons
- Aid visualization, minimally-invasive operations. Training.
  - Ultrasound [UNC Chapel Hill]
  - MRI, CT data



Courtesy UNC Chapel Hill

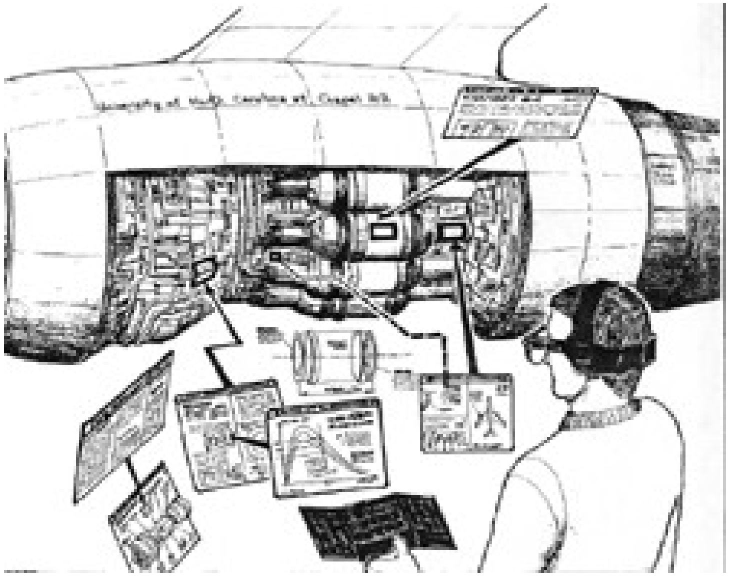


Kompleksni stroji

- **Instructions for assembly, maintenance, and repair of complex equipment**
  - **Aircraft [Boeing]**
  - **Printers [Columbia]**
  - **Engines**

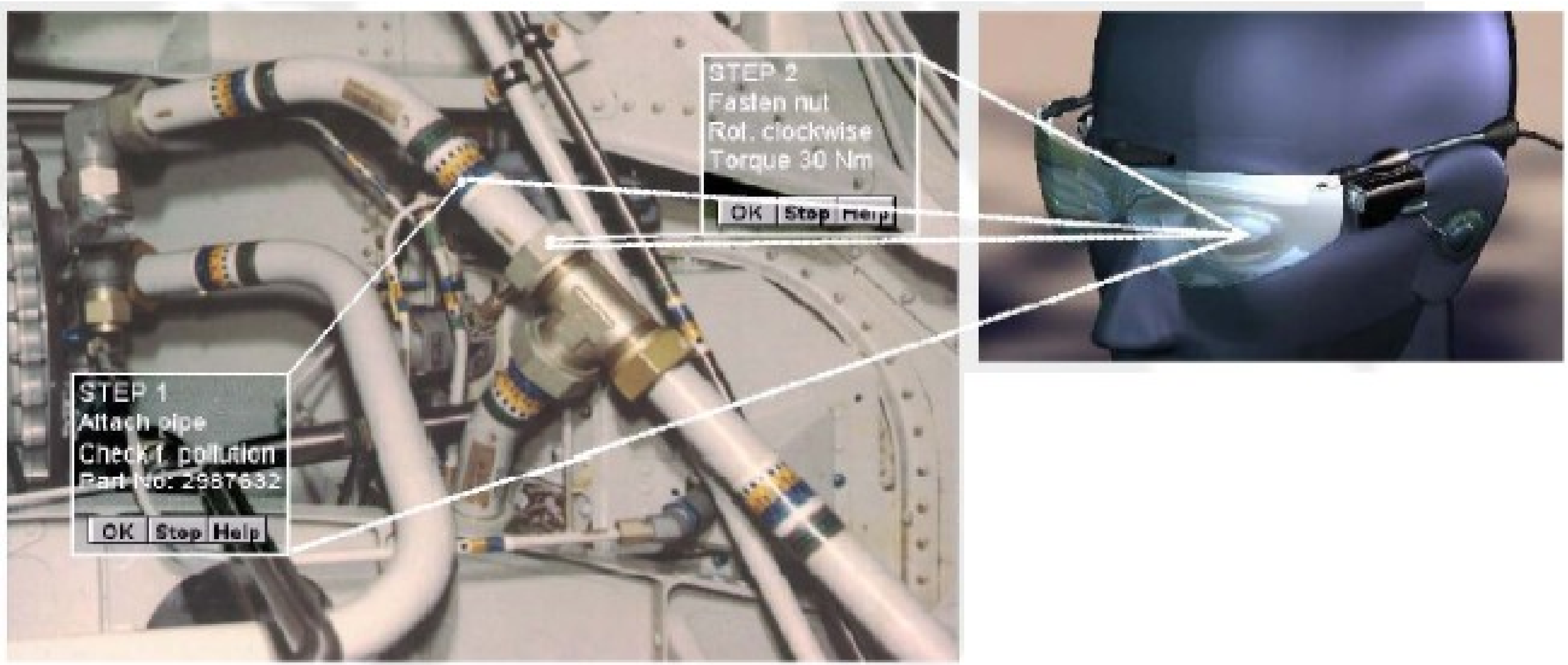
Sestavljanje in vzdrževanje (1)

Boeing wire harness assembly.
Adam Janin wearing HMD.
Courtesy David Mizell, Boeing

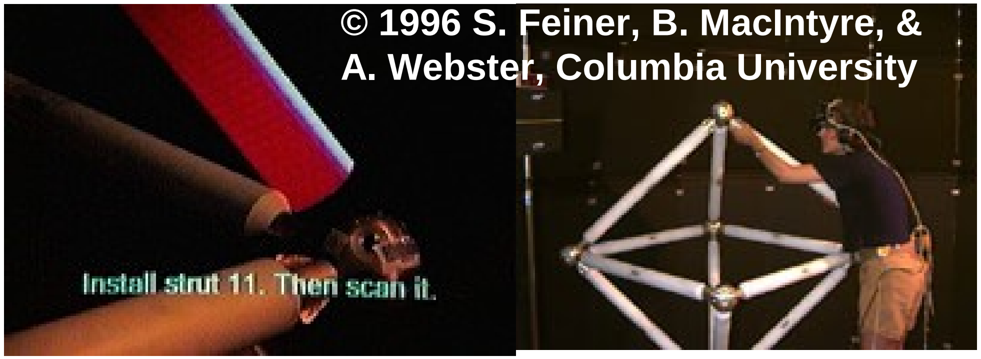


Courtesy Andrei State, UNC
Chapel Hill

Sestavljanje (montaža) in AR

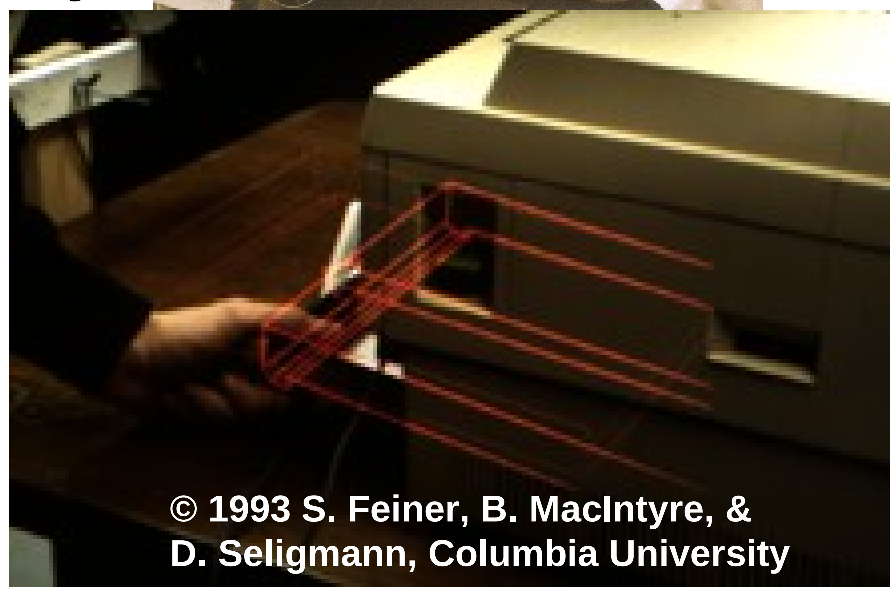


Sestavljanje in vzdrževanje

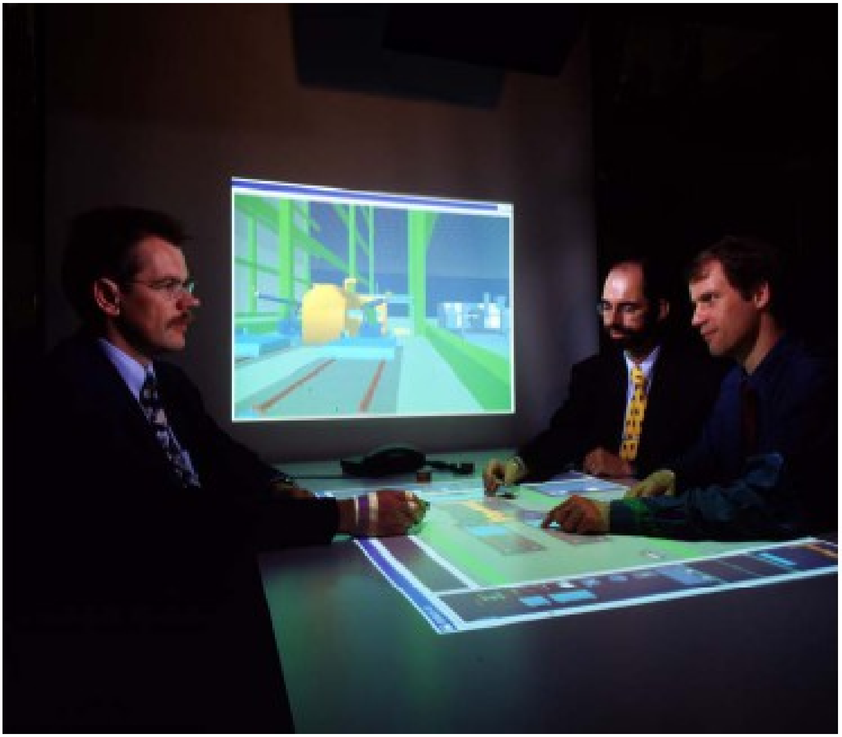


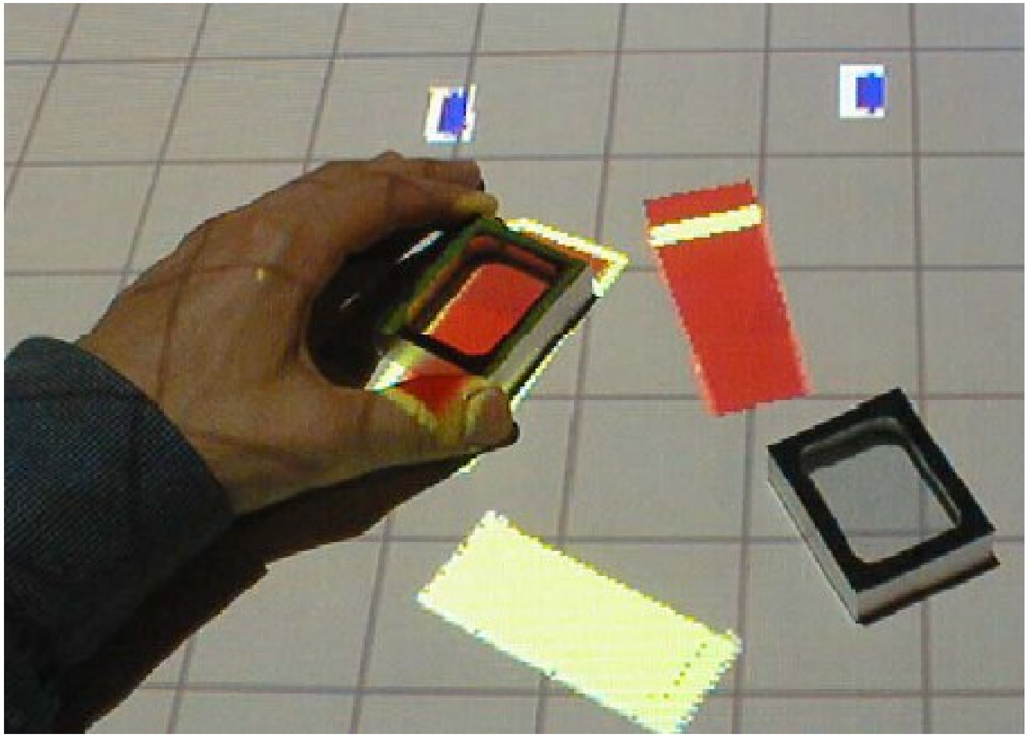
Columbia University


Eric Rose, et. al., ECRC

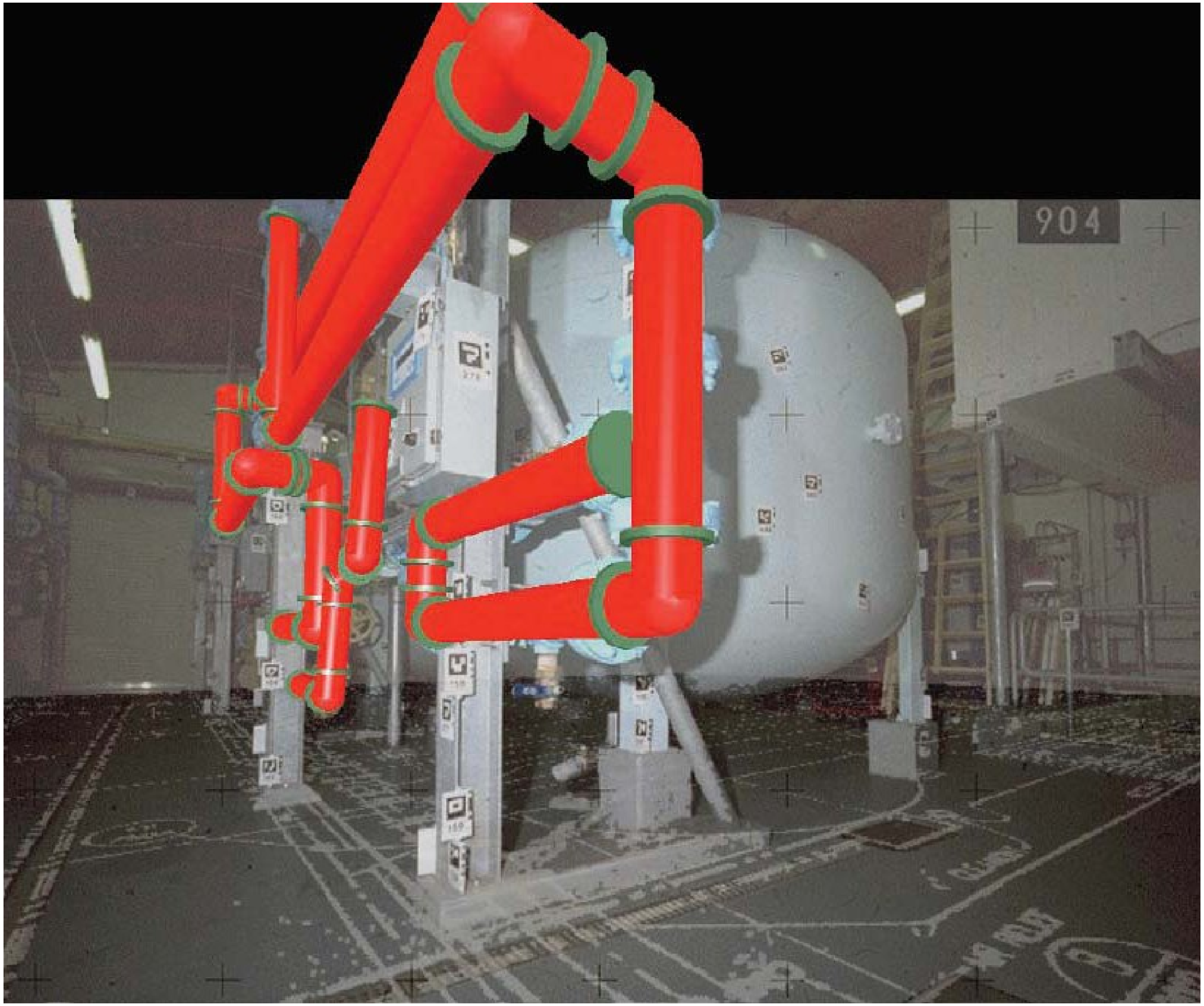


Planiranje razporedov naprav (arhitektura)





Planiranje razporeda naprav



Arhitektura

Označevanje okolja

- **Public and private annotations**
- **Aid recognition, “extended memory”**
  - **Libraries, maps [Fitzmaurice93]**
  - **Windows [Columbia]**
  - **Mechanical parts [many places]**
  - **Reminder notes [Sony, MIT Media Lab]**
  - **Navigation (directions, information)**
  - **Spatially-based information access**

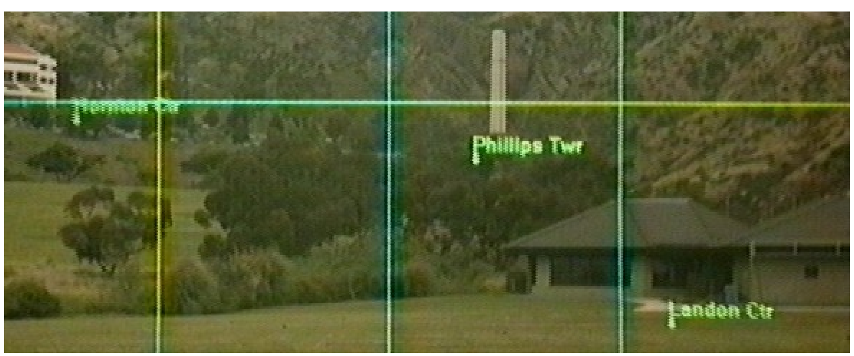
Označevanje pokrajin in objektov

Označevanje slik

© 1993 S. Feiner, B. MacIntyre,
M. Haupt, & E. Solomon,
Columbia University

Columbia
University

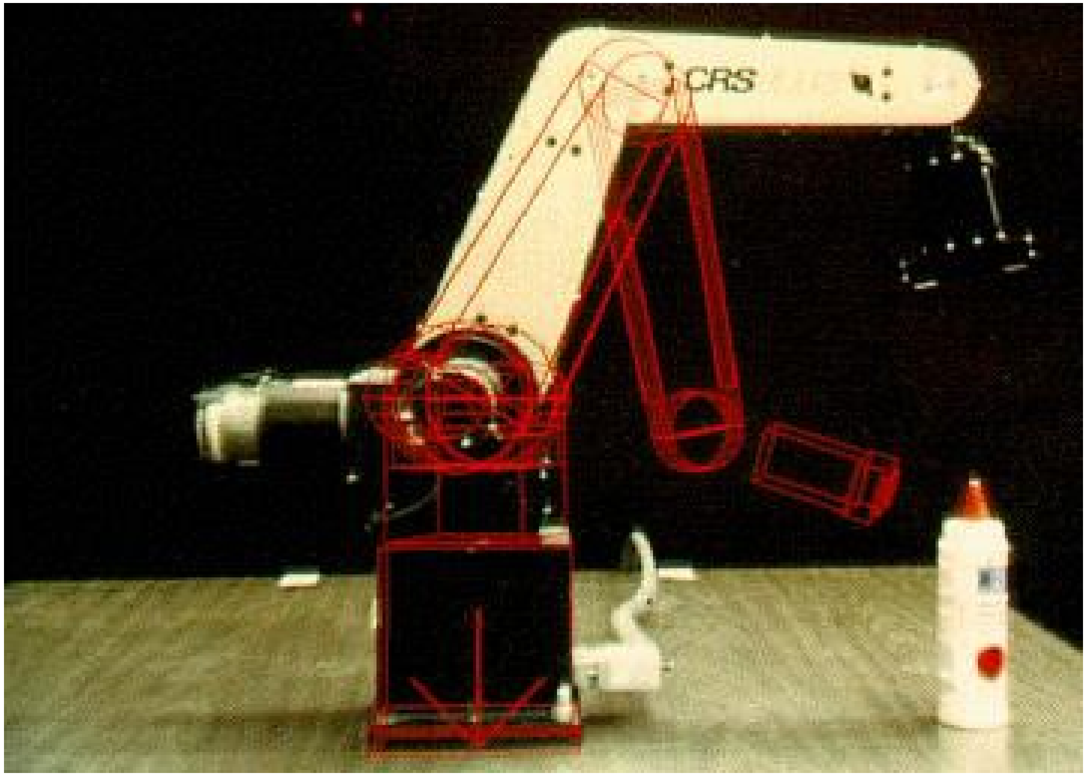
© 1997 S. Feiner, B. MacIntyre,
T. Hollerer, & A. Webster,
Columbia University



HRL

Robotika

- **Robotic path planning, previewing**
- **Remote manipulation**

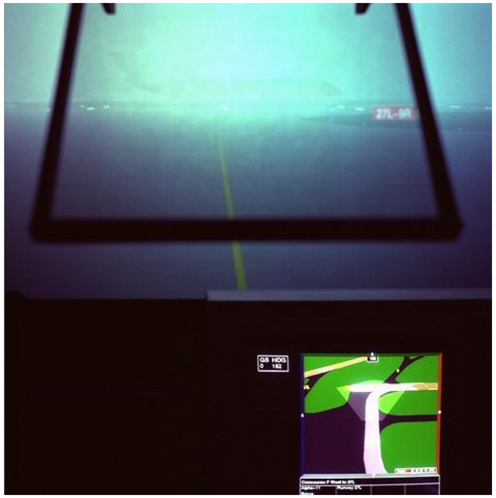


ARGOS,
U. Toronto

Ergonomics in Teleoperation
and Control Lab, MIE Dept.
University of Toronto

Letalstvo

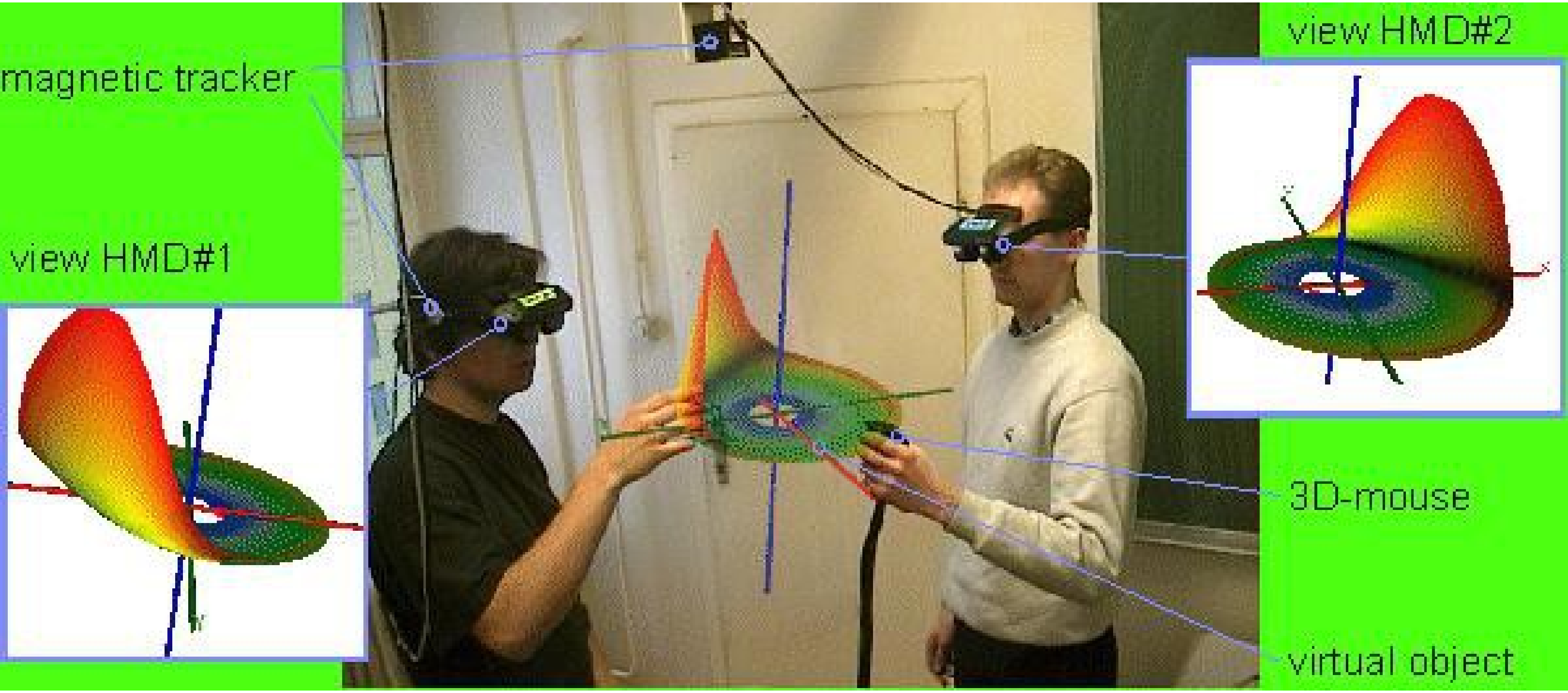
- **Supercockpit concept (Furness)**
- **Helmet-mounted sights**
- **Virtual runway markers**
  - **FAA has targeted runway collisions as a major source of accidents**
  - **T-NASA head up display system**



NASA Ames Imaging Library

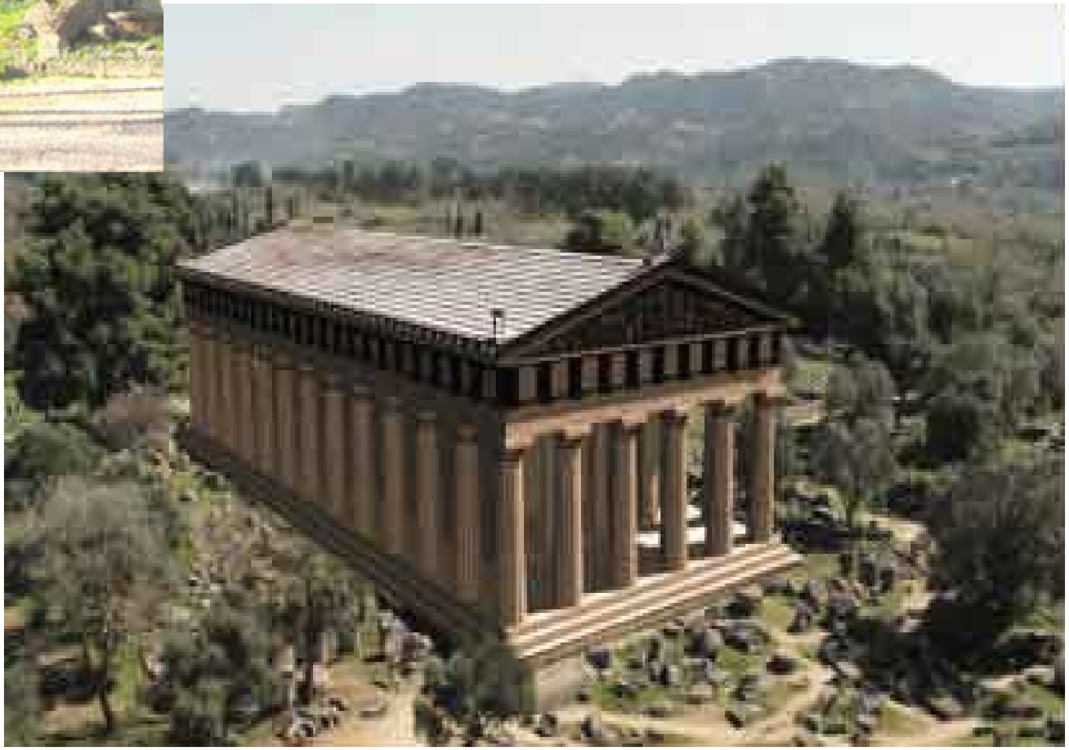
Sodelovanje

Sodelovanje na istem virtualnem objektu v realnem okolju

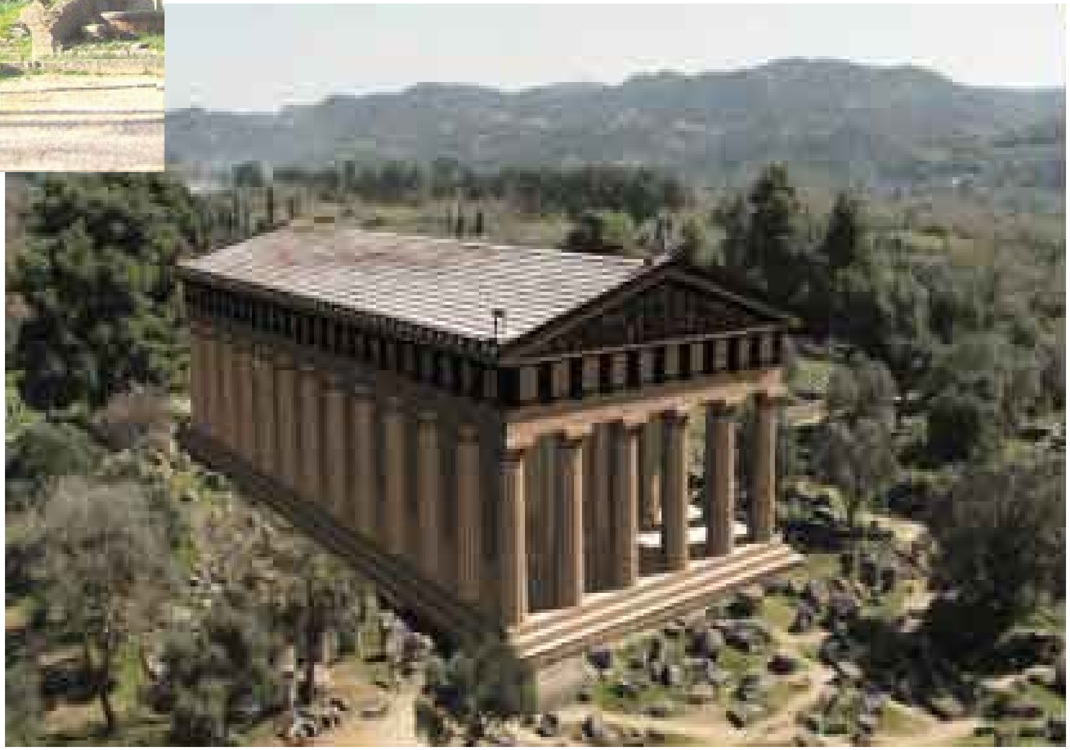


Obogatena resničnost na prostem (Outdoor Augmented Reality)

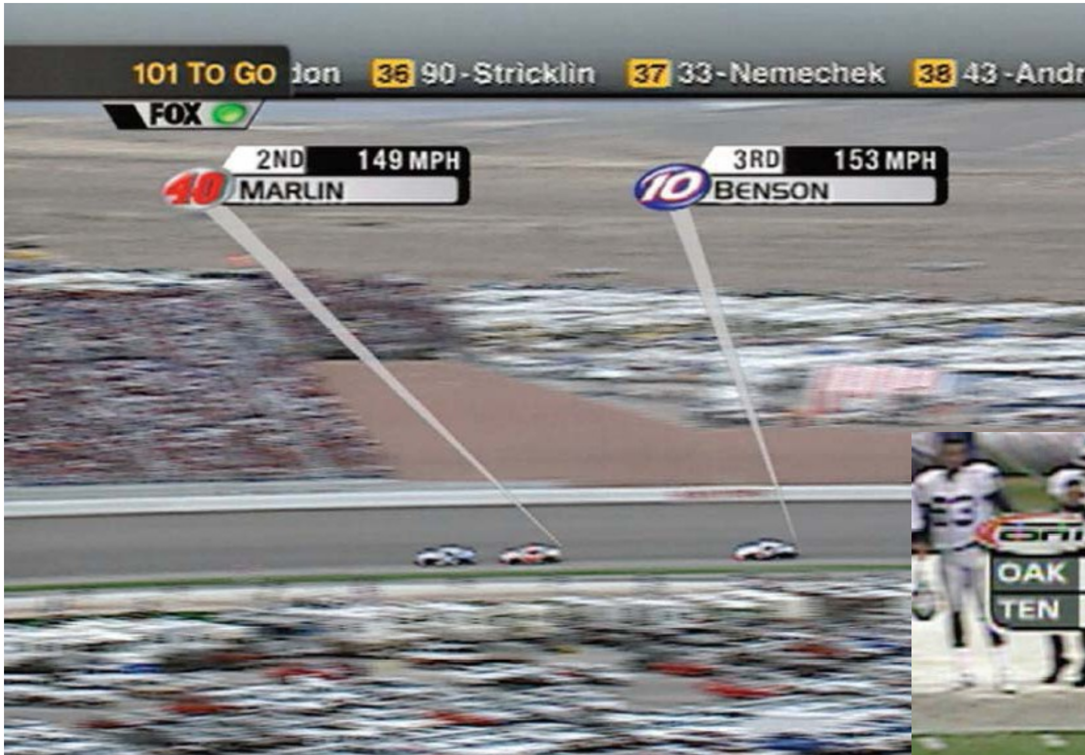
Kulturna dediščina



Kulturna dediščina



Šport


101 TO GO
90-Stricklin
33-Nemechek
FOX
2ND 149 MPH
MARLIN
3RD 153 MPH
BENSON


OAK 7 4TH
TEN 14 11:04

Reklamiranje

Nakupovanje

Kaj je torej cilj AR?

- **To enhance a person's performance and perception of the world**
- **But, what is the ultimate goal????**

Končni cilj AR

- **Create a system such that no user CANNOT tell the difference between the real world and the virtual augmentation of it.**

Primerjava navidezne in obogatene resničnosti

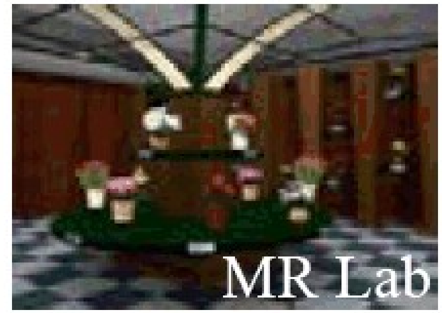
Augmented Reality

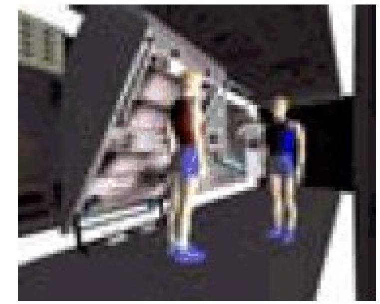
- System augments the real world scene
- User maintains a sense of presence in real world
- Needs a mechanism to combine virtual and real worlds

Virtual Reality:

- Totally immersive environment
- Visual senses are under control of system (sometimes aural and proprioceptive senses too)

Miligram’s Reality-Virtuality Continuum





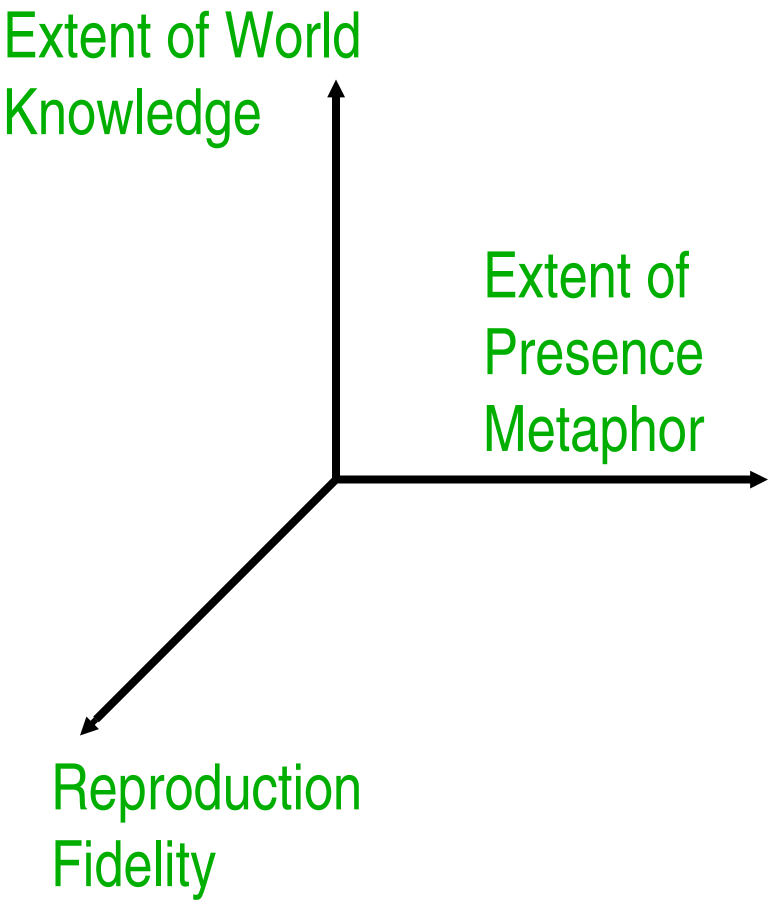
Mixed Reality (MR)

Real Environment → Augmented Reality (AR)

Augmented Virtuality (AV) ← Virtual Environment

Miligram coined the term “Augmented Virtuality” to identify systems which are mostly synthetic with some real world imagery added such as texture mapping video onto virtual objects.

Miligram’s Taxonomy for Mixed Reality Displays

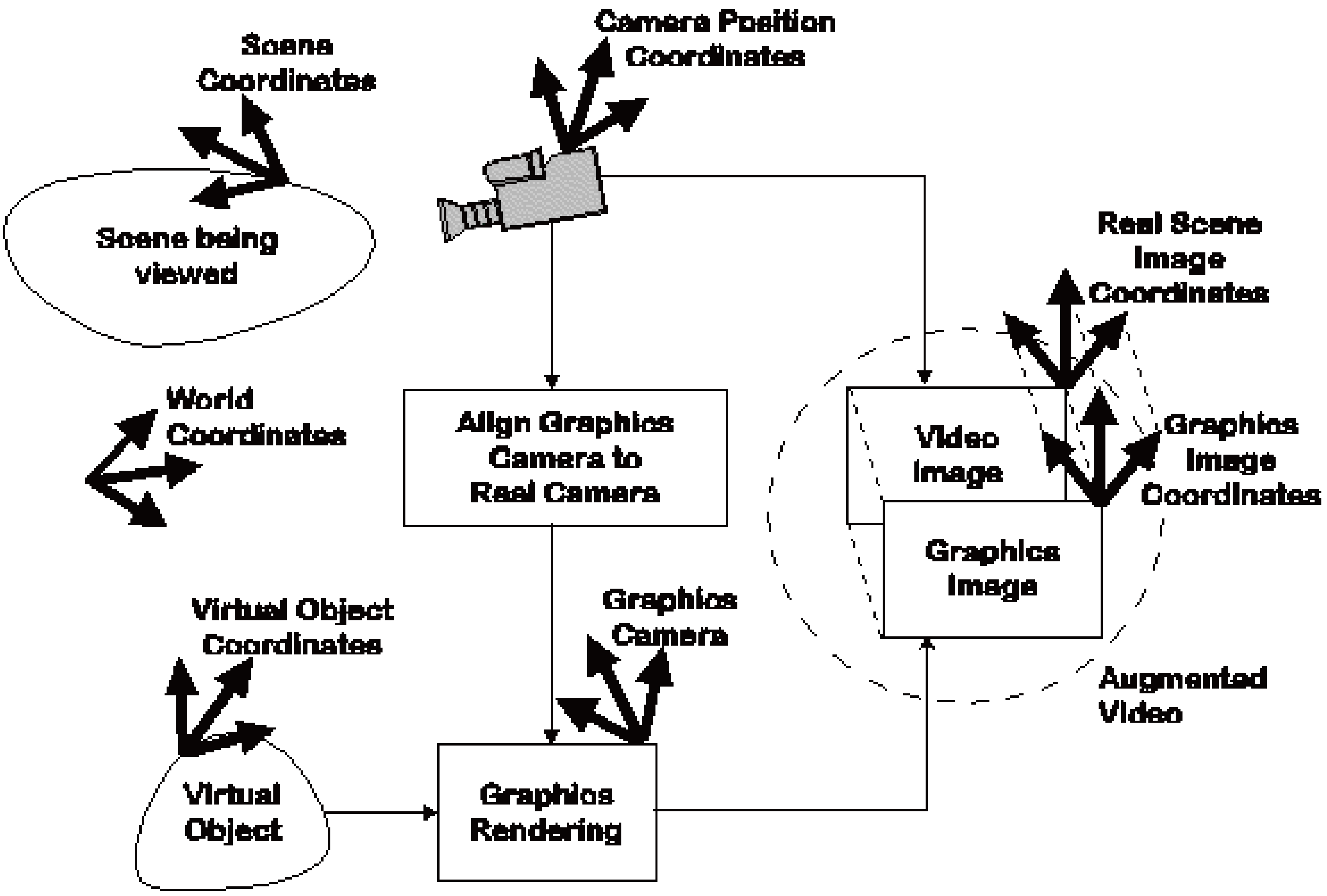


- Reproduction Fidelity – quality of computer generated imagery
- Extent of Presence Metaphor – level of immersion of the user within the displayed scene
- Extent of World Knowledge – knowledge of relationship between frames of reference for the real world, the camera viewing it, and the user

Osnovne značilnosti

- **Can replace, not just augment**
  - **Cover up the stuff you don't want!**
  - **Need not be photorealistic to be effective**
- **Potentially all senses**
  - **Auditory, haptic. Not yet tackled.**
- **Blending: Optical vs. Video**

Komponente sistema za obogateno resničnost

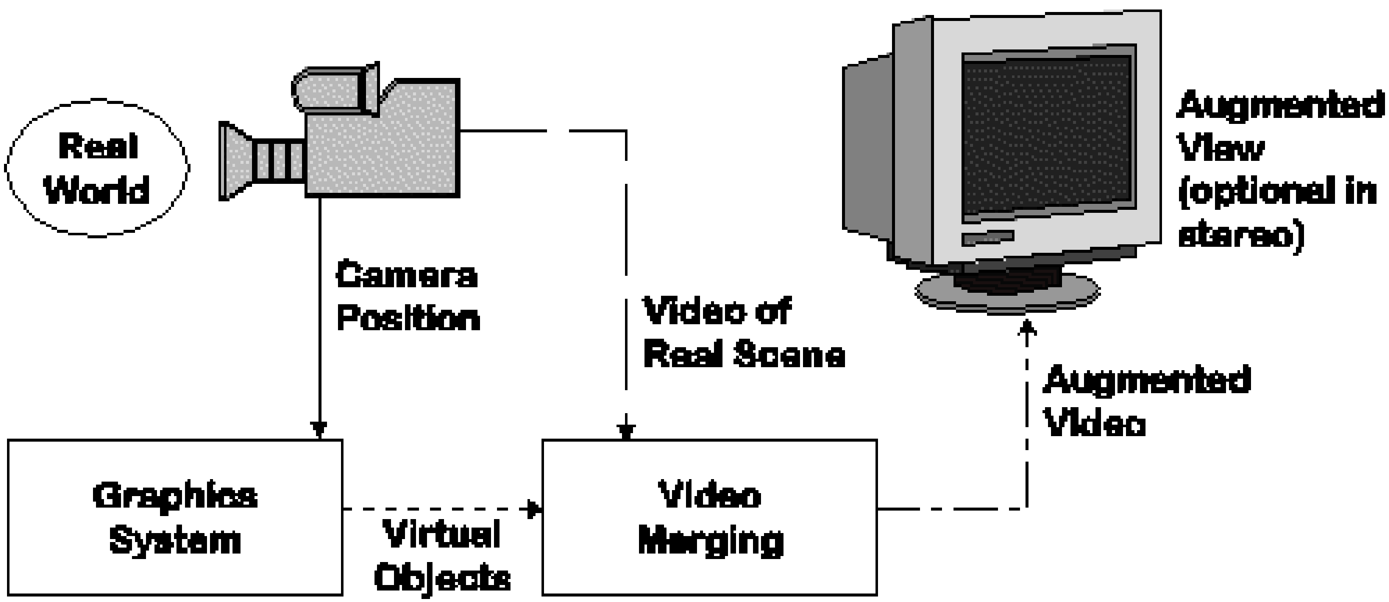


Prikazovalne tehnologije

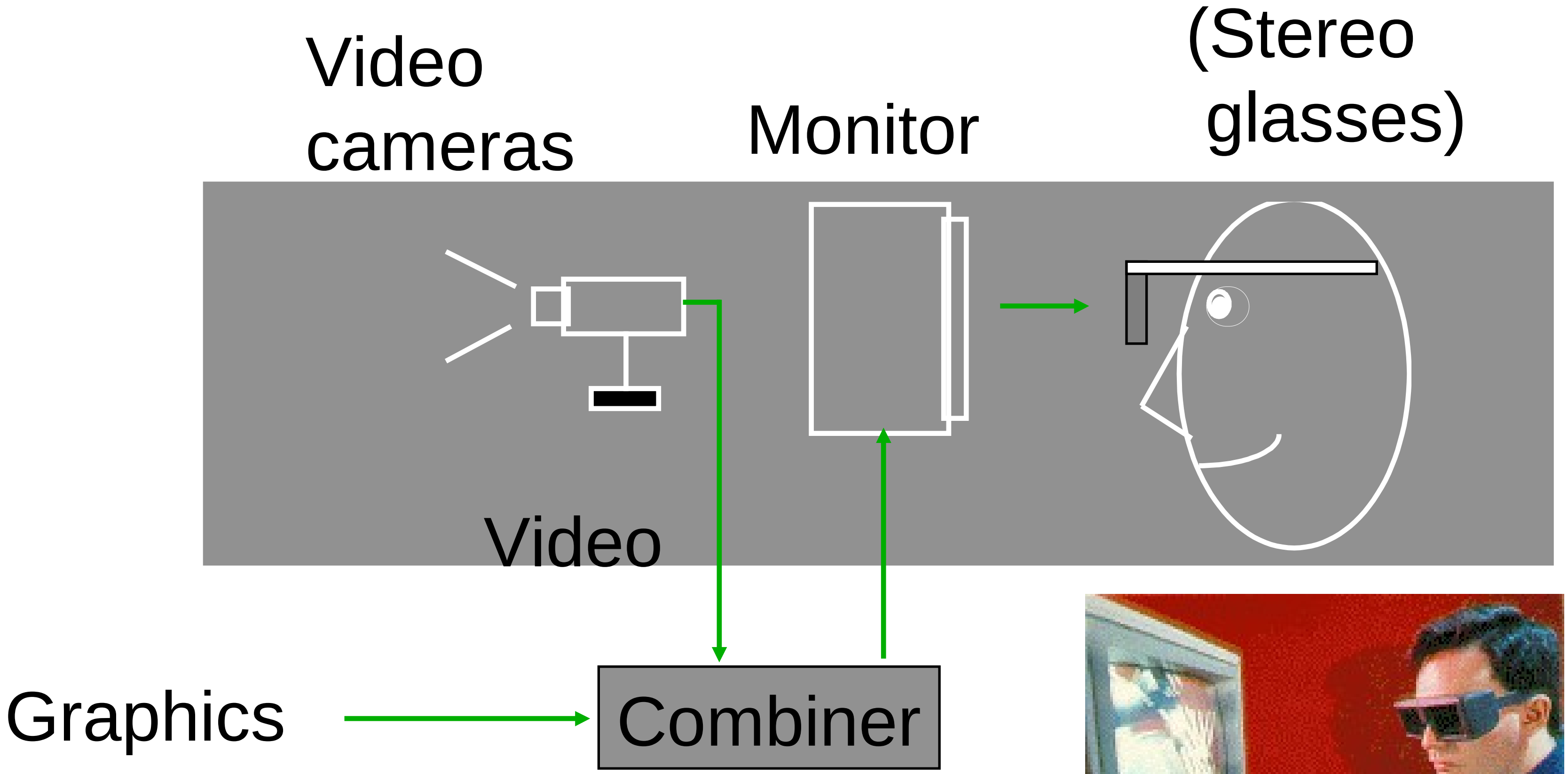
- **Monitor Based**
- **Head Mounted Displays:**
  - **Video see-through**
  - **Optical see-through**

AR, temelječa na monitorjih

- **Simplest available**
- **Little feeling of being immersed in environment**



AR s pomočjo video monitorja



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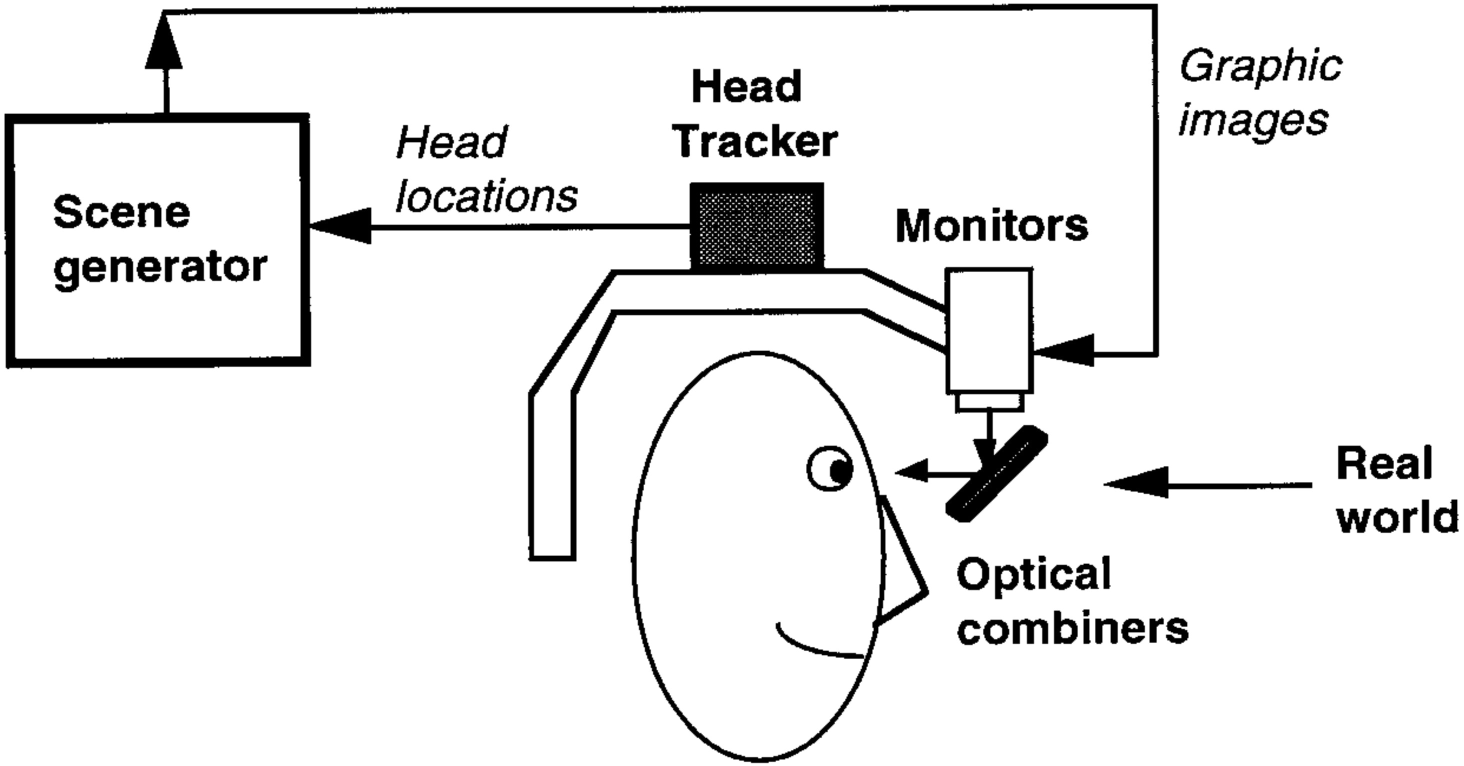
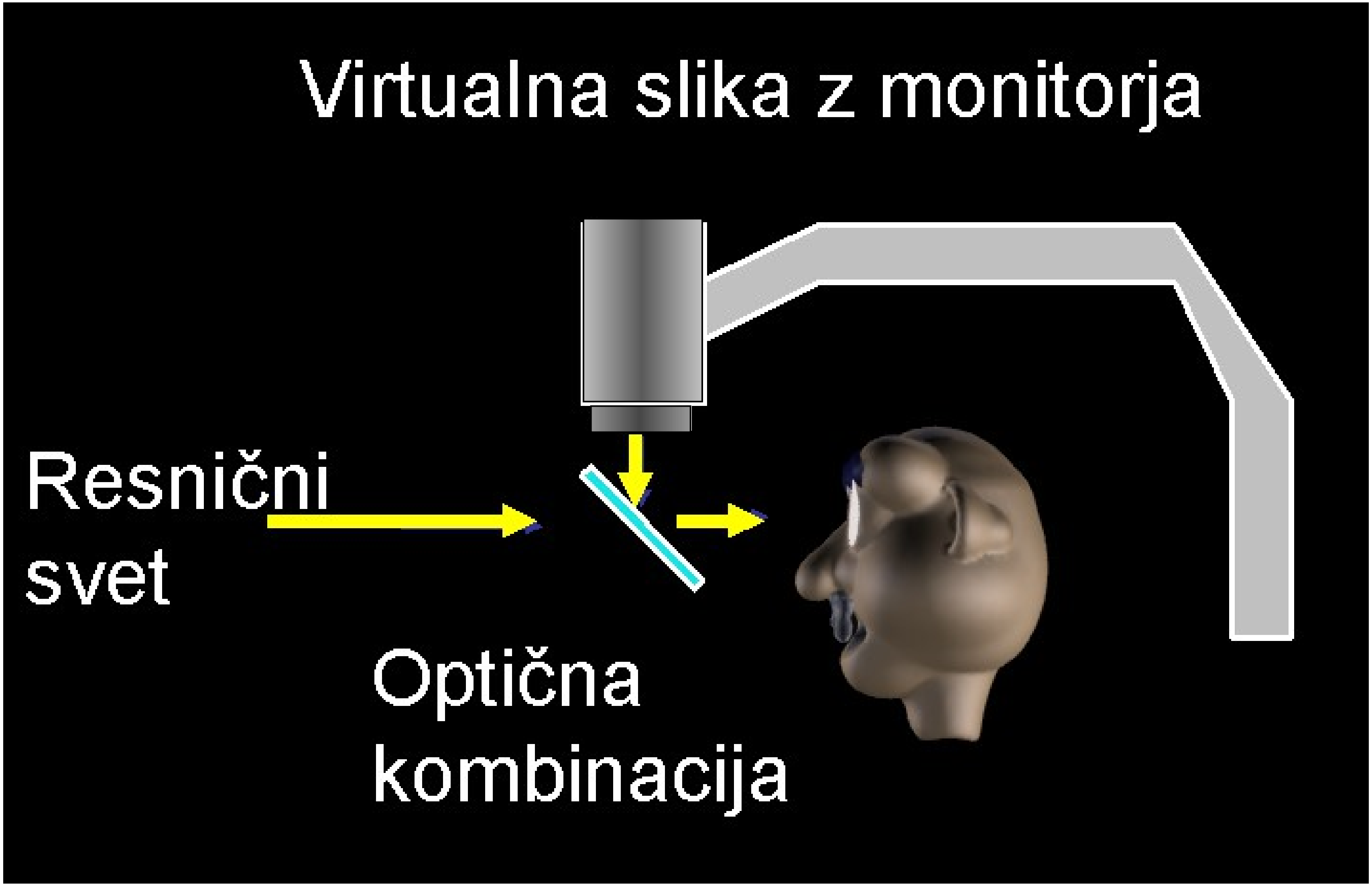
University of Toronto

Tehnologija “Optical see-through”



Tehnika optičnega gledanja

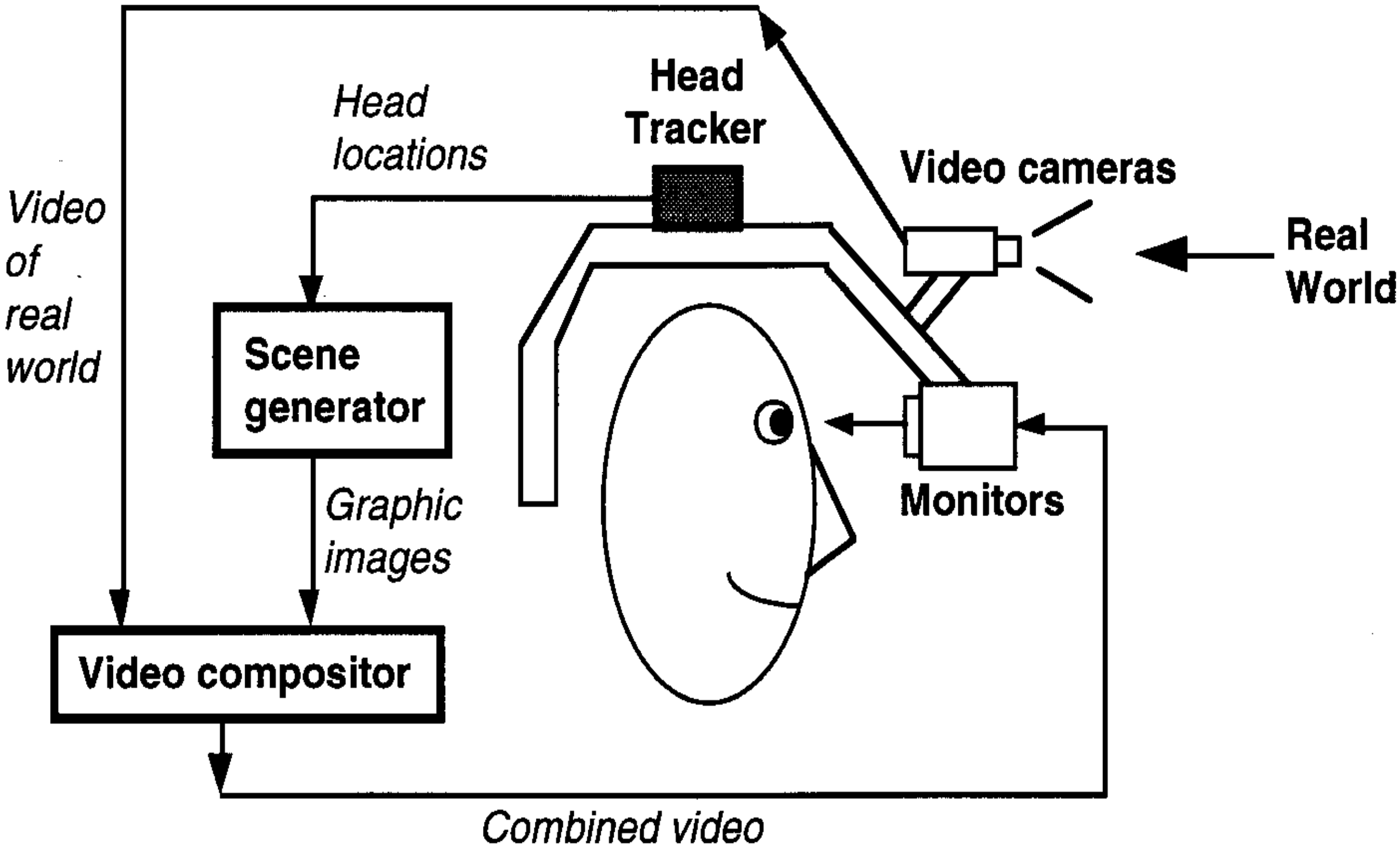


Naprave za “optično gledanje skozi”

Sony Glasstron

Virtual Vision VCAP

Video see-through



Naprave za video see-through

Custom designed Fisheye cameras Courtesy of Jannick Rolland at the Optical Diagnosis and Applications Laboratory (ODALab) at UCF, Orlando, Florida

Joint paper with Frank Biocca, work done at UNC Chapel Hill

Video kompozicija za Video see-through

- **Chroma-keying**
  - **Used for special effects**
  - **Background of computer graphics images is set to a specific color**
  - **Combining step replaces all colored areas with corresponding parts from video**
- **Depth Information**
  - **Combine real and virtual images by a pixel-by-pixel depth comparison**

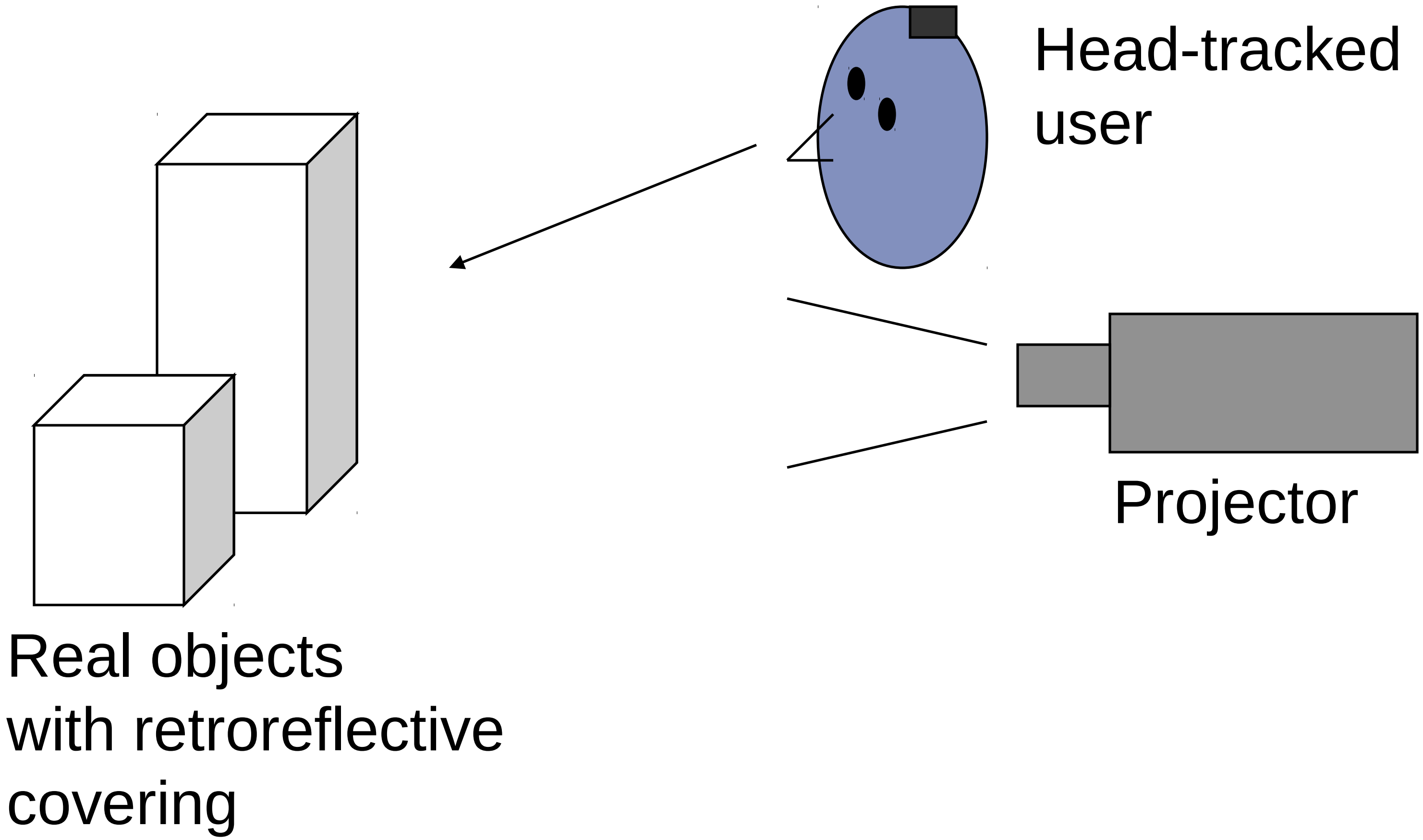
Prednosti Video see-through

- **Flexibility in composition strategies**
- **Wide field of view**
- **Real and virtual view delays can be matched**

Prednosti Optical see-through

- **Simplicity**
- **Resolution**
- **No eye offset**

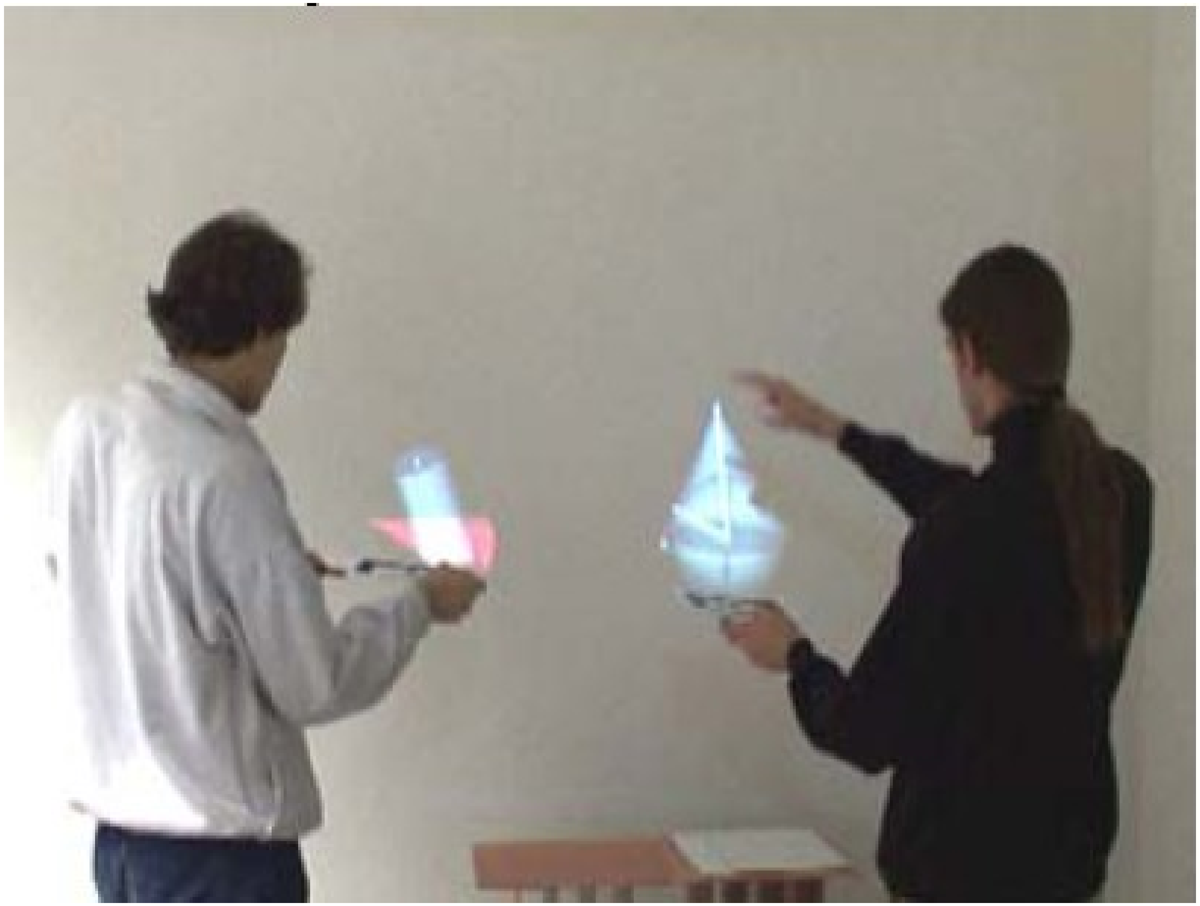
AR osnovana na projekciji



AR osnovana na projekciji: primer

Ramesh Raskar, UNC Chapel Hill

Interakcija z modeli pred projekcijskim platnom



Prednosti optičnih rešitev

- **Simpler (cheaper)**
- **Direct view of real world**
  - **Resolution**
  - **Time delay**
  - **Safety**
  - **Lower distortion**
- **No eye displacement**

Prednosti video rešitev

- **True occlusion**
- **Digitized image of real world**
  - **Flexibility in composition**
  - **Matchable time delays**
  - **More registration, calibration strategies**
- **Wide FOV is easier**

Povzetek optičnih in video rešitev

- **Both have proponents**
- **Roles for both**
- **Depends on application?**
  - **Manufacturing: optical is cheaper**
  - **Medical: video for calibration strategies**

Fokus in kontrast

- **Focus**
  - **Need to measure eye accommodation?**
  - **Autofocus video camera?**
- **Contrast**
  - **Desirable to match brightness**
  - **Real world has large dynamic range!**
  - **More difficult with optical?**

Prenosljivost

- **VE: User stays in one place**
- **AR: User moves to task location**
  - **Want to use in factories, outdoors**
  - **Less controlled environments**
  - **Very demanding of the technology**

Requirements vs. VE

- **Rendering**
- **Display (resolution, FOV, color)**
- **Tracking and sensing**
  - **a big problem for registration!**

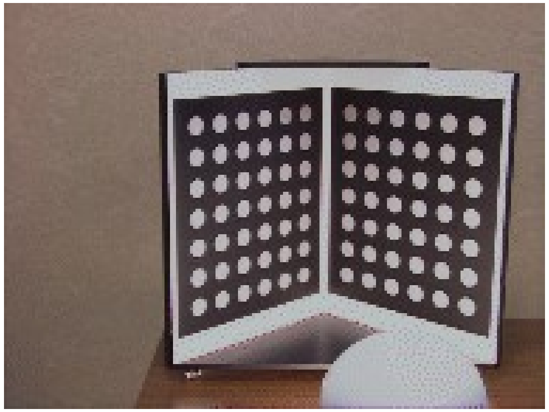
Kombiniranje navideznih in realnih svetov

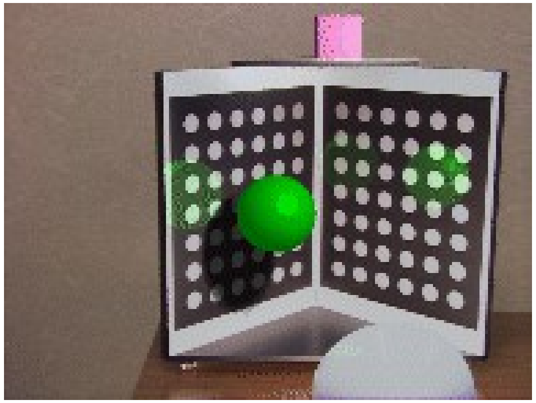
We need:

- **Precise models**
- **Locations and optical properties of the viewer (or camera) and the display**
- **Calibration of all devices**
- **To combine all local coordinate systems centered on the devices and the objects in the scene in a global coordinate system**

Kombiniranje navideznih in realnih svetov

- **Register models of all 3D objects of interest with their counterparts in the scene**
- **Track the objects over time when the user moves and interacts with the scene**





Realistično zlivanje

Requires:

- **Objects to behave in physically plausible manners when manipulated**
- **Occlusion**
- **Collision detection**
- **Shadows**

****All of this requires a very detailed description of the physical scene**

Registracija in sledenje

Problem registracije

- Virtual and Real must stay aligned
- If not:
  - Compromises illusion that the two coexist
  - Prevents acceptance of many serious applications

Geometrična registracija

- In order to achive MR:
  - 3-D coordinates of real and VE has to be aligned to each other.
  - User´s position and orientation must be measured.
    - Using sensors, magnetic, ultra-sonic or mechanical sensors.
    - Estimating position/orientation from camera images from viewpoint → Vision based tracking.
    - Hybrid, for improvement of accuracy.

Senzorji

- Standard sensors
  - Requires special equipment
  - Limited measurement area
  - Sensitive for metal (magnetic)
- Vision Based
  - Estimates viewpoint position from images → CPU intensive calculations.
  - Potentially no limitation in measuring area.

Fantomska plošča

Težave registracije

- Accurate registration is difficult!
  - Sensitivity of visual system
    - Few mm, small fraction of degree
    - Coin test
  - Many sources of error
- Demonstrate with ultrasound footage

Courtesy
UNC Chapel Hill

Vrste registracije

- Accuracy required depends on the senses involved
- Visual - visual
  - Very obvious. 0.5 minutes of arc.
  - This is what we focus on for Augmented Reality
- Visual - kinesthetic, proprioceptive
  - Main VE conflict. Less obvious. Visual capture can override.
- Visual - auditory, haptic

Vrste registracije in problemi

- Open-loop and closed-loop: precise in restricted cases
- Problems: limited range, motion, & environment
- Much work remains to be done!

Vision-based techniques (1)

- Digitized video allows “closed-loop” approaches
- Difficult, but not “AI-complete” problem
- Popular due to accuracy, made video see-through more common

Courtesy
UNC Chapel Hill

Vision-based techniques (2)

- Approaches used
  - Fiducials in environment (LEDs, colored dots)
  - Template matching
  - Restricted environment, known objects
  - More sensors (e.g. laser rangefinder)
  - Keep user in the loop (e.g. manual ID)
- Requires compute power, special devices

Calibration-free approaches

- Registration generally involves significant calibration
- Rendering techniques that avoid certain calibration steps
- May not support general rendering
  - Weak perspective projection model

Izpadi registracije

Failures in registration due to:

- Noise
  - Position and pose of camera with respect to the real scene
  - Fluctuations of values while the system is running
- Time delays
  - In calculating the camera position
  - In calculating the correct alignment of the graphics camera

Izvori napak registracije

- Static errors
  - Optical distortions
  - Mechanical misalignments
  - Tracker errors
  - Incorrect viewing parameters
- Dynamic errors
  - System delays

Zmanjšajmo statične napake

- Distortion compensation
- Manual adjustments
- View-based or direct measurements
- Camera calibration (video)

Zmanjšajmo dinamične napake

- Reduce system lag
- Reduce apparent lag
  - Image deflection: [Burbidge89] [Regan94] [So92]
  - Image warping: [Mark 3DI 97]

Zmanjšanje dinamičnih napak

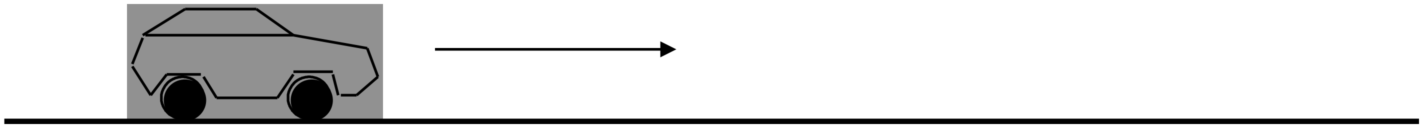
- Filtriranje
- Napovedovanje

Ocenjevanje in napovedovanje

- Examine the software side of tracking
- Estimation = determining our best estimate of the current position and orientation
- Prediction = guessing where the position and orientation will be in the future
- Both are important for accurate registration
- Why predict?
  - Dynamic error is largest single source
  - System delay is main source of dynamic error

Primer problema napovedovanja

- Car moves along straight road
  - 1-D problem
  - Remote observer occasionally measures position. Velocity & accel. not measured.
  - Goal: estimate car's current and future positions and velocities



Problem napovedovanja

- Accurate prediction can be difficult
- “Like driving a car using only the rear view mirror”
  - Straight road = trivial
  - Curved road = maybe possible?
  - Right angle turns = forget it!

Značilnosti problema

- Most head-motion energy < 2 Hz
- Prediction interval < 100 ms
- Multidimensional
  - Translation and orientation
- Nonstationary (statistics change)
- Data are noisy
- Linear or nonlinear?

Metode napovedovanja

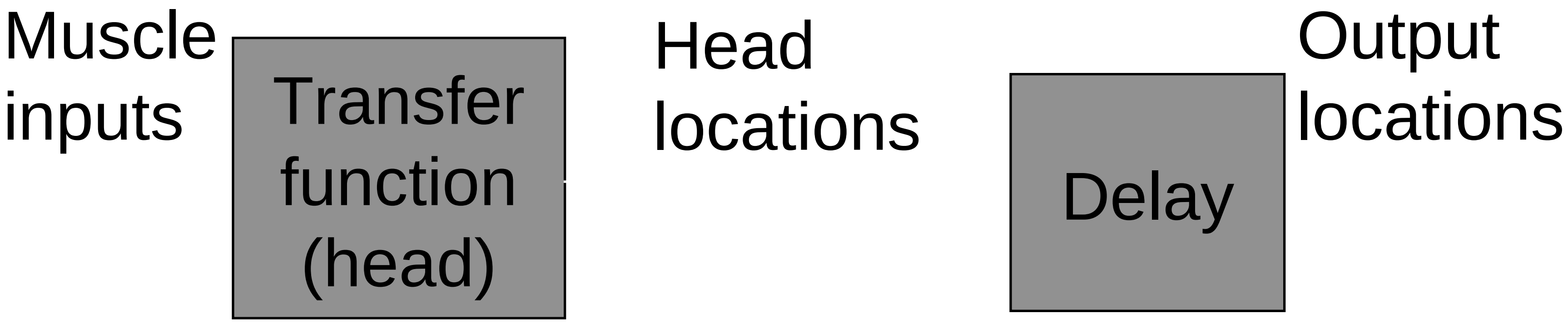
- Curve fitting
- Information theory
- Control theory
- Time-series analysis
- Wiener filters
- Kalman filters
  - Examine in more detail as an estimator

Metode napovedovanja (2)

- **Curve fitting**
  - **Fit splines, other curves. High-order -> wiggles**
  - **Good for smoothing, bad for prediction.**
- **Information theory**
  - **If stationary, bandlimited, and no noise, then perfect prediction is possible!**
  - **Interesting theoretically but not practical.**

Metode napovedovanja (3)

- **Control theory**
  - **Model behavior by “transfer function”**
  - **But for us, transfer is “delay only” unless…**



Metode napovedovanja (4)

- Time Series Analysis
  - Usually assumes 1-D noisy stationary linear signal
  - Fits models to curves (ramps, sinusoids)
  - Autoregressive (AR), moving average (MA), ARMA, Box-Jenkins [Montgomery90]
  - Often used for economic problems with cyclical components

Metode napovedovanja (5)

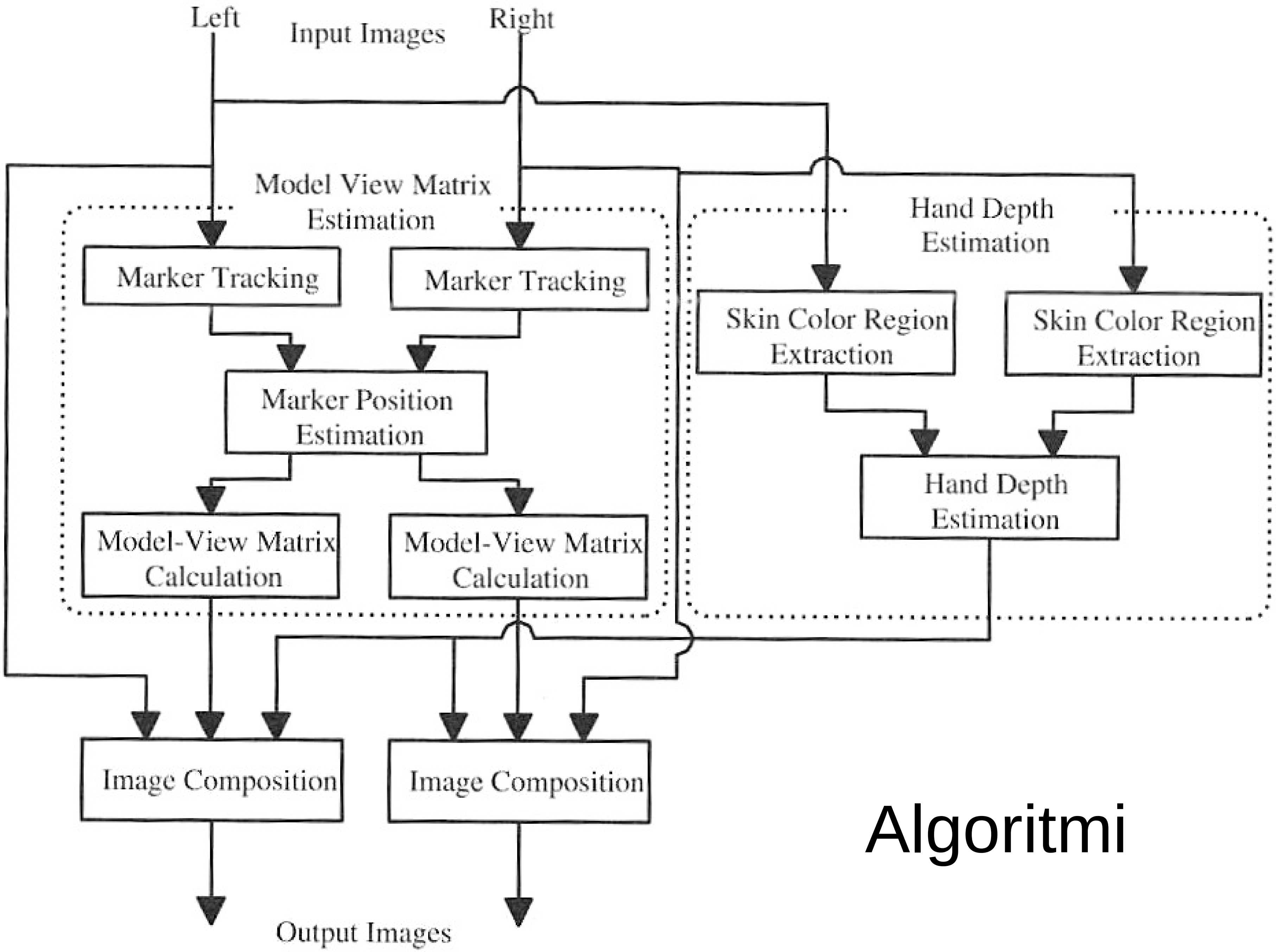
- Kalman and Wiener filtering
  - Optimal linear estimators (minimize expected mean-square error)
  - Wiener assumes “noiselike signal”
  - Kalman requires user to provide model
  - Kalman needs less computation, especially for multiple signals

Smiselnost uporabe Kalmanovega filtra

- Advantages of Kalman filter
  - Takes advantage of measured derivatives
  - Allows correlation among multiple signals
  - Empirically, still works with nonideal models
  - Linear approximation for nonlinear (EKF)
  - Computationally efficient
  - Combines multiple measurements, when available, to reduce overall error

Sistem sledenja

- Allows the AR system to correctly align the overlaid material with the user’s view of the world
- Must track
  - the position of the user’s head and eyes
  - the location of the user with reference to the surroundings



Left
Input Images
Right
Model View Matrix
Estimation
Hand Depth
Estimation
Marker Tracking
Marker Tracking
Skin Color Region
Extraction
Skin Color Region
Extraction
Marker Position
Estimation
Hand Depth
Estimation
Model-View Matrix
Calculation
Model-View Matrix
Calculation
Image Composition
Image Composition
Output Images

Algoritmi

AR sledenje in senzorske zahteve

- **AR sensing requirements are much tougher than VE requirements**
  - **Greater variety and bandwidth**

    (not just head, hands, and body)
  - **Higher accuracy (for registration)**
  - **Longer range (portability)**
- **Commercial solutions for VE, not AR**

Raznolikost naprav in pasovna širina

- **Range data**
  - **Need for occlusion and data merging!**
  - **Vision-based approaches**
  - **Direct sensors (rangefinders)**
- **Knowledge of environment**
  - **Database access, vision approaches**
- **CT, MRI, IR, Video**

Sledilne tehnologije

- **Active sources**
  - **Optical, magnetic, ultrasonic**
  - **Requires structured, controlled environment**
  - **Restricts range**
  - **Magnetic vulnerable to distortions**
  - **Ultrasonic: ambient temperature variations**
  - **Optical is often expensive**
- **Scalable active trackers**
  - **InterSense IS-900, 3rd Tech HiBall**

3rd Tech, Inc.

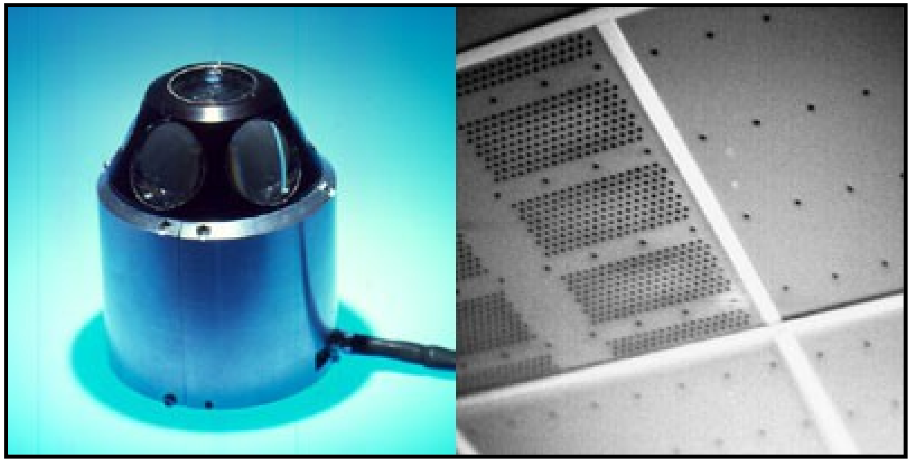
Tehnologije sledenja

- **Passive optical**
  - **Line of sight, may require landmarks to work well. Can be brittle.**
  - **Computer vision is computationally-intensive**
- **Electromagnetic compass, tilt sensors**
  - **Passive and self-contained**
  - **Vulnerable to distortions**
- **Mechanical**
  - **Can be accurate but tethers user**

TCM2

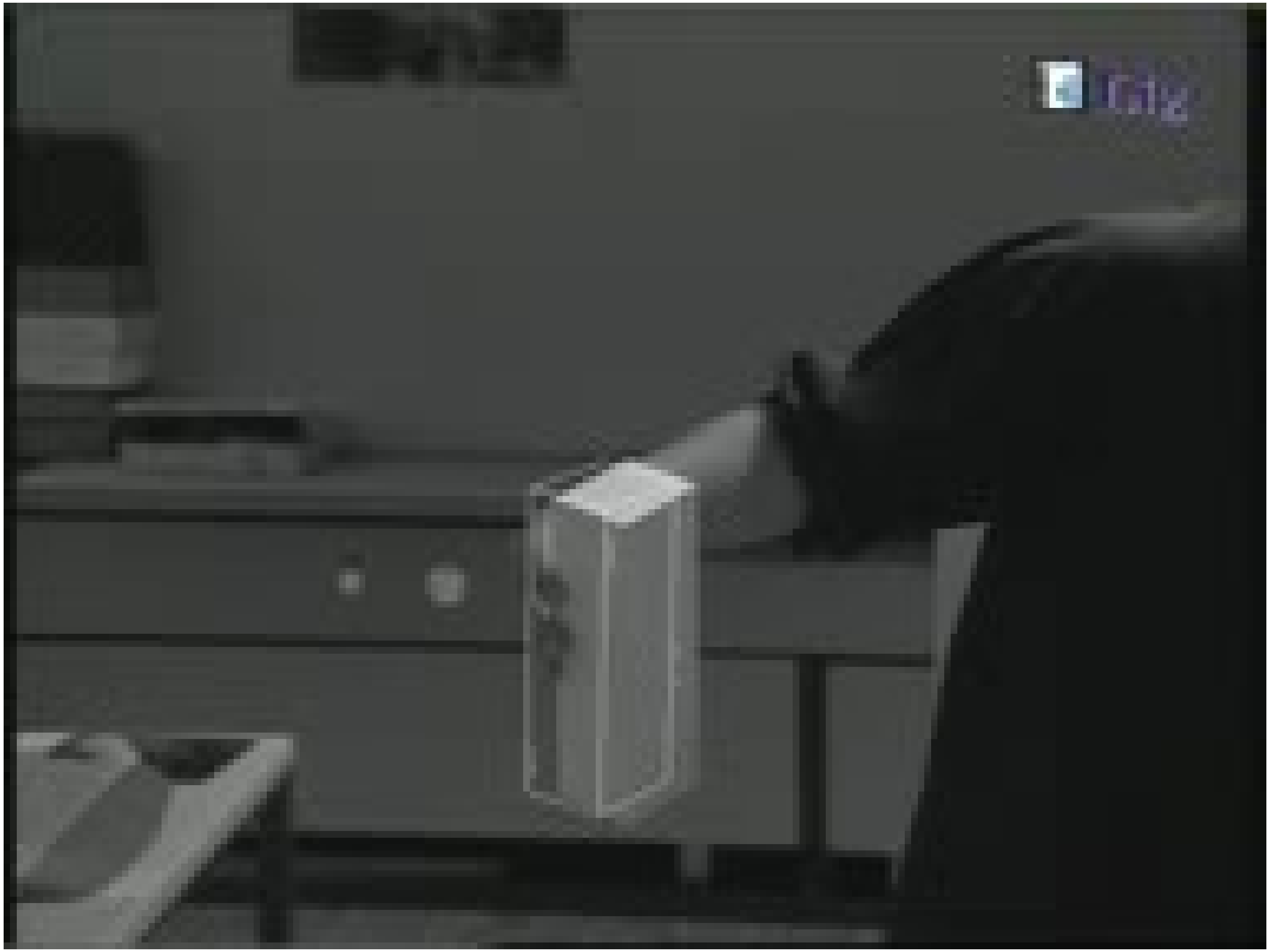
Sledenje v zaprtem prostoru

- **Usually consist of two parts**
  - **Target – LEDs or reflectors**
  - **Optical sensors – determine the user's position by calculating the distances and angles to each target**
- **Example: HiBall Tracking System**



  - Developed by University of North Carolina
  - Works within an area of 500 square feet
  - Accuracy:
    - linear motion within 0.2 millimeters
    - angular motion within 0.03 degrees

Še nekaj primerov

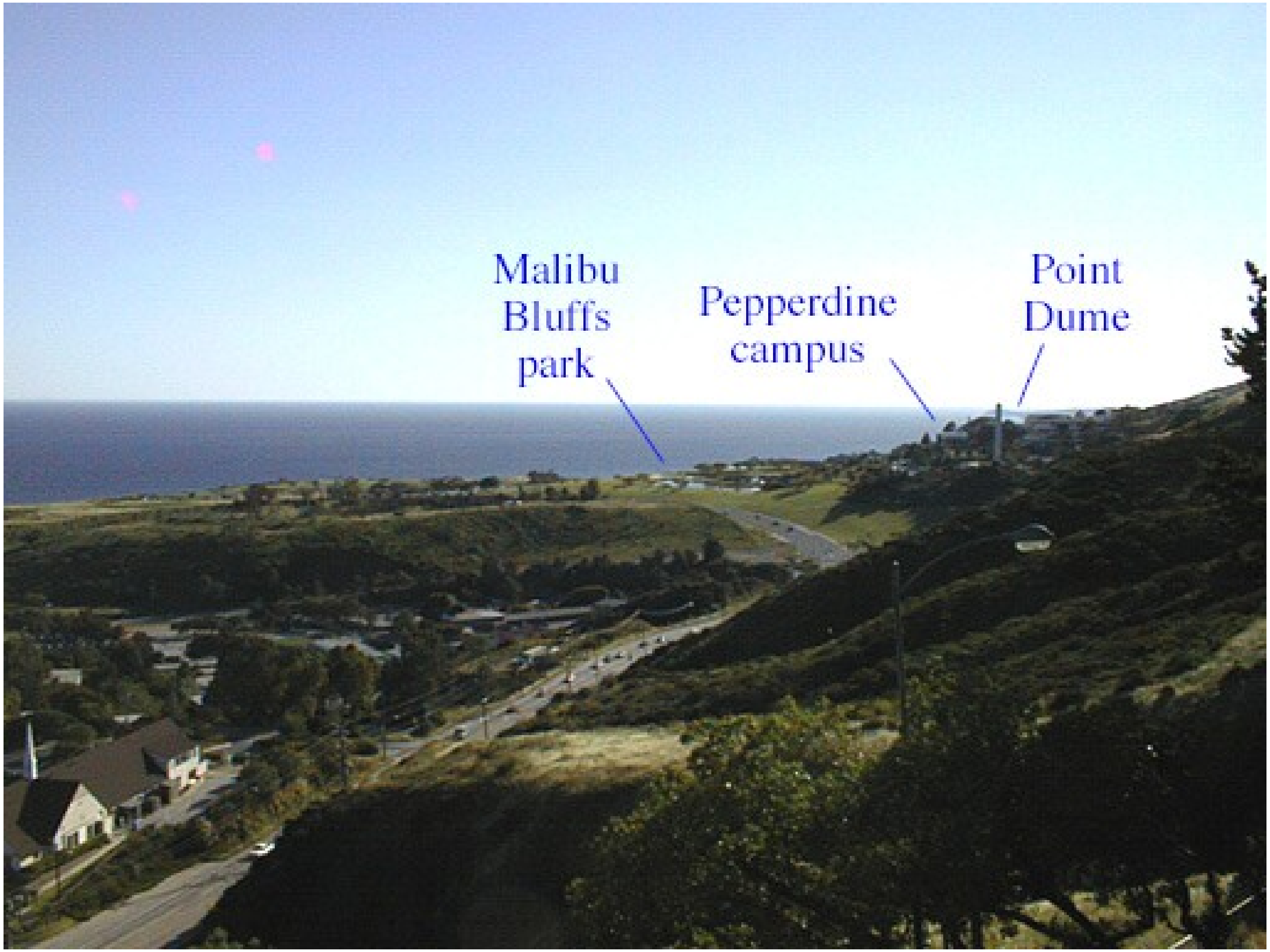


Še nekaj primerov

Sledenje na prostem (outdoor)

- **Most popular outdoor tracking system is the Global Positioning System (GPS)**
  - **Monitors radio signals from navigation satellites**
  - **Accuracy is very coarse – can be off by several meters**
- **Differential GPS**
  - **Also monitors another GPS receiver and radio transmitter at a fixed location on earth**
  - **Accurate within one meter**
- **Real-Time Kinetic (RTK) GPS**
  - **Being developed by Condor Earth Technologies**
  - **Provides centimeter-level accuracy**

Okolje na prostem (Outdoor Environment)



Tehnologije sledenja (uporabne v AR)

- **GPS**
  - **Regular ~30 meters**
  - **Differential: ~3 meters**
  - **Carrier phase: centimeters, but multipath and initialization problems**
  - **Line of sight, jammable**
- **Inertial and dead reckoning**
  - **Sourceless but drifts**
  - **Cost and size restrict man-portable choices**

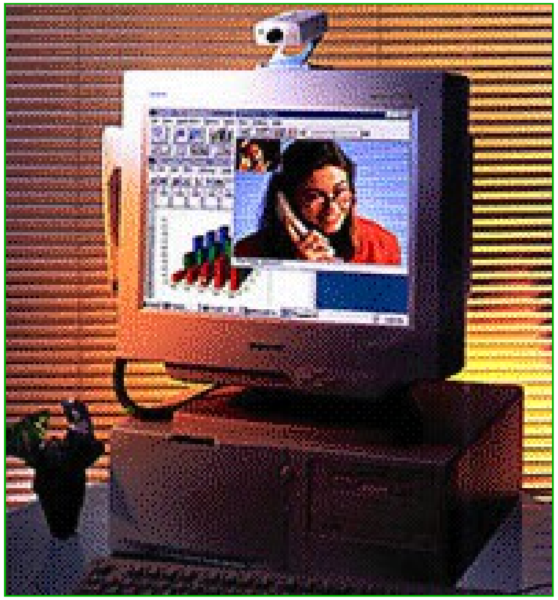
Trendi v registraciji in sledenju

- Hybrid tracking systems
  - combine approaches, cover weaknesses
- Systems built for greater input variety and bandwidth [Buxton93][Robinett92]
- Hybrid systems and techniques
  - e.g. use multiple registration techniques

Collaborative Augmented Reality

Today's Technology

- Video Conferencing
  - lack of spatial cues
  - limited participants
  - 2D collaboration
- Collaborative VEs
  - separation from real world
  - reduced conversational cues



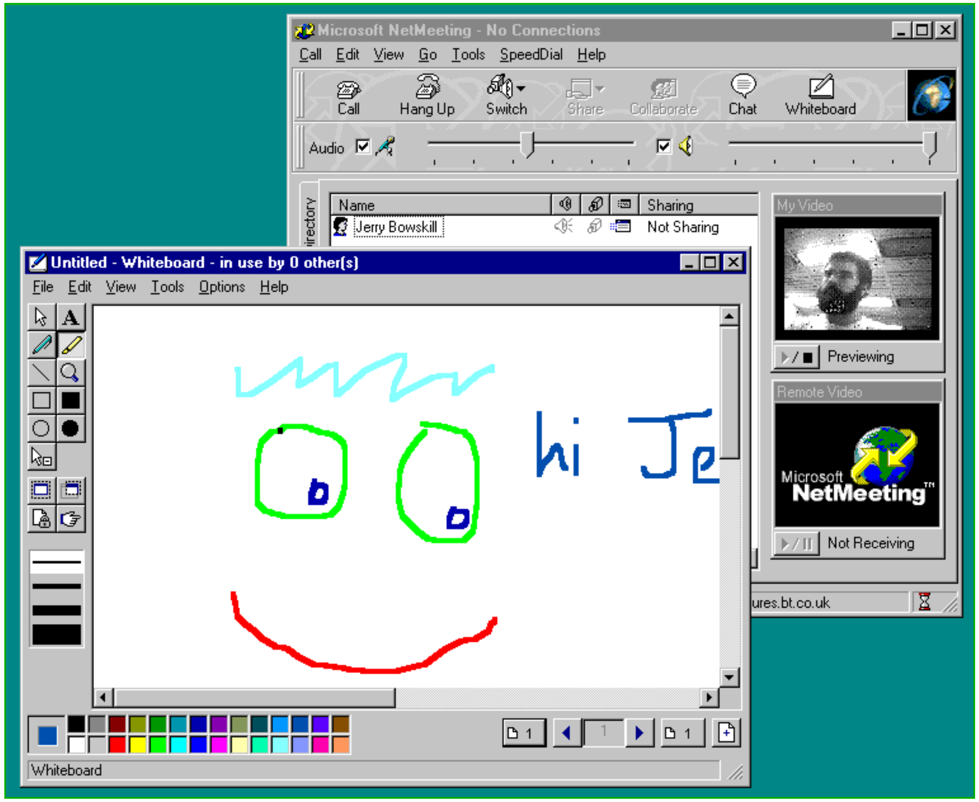
Beyond Video Conferencing

- 2D Interface onto 3D
  - **VRML**
- Projection Screen
  - **CAVE, WorkBench**
- Volumetric Display
  - **scanning laser**
- Virtual Reality
  - **natural spatial cues**

Seamless CSCW

- Seam spatial, temporal, functional discontinuity
- Types of Seams
  - Functional
    - between different functional workspaces
  - Cognitive
    - between different work practices

Functional Seams



Effect of Seams

- Functional Seams:
  - Mediated differs from F-to-F Conversation
    - Loss of Gaze Information
    - Degradation of Non-Verbal Cues
- Cognitive Seams:
  - Learning Curve Effects
  - User Frustration

Collaborative Augmented Reality

- Attributes:
  - Virtuality
  - Augmentation
  - Cooperation
  - Independence
  - Individuality
- Merges task space and communication space
  - No Functional Seams
- Blends Reality and Virtual Reality
  - No Cognitive Seams

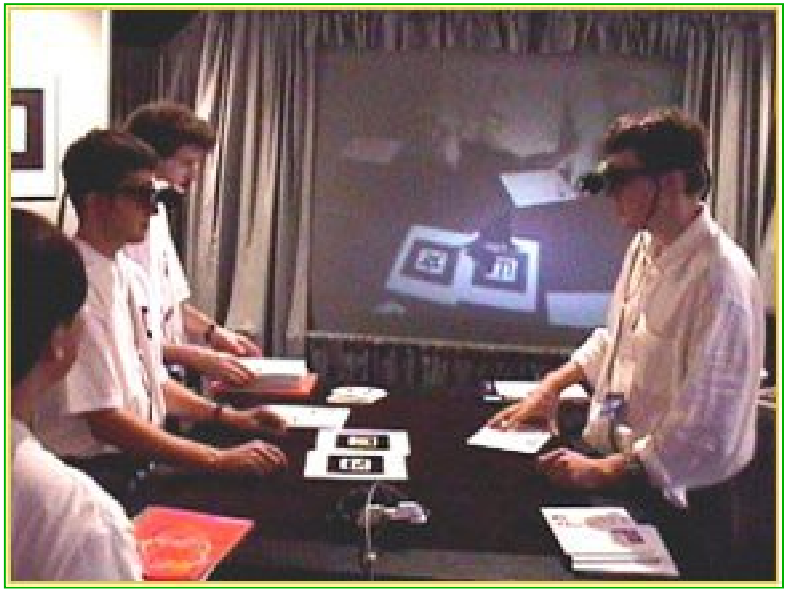
Collaborative AR Systems

- Face to Face Conferencing
  - Studierstube (TU Vienna)
  - Shared Space (HITL)
  - AR2 Hockey (MR Systems Lab)
- Remote Conferencing
  - WearCom (BT/HITL)
  - AR Conferencing Space (HITL)
- Transitional
  - VLEGO II (NAIST)
  - MagicBook (HITL)

Face to Face Conferencing

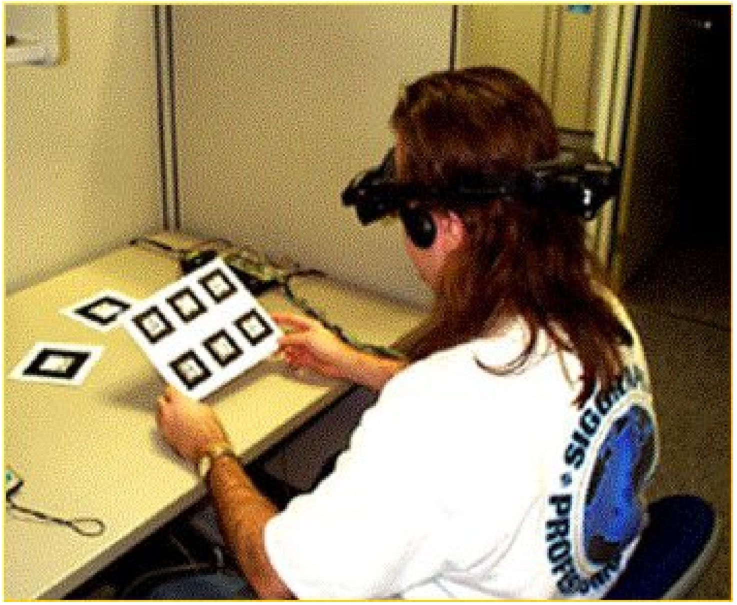
Shared Space

- Goal
  - create compelling collaborative AR interface usable by novices
- Exhibit content
  - matching card game
  - face to face collaboration
  - physical objects
    - 5x7” cards
  - built on VRML parser



Augmented Reality Conferencing

- **Moves conferencing from the desktop to the workspace**



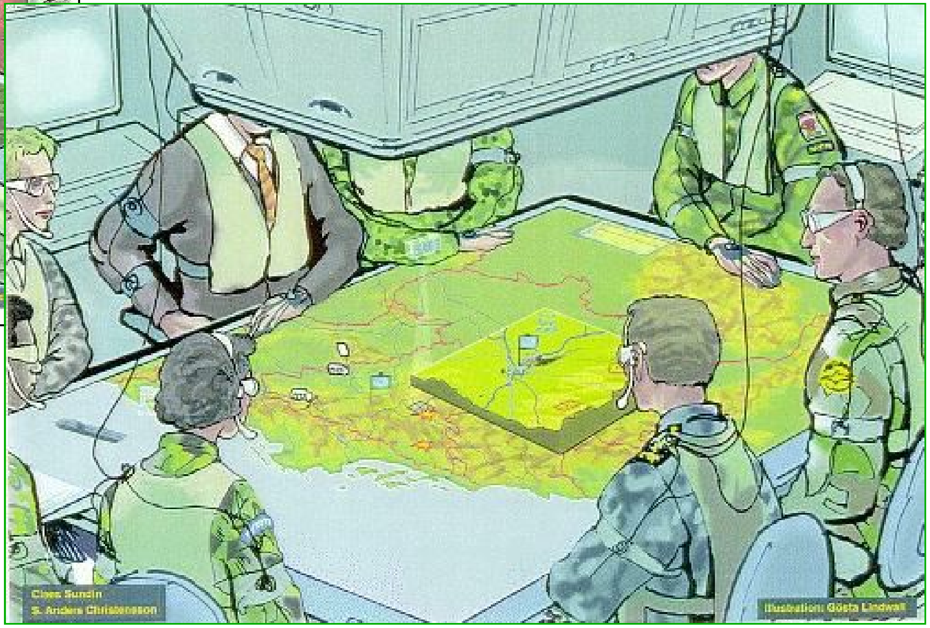
Lessons Learned

- Face to face collaboration
  - AR preferred over immersive VR
  - AR facilitates seamless/natural communication
- Remote Collaboration
  - AR spatial cues can enhance communication
  - AR conferencing improves video conferencing
  - AR supports transitional interfaces

Areas for Future Work

- Wearable collaborative AR system
  - opportunistic collaboration
  - just in time training
- Communication Asymmetries
  - interface, expertise, roles
- Usability Studies
  - multi-user AR systems
  - communication tasks

Data Visualization in the Future



Performance Issues

Augmented Reality systems are expected:

- **To run in real-time so that the user can move around freely in the environment**
- **Show a properly rendered augmented image**

Therefore, two performance criteria are placed on the system:

- **Update rate for generating the augmenting image**
- **Accuracy of the registration of the real and virtual image**

Trends (2)

- **True real-time systems**
  - **Must synchronize with the world**
  - **Time becomes a first class citizen**
  - **Time critical rendering**
- **Perceptual and psychophysical studies: when is registration critical?**
- **Accurate tracking at long ranges, unstructured environments**

Galerija poskusov

NRC

Dlančniki in AR

Hybrid Vision-assisted Tracking
and Augmented Reality Research at UNC