The blessing and the curse of the big image

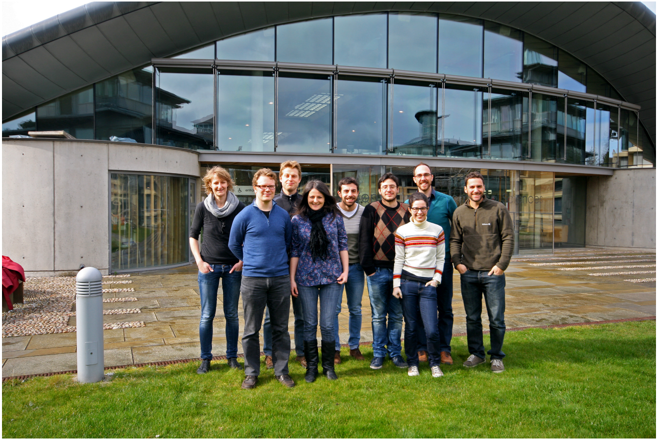
Carola Schönlieb, Jan Lellmann
Cambridge Image Analysis

Department for Applied Mathematics and Theoretical Physics
University of Cambridge, UK

UNIVERSITY OF CAMBRIDGE

Cambridge
Centre for
Analysis

Cambridge Image Analysis (CIA)



1 PI, 3 PostDocs, 6 PhD students, 3 Masters students

www.damtp.cam.ac.uk/research/cia/

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The blessing

Images are *big*

HD video	6 MB/image uncompressed 180MB/second
Digital cameras	80-200 million pixels 480-1,200MB/image
MRI	16 MB/volume at 1mm^3 590MB/volume at 0.3mm^3

- High number of dimensions:
  - 2D–3D astronomical imaging, global terrestrial seismic tomography, arts applications (Fitzwilliam Museum)
  - 3D dynamic microscopy (CAIC)
  - 3D–4D (dynamic) MRI (MRRC), PET/SPECT (WBIC)
  - 5D Diffusion MRI

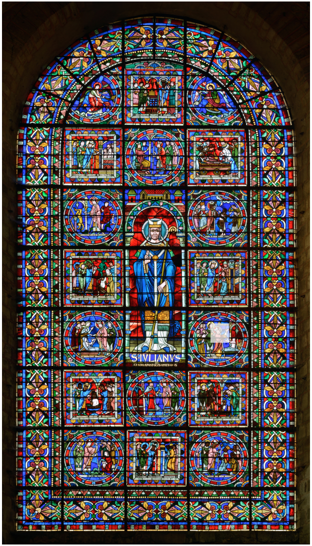


Image credit: Wikimedia/Selbymay

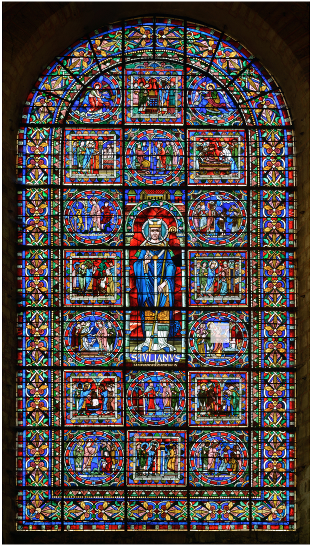
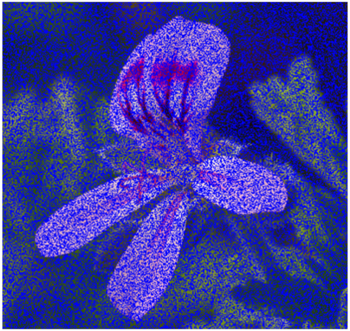


Image credit: Wikimedia/Selbymay

The curse

- Images are *redundant*

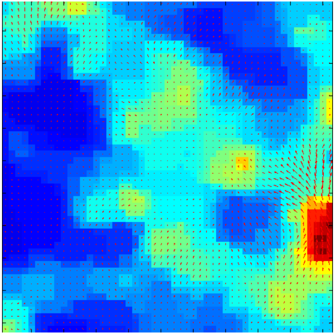


Challenges

1. How to extract the interesting information?
   - classification, image labelling, segmentation, sparse representation, image parametrisation
   - methods from machine learning, statistics

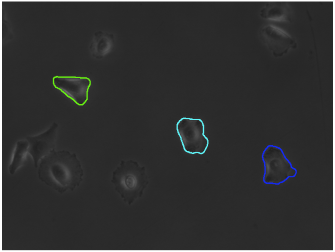
Dynamic image analysis for light microscopy

Optical flow estimation:



Computations by Hendrik Dirks/CIA, image data from Goldstein Lab

Cell tracking:



References: Möller et al. '12; . . . ; cell tracking through mitosis with Burger, Grah, Reichelt (CRUK CI)

Challenges

1. How to extract the interesting information?
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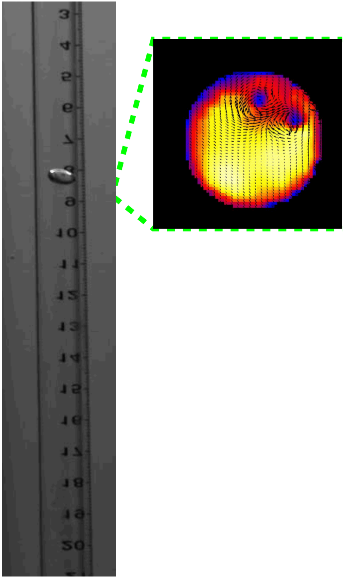
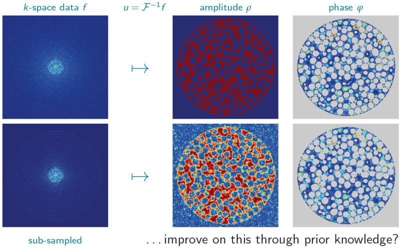
Challenges

1. How to extract the interesting information?
   - classification, image labelling, segmentation, sparse representation, image parametrisation
   - methods from machine learning, statistics
2. How to deal with incomplete data?
   - only limited measurements available, or
   - deliberate reduction for speeding up the imaging process
   - methods from statistics, inverse problems, partial differential equations, variational methods, regularisation, large-scale optimisation

Image reconstruction from phase-encoded MR data



Phase difference $\phi_1 - \phi_2$ of two images u_1 and u_2 proportional to velocity of a fluid along a gradient.



References: Gladden et al. ’90-; . . . ; Benning, Gladden, Holland, CBS, Valkonen, Journal Magnetic Resonance ’13. Animations courtesy of Alex Tayler.

Mathematical framework

The problem

Given data f, find the image information u that solves

$$f = T(u) + n$$

where T models the relation between u and f, and n is noise.

Issues

In most real-world applications, reconstructing f from u is

- not unique (T “forgets” data), or
- not stable (small variations in $f \to$ large variations in u),
- not clear, because the noise n is unknown

We need additional prior knowledge on u…

Mathematical framework

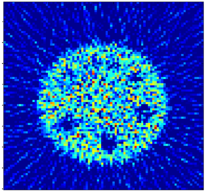
Energy minimisation framework

Reconstruct image information u from data f by minimising

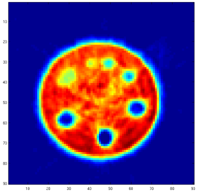
$$\min_u \underbrace{R(u)}_{\substack{\text{prior knowledge}\\ \text{class-specific}}} + \underbrace{D(T(u);f)}_{\text{fit to measurements } f}$$

$\rightarrow$ state of the art optimisation for large-scale computing

- convex optimisation, operator splitting
- subspace decomposition, parallelisation, GPU computing



naive PET reconstruction



result of energy minimisation

Closing gaps: restoration of paintings

Figure: Adoration of the Shepherds, Sebastiano Del Piombo (1519)

References: Bachelor thesis Marie Autume (intern from ENS Cachan) in collaboration with Spike Bucklow (Hamilton Kerr Institute)

Closing gaps: restoration of paintings

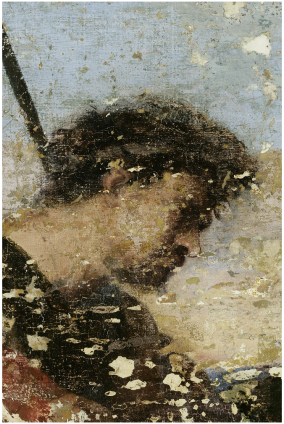


Figure: Detail

References: Bachelor thesis Marie Autume (intern from ENS Cachan) in collaboration with Spike Bucklow (Hamilton Kerr Institute)

Closing gaps: restoration of paintings

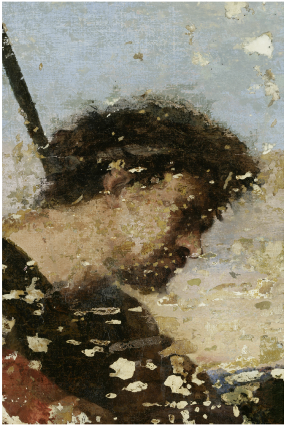


Figure: Small damages restored with structure inpainting

References: Bachelor thesis Marie Autume (intern from ENS Cachan) in collaboration with Spike Bucklow (Hamilton Kerr Institute)

Closing gaps: restoration of paintings

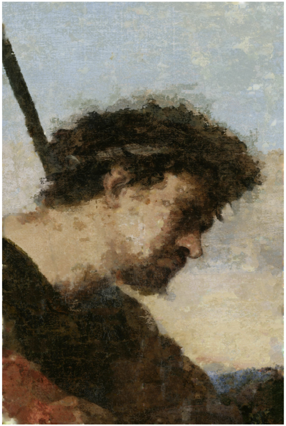


Figure: Large damages restored with structure & texture inpainting

References: Bachelor thesis Marie Autume (intern from ENS Cachan) in collaboration with Spike Bucklow (Hamilton Kerr Institute)

Cambridge Image Analysis (CIA)

- Dr Carola Schönlieb
- Dr Jan Lellmann
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- Evangelos Papoutsellis
- Simone Parisotto (CCA)

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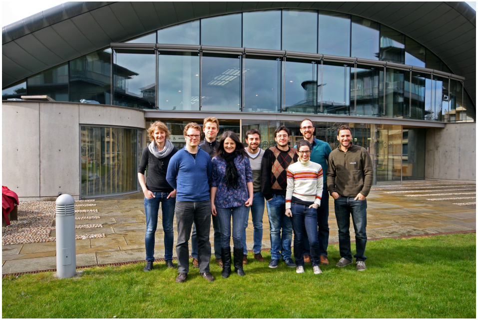

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