SEEING IS BELIEVING?

Chris Glasbey

Biomathematics and Statistics Scotland
Image analysis is the extraction of information from pictures

Which line is the longer? Who is this?
The human eye/brain is a superb image analyser

So, why use a computer?

- better for quantitative tasks (repeatable/non-subjective)
- cheaper, faster and less tedious
- capable of different techniques
An example of non-automated image analysis:

Cross-section of turbinate bone

Using sno-pake and black ink.
But automating image analysis is hard, because all a computer ‘sees’ is:

Could you recognise Mona Lisa from this?
What are the data?  
- microscopy  
- medical scanner  
- remote sensing

What is image size?  
- 20μm  
- 50cm  
- 15km

What is measured?  
- transmitted light  
- X-ray absorption  
- reflected light

How is object sampled?  
- focal plane  
- cross-section  
- perspective view
Three questions: 1. What is the 3-D shape of this diatom?
Question 2: How fat is this sheep?

SAC-BioSS CT Unit, led by Geoff Simm
Question 3: Can we distinguish between fish species?

haddock

whiting
PLAN

0. Introduction
1. Microscopy
2. Medical scanners
3. Remote sensing (and fish)
1. Microscopy

Using computers, we can

- Visualise images in ways not possible optically
We can superimpose different microscope images of algae and bacteria.
DIC + fluorescent

(Nick Martin, SAC)
1. Microscopy

Using computers, we can

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- Count and measure more easily
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However, identifying objects to count and measure is more challenging if

- Objects vary in appearance
DIC image of yeast cells – example of template construction

integrate → rotate → differentiate
1. Microscopy

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- Optical effects distort what is seen
Brightfield image of cashmere fibres

These fibres are the same thickness, but look different
(Angus Russel, Macaulay Land Use Research Institute)
We use a mathematical model to understand how a fibre appears in different focal planes.

And use it to adjust for errors in measuring fibre thicknesses in images.
1. Microscopy

Using computers, we can

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However, identifying objects to count and measure is more challenging if

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Though optical distortions are sometimes an advantage
In answer to question 1: we can reconstruct the 3-D shape of this diatom

Brightfield images at series of focal planes
(Ed Breen, CSIRO – Mathematical and Information Sciences)
Step 1: compute local gradients in intensity
Step 2: smooth the gradients
Step 3: at each location, choose image with maximum gradient
Step 4: reconstruct the 3-D surface
PLAN

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Ultrasound

(Geoff Simm, SAC)
To measure fat depth, we need to draw the red lines
We consider the pattern of pixel values on either side of a boundary, averaged over many images.
We compare the patterns with the different possible locations of a boundary, where darker values denote better fits:

The best boundary is the darkest path between the two sides of each image.
Illustration of Dynamic Programming:

Find connected path from left to right with minimum cost
One of 700 possible paths
Minimum cost paths to column 2
Minimum cost paths to column 3
All minimum cost paths
Minimum cost in final column
Trace path back to first column
Minimum cost path
Here we see the resulting **automatic**, and **hand-drawn**, boundaries:
In CT, pixel values range from $-1000$ to $+1000$ Hounsfield units. According to how we display these values we obtain different images.
For segmentation, we first ‘unroll’ the images

polar transformation  boundary pattern
We then use level of X-ray attenuation to identify tissues

In answer to question 2: we predict sheep fatness from these measured areas
With a 3-D scanner there is more information but segmentation is harder.

sheep skeleton

leg muscles in pelvic region
PLAN

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Landsat image of St Andrews, Scotland

It is rare to get such a cloud-free scene in Britain. Venus is even cloudier.
NASA Magellan mission → SAR image of Mona Lisa crater, Venus
SAR (synthetic aperture radar) is also used on Earth

SAR image, East Anglia

Map of field and road boundaries

(European Space Agency)
How the SAR image was obtained

We need to **warp** the SAR image to align with the map
Arad et al. (*CVGIP: Graphical Models and Image Processing, 1994*)

Venus warped average
edges in SAR image

after warping
Estimated elevations
Resulting alignment
We can also use warping to identify fish

haddock 1

whiting 1

haddock 2

whiting 2

(Norval Strachan, Torry Research Centre)
Fish warping has a long history.

D’Arcy Thompson, *On Growth and Form* (1917)
Dissimilarity between fish = difference after warp + distortion in warping
haddock 1

warping

haddock 1 ‘impersonating’

whiting 1
In answer to question 3: we can distinguish between fish species

Haddock are more similar to the average haddock

Whiting are more similar to the average whiting
Summary

Automated image analysis is a challenging problem, but offers the possibility of

- more accurate,
- faster,
- more sophisticated, measurements.

For further details, see


and research papers on

http://www.bioss.ac.uk/~chris