Augmented reality

Principles and materials
Examples

Visualization in guiding systems

- Passive systems (navigation)
  - Classically: a screen with localization information (GPS type)
  - Augmented reality systems: information merged to the reality
- Expected advantage of AR
  - Information easier to interpret
  - Located where the surgeon has to focus his/her attention
Technical possibilities

- Merging mode: optical / video (digital)
- Display: head-mounted display (HMD) / external screen / specific display (i.e. surgical microscope)
- Visualization: mono / stereo

Image superimposition

- Requires to register the patient (reality) to the data (augmentation)
- Video overlay:
  - Capture the real environment
  - Compute the data in the right location
  - Merge reality and data images
  - Display
- Optical overlay:
  - Compute the data in the right location
  - Display
- Involves calibration
Example: video overlay

- Real camera position
- Merged view
- Align graphics camera to real camera
- Graphics rendering
- Graphics camera

Virtual object

Real environment

Display Screen/HMD

Overlay Video/Optical

Univ. of Rochester

MIT – Harvard Med School

CMU – Shadyside Hospital
Example I (video/screen)
Harvard-MIT system [Grimson, Kikinis]

- Pre-operative MR imaging and 3D modeling
- Intra-operative surface acquisition and registration
- Video overlay on a screen

Example 2: Technical components
Reference frames to be linked

- MRI reference
- Intra-operative reference
- Laser reference
- Camera reference
- Image reference
- Patient reference

Data acquisition — Registration — Calibration (intrinsic, extrinsic)

Example 2 (video/HMD)
UNC — Fuchs and colleagues

- For ultrasound guided procedures

HMD cameras

US acquisition and planning

Video overlay in the HMD
Example 3 (optical/surgical microscope)

- Application in neurosurgery/ENT
- Add planning information in the images coming from the binocular
- Integrated into products
- Easy to use in clinical practice (natural evolution of existing device)
- Simple visualization

Example 3: Technical components

Pre-operative MRI → Registration → Patient → Optical overlay

Localizer → microscope position → patient position

HMD version [Birkelfelner et al.]
Other “natural” displays

- **Endoscopic images**
  - Bricault et al. IEEE TMI1998
  - Shahidi et al. IEEE TMI2002

- **Fluoroscopic images**

From Sielhorst et al. JOURNAL OF DISPLAY TECHNOLOGY, VOL. 4, NO. 4, DECEMBER 2008

- 1896 Invention of X-ray imaging
- 1938 Steinheil's publication on a needle tip augmentation
- 1955 First mobile C-arm
- 1967 2D real-time ultrasonography available on market
- 1968 Sutherland’s “Ultimate Display” - optical see-through HMD
- 1974 Computed tomography (CT) available on market
- 1980 Magnetic resonance imaging (MRI) available on market
- 1982 Navigation system reported
- 1985 First augmented operating microscope
- 1987 First laparoscopic cholecystectomy with a video endoscope
- 1992 First video see-through technology for AR, medical HMD augmentation
- 1995 First augmented sterile operating microscope
- 1997 First augmented endoscope
- 1998 First AR window
- 1999 First camera augmented C-arm
- 2000 First augmented binoculars, first augmented ultrasound device
Other devices (1)

- Sonic flashlight (Stetten et al. CMU)
  - To visualize US data where they are acquired

Other devices (2)

- CamC (Navab et al. & Siemens)
  - Combine X-ray views to video views of the patient
  - Modified X-ray system (camera+mirrors)
Technical issues

- Right place: calibration
  - Optical overlay less accurate (user-based subjective calibration)

- Right time: synchronization
  - Video overlay: ability to synchronize but possible delay
  - Optical overlay: time lag
  - May be an issue for instrument guidance

Technical issues (2)

- Right way: visualization and perception
  - Brightness (low for see-through systems)
  - Virtual object always appears sharp whatever the distance
  - Spatial relationships of the objects

- Other constraints: sterility, clinical usability
Some conclusions

- Advantages of video overlay
  - Good quality
  - More precise
  - Data synchronized
  - Possible storage

- Advantage of “natural” live images
  (surgical microscopy, endoscopy, fluoroscopy, etc.)
  - Already in the OR

- Very few clinical evaluations