Computer Graphics and Image Processing Introduction

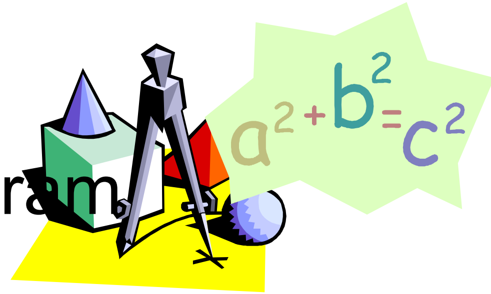
Part 3 – Image Processing

Lecture 1

Image Processing

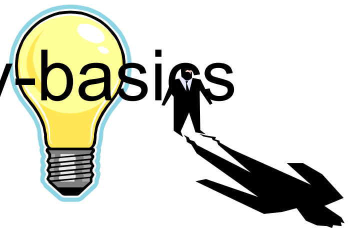
- **Lecturers:**
  - **Patrice Delmas (303.389)**
    - Contact details:
      p.delmas@auckland.ac.nz
      Office: 303 - 391 (3rd level CompSci building)
  - **Associate Professor Georgy Gimel'farb (303.391)**
- Office hours: whenever the door is open
- Particularly available right after each lecture
- **Lecture time: Tuesday 12pm-1pm Wed/Fri 8am-9am**
- **Marking:**
  - 25% assignments, 20% test, 55% examination
- **Assignment 3:**
  - 8.33 marks
  - Out: 19/05/2011; due: 05/06/2011

Part 3 Overview



Week 1: Introduction and histogram

Week 2: Filtering and Image Segmentation

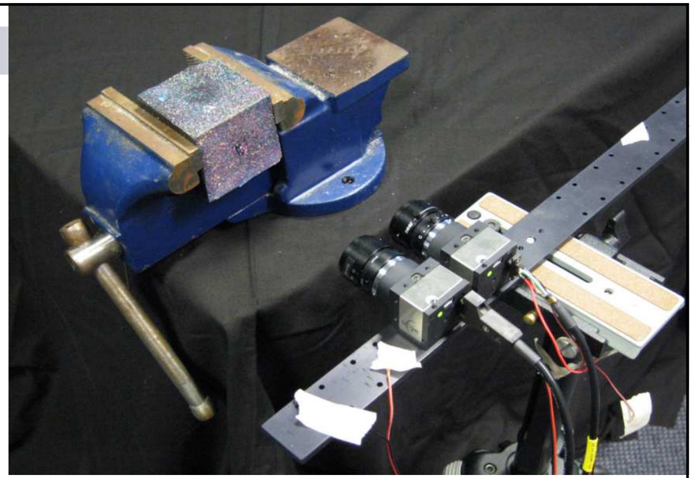


Week 3: Mathematical morphology-basics

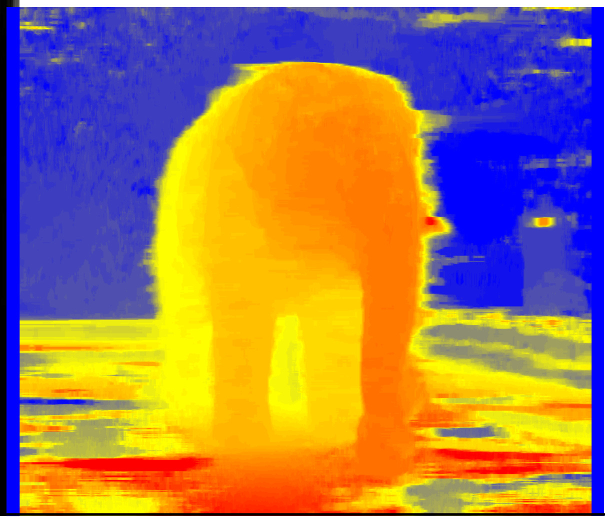
Week 4: Mathematical morphology-advanced

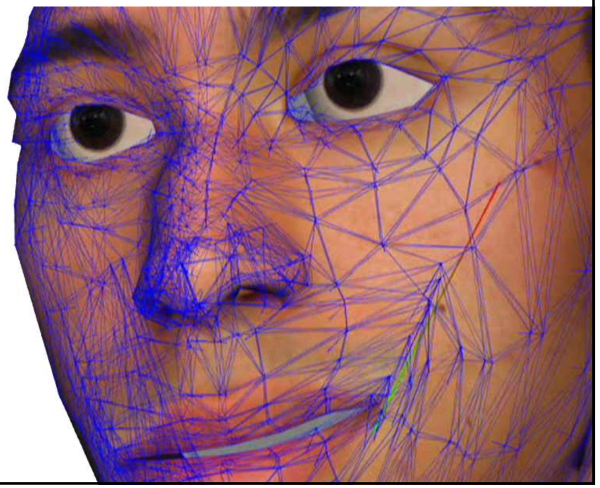
Research group

- Quick overview of the research in the Intelligent Vision Systems group
- 373 is the direct pathway to postgraduate studies (vision and graphics)
  - I would recommend 369-373-367-345-320
  - 767-773/775-715
- You have the possibility to undertake 380 projects
- Next: 780, honours, MSc



Intelligent Vision Systems New Zealand:





http://www.ivs.auckland.ac.nz/new_site_d/index.php

iVS Intelligent Vision Systems New Zealand

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Intelligent 3D multimedia applications

Intelligent Vision System research team - a leader in advanced low cost computational 3D vision solutions

Developing intelligent vision system to detect, classify, or retrive natural 3D objects under varying imaging conditions and operating environments is one of the most challenging artificial intelligence and computer vision problems having consideratble practical interest.

In particular, computer stereo vision can serve as an important tool in photogrammetry, cartography, civil enginerring, mining, forensics, archaeology, biometrics, autonomous navigation, augmented reality, game industry, special movie effects, etc. Manyu applications is trong demand (e.g. security checks by face recognition, or terrain changes detection_ require fast and accurate respondes. We are develoing efficient solutions for various application problems that need real-time or near real-time modelling of close-range 3D environment.

Our current applications:

- Rapid prototyping of indoor and outdoor 3D scene and objects
- 3D modelling and animation of faces
- Web-based 3D computer vision
- 2D and 3D face recognition
- Real-time visualisation of 3D scenes

Technology showcased:

- Robust stereo-matching under adverse lighting and contrast conditions.
- GPU programming with CUDA
- Multi-sensor data fusion techniques for scene and environment modelling
- Visualisation on 3D display
- 3D face modelling from depth maps acquired by stereo
- Integrated acquisition-to-visualisation system using stereo acquisition setup, powerfull PC and 3D display output.

NEWS

- Twenty-sixth International Conference on Image and Vision Computing New Zealand IVCNZ 2011, November 29 - December 1, 2011, Auckland.

Coming events:

IVCNZ Image and Vision Computing New Zealand 2011

Twenty-sixth International Conference on Image and Vision Computing New Zealand IVCNZ 2011, November 29 - December 1, 2011, Auckland.

Spotlight:

Real-time depth display with Minoru webcam

IVS NZ: People

- ◇ Dr. Patrice Delmas, Dr. Georgy Gimel'farb
- ◇ Dr. Al Shorin (postdoc, 2010–2011)

PhD students in 2006 – 2011

- Edwin Chan
- Pavan Gamage
- Minh Nguyen
- Alfonso Gastelum Strozzi
- Ni Liu (pending)
- Matthias Krueger (Dr.: 2011)
- Al Shorin (Dr.: 2010)
- Alex Woodward (Dr.: 2009)
- Jiang Liu (Dr.: 2007)
- Dongxiao Zhou (Dr.: 2006)

MSc students in 2006 – 2011: A. An, E. Chan, P. Fan, R. Gong, J. James, A. Lau, P. Liu, M. Nguyen, V. Sharma, P. Xie, Z. Zhang

3D Vision Lab: a unique system of locally designed and commercial active/passive stereo vision and 3D display tools

3D vision Lab (city campus)

- **New Lab located on the 5th floor CS building**
  - Lab supervisor: PhD candidate A. Gastelum, E. Chan
  - Funded by CS, FoS staff research fund, FRST
- **3D acquisition/processing/visualization capabilities:**
  - 3D scanner (sub-mm accuracy on a $0.5m^3$ volume)
  - 3D stereo vision (active, passive, still or video up to 80 fps)
    - Synchronised USB video cameras (80fps)
    - Synchronised Firewire video cameras (30fps)
  - CUDA server (remote-local real-time processing)
  - 3D display panels
- **Projects**
  - 3D face animation (RT acquisition, 3d face features extraction, automatic prototyping, High res multi-layer SPH model)
  - Real-time 3D face features
  - Stereo algorithms benchmarking
  - 3D characterisation of solids deformation

IVS NZ: Main Research Directions

Original theoretical tools and innovative technologies for solving practically important real-world 2D/3D image analysis problems

- Real-time stereo vision and template matching
- Probabilistic texture modelling and object detection
- Image analysis in applied soil science
- Image analysis in computer-assisted medical diagnostics
- 3D scene description by fusing range and image data

National and international collaboration:

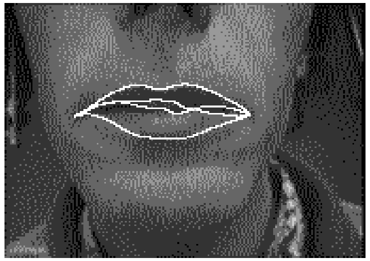
UoA Photogrammetry Lab (CS/ECE); Mechatronics; Civil Engineering

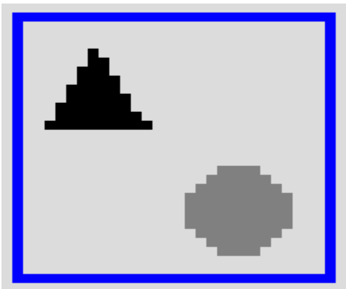
NZ AgResearch Hamilton; HortResearch Palmerston North; Industrial Research Ltd, Auckland

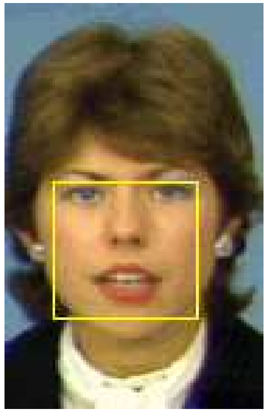
World LHTE-IRD, France; University of Grenoble, France; INRIA Sophia Antipolis, France; Tokyo University, Japan; UNAM, Mexico; HRAE, Mexico; University of Louisville, USA

2D face feature extraction (1996-2002)

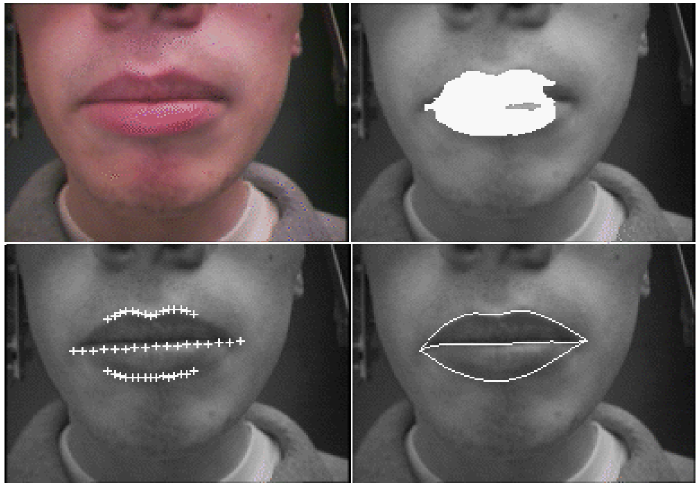
(Geodesic) Active Contours for face feature





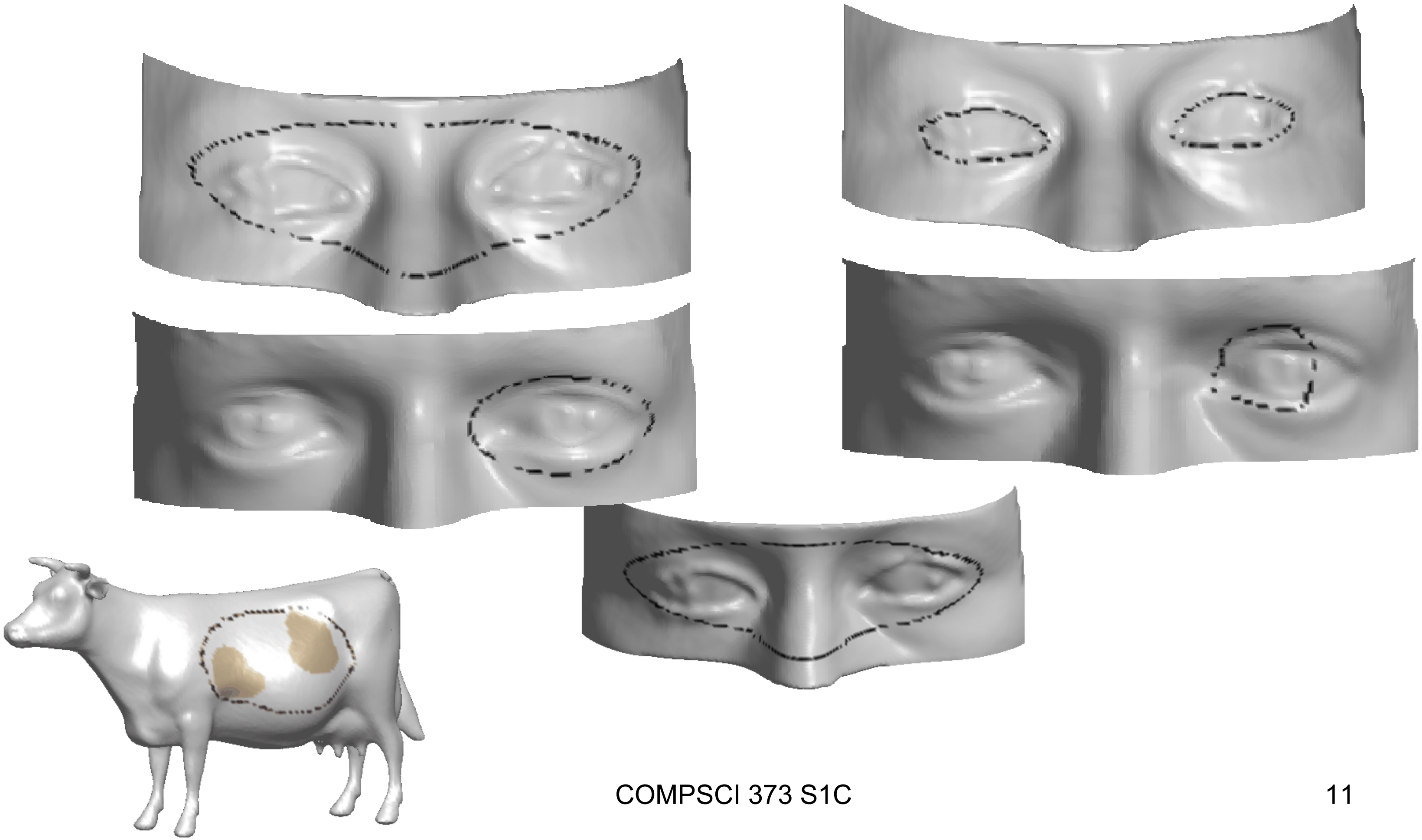


C. Petitjean



With M. Lievin

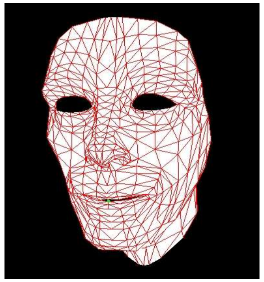
3D geodesic active contours



Interface between Raw Data and Generic Model (2005)

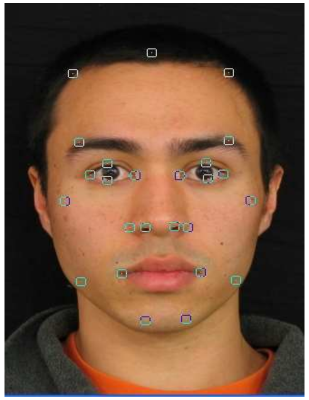
2 modes: semi-automatic, automatic

Automatic: AAM on colour image, correspondences to 3D values on depth map, mapping of fiducial points to animated 3D model



Model with animation system

Depth map



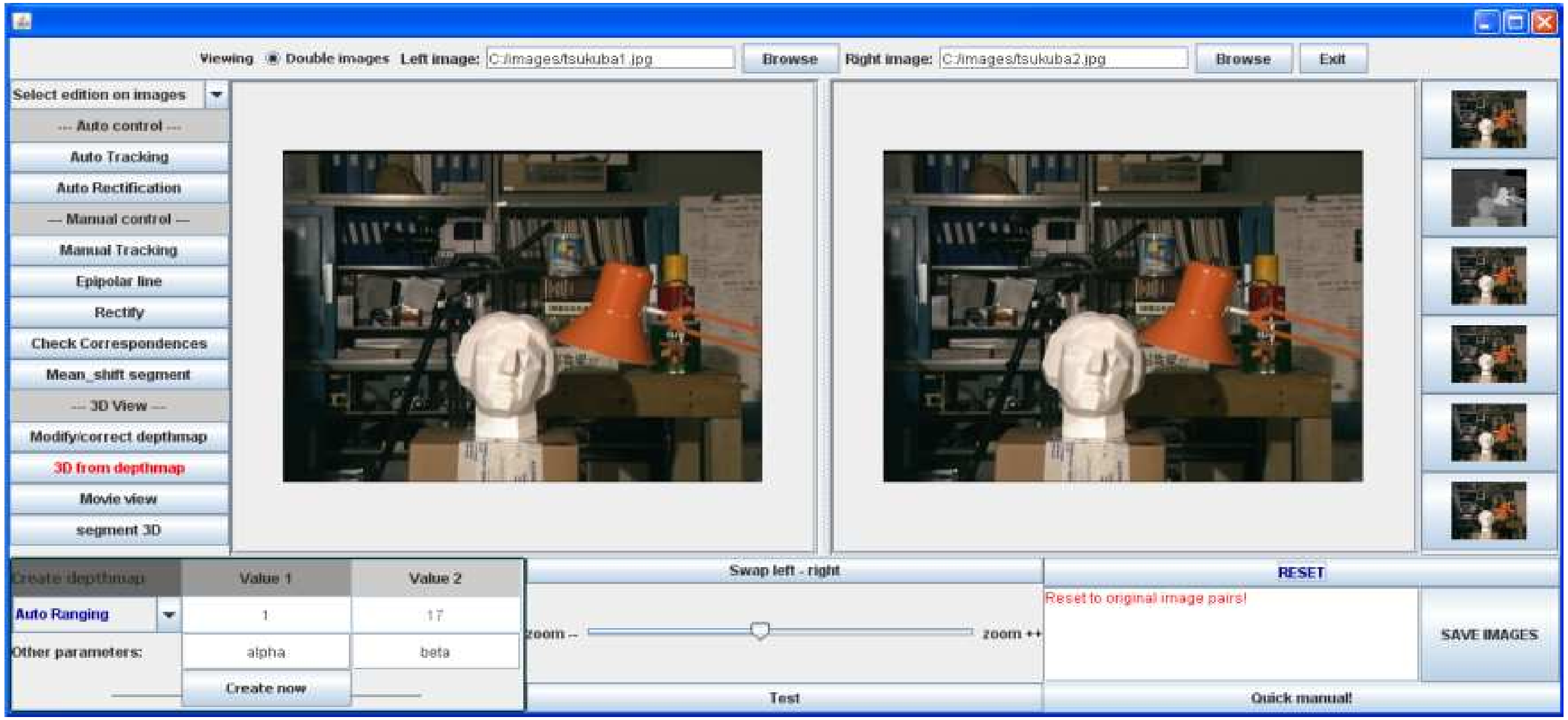
Correspondences made and mapped via RBF with a final nearest point map and texture projection

Results in a custom face with animation system in place

Web-based Stereo-vision Interface
Best Poster IVCNZ 2008

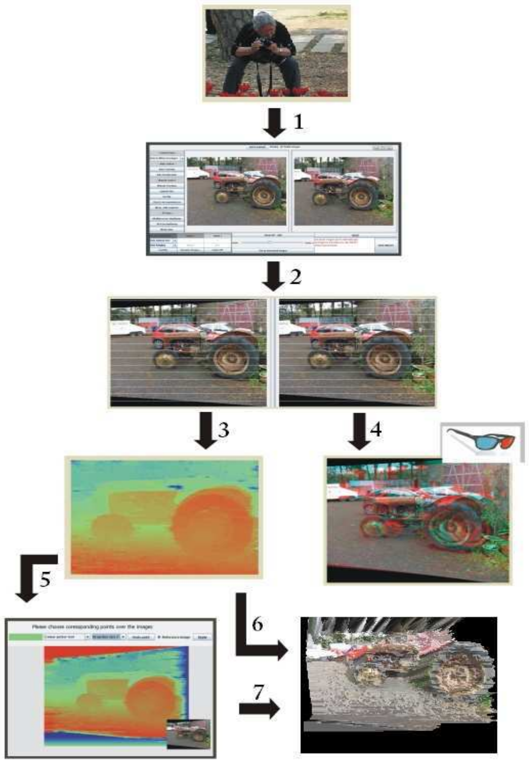
- Make Stereo Vision field more accessible to Internet users.
- Quickly build a fast 3D model of a scene from two images captured by an off-the-shelf hand-held digital camera.
- It can be developed as a:
  - Learning/teaching tool on Stereo Vision applications and methods
  - Web community for shared computational Stereo Vision algorithms
  - http://www.cs.auckland.ac.nz/~mngu012

Application's interface

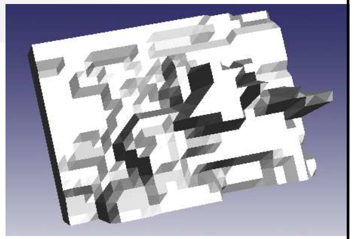


Processing steps

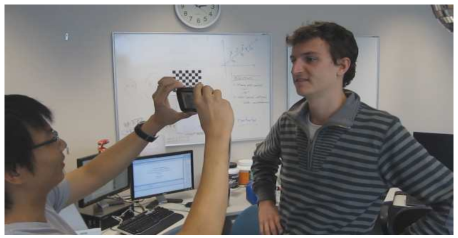
- *Step 1: Upload images*
- *Step 2: Rectify images*.
- *Step 3: Applying Stereo Matching algorithms.*
- *Step 4a: Create an anaglyph*
- *Step 4b: Refine the depth map*
- *Step 5, 6: 3D scene reconstruction.*

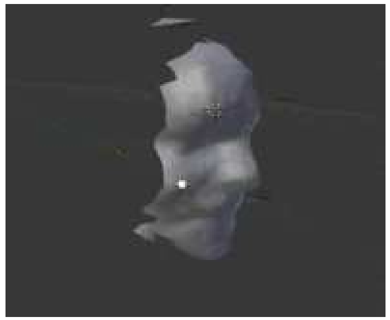


Fast Web-based Stereo Vision for 3D object reconstruction (2010-2011)



- Work 100% on web-environment:
  - Allow to upload any stereo image pairs with wide range of parameters either set automatically or interactively:
    - Manual input of disparity ranges, smoothing parameters, number of 3D vertices returned.
  - It returns within seconds:
    - Gray-scaled depth-map
    - 3D .obj file editable by Blender, Maya, etc...
- Applications:
  - Semi-automatic low-cost building of 3D model used by 3D designer for games, movies…





Interactive 3D face model mapping: Expression Friendly Avatars (2011)

- Automatically build a 3D avatar from single capture from 3D camera:
  - 3D face is built with skin texture taken from capture and facial topology is preserved.
  - Emotional expression
    - Manually controlled by users
  - Interaction with internet user via webcam:
    - Avatar copies emotion from user using 2/3D facial expression recognition (development)
- Applications:
  - Gaming industry with real user face
  - Instant messenger with interactive expression avatar

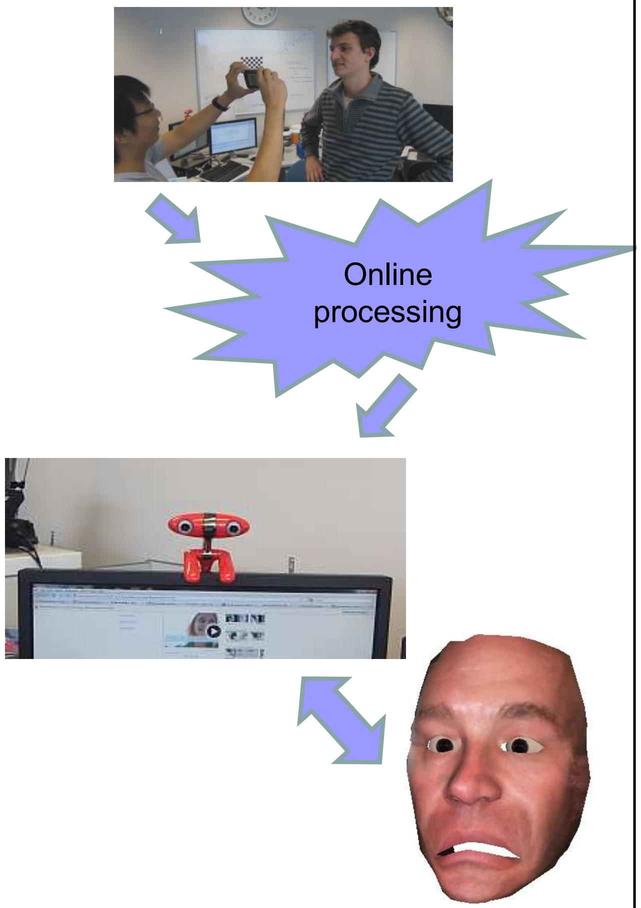


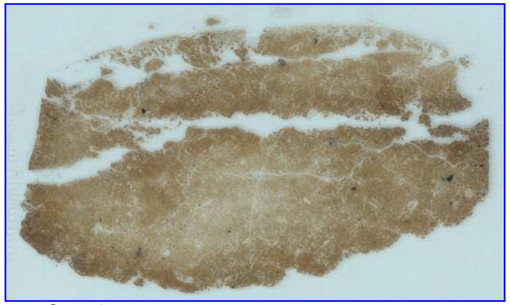
Image Analysis in Soil Science

(in collaboration with NZ, France, Mexico, Germany)

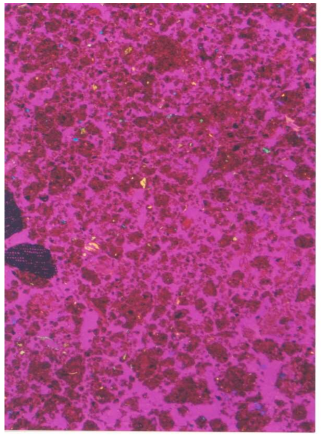
- **Aim**: (low cost) quantitative study of preferential flow using dye solution infiltration
  - *Field and lab work*: calibration and column images
  - Image processing for quantitative reconstruction of the infiltration pattern
  - Relate concentration of dye to gray-level of images
  - Produce 3D maps of preferential flows

C. Duwig, P. Delmas, K. Müller, B. Prado, K. Ren, H. Morin, A. Woodward: Quantifying fluorescent tracer distribution in allophanic soils to image solute transport. *European Journal of Soil Science, 2007*

Estimating Soil Properties Using Image Processing Techniques



Optical scan of soil core thin section



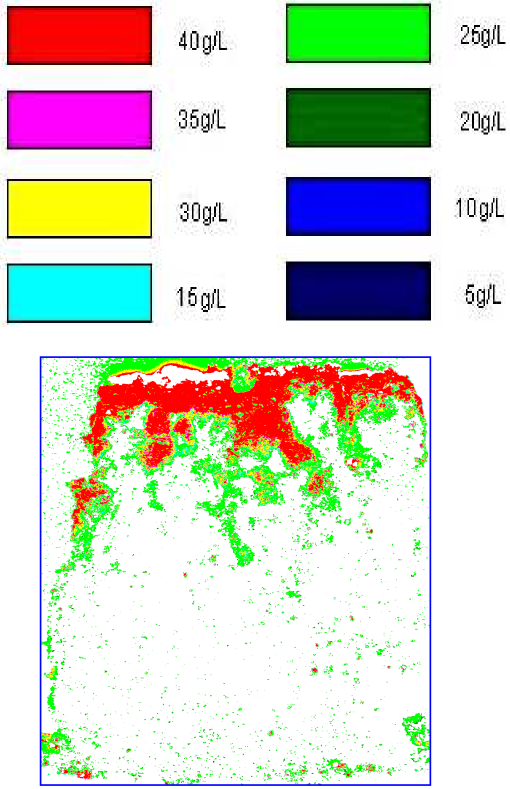
Electronic microscopy of soil core thin section

Dyed Soil Core Section

Results

Image of a soil core cut vertically under black light illumination for 30 seconds

Segmented image:
White: area with dye
Black: area without dye



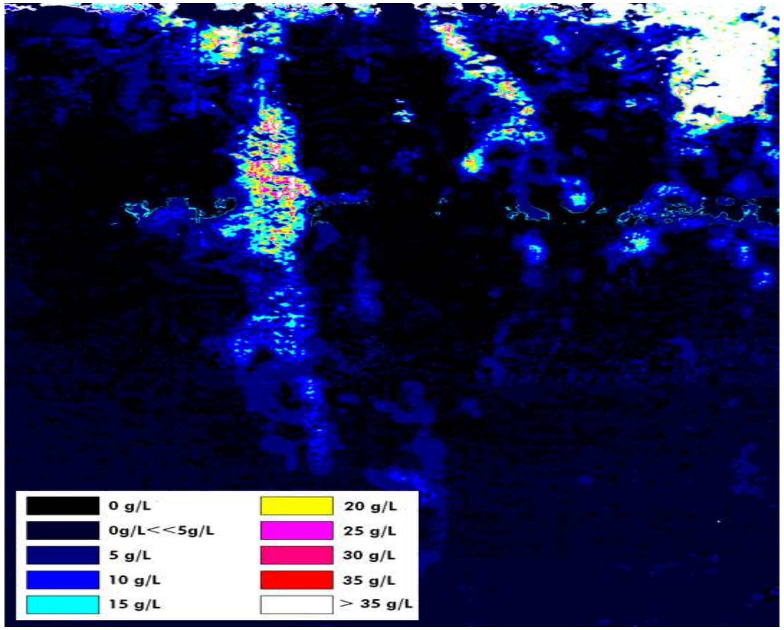
Dye concentration and flow pathways for a given soil core cut

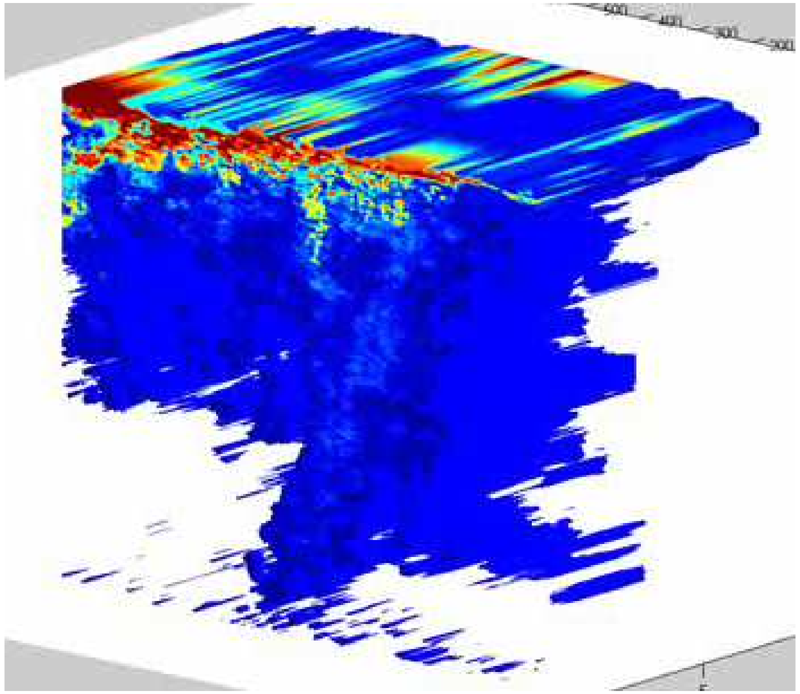
Next steps:

- Reconstruct volume of flow pathways for a soil core
- Analyse variations over several soil cores
- Model the soil flow pathways

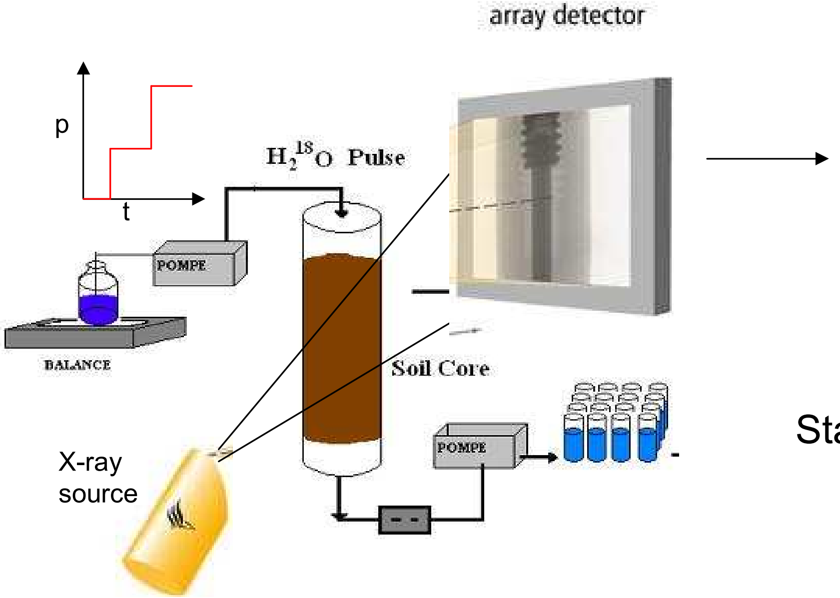
Image Analysis in Soil Science

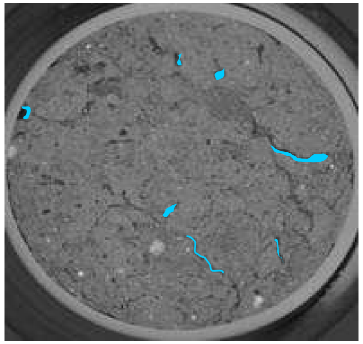
- 2D slice and 3D reconstruction



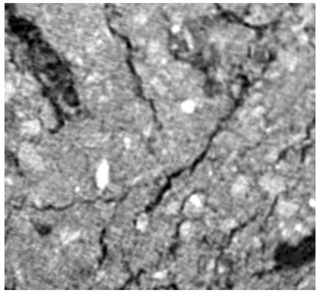


Ct-scan imaging, 3D segmentation and porous network

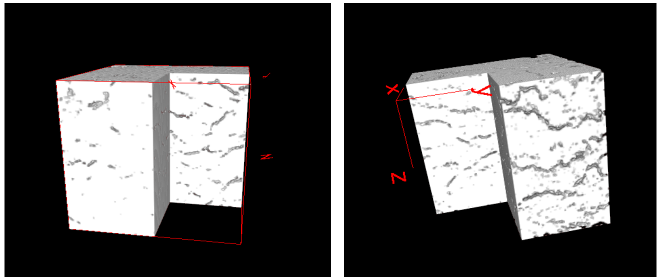




Static/dynamic comparison



CT scan images

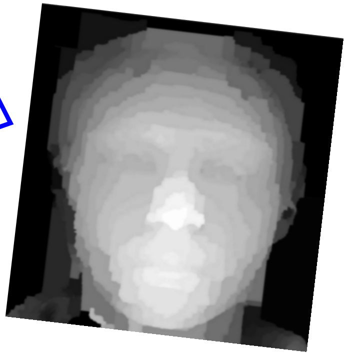


Segmented Images with different thresholds(L:85, R:100)

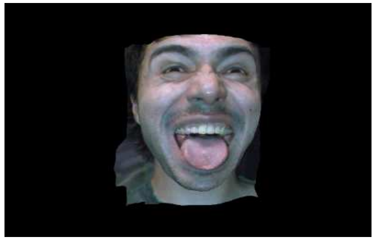
Exemple de REV

DIGITAL IMAGES

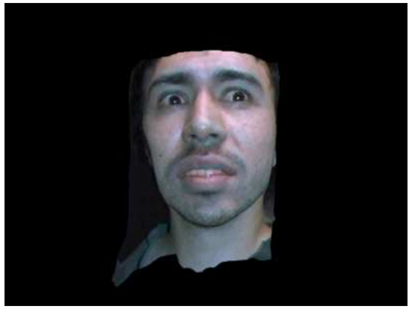
2D



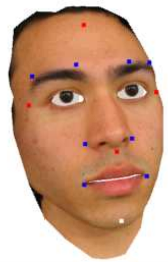
Depth map



3D



3D



4D

Computer graphics

What to Do with Digital Images?

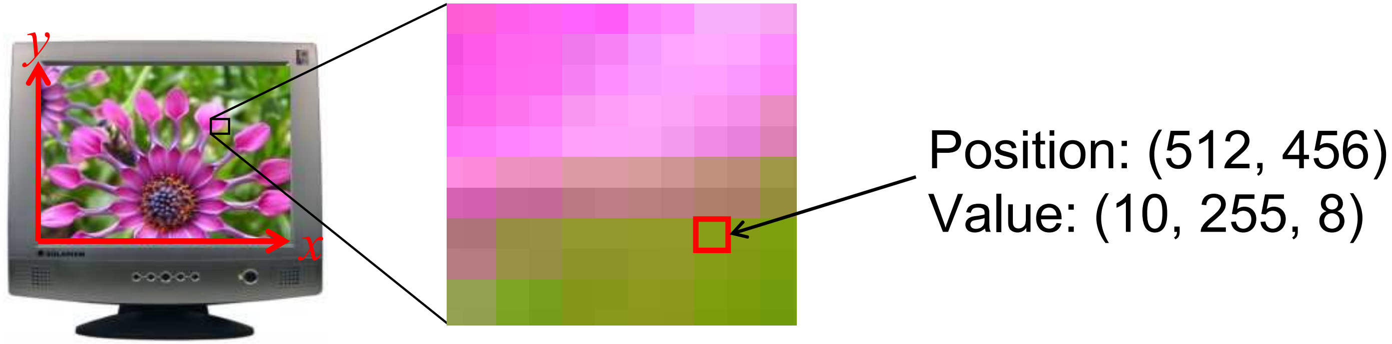
- **Image Processing**: process them to get new images
- **Computer Vision**: analyze them to get information about what is in the image
- **Computer Graphics**: generate them

OUTPUT

INPUT		**Descriptions**	**Images**
	Descriptions		Computer Graphics
	Images	Computer Vision Histogram Image Segmentation	Image Processing Erosion, dilation Opening, closing

Pixels and Resolution

- **Pixel** or **pel** (picture element)
  Position (x,y) + signal value v (greyscale or colour)

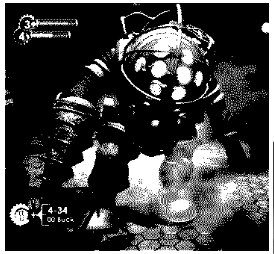


  Origin (0,0) of pixel coordinates sometimes in top left corner

- **Resolution:** how many pixels? width × height
- **Warning on origin and axes**
  - Origin may be sometimes at top left corner with y-axis pointing downwards
  - Some software (Matlab) may not accept 0 as a valid index

Encoding of Colors

- **Bit-depth:** number of bits used to represent each pixel's value (typically 1, 8, 24 or 32)
- **Binary image:** bit depth is 1;
  only code values 0 (black) and 1 (white)
- **Scalar/monochrome/greyscale image:**
  - scalar code values
    (e.g. just a single number per color)
  - only grey values (from black to white)
    and no colour



- **Vector-valued image**
  - vector code values
    (e.g. several numbers per color)
  - All the colors can be represented

- **We will mostly consider binary and grey-scale images only in 373**

Defining Images Mathematically

Images can be defined on an $M \times N$ arithmetic grid (or lattice)

$$\mathbf{R}_{M,N} = \{(x, y) : 1 \le x \le M \wedge 1 \le y \le N\}$$

- Pixel coordinates x and y with $x = 1,\ldots,M;\ y = 1,\ldots,N$
- Image as a function f: $\mathbf{R} \to \mathbf{V}$
- $\mathbf{V}$ is a set of signal values, e.g. grey levels or colors
- **Example**:
  pixel at position (100, 100) has value 255,
  i.e. $f(100, 100) = 255$

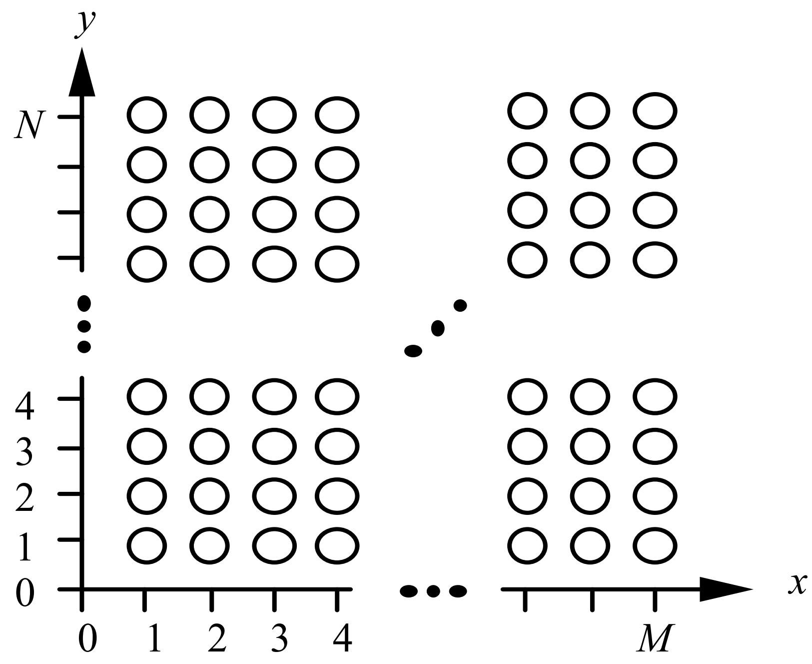


Image Histograms

In an image processing context, the histogram of an image refers to the distribution (count, probabilities, cumulative count) of the pixel intensity values.

The histogram shows the number of pixels in an image at each different intensity value found in that image

For an 8 bit image, each pixel has an intensity value between 0 and 255.

Assume you have a greyscale image containing N pixels (m rows by n columns e.g. m*n=N)

- Each pixel has an intensity value *k* where *k* is an integer from 0 to 255.

The histogram for that image records the number of pixels that equal each value of *k*. To compute the histogram:

- The image is scanned in a single pass
- A running count of the number of pixels found at each intensity value is kept.
- These values are graphed to construct a suitable histogram

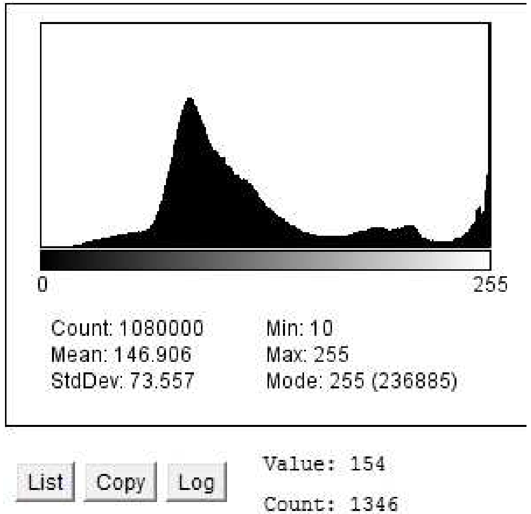
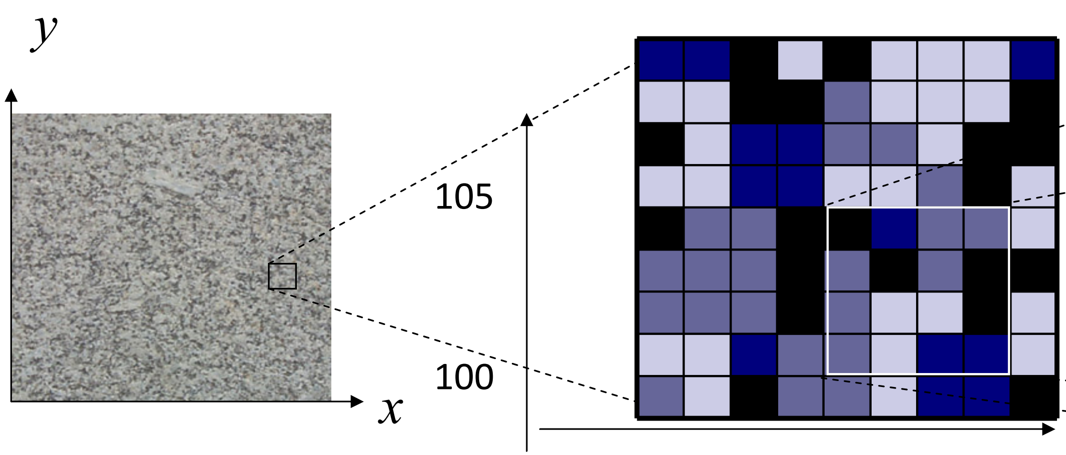


Image Histogram-example



0	50	75	75
175	30	105	75
150	205	30	25
150	150	175	0

Let's look at a very reduced size of image for sake of example

THE UNIVERSITY OF AUCKLAND
NEW ZEALAND

Image Histogram-example

0	50	75	75
175	30	105	75
150	205	30	25
150	150	175	0

Is an image uniquely defined by its histogram ?

0	0	25	30
30	50	75	75
75	105	150	150
150	175	175	205

Image Cumulative Histogram

An Image cumulative histogram is a mapping that counts the cumulative number of pixel intensity values in all of the bins up to the current bin.

The cumulative histogram M_i of a histogram m_j is given by:

$$M_i = \sum_{j=1}^{i} m_j$$

The cumulative histogram is useful for some image operations that use histograms: such as Image histogram equalisation.

Image Cumulative Histogram example

0	50	75	75
175	30	105	75
150	205	30	25
150	150	175	0

Uses of Histograms

An image histogram is a useful tool for assessing the brightness and contrast of an image.

The histogram for the accompanying dark image shows the majority of intensity values distributed to the left.

Uses of Histograms

The histogram for the accompanying light image shows the majority of intensity values distributed to the right.

Histogram stretching