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Augmented Reality

Lecture 8-1

Augmented Reality (AR)

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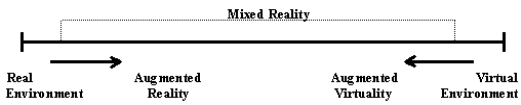
- AR combines real and virtual, is interactive in real time and is registered in 3D
- Augmented reality alters how we see the real world
  - AR supplements reality
  - VR completely replaces reality
- Blends real and virtual in a real environment
- Applies to other augmented senses too!
  - Adds graphics, sounds, haptics and/or smell to the natural world
- On the spectrum between virtual reality and the real world, augmented reality is closer to the real world



Example AR Images

3

Youngkwan Cho,
STAR system

Blackmagic,
AR Toolkit

Augmented Reality...

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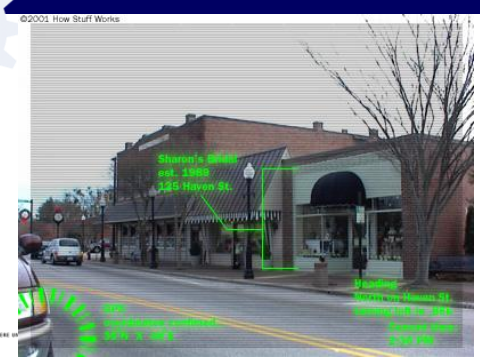

AR History

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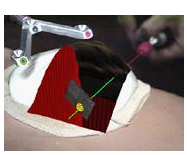
- Sutherland 1965-68!
- Boeing 1990: AR
- Ultrasound project, UNC
- Late 1990's: collaboration, outdoors, interaction, AR sports broadcast
- 1998: dedicated conferences
  - ISMAR
- Close connections to ubiquitous computing and wearable computing



AR / VR Evolution

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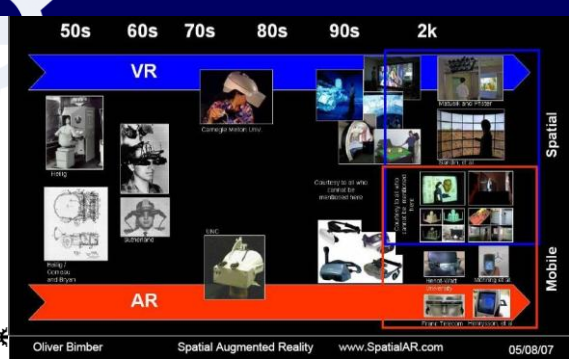


AR Now

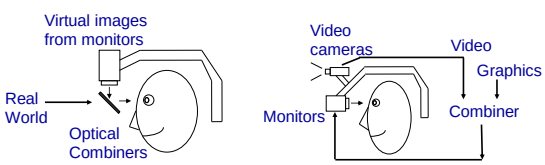
- Many flavours!
- Mostly at research, prototype phase
- Some commercial experiments, prototyping
- Synthetic objects registered in 3D
  - Text, images, 3D graphics
  - Real-time interactive
  - Not necessarily photorealistic or HMD!
  - Fast, accurate, driftless tracking
    - Exact registration (alignment) very difficult
- Has just started, holds great promise for the future, real applications are emerging
- Not too difficult to make
- Runs real-time

Basic Types of Augmented Reality

- HMD-based AR
  - Optical see-through, transparent HMD
  - Video see-through, videomix HMD
  - HMD-AR is the ”classic” AR style
- Projector-based AR
  - AR on real surfaces
- Monitor-based AR
  - Videomix for monitor/handheld display
  - Augmented sports broadcasts
  - Computer games mixing real images and computer graphics (Sony Eye-toy etc.)

HMD-based AR Systems

- Blending: optical vs. video
- Focus, contrast, portability
- Sensing and bandwidth



Strengths of Optical AR

- Direct view of the real world
  - Full resolution, no time delay (for real world)
  - Safety
  - Lower distortion
- Better depth perception of virtual
- Inconsistency due to tracking latency/precision, optical occlusions and illumination
- No eye displacement
  - Some video see-through HMDs avoid this problem
  - Canon COASTAR, Trivisio

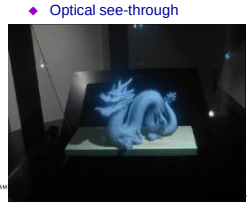
Strengths of Video AR

- Low-cost
- Digitized image of the real world
  - Flexibility in composition
  - Matchable time delays
- Pixel-precise registration
- Consistent occlusion (but note complex Kiyokawa optical display that supports occlusion)
- Consistent lighting
- Easy tracking (marker-based or marker-less)
- Wide FOV is easier to support
- Limitations: usually monoscopic, limited to resolution of camera and display

Optical vs. Video AR summary

- Both have proponents
- Video is more popular today?
  - Depends on available optical products
- Depends on application?
  - Manufacturing: optical is cheaper
  - Medical: video for calibration strategies

- Optical see-through



Video see-through

Focus, Contrast, Portability

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- Focusing
  - Need to measure eye accommodation?
  - Autofocus video camera?
- Contrast
  - Match the display and environmental brightness
  - Real world has large dynamic range! (night to sunshine)
  - More difficult with optical?
- VE: User stays in one place
- AR: User moves widely in the task location
  - Use in factories, outdoors, etc.
  - Less controlled environments
  - Very demanding for the technology

The Registration Problem

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- Virtual and real must stay properly **aligned**
- If not:
  - Compromises illusion that the two coexist
  - Prevents acceptance of many serious applications
  - Do you want a surgeon cutting into you if the virtual cut-marks are misaligned?
- Static errors
  - Optical distortions
  - Mechanical misalignments
  - Tracker errors
  - Incorrect viewing parameters
- Dynamic errors
  - System delays

ARToolKit

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- HITL open source
  - http://www.hitl.washington.edu/artoolkit/
- Vision-based AR library
- Recognizes patterns, markers
- Applications: MagicBook, VOMAR, ARGroove, Tiles, Shared space, …
- ARToolkit iPhone: http://www.youtube.com/watch?v=5M-oAmBDcZk
- Other AR authoring and development tools:
  - ARToolWorks, Metaio, Total Immersion, HandVu

How Does ARToolKit Work?

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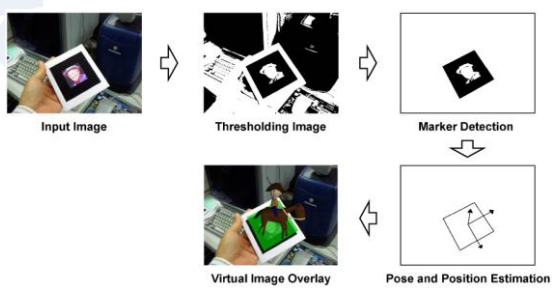

Projector-based AR (Spatial AR)

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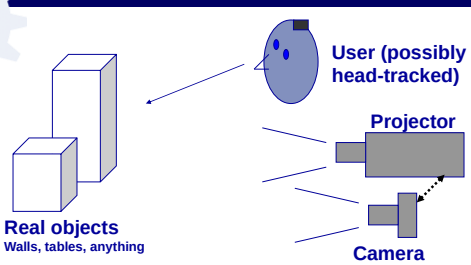

Examples:
Raskar, UNC Chapel Hill, Inami, Tachi Lab, U. Tokyo, Bimber

Spatial AR

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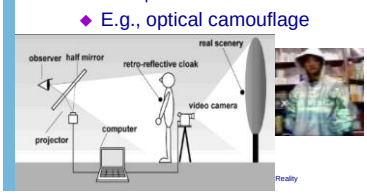
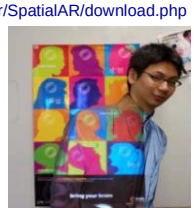
- Projections, augmentations to arbitrary surfaces
- Corrected view of (almost) any image to any surface
- Fusion: real world with graphics
- Free online book: Spatial AR
  - http://www.uni-weimar.de/medien/ar/SpatialAR/download.php
- E.g., optical camouflage





Example of Projector-based AR

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Ramesh Raskar, UNC Chapel Hill

Another Example of Spatial AR

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- HMD vs. Projected AR

Spatial AR Examples

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VeinViewer

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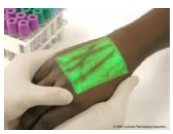
- Near-IR camera locates subcutaneous veins and project their location onto the surface of the skin



Car HUDs

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- Heads-Up Displays are emerging
  - Projected onto the windscreen

- HUDs with IR cameras
  - Cadillac NightVision system

  - BMW night vision system

Pocket / Pico Projectors

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- Miniature or integrated projectors
- Microprojectors are existing and coming
  - ”Pico projector market to hit 6.5M units in 2011”
  - E.g., Mitsubishi

Projection onto non-optimized surfaces

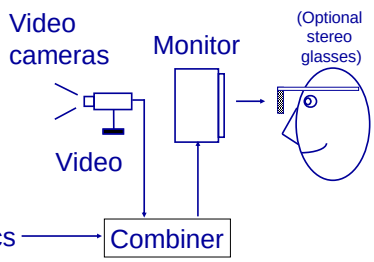
- Smart projector-camera systems
- Future: home CAVEs?

Projectors vs. Displays

- Projectors have three distinct advantages over other displays
  - The size of the image is decoupled from the size of the device, enabling large image from a small device
  - The projected image can be overlaid on real objects, making the composition ideal for visual augmentation of real world surfaces even if surfaces are colored and non-planar
  - Images from two or more projectors can be superimposed and physically blended together, allowing configurations that improve resolution, aspect ratio or brightness

Monitor-based AR

- Weather broadcasts etc.



Monitor Based AR

- Augmented sports, virtual signage, e.g., TrackVision by Orad
- CNN hologram, http://www.youtube.com/watch?v=thOxW19vsTg
- AR easily on your desktop, by GE http://ge.ecomagination.com/smartgrid/#/augmented_reality
- Sony PS3 AR-game: The eye of judgment, http://www.youtube.com/watch?v=hWBQ9UE-OkM
- Someday iHoloPhone?: http://www.youtube.com/watch?v=_n83XjFSSvM

AR + CV on desktop

- Facetracking AR, e.g., http://www.youtube.com/watch?v=i_bZNVmhJ2o
- Bodytracking AR with effects

Mobile AR

- Location-aware, situated computation
- AR is a powerful UI for mobile computing
  - Interface is everywhere
- Wearable computing
  - Mobility, intimacy, context sensitivity, consistancy
- Many levels, forms:
  - On a hand-held screen
  - Non-tracked HMD
  - Stereo head-tracked, position tracked, AR with full overlay registration

What is Mobile AR?

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- **on a hand-held screen**
- **wearable display, no tracking whatsoever**
- **body-stabilized wearable display (orientation tracking)**
- **location-dependent audio augmentation (with or without spatialized audio)**
- **location-dependent screen-stabilized augmentation (possibly monocular)**
- **location-dependent body-stabilized augmentation (projection cylinder/sphere surrounding the user)**
- **stereo head-tracked, position tracked, AR with full overlay registration**

Handheld VR / AR

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- Handheld or palm-VR display
- Works well with augmented reality
- Consists of a screen small enough to be held by the user
- Spatially aware
  - React to changes in the viewing vector between it and the user

Mobile AR Systems

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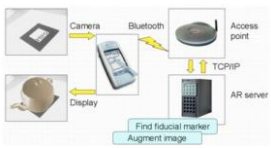
- Existing outdoor systems
  - Focus on tracking: HRL, Rockwell, USC, …
  - Focus on systems/UI: Columbia, Univ. of South Australia, Naval Research Lab, Mixed Reality Systems Lab, …
  - ISAR and ISMR symposia => nowadays **ISMAR**
- Camera phones, PDAs, smart phones
  - www.cs.usyd.edu.au/~ahudson/docs/arphone_ozchi2003.pdf
  - Apple's iPhone, smart phones, Netbooks, watchphones, …



Oqo model 2+

Handheld AR examples

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- A simple wall map of Canada for viewing weather or demographic data by holding the palm display over the region of interest
  - The palmtop display becomes a magic lens to a virtual information base

Handheld AR examples

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- To augment the terrain surrounding a user
  - A farmer in the field might check the display for information on that particular field
- A soldier could access information about what is over the next ridge / building
- Walking down the main street in your hometown and seeing a set of clickable signs pop up over the various buildings. Each sign allows you to link, on the spot, to more information about the building, to a related service, or even to a private message left for you by someone else who has recently visited that same location

Components of handheld AR / VR

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- The screen
  - Typically a small LCD display
  - The resolutions are still low for a large amount of detail and text
- Some kind of tracking
  - Presents a difficult challenge
  - Systems require mobility
  - Computer vision-based tracking
  - GPS, possibly combined with inertial trackers etc.
  - Magnetic trackers
- Transferring imagery to the screen?
  - Heavy calculations may be done in a PC-based server
  - Transfer over WLAN etc.
  - Smartphones are getting powerful

Features of handheld AR / VR

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- The characteristic feature is see-around functionality
  - The user can look at the information provided by the display or ignore it by looking directly at the physical world
- Could also be used together (e.g., as a control tool) with other VR displays such as CAVE
- Handheld computers, netbooks and smart phones have the potential to introduce AR to large audiences outside of a constrained laboratory environment
- 3D tracking with camera phones
  - http://people.csail.mit.edu/kapu/EG_09_MGW/EG2009_Wagner.pdf
- Course notes on mobile 3D graphics
  - http://people.csail.mit.edu/kapu/EG_08/Mobile3D_EG08.pdf

AR on Smartphones

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- Mobile AR cv-tracking on an iPhone 3G: http://www.youtube.com/watch?v=pBI5HwitBX4
- iPhone: Nearest subway, http://latimesblogs.latimes.com/technology/2009/07/augmented-reality-iphone-apps-subway-twitter.html
- Mobile AR for Android: Layar is the worlds first mobile AR browser, which displays real-time digital information on top of reality in the camera screen of the mobile phone. http://layar.eu/
- Location-based Augmented Reality for Android: Enkin, http://www.enkin.net/
- AR GIS maps, http://www.youtube.com/watch?v=yFwzFby2eNo

Mobile AR Challenges

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- Powerful wearable computing is difficult
- Tracking, registration is VERY difficult
  - indoor, outdoor
- Limited resources
- Size, weight, power consumption
- HMDs, computers
- Input devices, UIs
- Complementary hand-held / palm-top / wrist displays

Mobile AR vs. Spatial AR

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- Mobile Augmented Reality
  - supports mobile applications
  - supports an arbitrary large number of users
  - current limitations: tracking, image quality (resolution, size, FOV, accommodation), ergonomics (size, weight)
- Spatial Augmented Reality
  - doesn't support mobile applications
  - supports a limited number of users
  - advantages: offers very high quality and realism (technological issues are less critical for controlled environments, technology is not body-attached)

AR Classification

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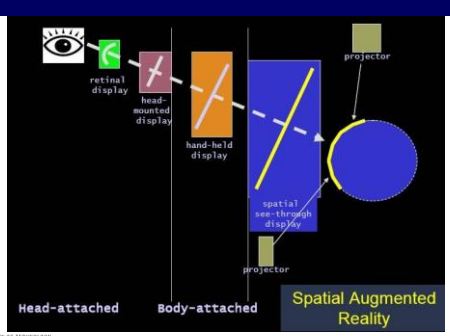

Augmented Reality Applications

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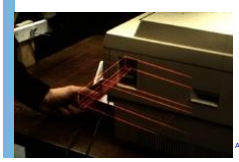
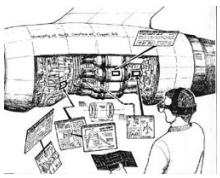
- The manuals of the maintenance man
  - Thousands of pages of manuals, images, videos, and animations are handy and available. Assembly instructions etc.
  - Architectural anatomy
  - BMW AR service





AR Applications

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- Extended senses, memory
  - Night vision, IR, UV
  - Memory aid
- Mann: diminished reality
  - Protective eyeglasses help to filter out distracting ads etc.
  - wearcam.org/diminished_reality.htm

Augmented Reality Applications

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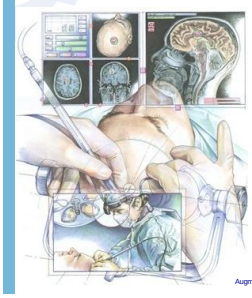
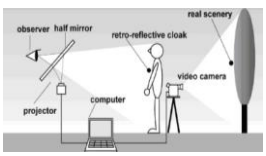
- Image-guided surgery, “X-ray vision”, invisible cloak





AR Military Applications

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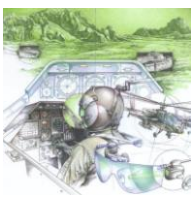
- Gun view, battle info
  - Used for pilots, tanks etc. Also for infantry
  - Terrorism & wars boosts development
  - Reduce losses, improve 2-way information flow, provide real-time data for commanders and men



AR Applications

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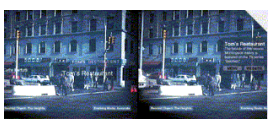
- Design, decoration

- Tourism
  - Virtual Post-it notes



- Services
  - AR for postal service
  - https://www.prioritymail.com/simulator.asp

Augmented Reality Applications

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- User interfaces
  - Marisil etc.

- Modeling
  - Tinmith etc.
    - http://www.cis.unisa.edu.au/~ciswp/tinmith.htm

Augmented Reality for Blind

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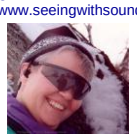
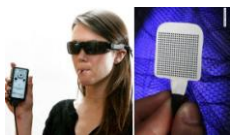
- Augmented Reality for the totally blind
- The vOICe Learning Edition translates arbitrary video images from a regular PC camera into sounds. Also for mobile phones
  - http://www.seeingwithsound.com/

- BrainPort lets you see with your tongue, http://vision.wicab.com/
  - The camera image is sent through an electrode array, via the tongue, to the person's brain

Augmented Reality Applications

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- Wearable conferencing space
  - Moves tele-conferencing from desktop to workspace
- AR characters for play, entertainment
  - AR imagination friend for kids?
- Gaming
  - Tinmith ARQuake
  - AR^2 Hockey
  - Oulu street gaming AR visions
  - Sony, The eye of judgment
  - Tweetmondo pairs Twitter posts with geographical info and will let see tweets through the video camera on the phones
  - Baseball cards go live, http://www.t-immersion.com/

AR Information Browsers

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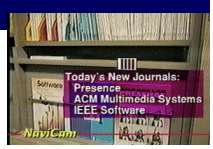
- Information is registered to real-world
- **Hand-held AR displays**
  - Video-see-through (Rekimoto 1997) or non-see through (Fitzmaurice 1993)
  - Magnetic trackers, inertial sensors and/or computer vision-based
- Interaction: manipulation of a window into information space
- Applications
  - Context-aware information displays
  - E.g., Wikitude AR travel guide



Rekimoto et al. 1997

Collaborative AR

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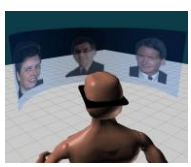
- Face-to-face conferencing
- Remote conferencing
- Merges task and communication space
- Independent views
- New forms of 3D interaction


3D AR Interfaces

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- Virtual 3D objects displayed in physical space, can also be freely manipulated
  - See-through HMDs and 6DOF head-tracking are required
  - 6DOF magnetic, ultrasonic, etc. hand trackers for input
- Interaction
  - Viewpoint control
  - Traditional 3D user interface interaction: manipulation, selection, adding, removing, etc.

Kiyokawa et al. 2000

Some AR UIs

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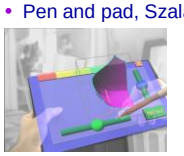
- Personal Interaction Panel: AR + GUI
  - Pen and pad, Szalavari -97




- VOMAR: Tangible + AR, Kato -00

Some AR UIs

- Datatiles: Tangible + GUI, Rekimoto -01

- MARS: GUI + indoor + outdoor AR
  - Campus Info, Höllerer -99

Some AR UIs

- Office of the future
  - Raskar -98 =>
  - Bimber spatial AR, Cisco tele-conf.

- mediaBlocks
  - Carry "data containers" across physical space
  - Ullmer -98
- Tiles for designing layout
  - Collaborative project -00

Some AR UIs

- Studierstube Mix AR with projections
  - Schmalstieg –00

- Mix & match UI paradigms
  - AR, desktop, tangible, immersive, …
  - Real-virtual, # of displays, users, apps, …
  - Use most appropriate UI for any task
  - Don't think in categories, be creative!

Some AR examples

- Virtual Brownies
  - http://rogiken.org/vr/

- Straw-like User interfaces (SUI)
  - SUI is an evolutionary interface that allows to virtually experience the sensations of drinking. They are obtained by exerting pressure and vibration change to mouth thru the control of valve and speaker
  - http://www.hi.mce.uec.ac.jp/inami-lab/en/projects/SUI/index.html

Possible Future of AR

- Holds great promise for the future
- Technology will have countless applications
- More computing power and integrated tracking with the portable devices will make new & better applications possible
- Everyone from tourists to military troops will benefit from the ability to place computer graphics in their field of vision
- We will see mass-marketed augmented-reality systems
- AR displays may eventually look like a normal pair of glasses
- Informative graphics will appear in your field of view, and audio will coincide with whatever you see
- Integration with mobile phones?
- The retinal scanning display is promising because it has the potential to be small
- Nokia, Apple and others are researching & experimenting AR

Some AR Links

- Nov. 2001 IEEE Computer Graphics and Applications:
  Recent Advances in Augmented Reality
- Jul.-Aug. 2008 IEEE Computer Graphics and Applications
  The State of the Art in Mobile Graphics Research
- Hainich: The End of Hardware, 3rd edition
- Bimber – Raskar: Spatial Augmented Reality
  - Also online www.SpatialAR.com!
- Haller, Billinghurst and Thomas: Emerging Technologies of Augmented Reality: Interfaces and Design
- http://www.se.rit.edu/~jrv/research/ar/
- http://www.augmented-reality.org
- http://www.cs.unc.edu/~azuma/
- http://www.cis.unisa.edu.au/~ciswp/
- http://www.hitl.washington.edu/projects/
- http://www.augmented-reality.net/