

Image Processing

Paolo Favaro

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Image Processing B3.4SK2

- Lecturers:

Paolo Favaro

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Rm EM2.26

(weeks 1-5)

Andy Wallace

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Rm EM2.30

(weeks 6-10)

- Module Organisation (susceptible to changes)

- Lectures:

- Mondays 11:15 EM3.36
- Tuesdays 14:15 EM3.07
- Wednesdays 11.15 EM1.83

- Labs:

- Thursdays 10.15 EM2.52

- Examination in April (~first two weeks)
- Coursework
 - Investigation of image processing topic
 - Implementation in Matlab

Module Organisation

- Practical Exercises
 - Matlab exercises to re-inforce issues covered in class
 - Experiment with concepts
- Tutorial Exercises
 - Paper-based problems – exam preparation
- Weeks 1 – 5 Paolo
- Weeks 6 – 10 Andy

1. Introduction to Digital Image Processing

- Image Presentation
- Human perception
- Light and colour

2. Signals in 2 and more dimensions

- Discrete signal processing in 2D
- Concepts of Frequency Domain Analysis
- Fourier Analysis

3. Image Formats

- Computer applications and storage of images
- Image Compression

4. Image Enhancement - Spatial Domain

- Basic Image Enhancement Techniques
- Image Histograms
- Histogram equalisation & modification

5. Image Enhancement - Filtering

- Convolution and Correlation
- Spatial Domain
- Frequency Domain

6. Texture Modelling

- *Statistical*
- *Co-occurrence Matrix*
- *Fractals*
- *Markov Random Fields*

7. Segmentation and Classification

- *Basic thresholding and homogeneity measures*
- *Unsupervised classification and clustering*
- *Supervised classification: minimum distance*
- *k-means, discriminant functions, maximum likelihood,*
- *Bayesian classifiers*

8. Principal Component Analysis:

- *Image compression*
- *Object recognition by appearance*

- Textbooks
 - Digital Image Processing
 - R. Gonzales & R. Woods
 - Two Dimensional Signal and Image Processing
 - J.S. Lim
 - The Image Processing Handbook
 - J.Russ
 - Digital Image Processing
 - Pratt
 - HIPR –Hypermedia Image Processing Reference (web)
 - 3-D Shape Estimation and Image Restoration
 - Favaro & Soatto

Other Resources

- VISION site for module (in preparation)

<https://vision.hw.ac.uk>

<http://www.eps.hw.ac.uk/~pf21>

- Links to web based image processing resources

Image Processing: Course outline

- ▶ Image formation and perception
- ▶ Signals in 2 and more dimensions
- ▶ Image formats and coding
- ▶ Image enhancement
 - Spatial domain
 - Frequency Domain
- ▶ Texture modelling
- ▶ Segmentation and Classification
- ▶ Principle Component Analysis
- ▶ Multiple View Analysis

What is a digital image?

- A 2D array of values (pixels)
- Each value reflects certain properties of the scene being imaged, depending on the sensor.
 - Photographs
 - Sonars
 - Ultrasound
 - Radar
 - Infrared cameras
 - Xrays
 - MRI...



What is Image Processing about?

- The **management** and **exploitation** of image data
- Management:
 - Megabytes of redundant data
 - Representation/ formats/ digitization
 - Coding
 - Storage and transmission
- Exploitation: The grand challenge of Computer Vision
 - Extracting the useful information
 - Problem dependent...
 - For decision / action / knowledge
 - More and more needed for management (intelligent management to cope with vast amounts of data)

More on Image Exploitation

- Extracting the useful information
 - Image as physical 2D sensing
 - Camera motion btw 2 optical images -> control, 3D
 - Physical property of scene -> Temperature in IR images
 - Image as group of scene/object/areas
 - Abstract info: The challenge of computer vision
 - Data representation
 - Segmentation
 - Classification/decision

More on Image Exploitation

- Example applications:
 - Detect cancerous growth in x-ray images
 - Flag suspicious behavior in surveillance video
 - Retrieve images “like this one” from the web (keyword or image based search?)
- Our brain is highly trained to process (optical) images
- BUT: Highly difficult problem for machines
 - Sensory Gap
 - Semantic Gap

Applications of Image Processing

- Improvement of pictorial information for human interpretation
- Processing of scene data for autonomous machine perception

Image Processing Techniques

- **Enhancement**
 - Process image to give a result that is more suitable than the original for a given application
- **Restoration**
 - Process that attempts to reconstruct or recover an image that has been degraded by using some a priori knowledge of the degradation
- **Encoding**
 - Techniques for representing an image with fewer bits
- **Segmentation**
 - Descriptions of image components rather than whole images
- **Understanding**
 - Symbolically represents contents of an image

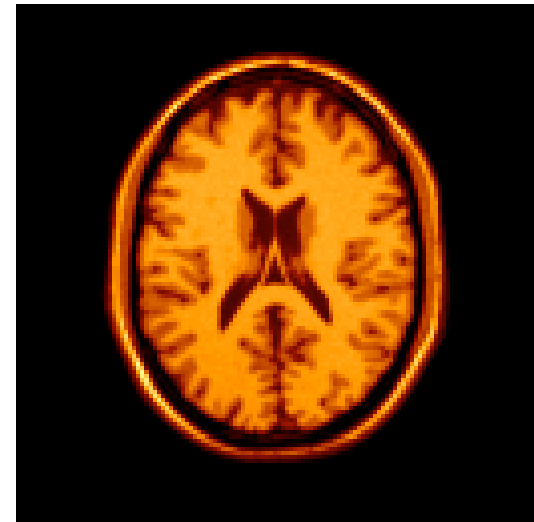
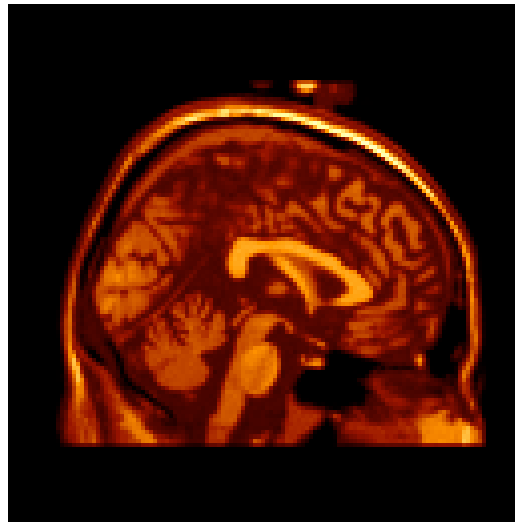
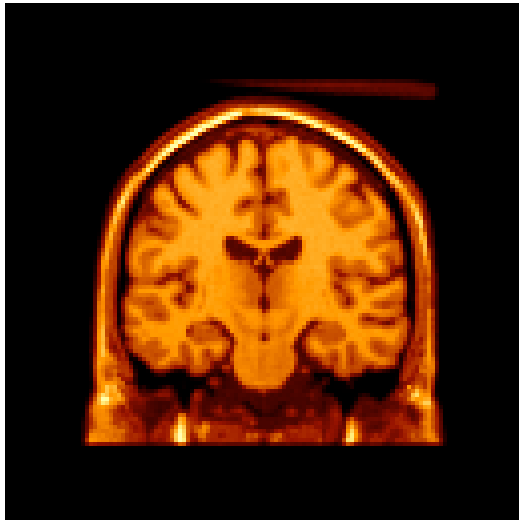
Example Images and Applications

Application Domains

- Space programs
- Medicine
- Remote sensing (geographers/geologists)
- Defence
- Law enforcement
- Forensic
- Physics
- Astronomy
- Industrial inspection
- Media (video games, films...)
- ...

Example sensors

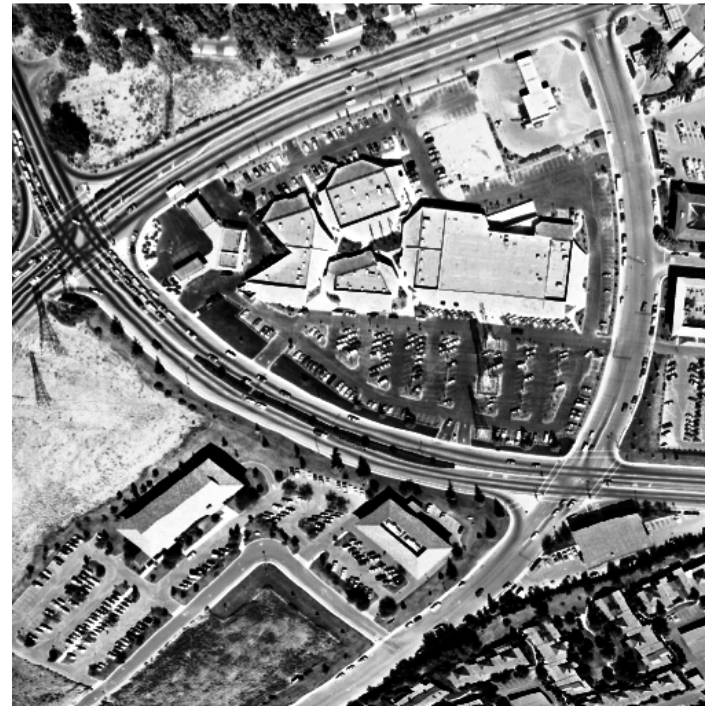
- Cameras, photographs
- Sonars
- Ultrasound
- Radar
- Infrared cameras
- Xrays
- MRI (magnetic resonance imager)
- ...



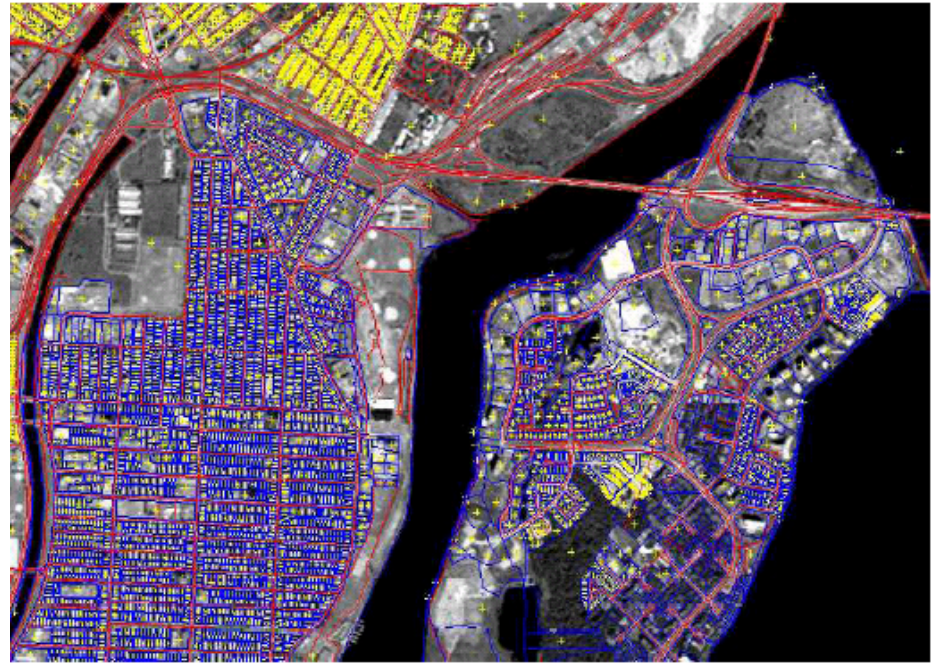
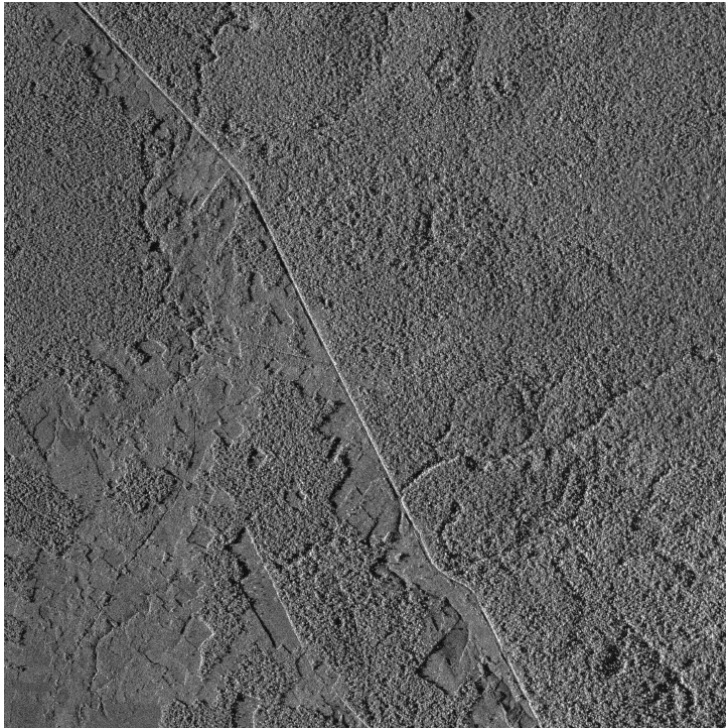
Original



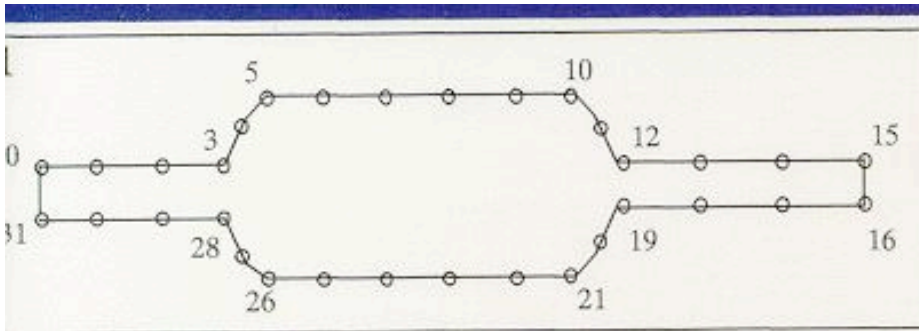
Histogram
equalisation



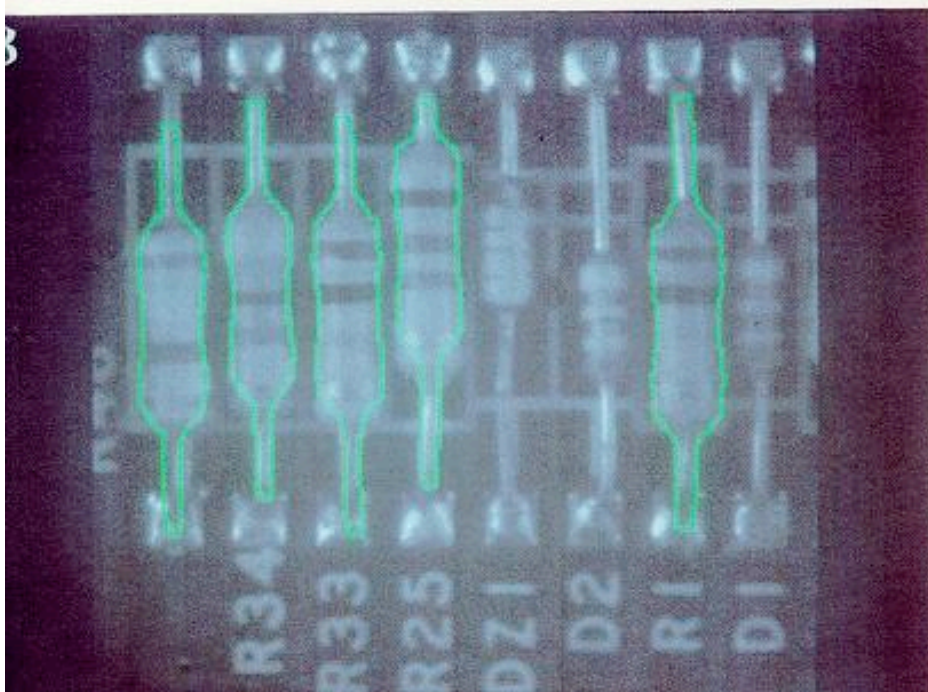
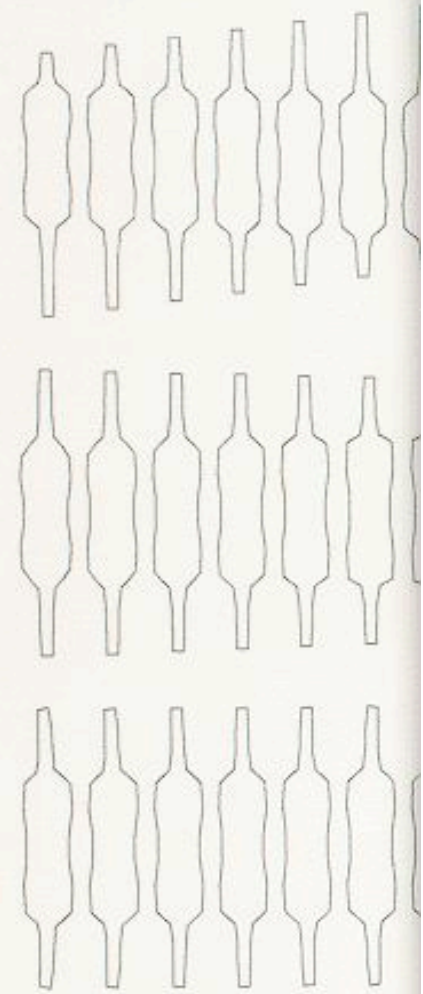
- Land occupation
 - Synthetic Aperture Radar
 - Vegetation, soil, built areas
 - Boundaries



Inspection



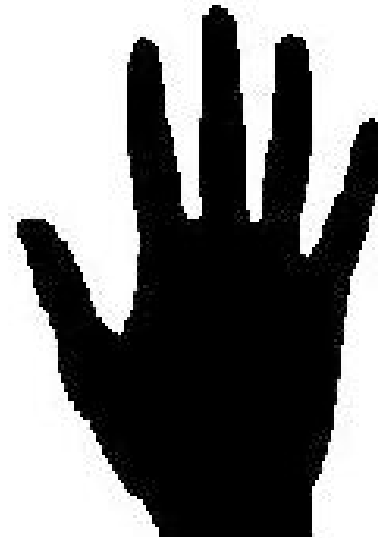
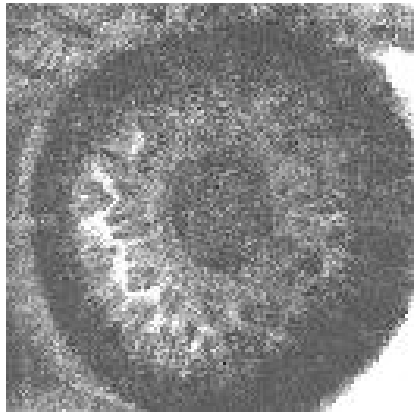
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Video Surveillance

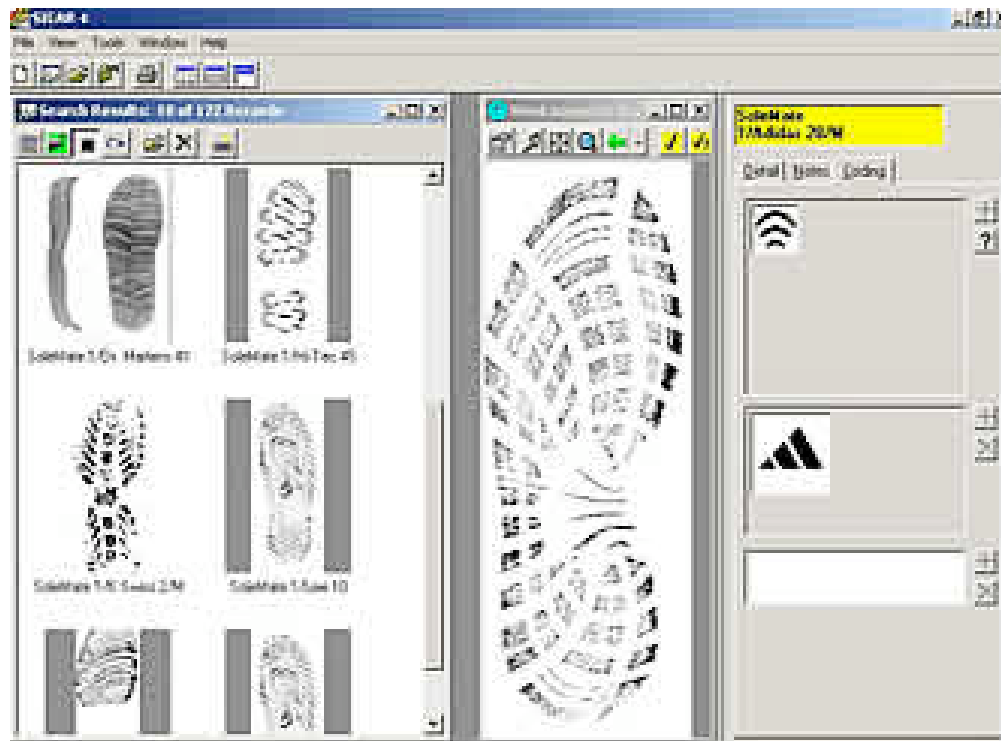


Biometrics

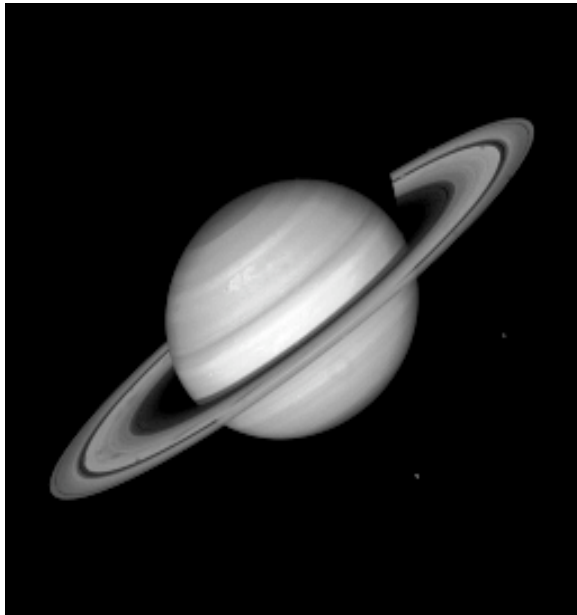
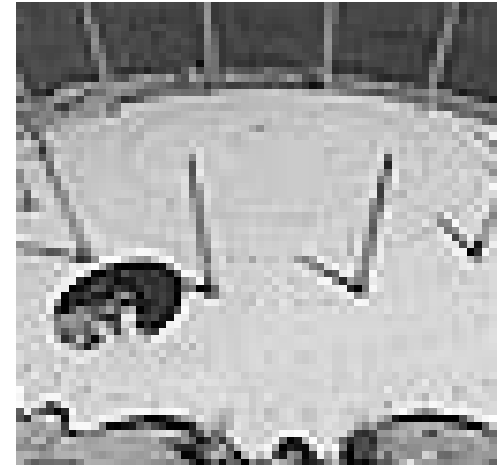
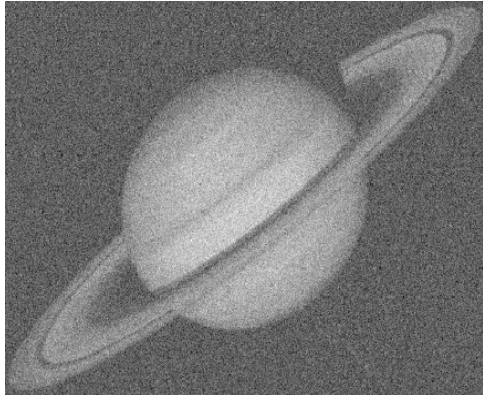


Digital Image data management

- Restoration
- Compression
- Coding
 - MPEG-2 DVD
 - MPEG-7
- Retrieval



Enhanced Visualisation

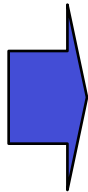


Content Based Image Retrieval

- “Fetch images like this”
- Web / databases applications



?



No



Yes



No



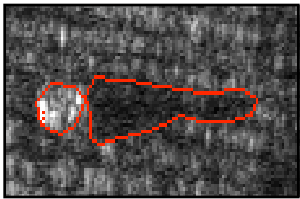
Example Applications at Heriot-Watt

Joint Institute on Image and Signal Processing
Oceans Systems Lab

Signal and Image Group at HW

Application Areas

DEFENCE



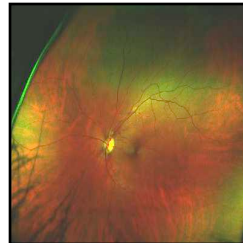
ROBOTICS



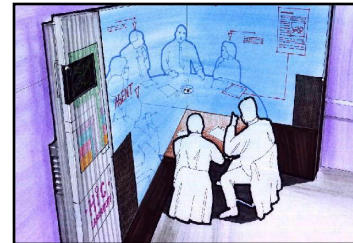
SURVEILLANCE



MEDICAL



TELEPRESENCE



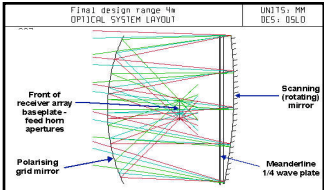
Some Recent Contracts

- Surveillance (e.g., EPSRC ThinkCrime ~ £220k)
- Defence (e.g., British Aerospace Strategic Alliance, ~£2M)
- Medical (e.g., QinetiQ, OPTOS plc, DTI/EPSRC ~ £100K)
- Telepresence, videoconf., comms (e.g., VIRTUE ~£270k)
- Robotics (especially subsea - Ocean Systems Lab)

Airport Surveillance

Concept

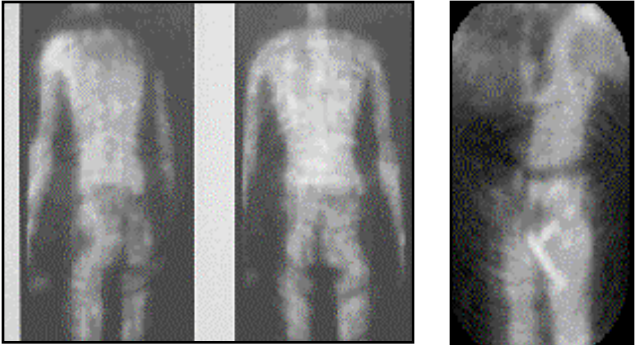
Current Operation:



mm-wave imager



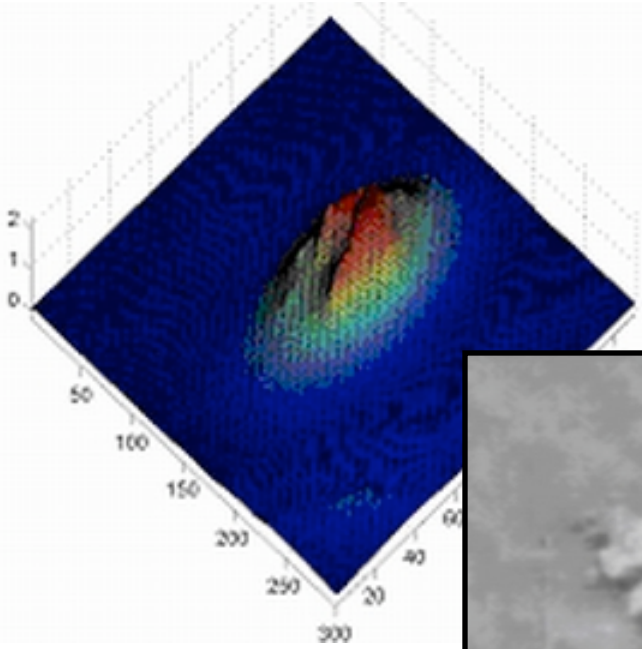
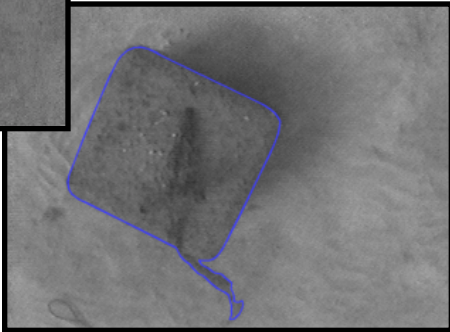
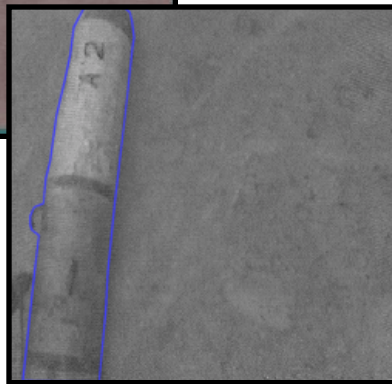
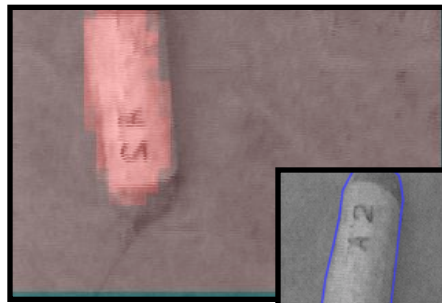
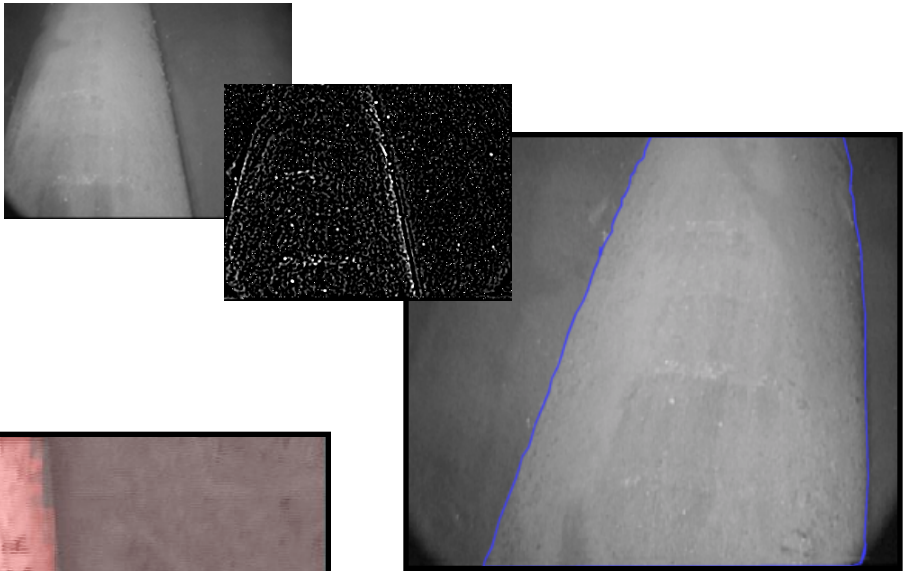
Problem: Privacy issue



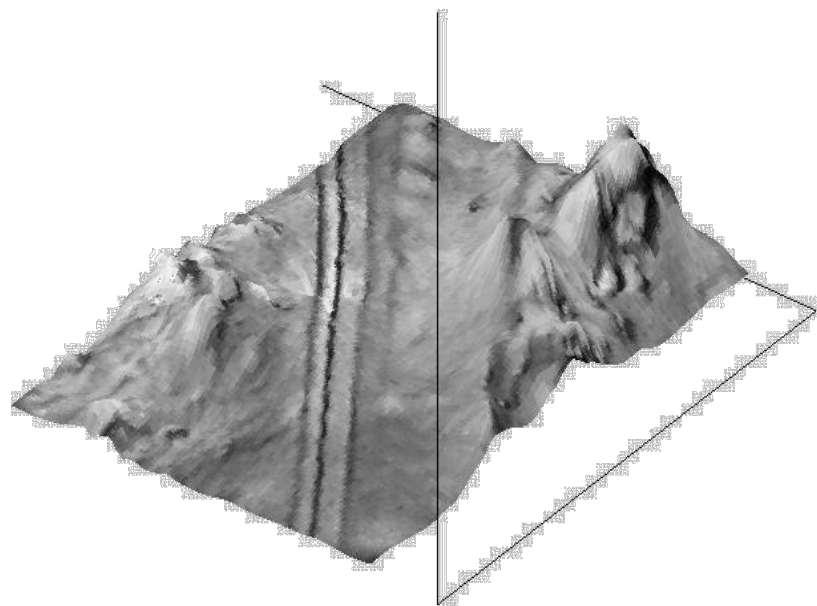
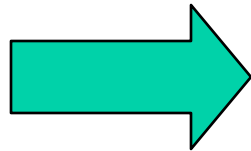
Mm-waves see through clothes!

Man made Object detection

- Pipeline Survey
- Mine Counter Measures
 - Detection
 - Identification



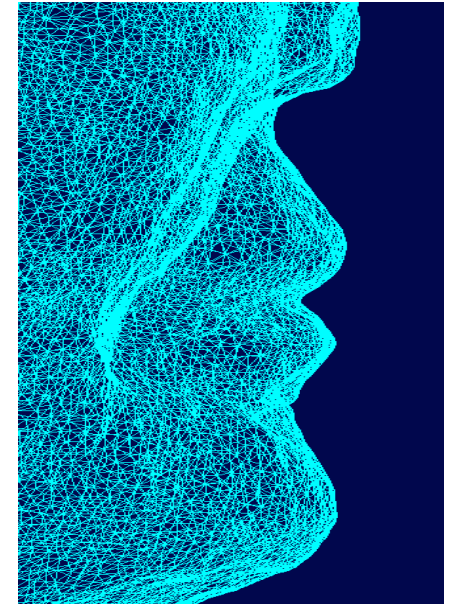
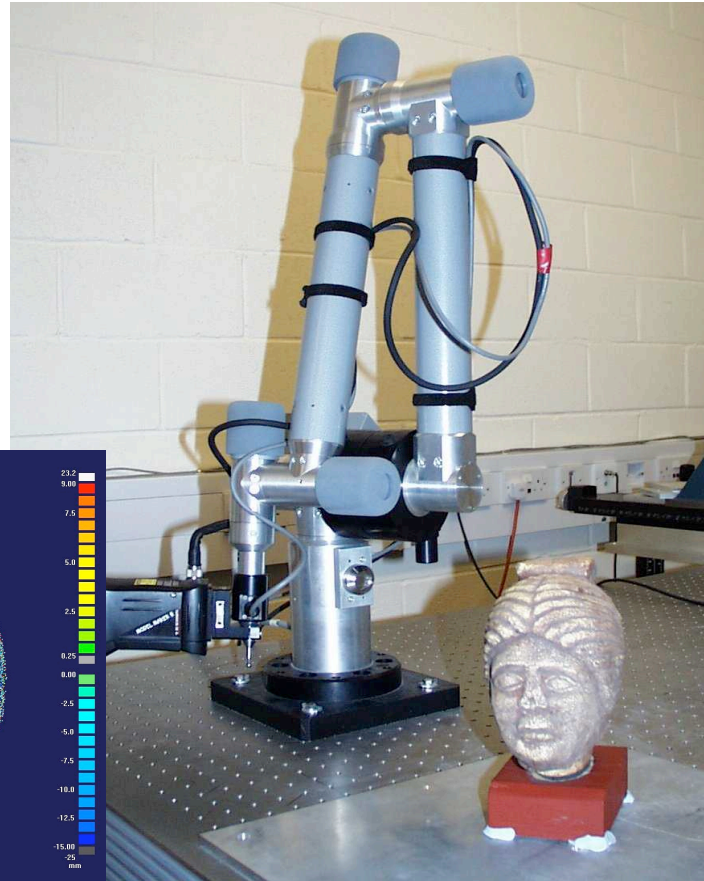
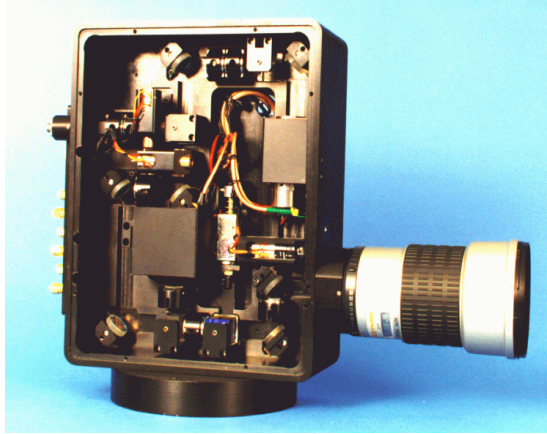
3D reconstruction



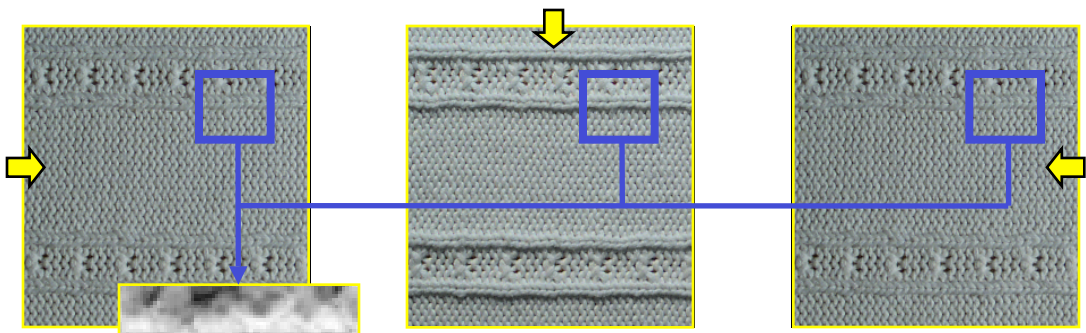
UUV Visual Servoing Station Keeping in Sea Current



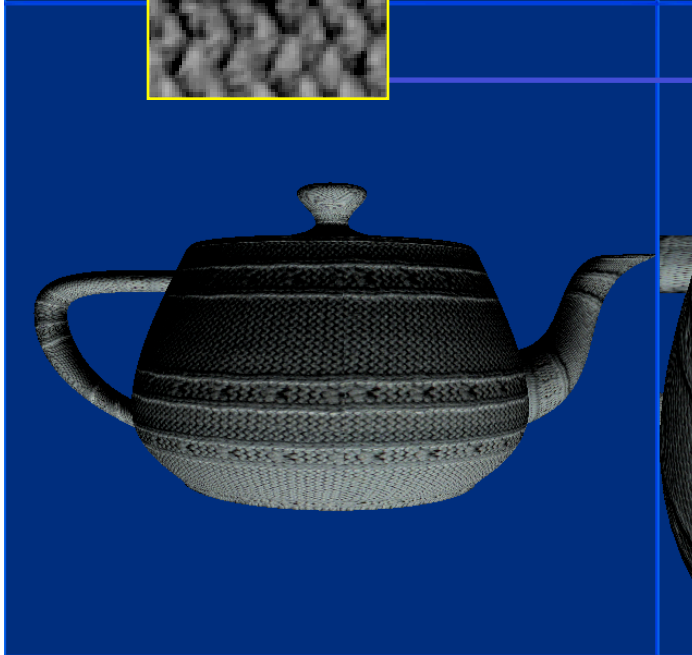
3D Triangulated and Lidar Depth Imaging



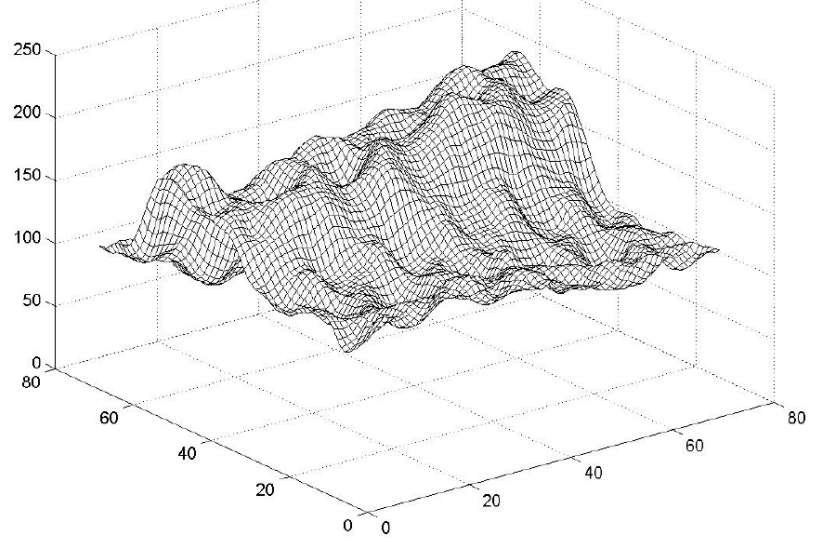
Virtual Textile Catalogues



3 images of the surface are captured using a 12 bit digital camera under different illuminations

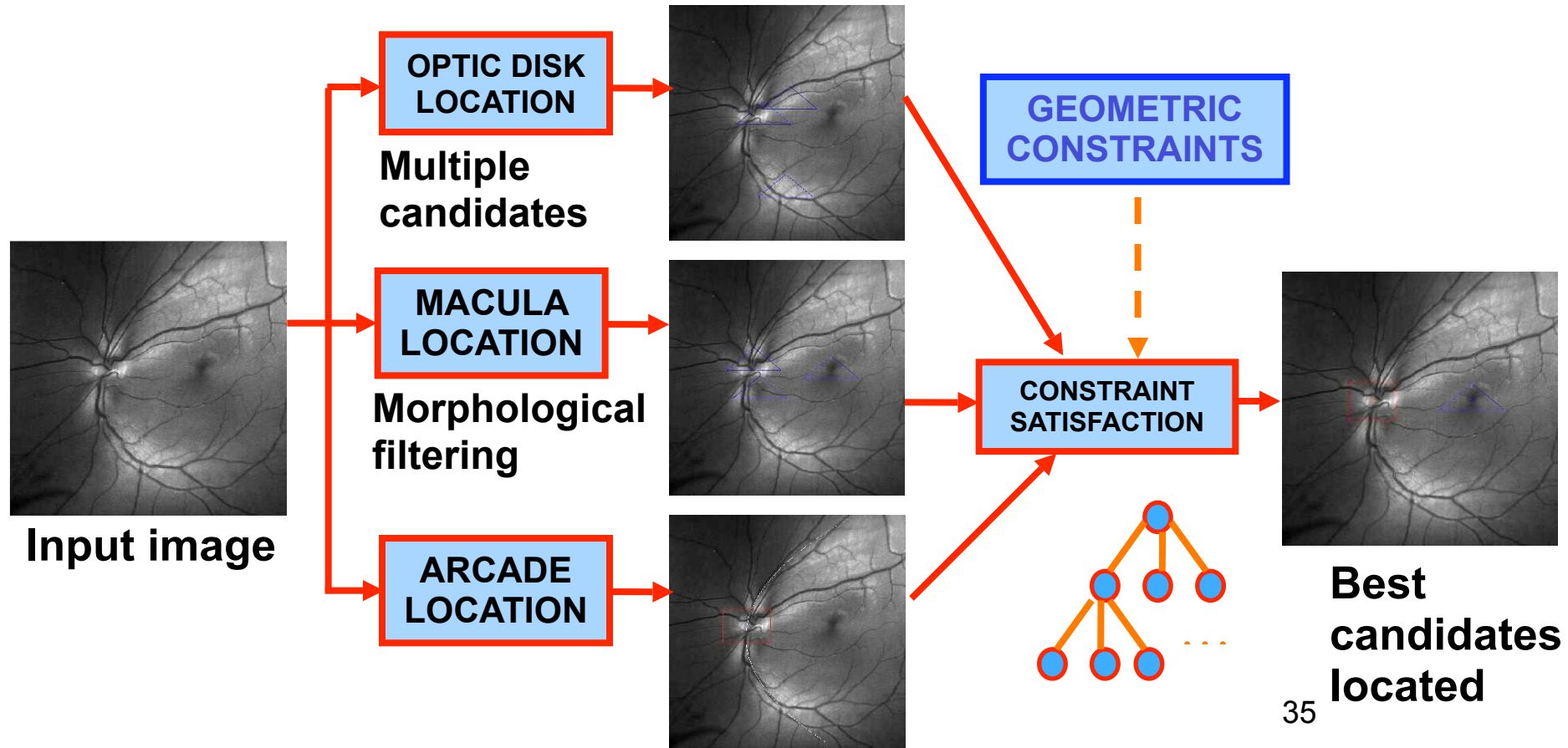


Textile designers in Europe produce hundreds of new textile designs each year



Retinal Imaging

Retinal Imaging: the object is to locate key retinal landmarks robustly, and use these as a basis for detecting abnormalities/diseases



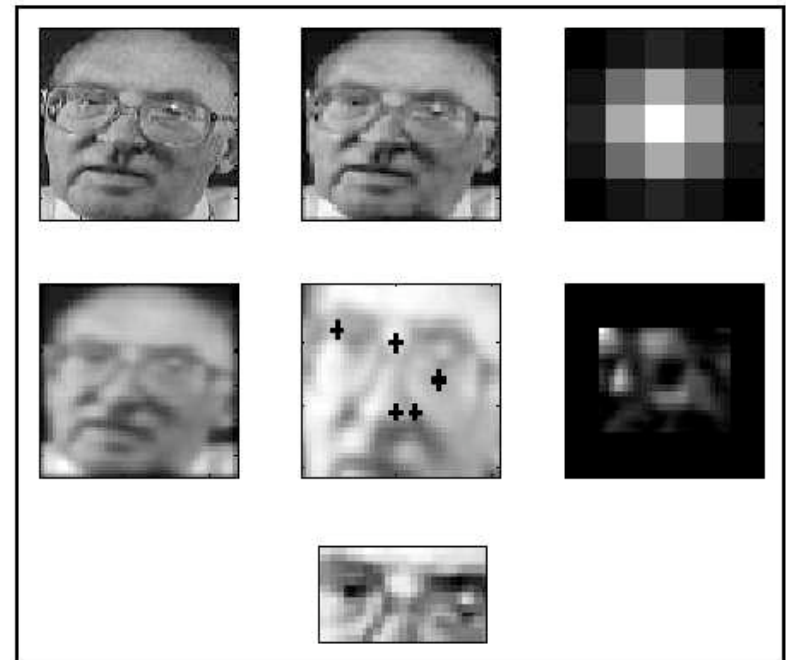
Virtual Conferencing and Eye Tracking



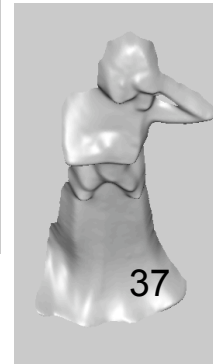
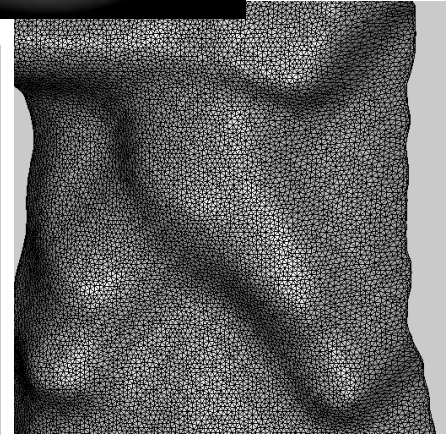
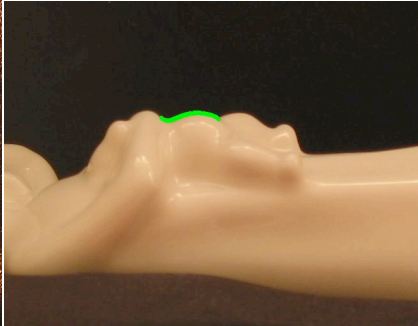
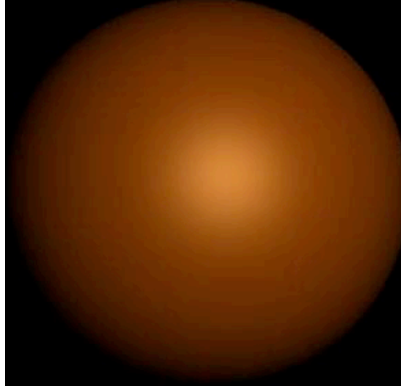
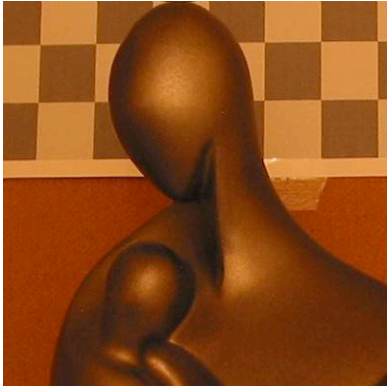
Virtue

Eye tracking to detect and track eyes in video sequences - can be applied to many human-computer interactive systems.

Stereo sequence capture and view synthesis for a virtual immersive teleconferencing system



Radiometry and 3-D Shape Estimation



Motion Deblurring

Copyright (C) 2004



Virtual Object Insertion

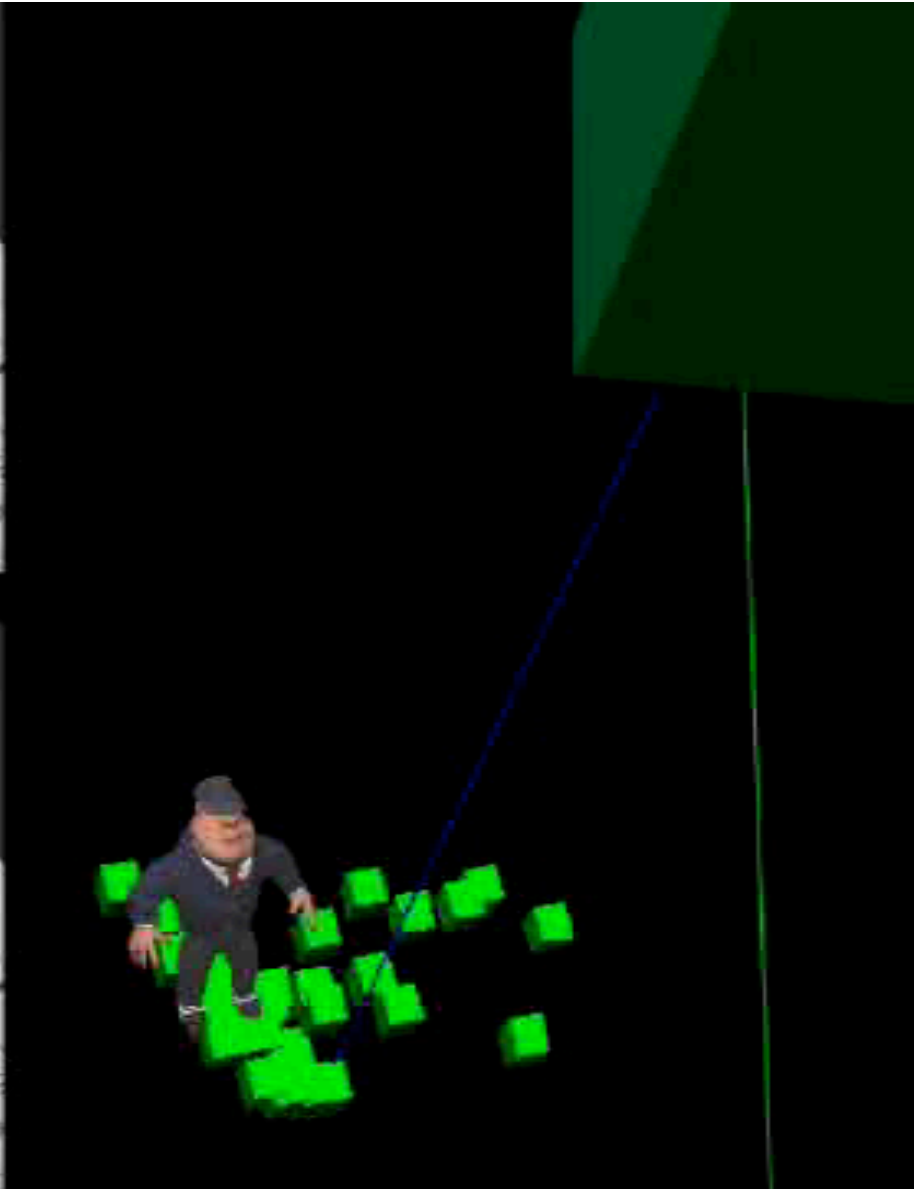


Image Processing: Example Applications

- Biomedical
- Forensic/surveillance
 - Biometrics
 - Video Surveillance
 - Security
- Inspection/Measurement
 - Industrial inspection
 - 3D reconstruction
 - Cartography/mosaicing
- Image Data Management
 - Coding/compression
 - CBIR
- Examples Underwater applications
 - Control
 - Automatic analysis of video/sonar data
 - Seabed Mapping
 - Target detection