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

• Virtual Environments (VE): Completely replaces real world
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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

AR Demo
ISL/HRL

Malibu Beach

Youngkwan Cho,
STAR system
Vzajemno prekrivanje realnih in sintetičnih objektov
• 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
• “X-ray vision” for surgeons
• Aid visualization, minimally-invasive operations.

Training.
  – Ultrasound [UNC Chapel Hill]
  – MRI, CT data
• 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

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Eric Rose, et. al., ECRC
Planiranje razporedov naprav (arhitektura)
Planiranje razporeda naprav
Arhitektura
• 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
• Robotic path planning, previewing
• Remote manipulation

ARGOS,
U. Toronto

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

Sodelovanje na istem virtualnem objektu v realnem okolju
Obogatena resničnost na prostem  (Outdoor Augmented Reality)
Kulturna dediščina
Kulturna dediščina
Šport
Reklamiranje
Nakupovanje
Kaj je torej cilj AR?

• To enhance a person’s performance and perception of the world

• But, what is the ultimate goal????
• Create a system such that no user CANNOT tell the difference between the real world and the virtual augmentation of it.
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 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

Diagram prikazuje raznolike komponente sistema za obogateno resničnost.

1. Scene Coordinates
2. Camera Position Coordinates
3. Align Graphics Camera to Real Camera
4. Video Image
5. Graphics Image
6. Augmented Video
7. Virtual Object Coordinates
8. World Coordinates
9. Virtual Object
10. Graphics Rendering
Prikazovalne tehnologije

- Monitor Based
- Head Mounted Displays:
  - Video see-through
  - Optical see-through
• Simplest available
• Little feeling of being immersed in environment
AR s pomočjo video monitorja

Video cameras  Monitor  (Stereo glasses)

Graphics  Combiner

Ergonomics in Teleoperation and Control Lab, MIE Dept. University of Toronto
Tehnologija “Optical see-through”
Tehnika optičnega gledanja

Virtualna slika z monitorja

Resnični svet

Optična kombinacija
Naprave za “optično gledanje skozi”

Sony Glasstron

Virtual Vision VCAP
Video see-through

Diagram:
- **Video of real world**
- **Scene generator**
- **Graphic images**
- **Head Tracker**
- **Video cameras**
- **Monitors**
- **Combined video**

Real World
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
• 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
• Flexibility in composition strategies
• Wide field of view
• Real and virtual view delays can be matched
Prednosti

• Simplicity
• Resolution
• No eye offset
AR osnovana na projekciji

Head-tracked user

Projector

Real objects with retroreflective covering
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
Both have proponents
Roles for both
Depends on application?
  - Manufacturing: optical is cheaper
  - Medical: video for calibration strategies
• **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!
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
• 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
• Virtual and Real must stay aligned
• If not:
  – Compromises illusion that the two coexist
  – Prevents acceptance of many serious applications
In order to achieve 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.
• **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
Accurate registration is difficult!
- Sensitivity of visual system
  - Few mm, small fraction of degree
  - Coin test
- Many sources of error

Demonstrate with ultrasound footage
• 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
• 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
• 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
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
• 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
• 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
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
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!
• Most head-motion energy < 2 Hz
• Prediction interval < 100 ms
• Multidimensional
  – Translation and orientation
• Nonstationary (statistics change)
• Data are noisy
• Linear or nonlinear?
• Curve fitting
• Information theory
• Control theory
• Time-series analysis
• Wiener filters
• Kalman filters
  – Examine in more detail as an estimator
• 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.
• Control theory
  – Model behavior by “transfer function”
  – But for us, transfer is “delay only” unless...
• 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
• 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
Algoritmi
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
• 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
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
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: \( \sim 30 \) meters
  - Differential: \( \sim 3 \) 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
• 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
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