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Computer Vision at Cambridge:

Reconstruction,Registration and Recognition

Roberto Cipolla

Research team
http://www.eng.cam.ac.uk/~cipolla/people.html

Cognitive Systems Engineering

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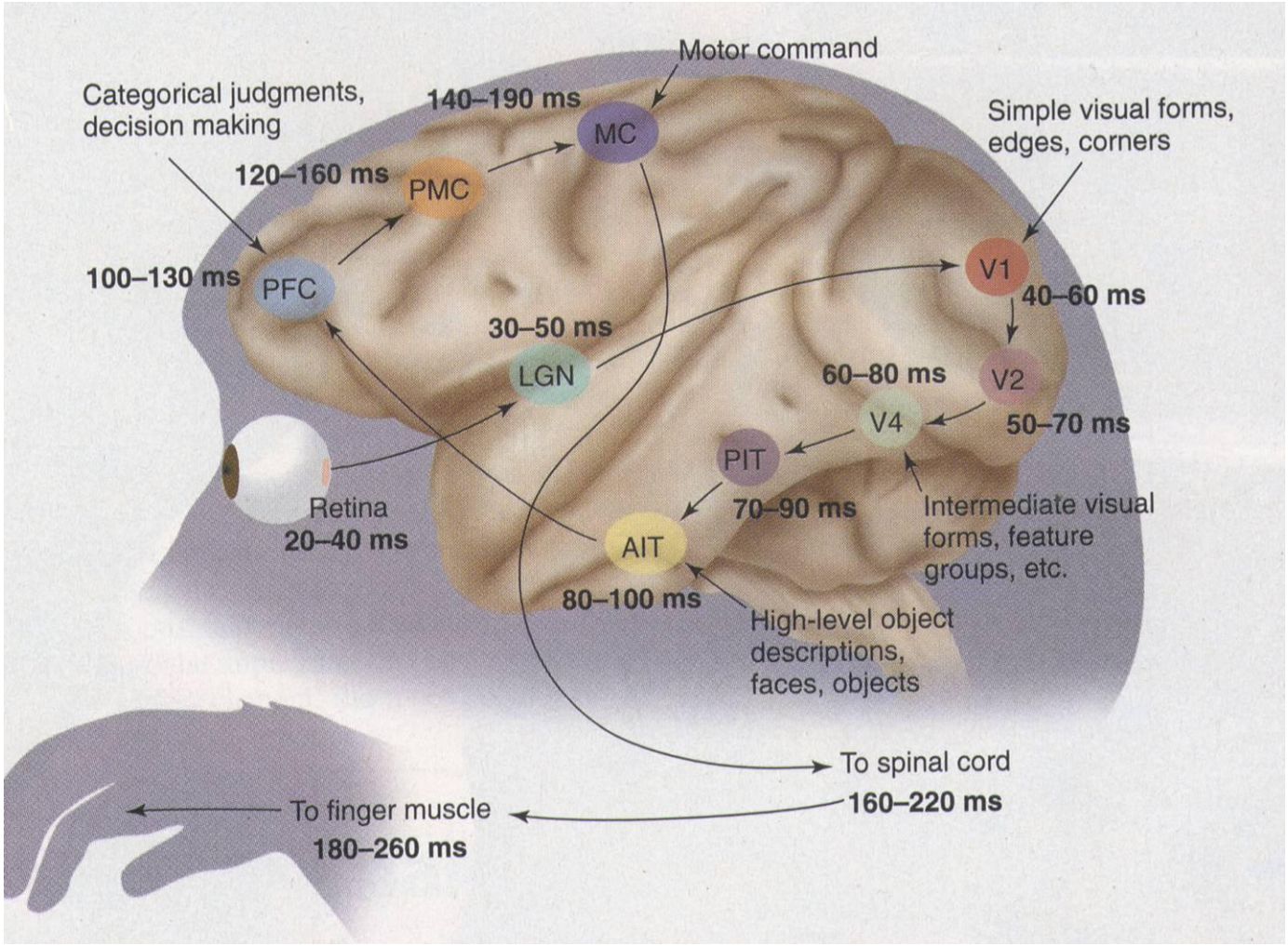

New applications

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Computer vision has now found a place in consumer products

- Mobile phones and PDAs
- Games
- Cars
- Image and video search
- Internet and shopping

Smart erase on a mobile phone

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I. Reconstruction:

Recovery of accurate 3D shape from uncalibrated images

Cipolla and Blake 1992
Cipolla and Giblin 1999
Mendonca, Wong and Cipolla 1999-2005
Vogiatzis, Hernandez and Cipolla 2006-2007
Hernandez, Brostow and Cipolla 2007

Digital Pygmalion – the myth

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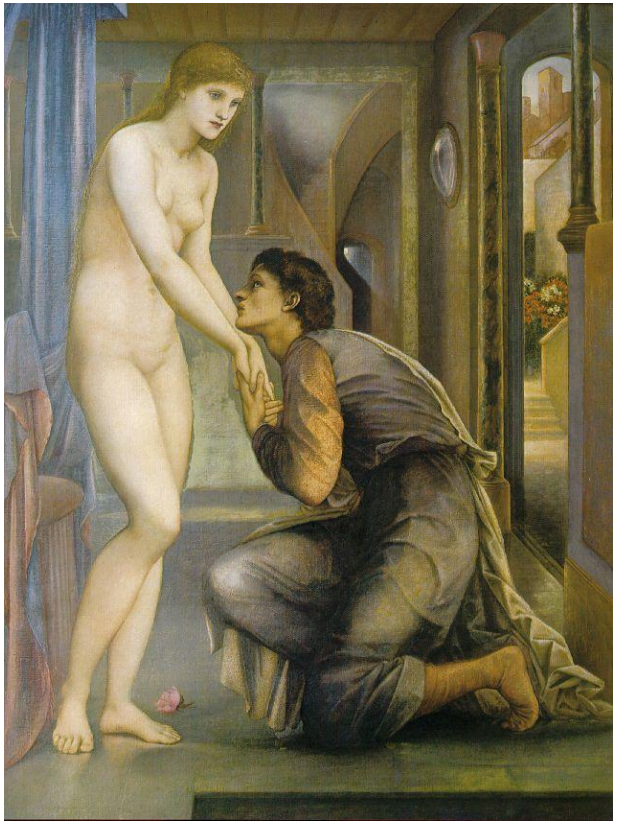

Digital Pygamlion Project

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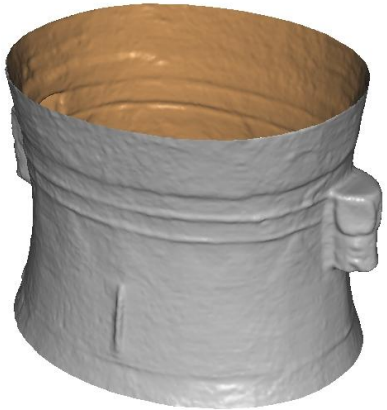

Scanning technologies

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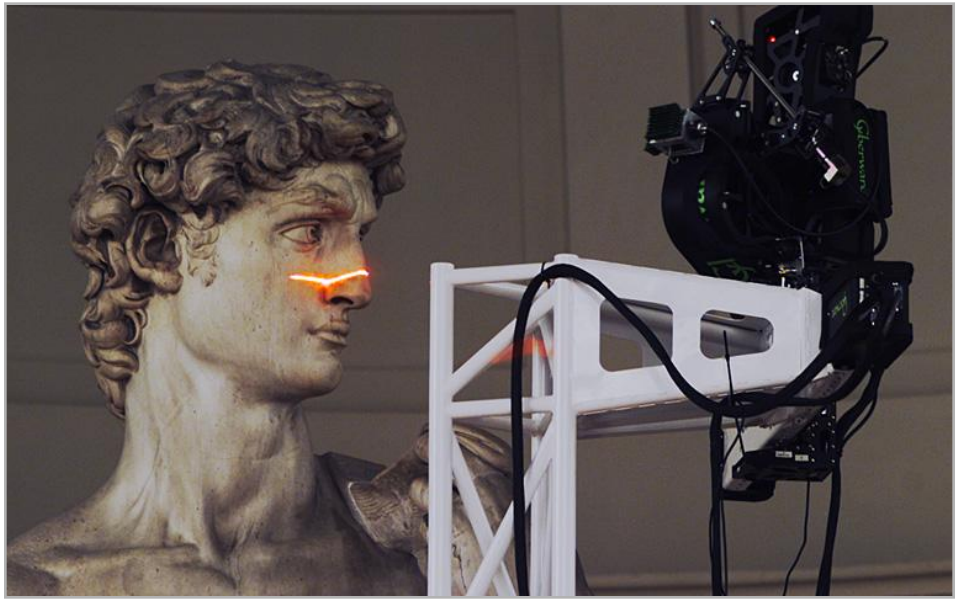
- Laser range finders
  - Very accurate
  - Very expensive
  - Complicated to use



3D models

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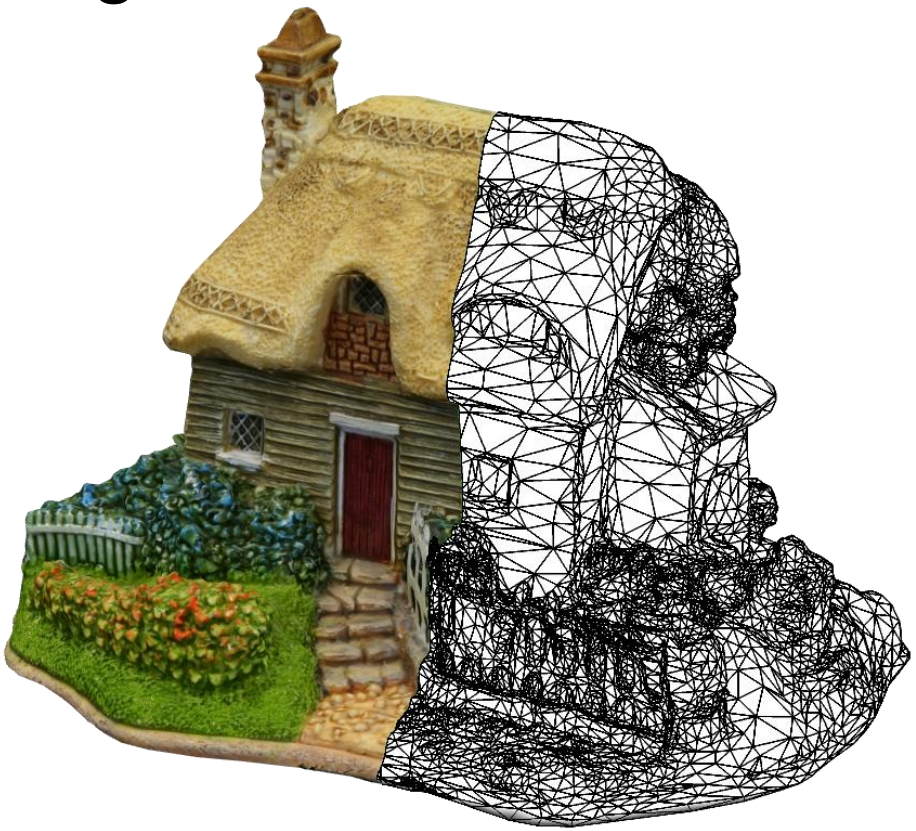
- We need a way to get them that is
  - practical
  - fast
  - non-intrusive
  - low cost



Stereo vision

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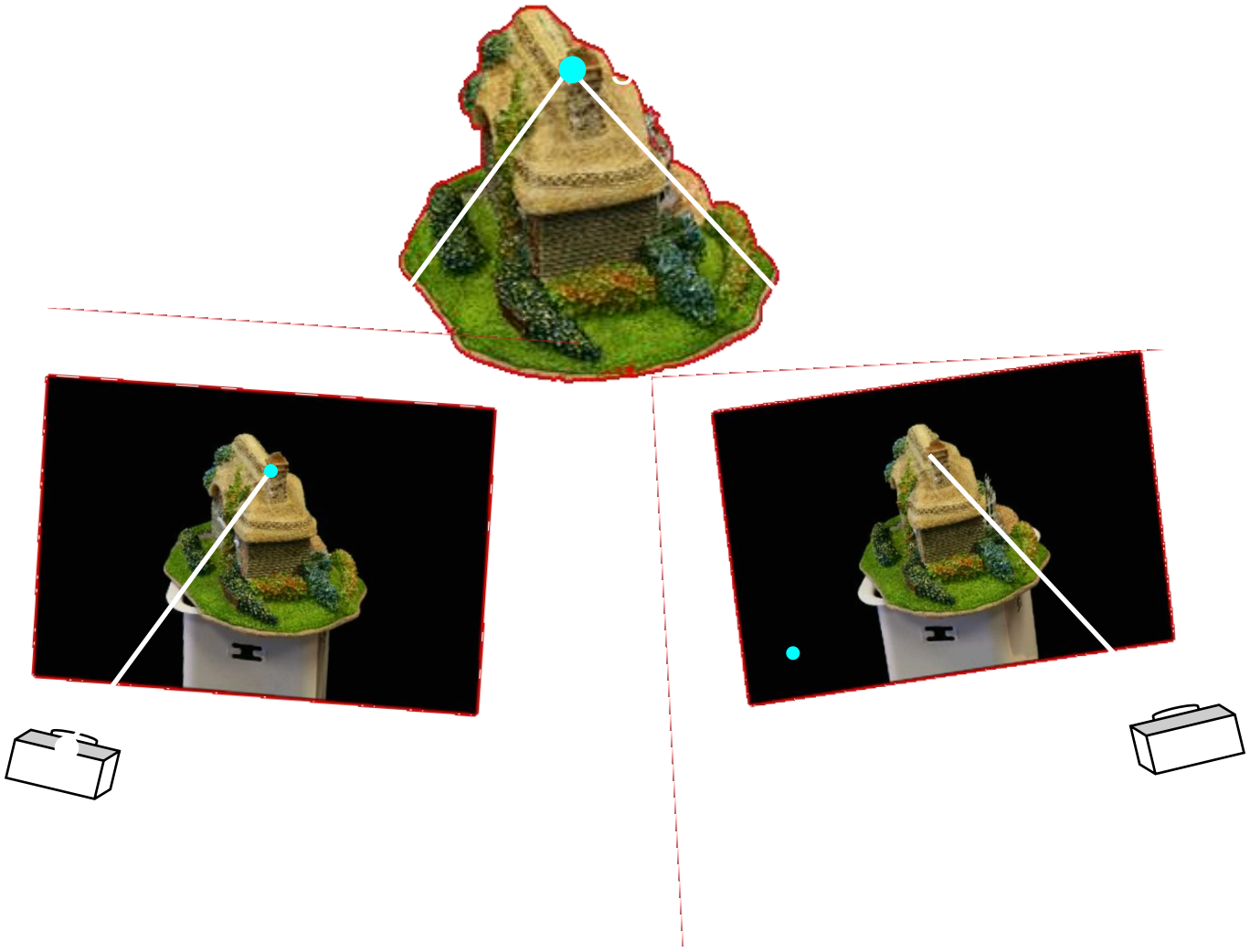

3D Models

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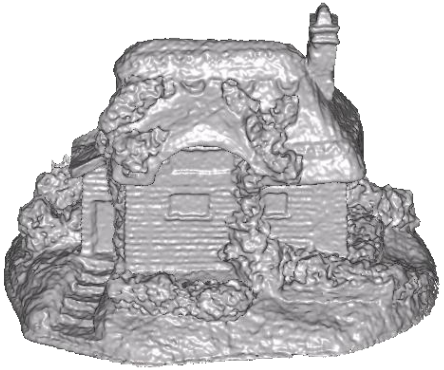

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1. Camera motion and multiview stereo

Cipolla and Blake 1992
Cipolla and Giblin 1999
Mendonca, Wong and Cipolla 1999-2005
Hernandez, Schmidt and Cipolla 2007
Vogiatzis, Hernandez and Cipolla 2007

Input Images

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Recovery of camera motion

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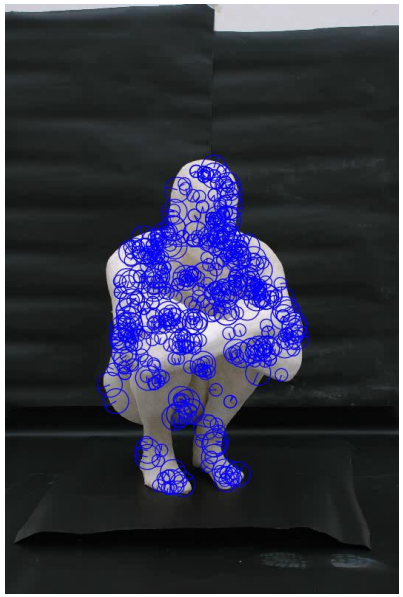
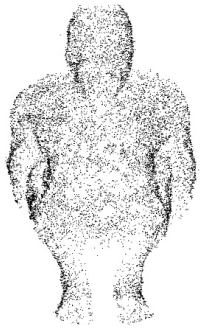
Input images



Feature extraction

Feature matching



Bundle adjustment

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2. Probabilistic 3D segmentation using graph cuts

Vogiatzis, Hernandez and Cipolla 2007

Probabilistic 3D segmentation

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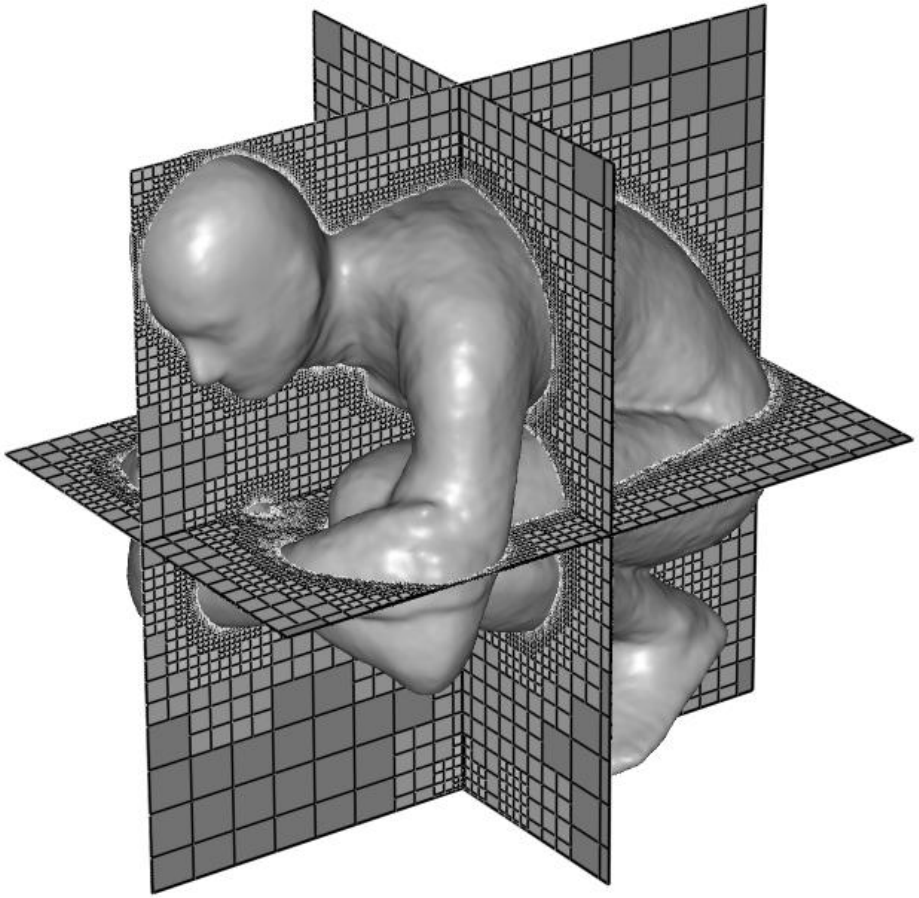

3D models

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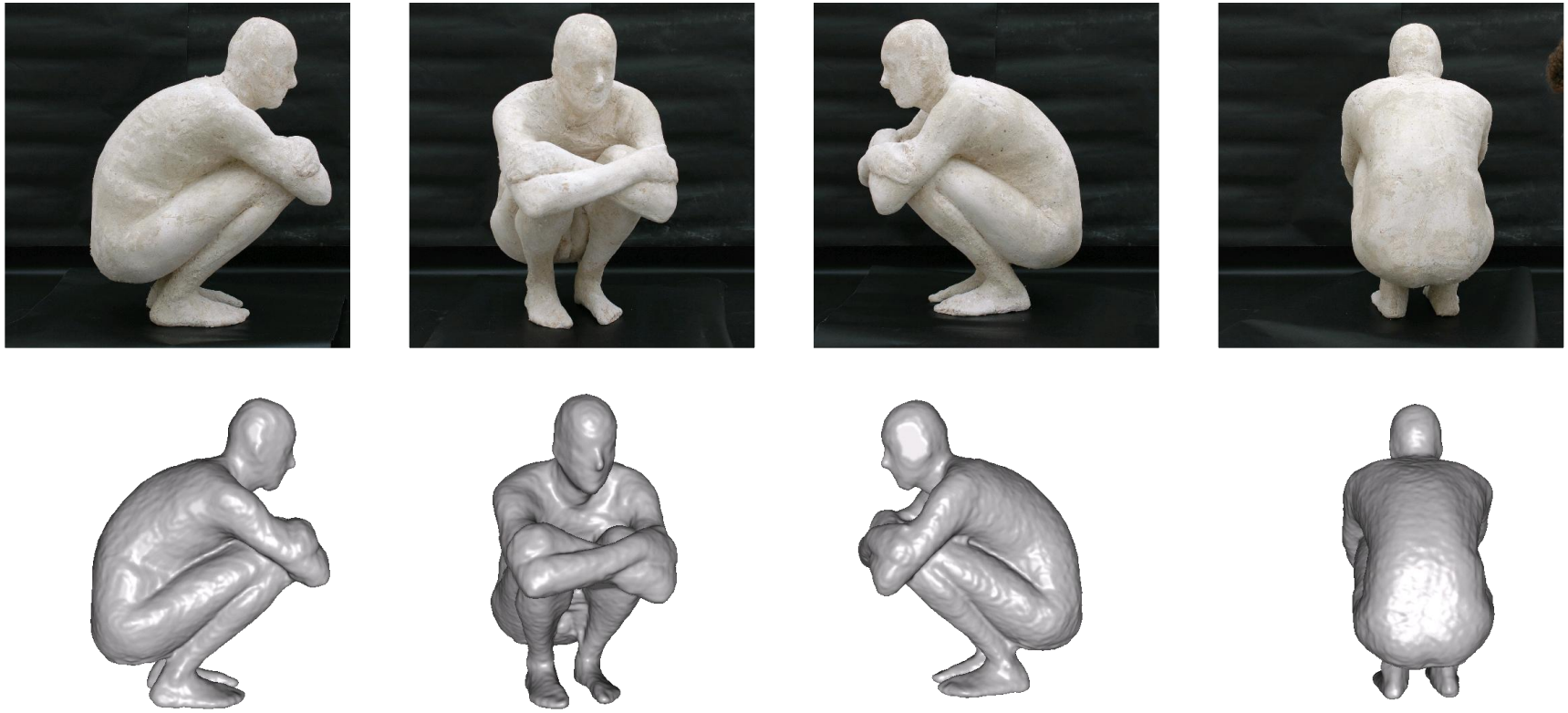

3D models

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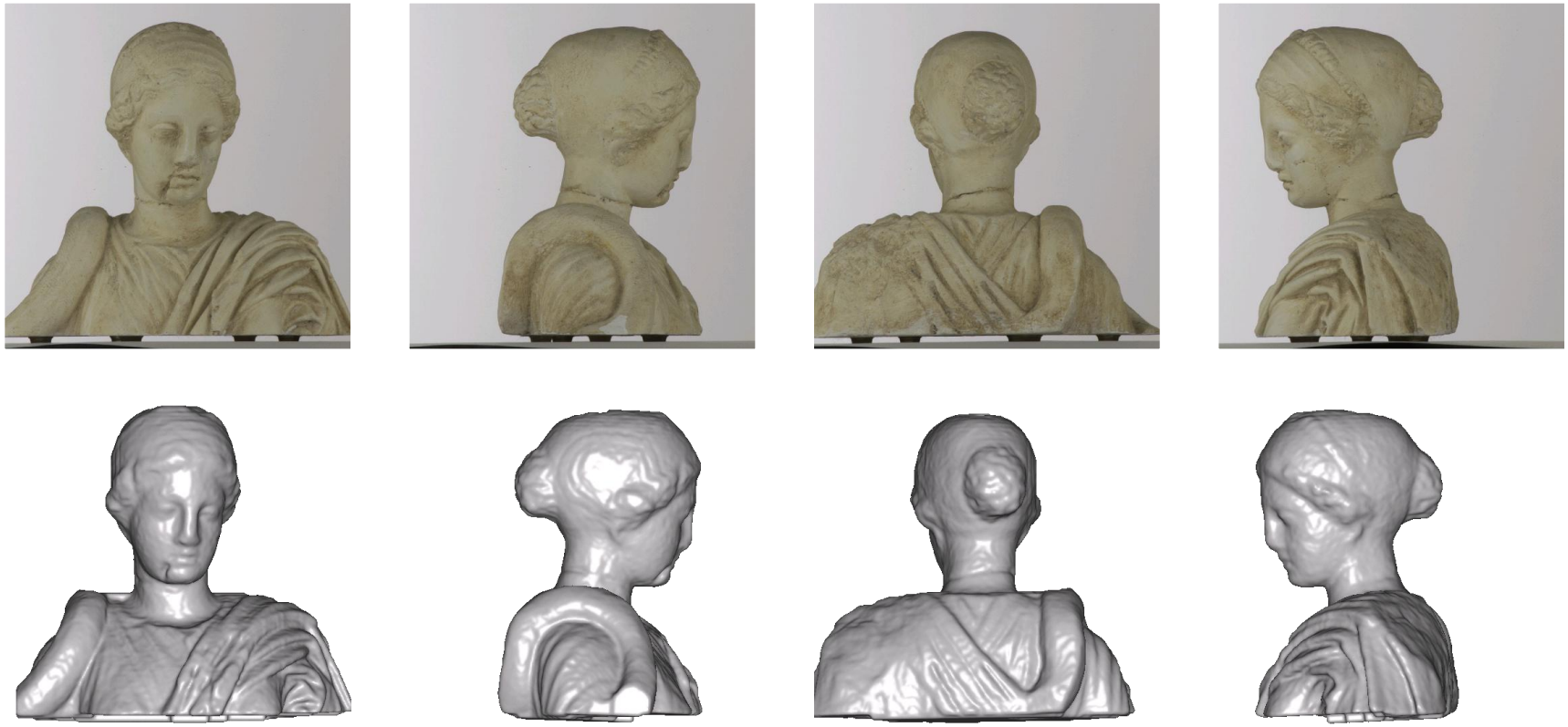

Advantages

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- Low cost
- Non intrusive
- Accurate
- Simple
  - Can work with about 5-30 images
- Fast
  - Approximately 15-30 minutes of computation for these models
  - We believe we can bring this down to minutes

Application requirements

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In order of importance

1. Simplicity	~25 images, no calibration
2. Cost	Digital camera + PC
3. Visual accuracy	Sub-pixel
4. Intrusiveness	Completely non-intrusive
5. Speed	Recently down to 15min
6. Robustness	tranparency, deformations
7. Geometric accuracy	1 part in 1000

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3.Multiview photometric stereo

Vogiatzis, Hernandez and Cipolla 2006

Untextured objects

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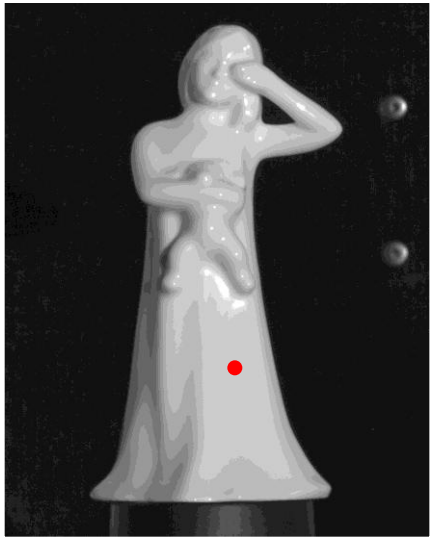
- Almost impossible to establish correspondence



Untextured objects

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Changing lighting uncovers fine geometric detail

- Assumptions:
  - Single, distant light-source
  - Silhouettes can be extracted
  - No texture, single colour

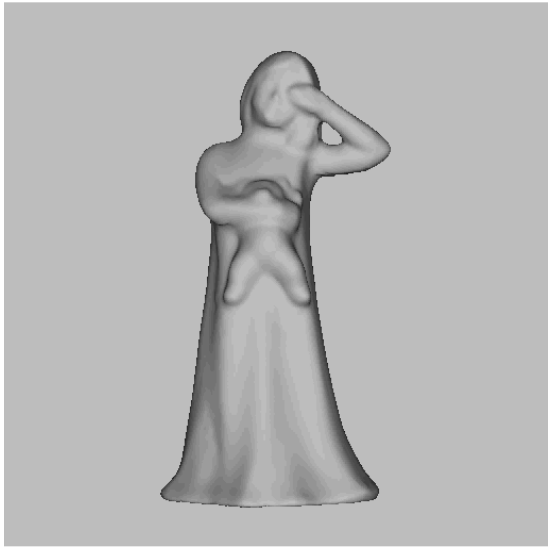

Image acquisition setup

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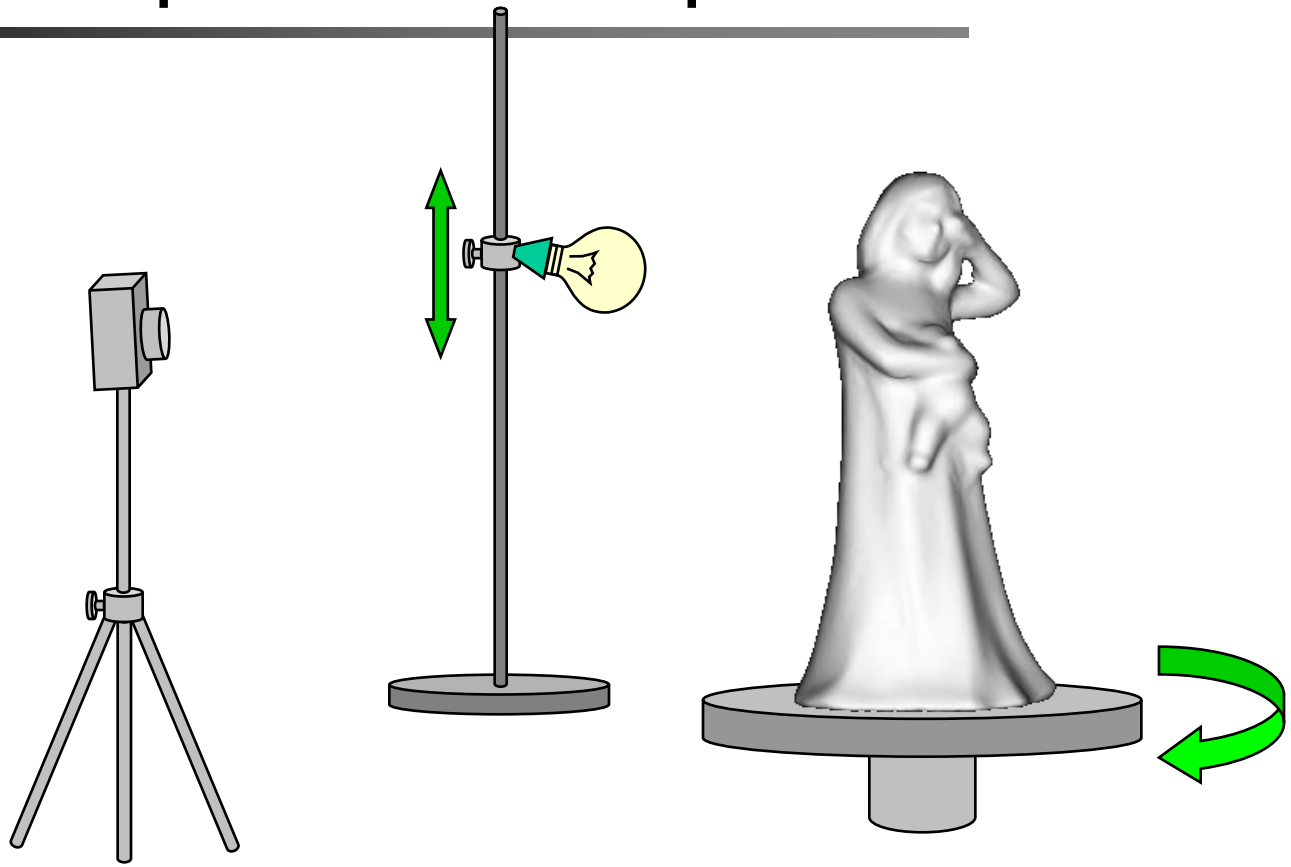

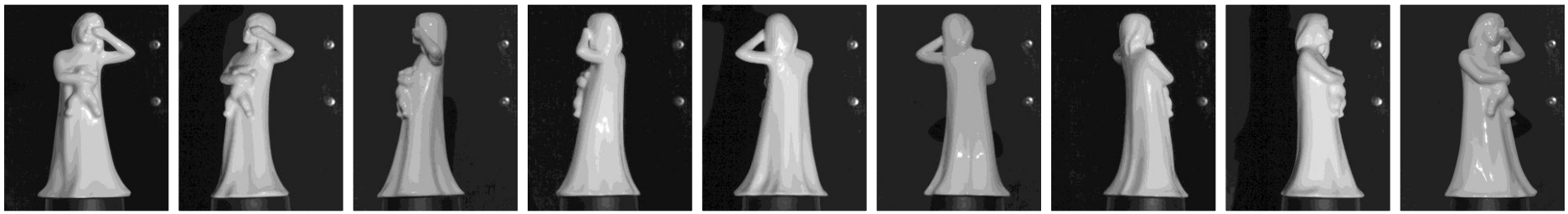

Surface Evolution: 3D Mesh

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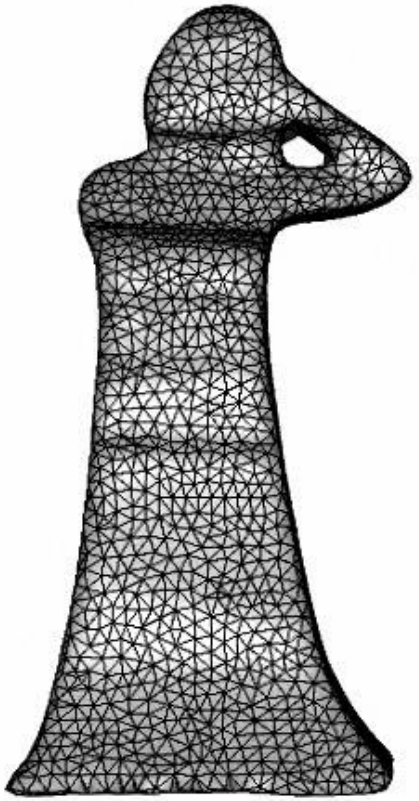

3D Models

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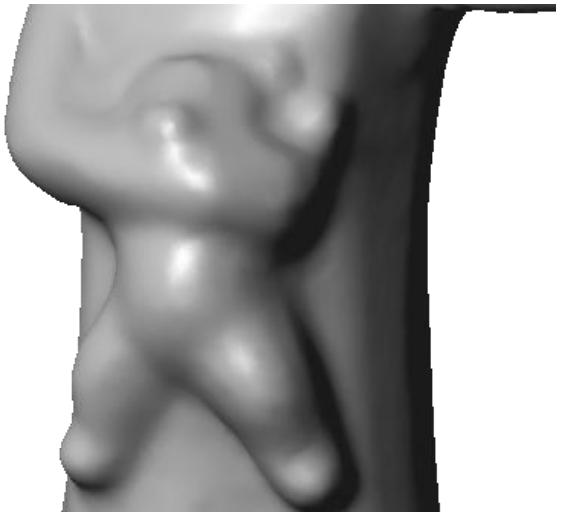

3D Models

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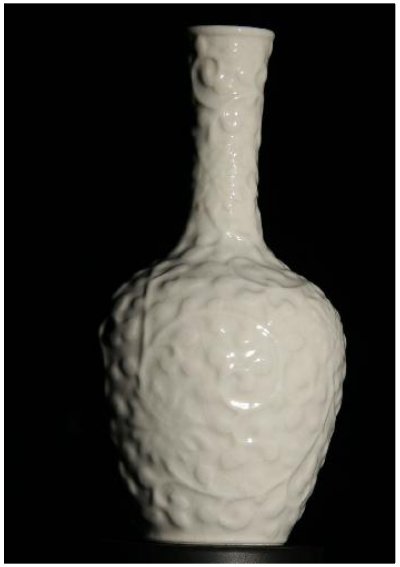

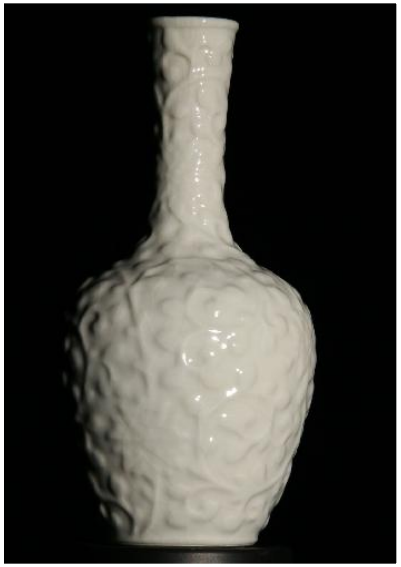


3D Models

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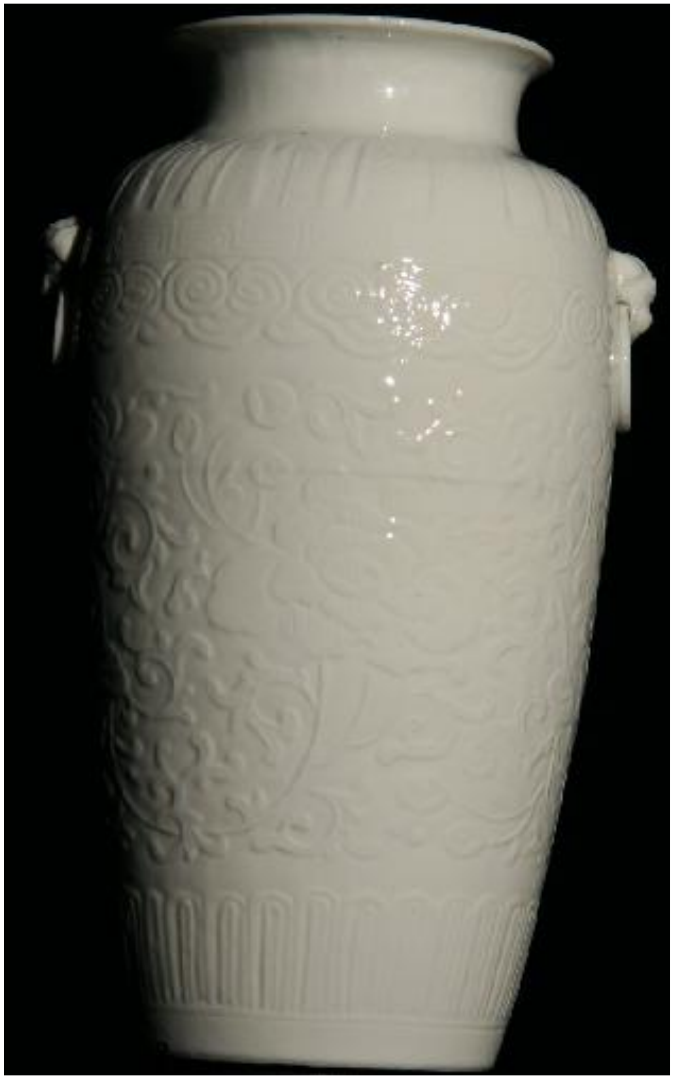

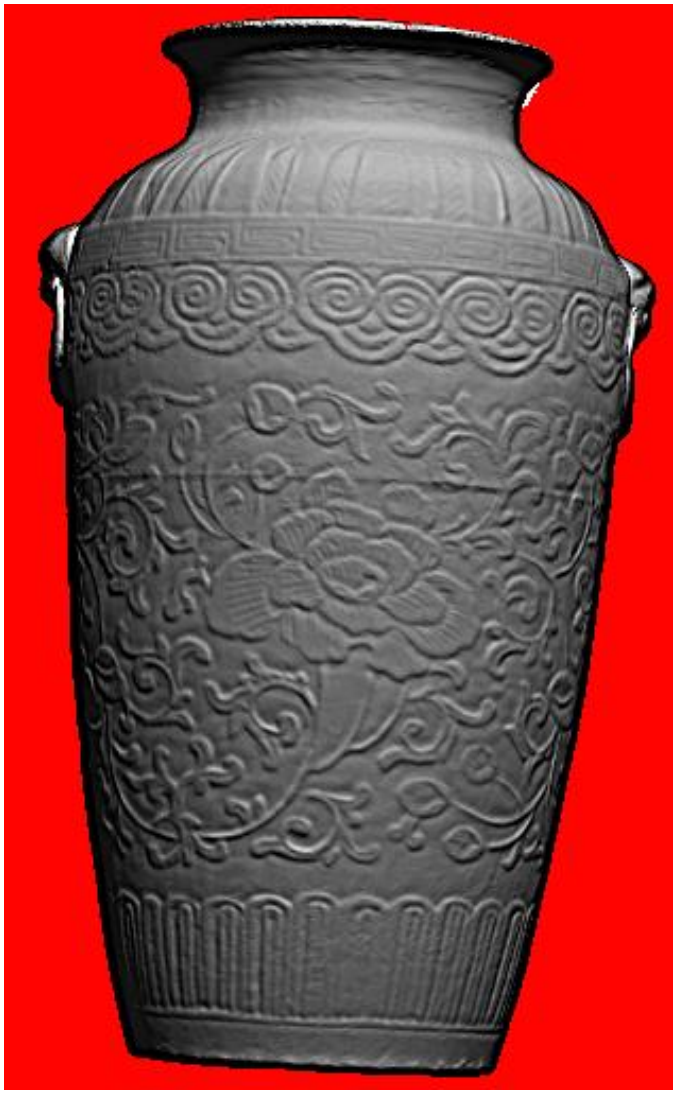

3D Models

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3D Models

UNIVERSITY OF CAMBRIDGE

3D Models

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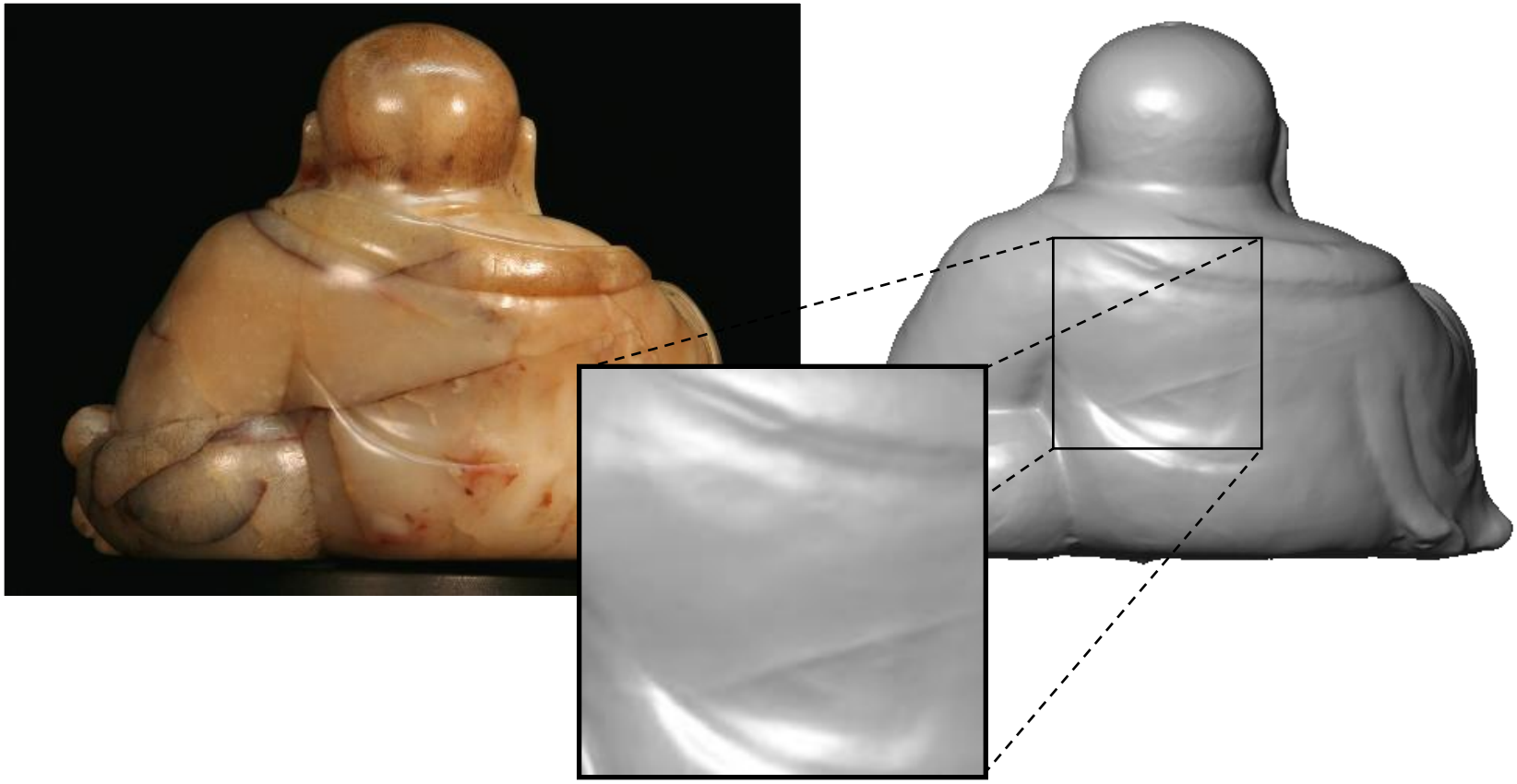

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II. Registration:

Target detection and pose estimation

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4. Registration:

Where am I?
What am I looking at?

Johansson and Cipolla 2002
Robertson and Cipolla 2004

Where I am?

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Determine pose from single image by matching

Register database view

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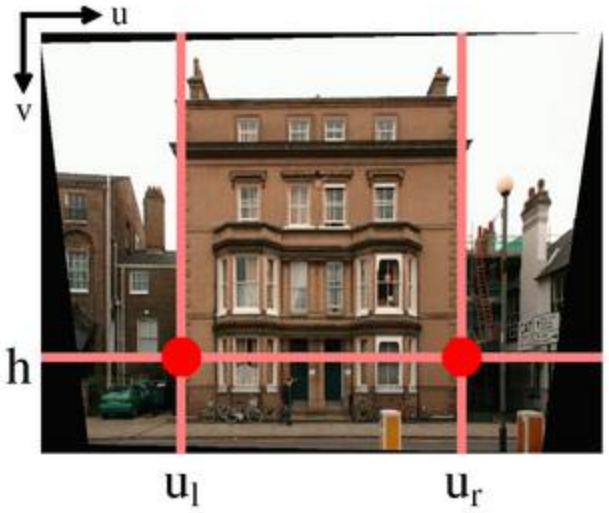
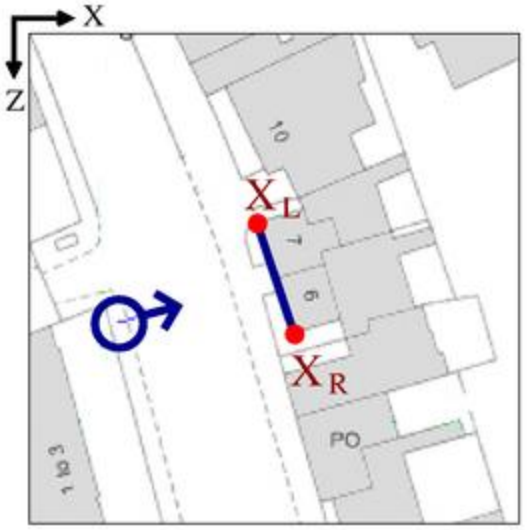
First align database view to map





Registration of input image

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Only difference is now scale + x translation

Matching

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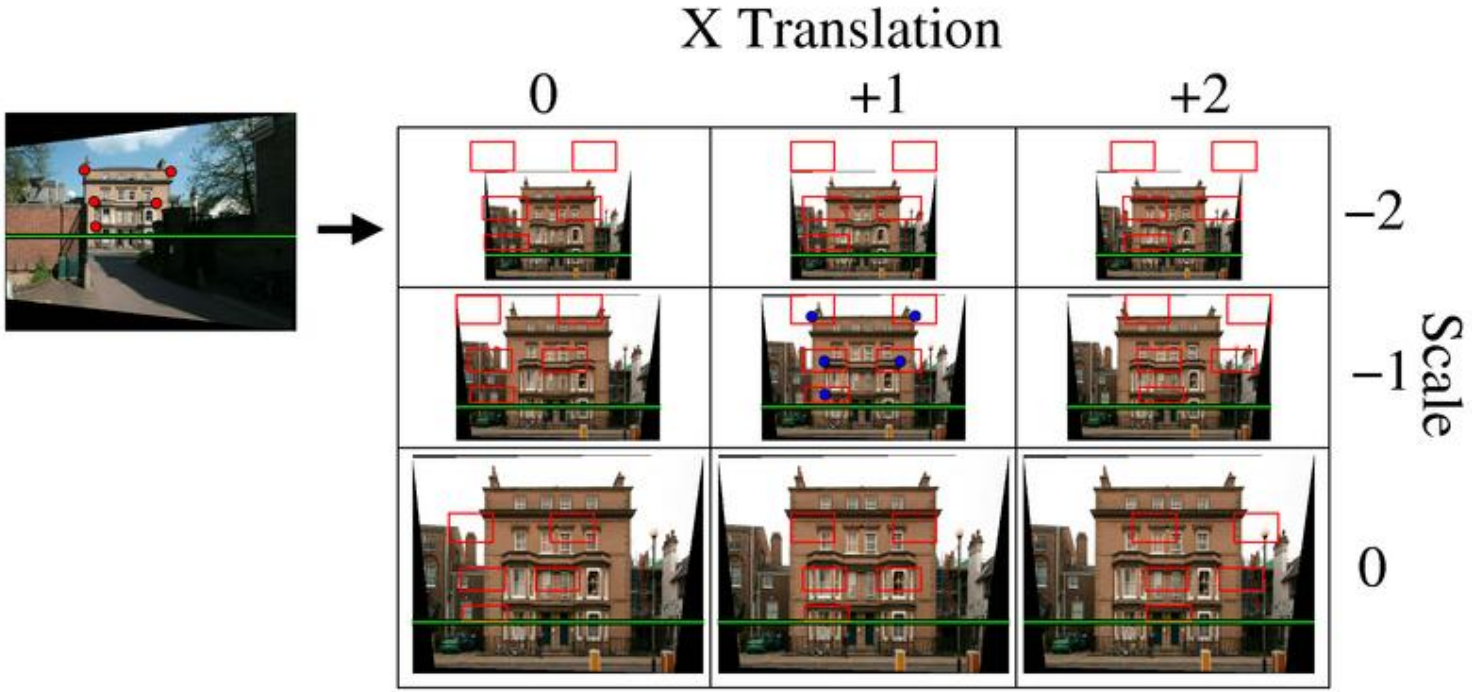
With only 2 params (s,t_x), can search rather than RANSAC.



Localisation of query view

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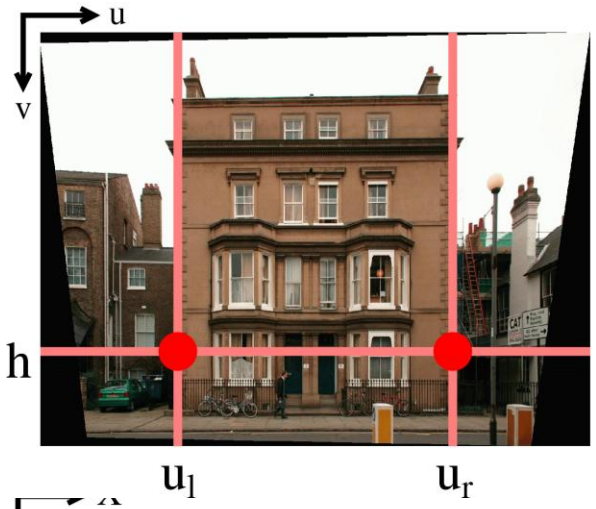

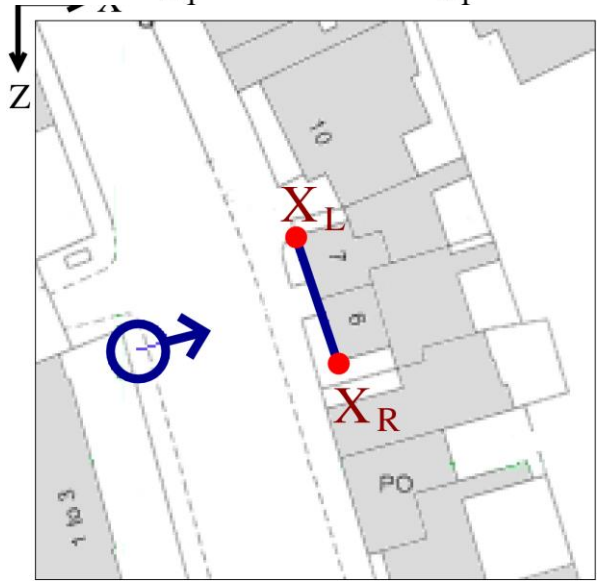

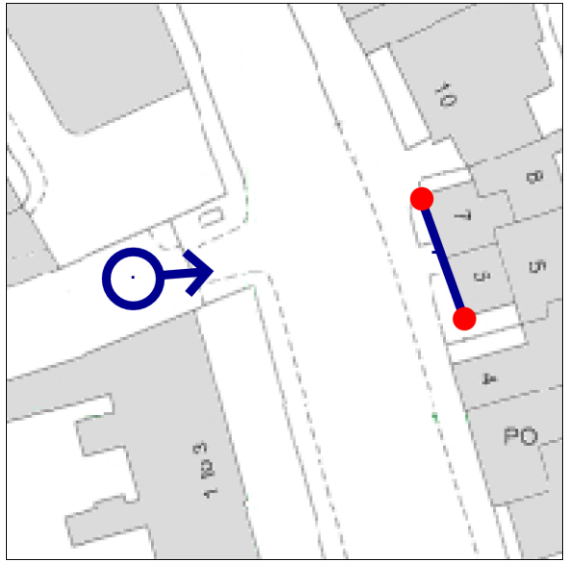

Image-based localisation

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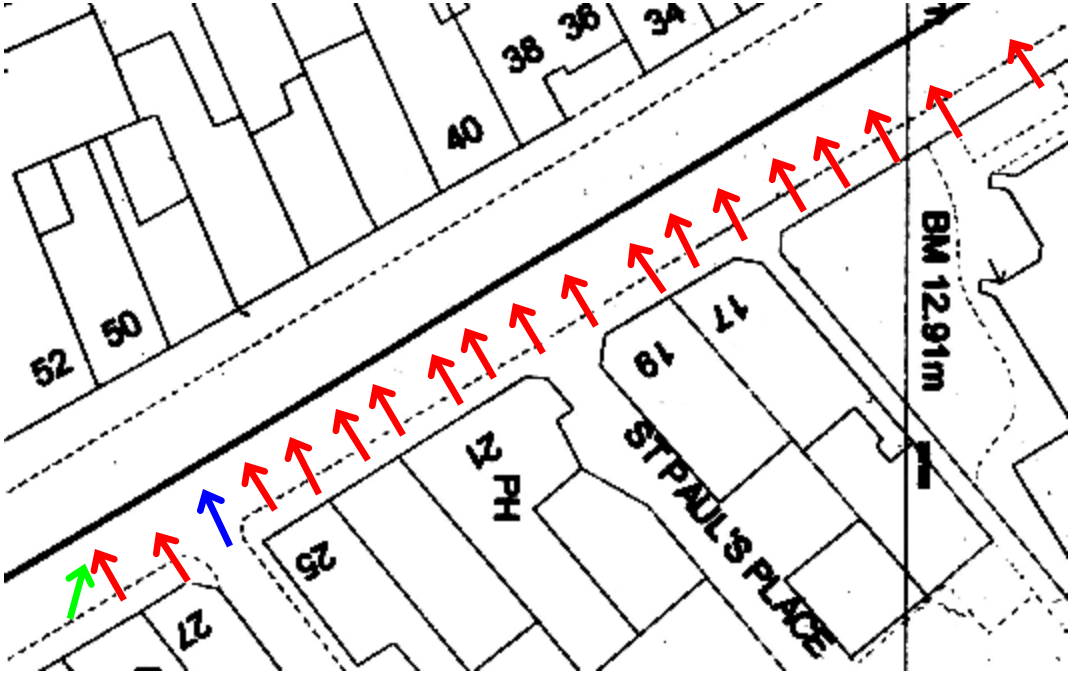

Image-based localisation

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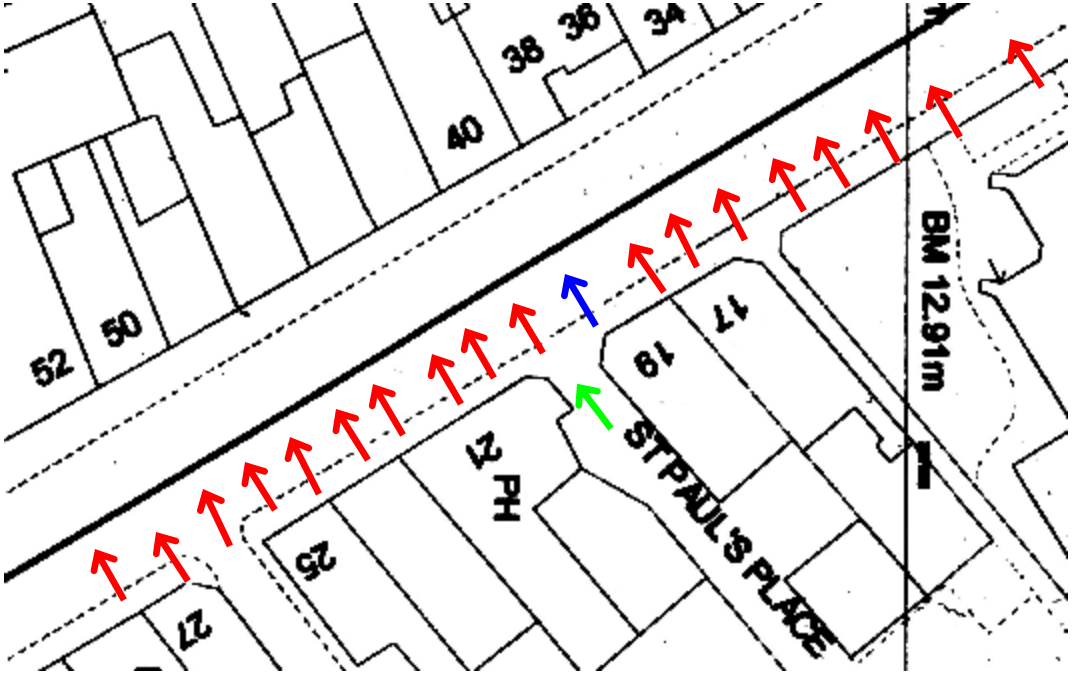

Image-based localisation

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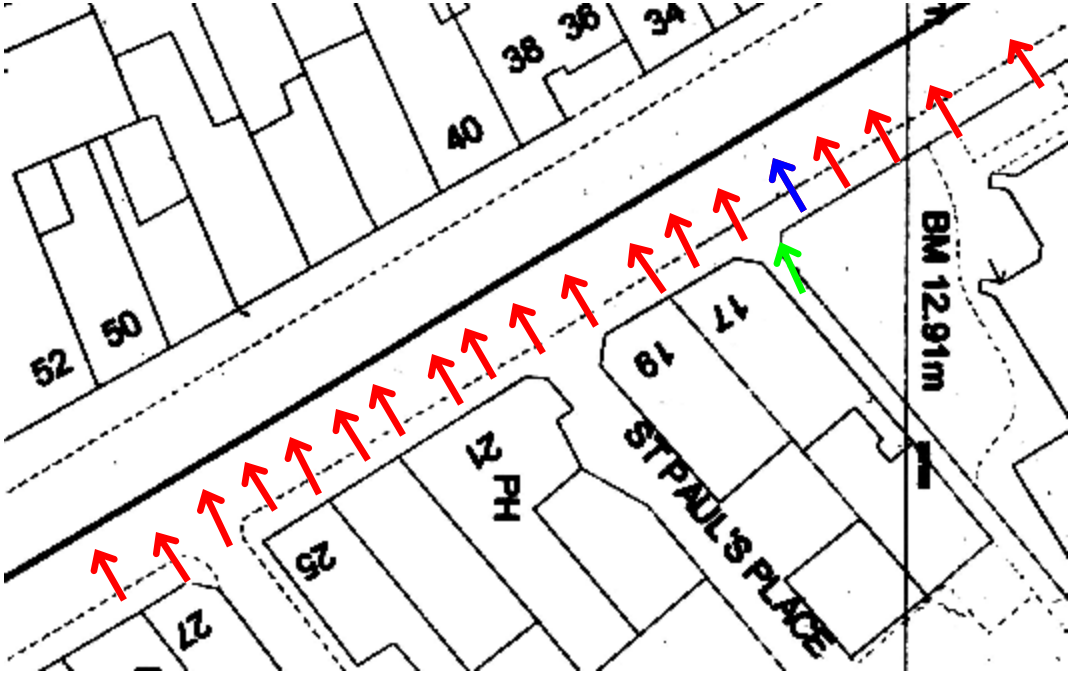

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5. Finding 2D shapes and applications to HCI

Stenger, Thayananthan, Torr and Cipolla 2003
Williams, Blake and Cipolla 2003 and 2006
Ramanan, Fitzgibbon and Cipolla 2006-2007

Matching shape templates

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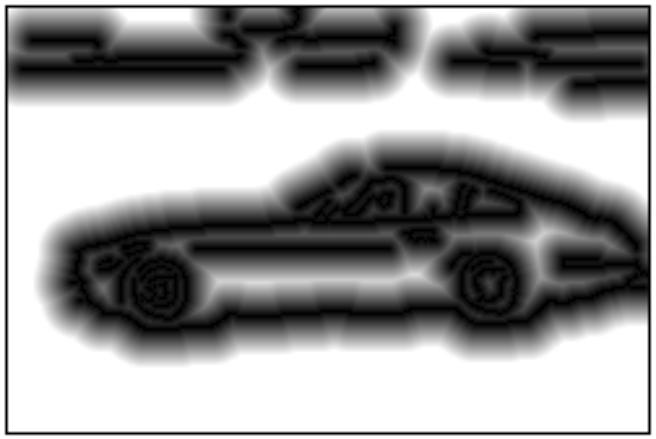
Oriented Chamfer Distance

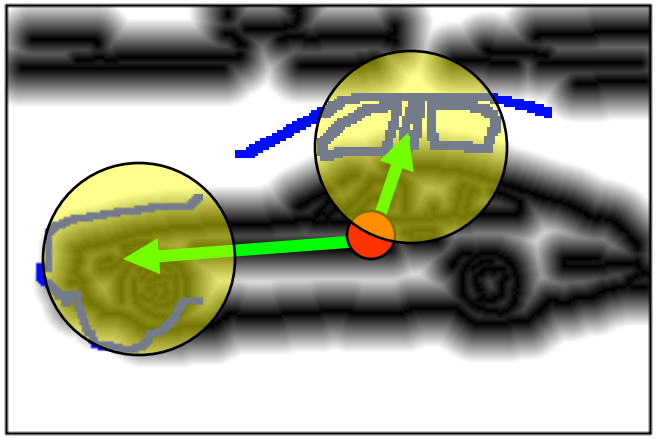
Oriented Canny Edge Detector

Transform

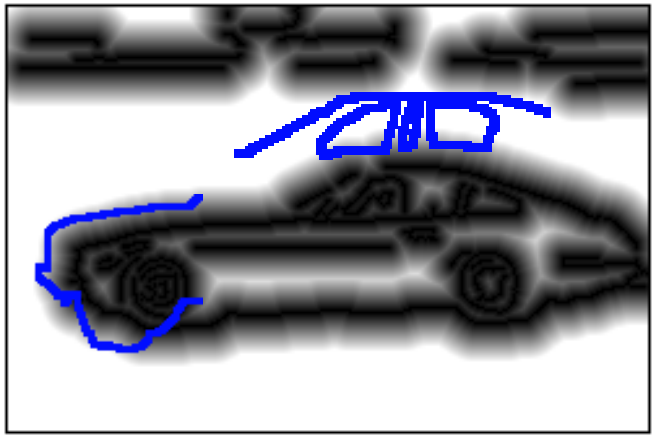


Matching shape templates

UNIVERSITY OF CAMBRIDGE



Oriented
Chamfer
Matching



Hand detection system

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Tracking - 3D mouse

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Real-time visual controller for Dasher

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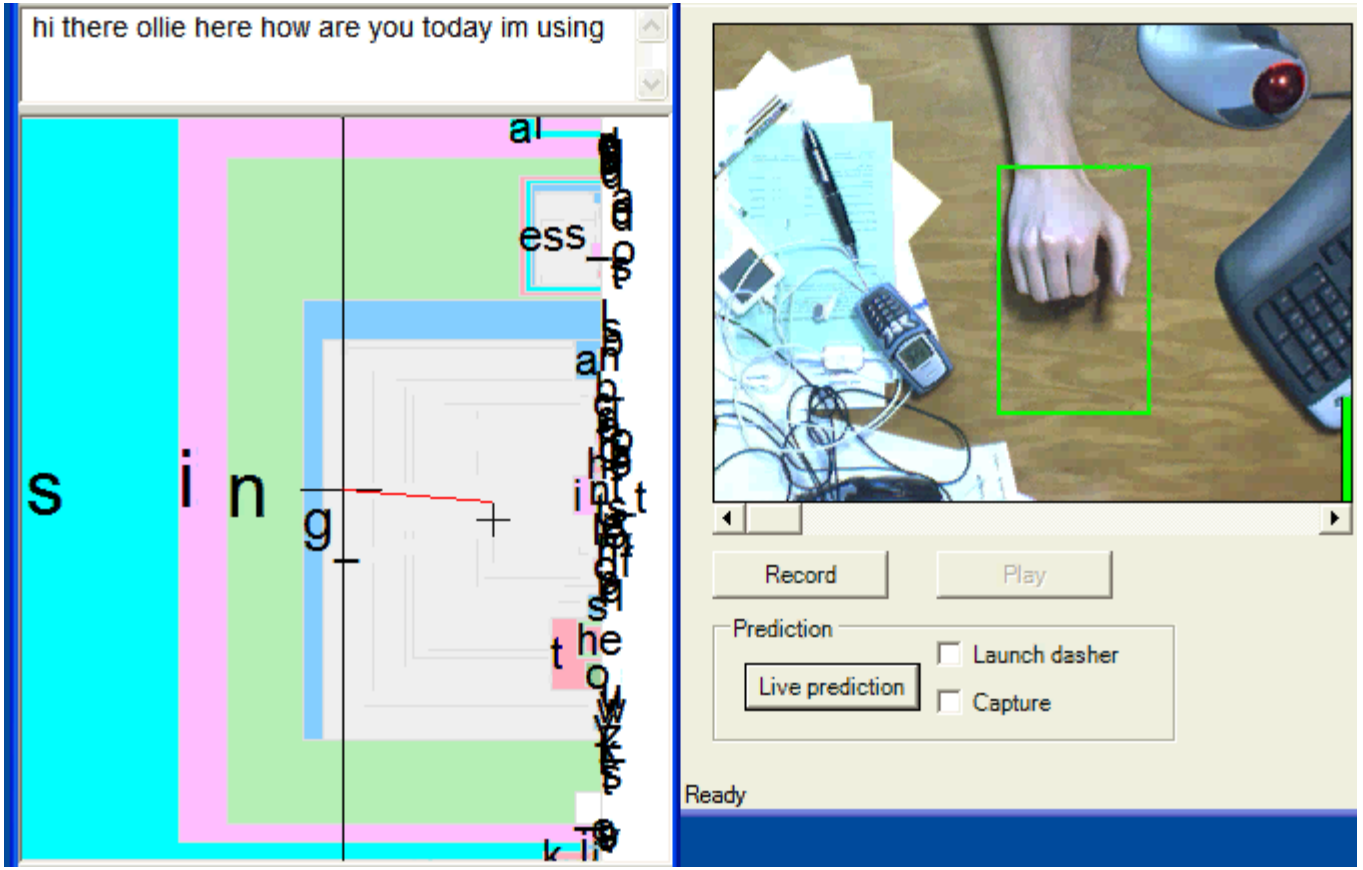

People and pose detection

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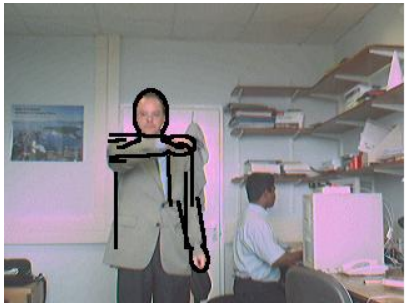
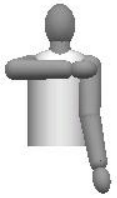
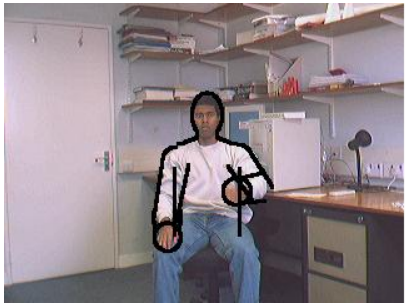

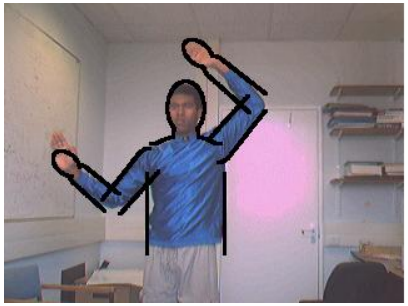


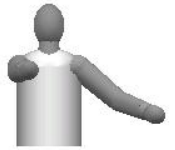
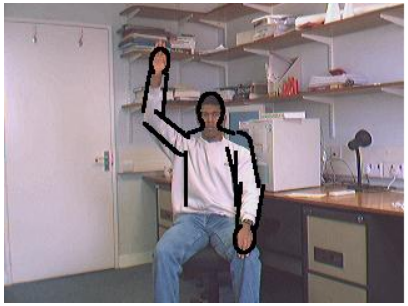

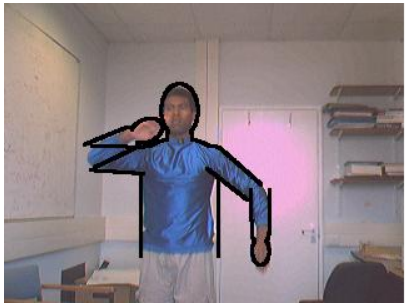


People and pose detection

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III. Object recognition and machine learning

Shotton, Blake and Cipolla 2005-2007

Kim, Kittler and Cipolla 2006

Johnson and Cipolla 2007

Overview

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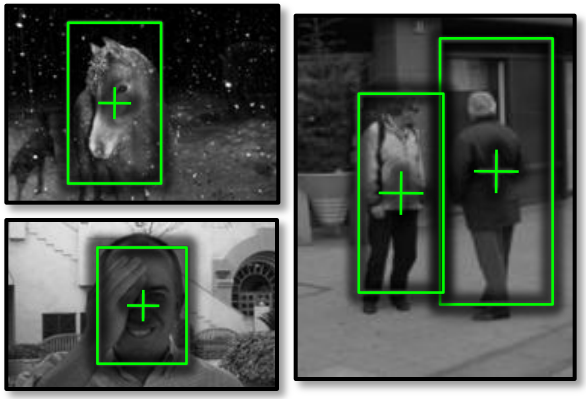
image classification

horses airplanes background

categorical object detection



semantic segmentation

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6. Using interest points and visual words

Johnson and Cipolla 2007

Image matching

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7. Using contour and shape

Shotton, Blake and Cipolla 2005-2007

Supervised learning

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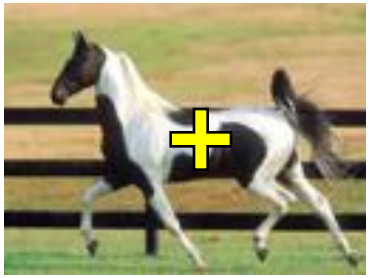
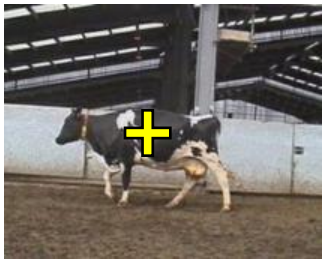
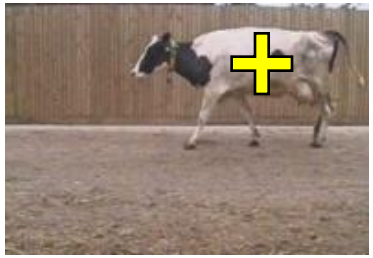
- Learn to recognise images of a particular class, localised in space and scale
- i.e. find the horse/cow/car etc!

Desired Results


Learning and Adaptability

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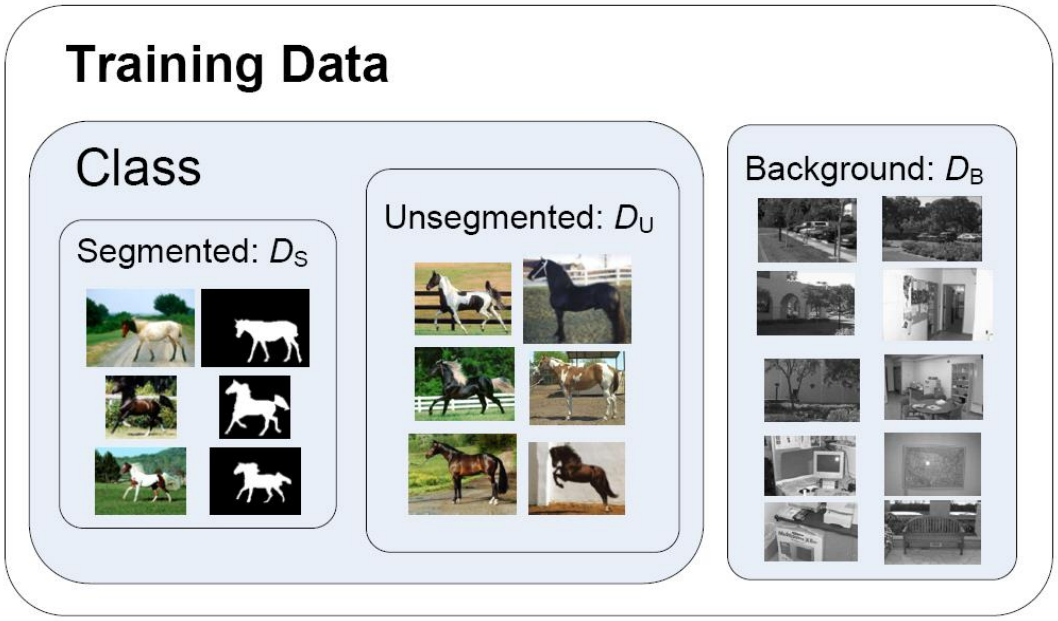

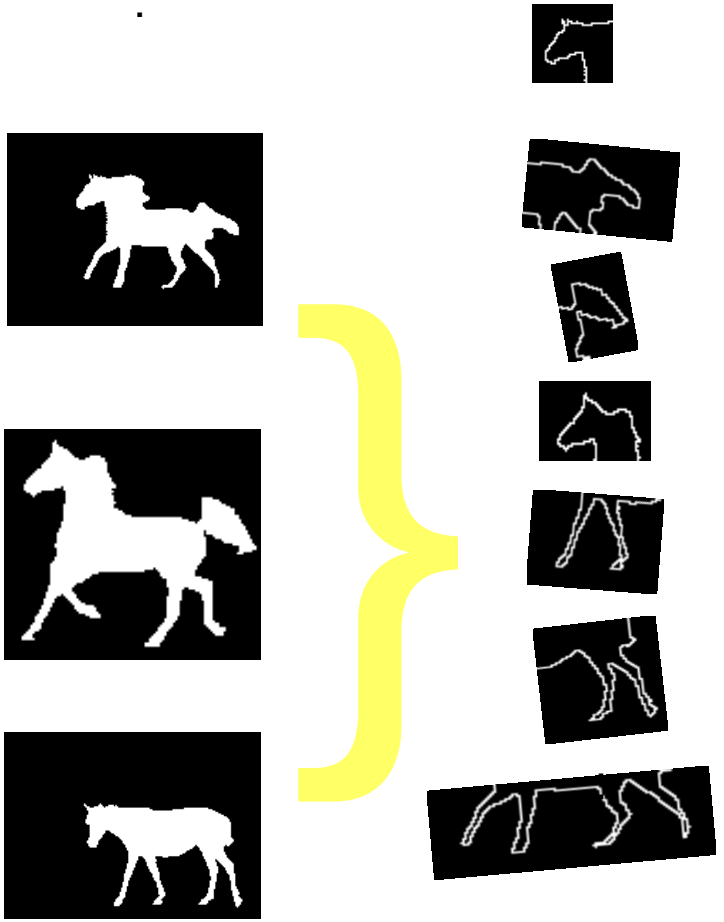

Object Model

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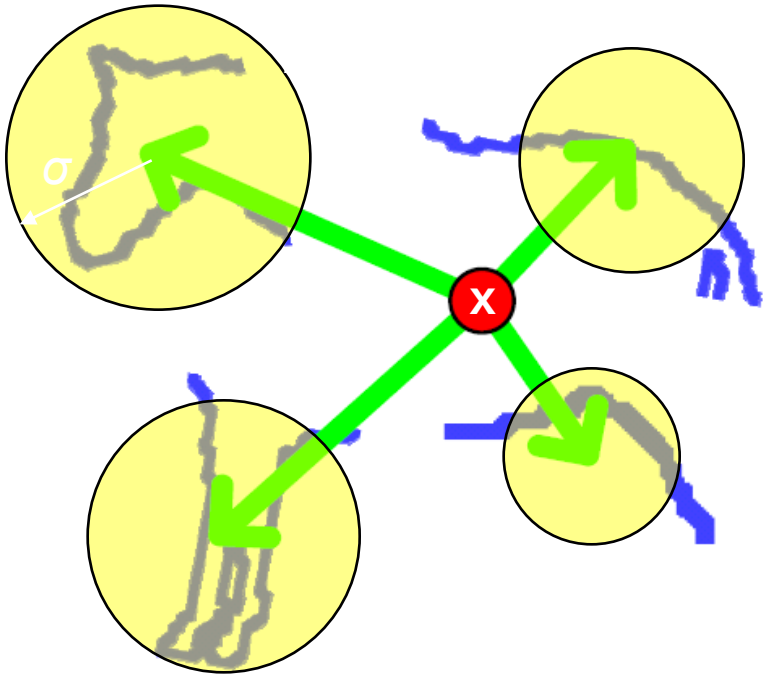

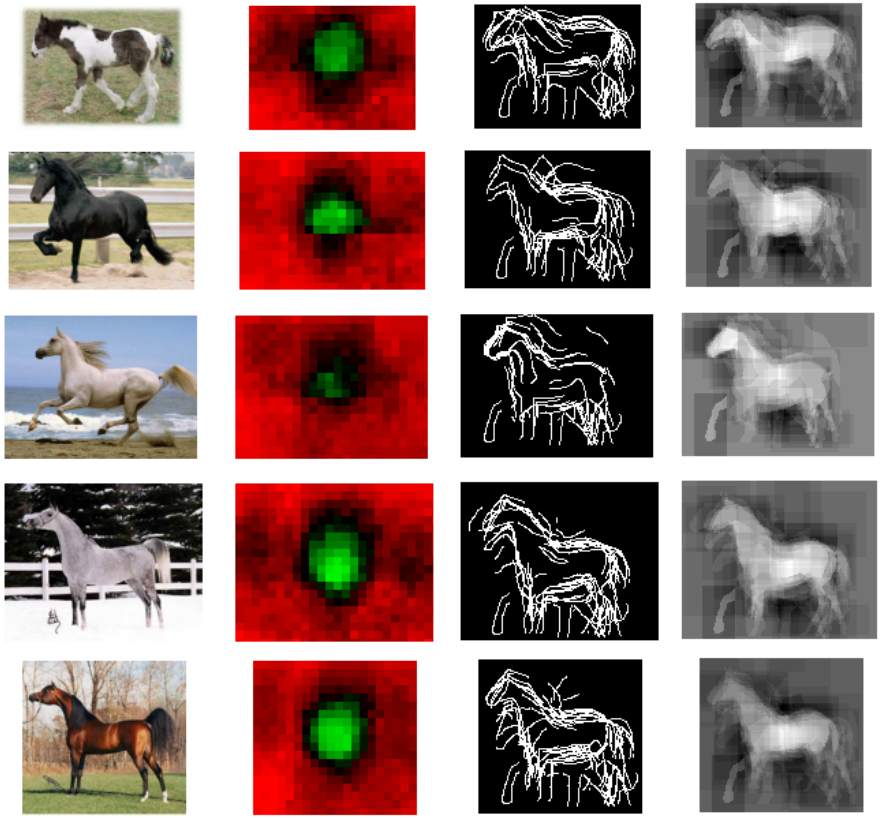

Approach

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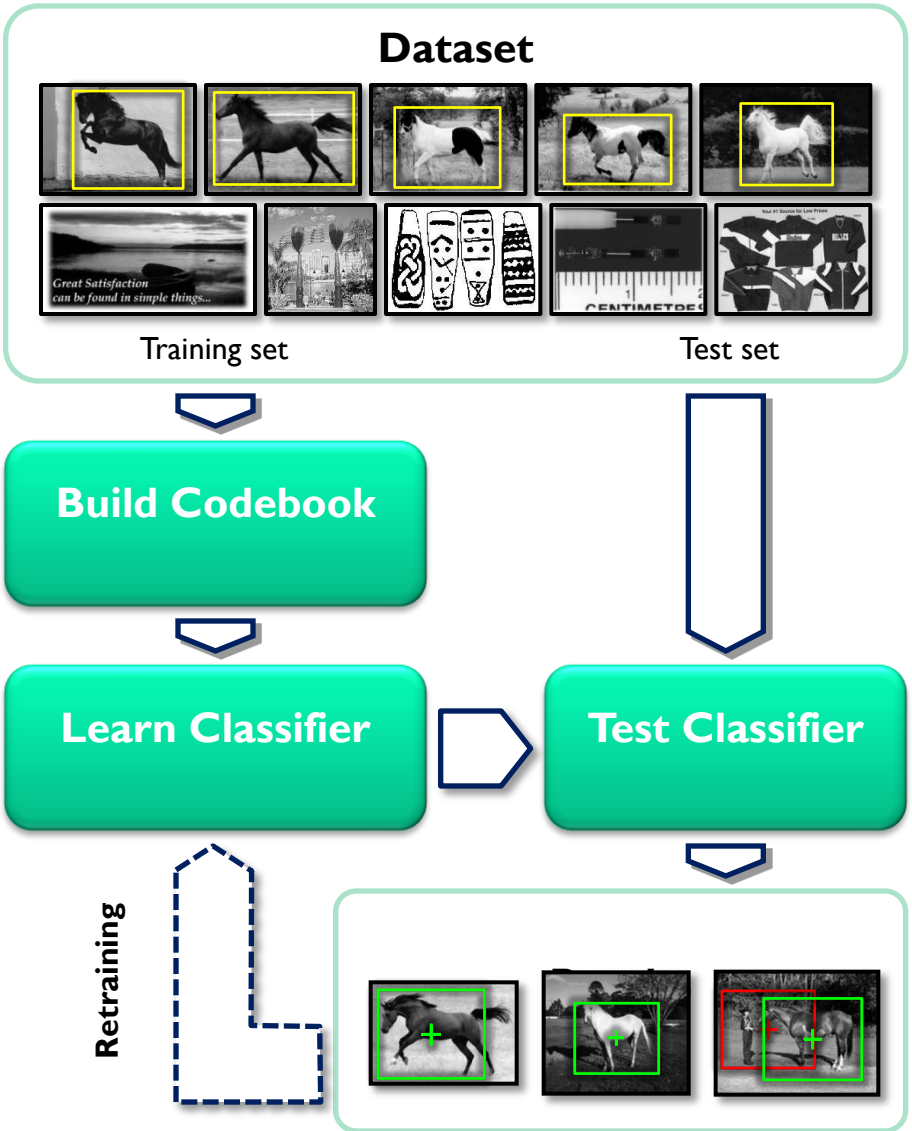

Dictionary of contour fragments

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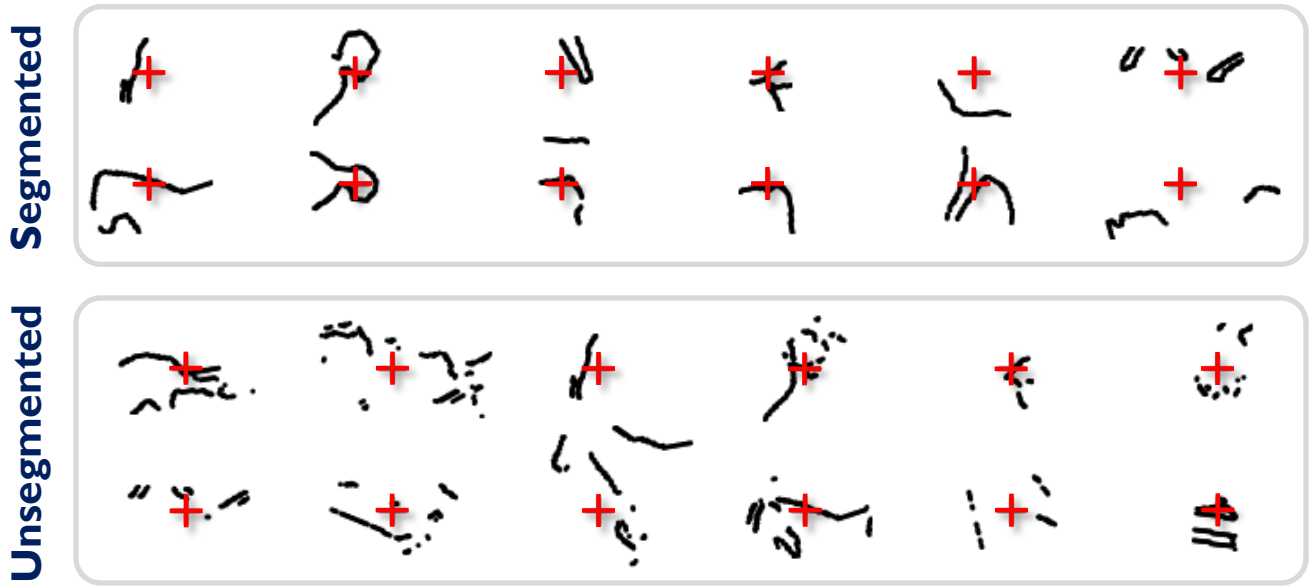

Shape

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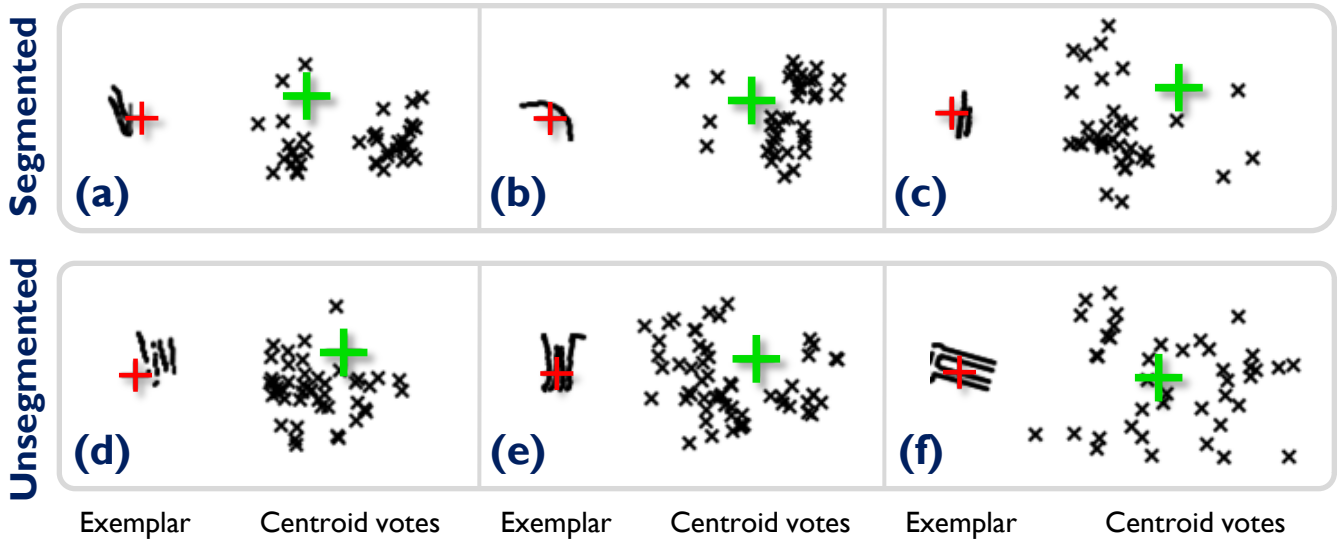
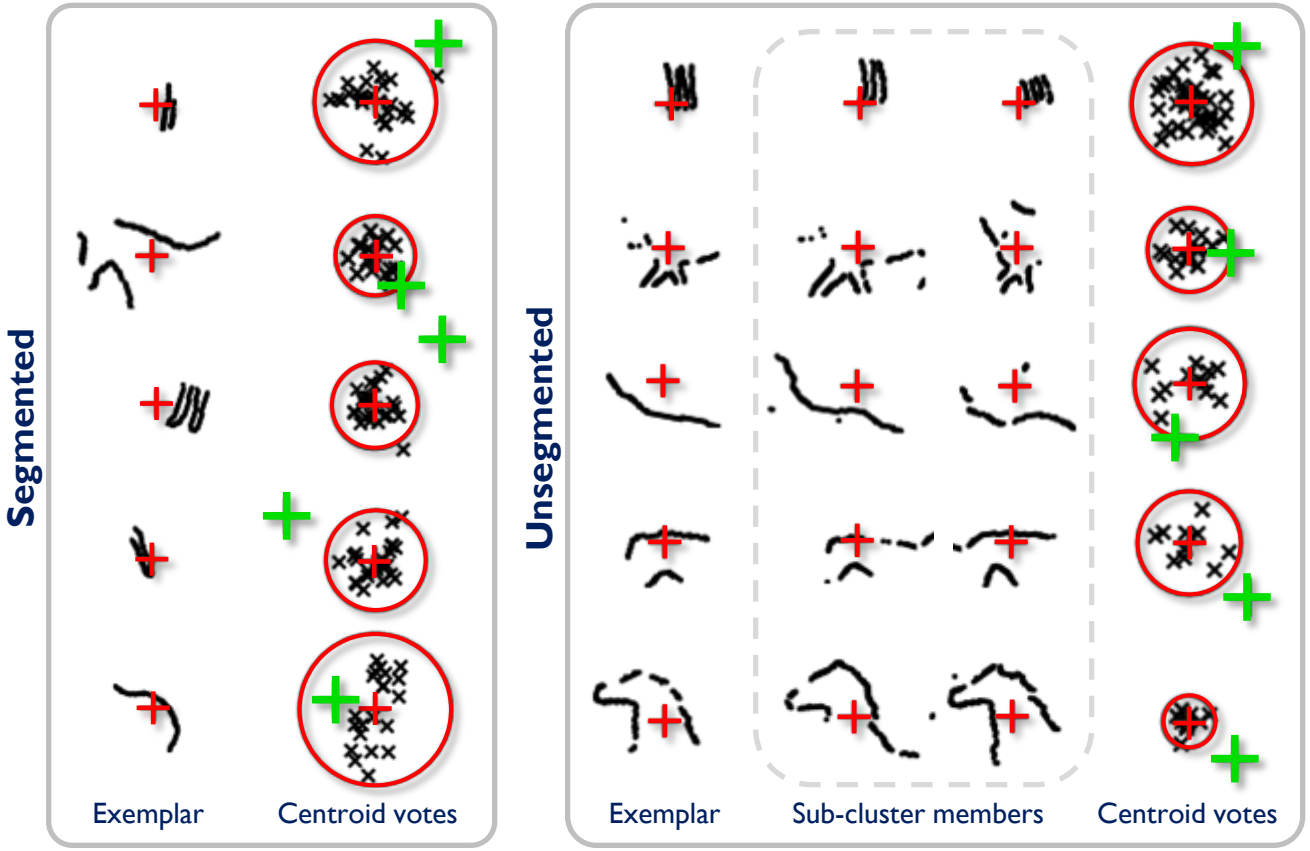


Shape

UNIVERSITY OF CAMBRIDGE



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8. Using texture and contour

Shotton, Blake and Cipolla 2005-2007

Texture-based segmentation

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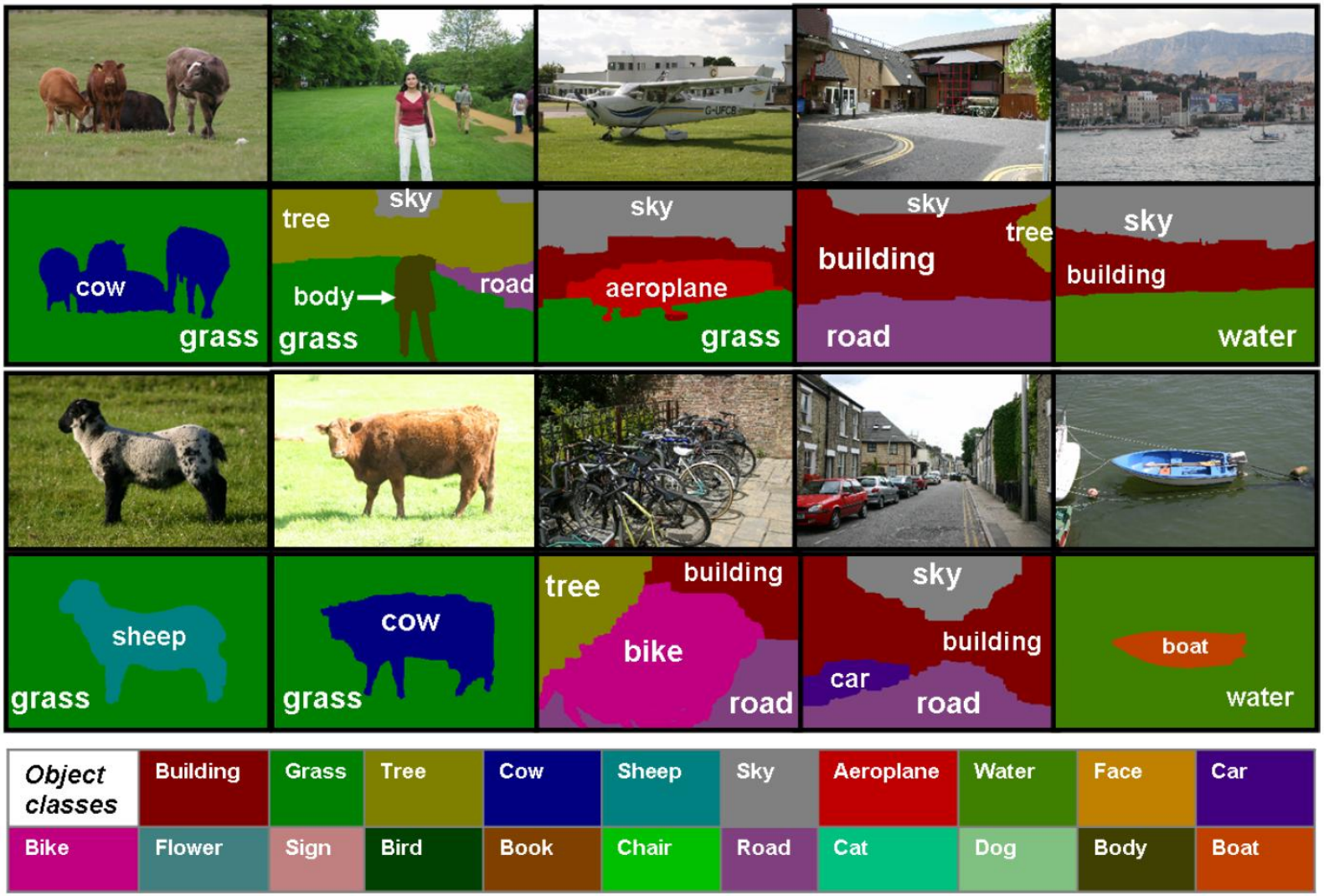

Extracting textons

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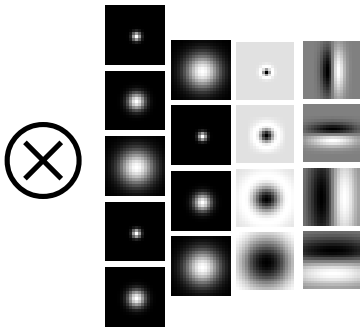
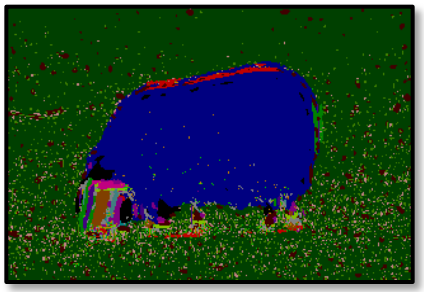
input image



filter bank

clustering and assignment



texton map
(colours ⇔ texton indices)

Extracted texton dictionary

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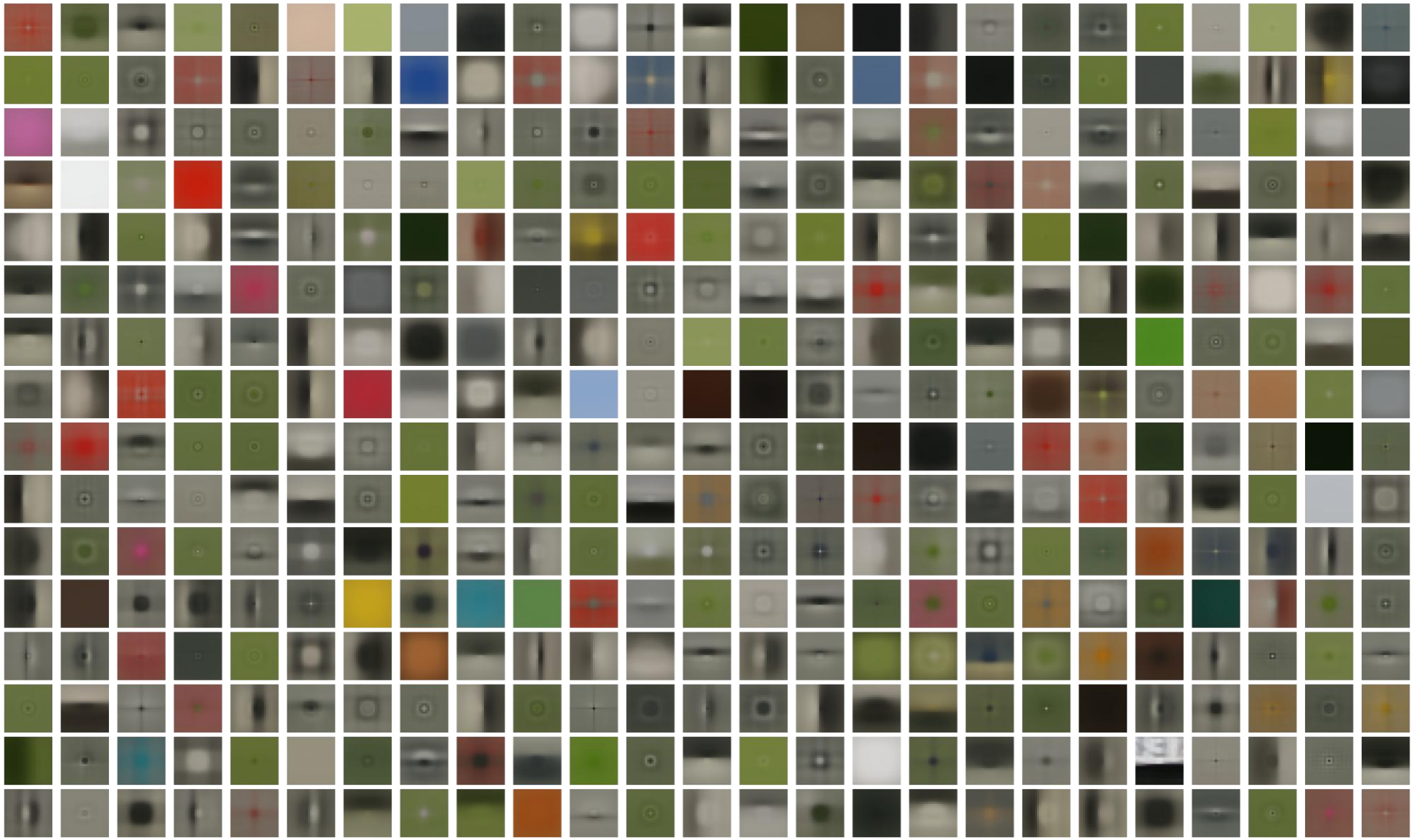

Use with contour shape model

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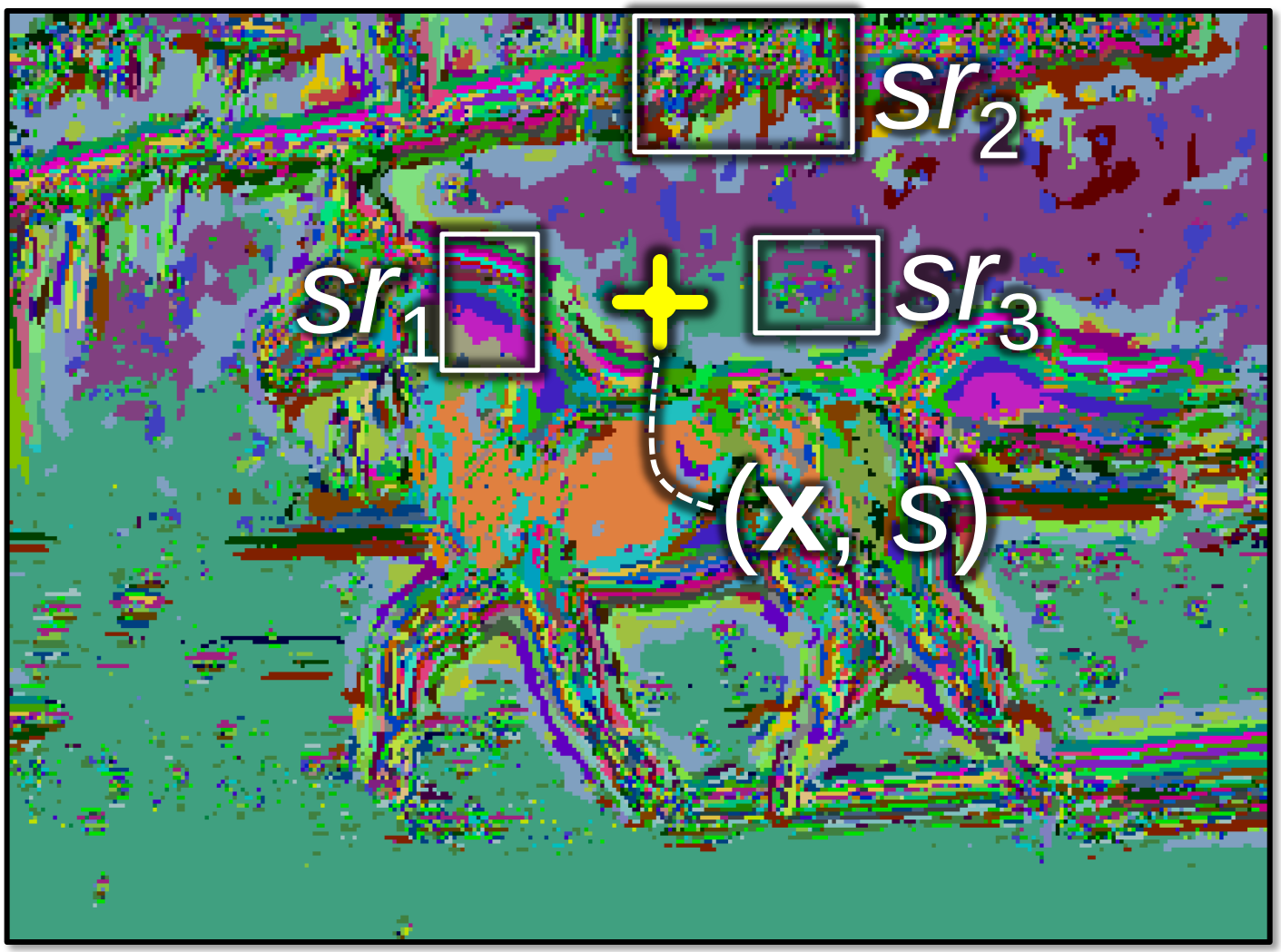

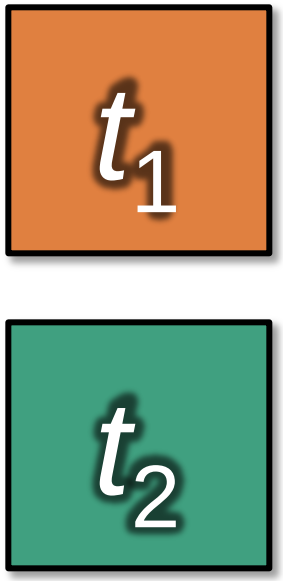

textons

Learned contour and texture

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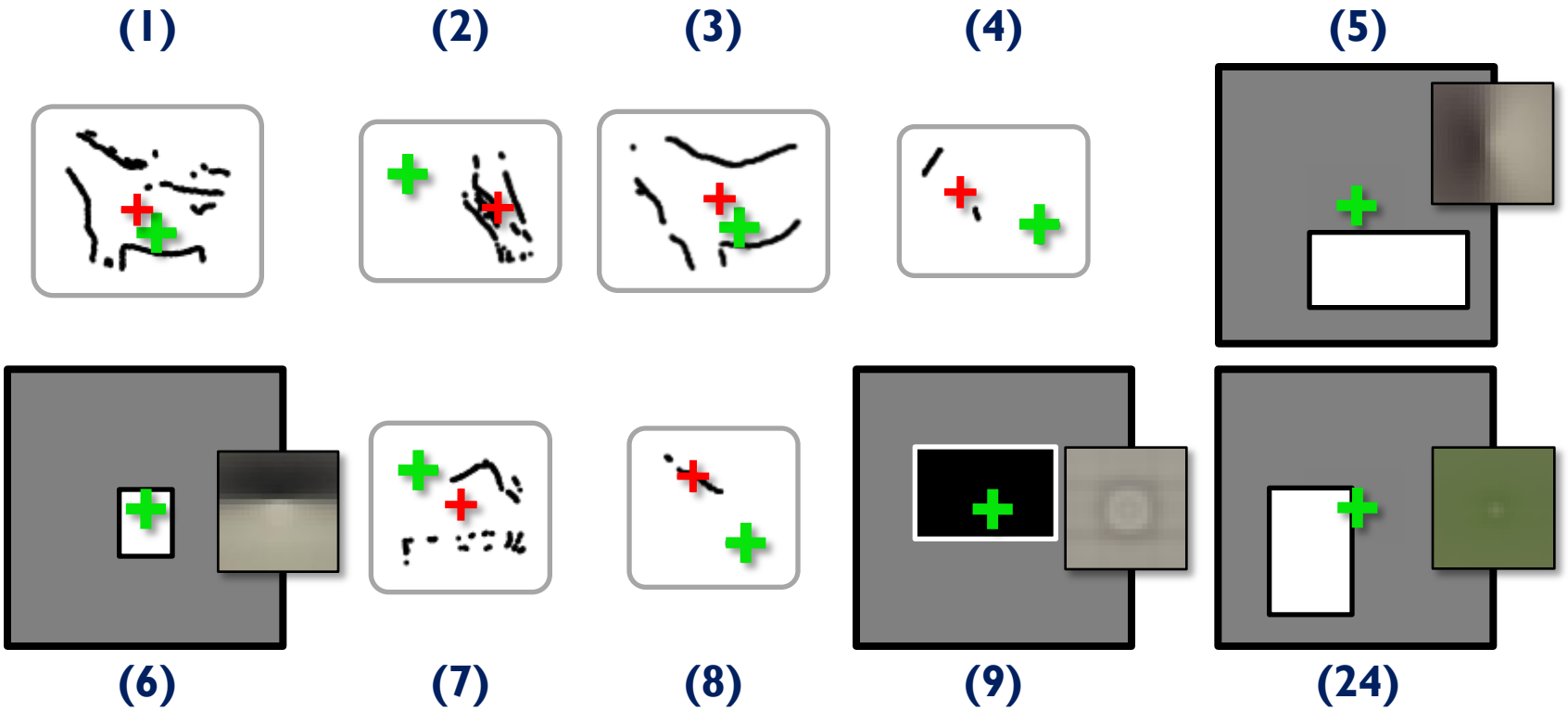

Performance

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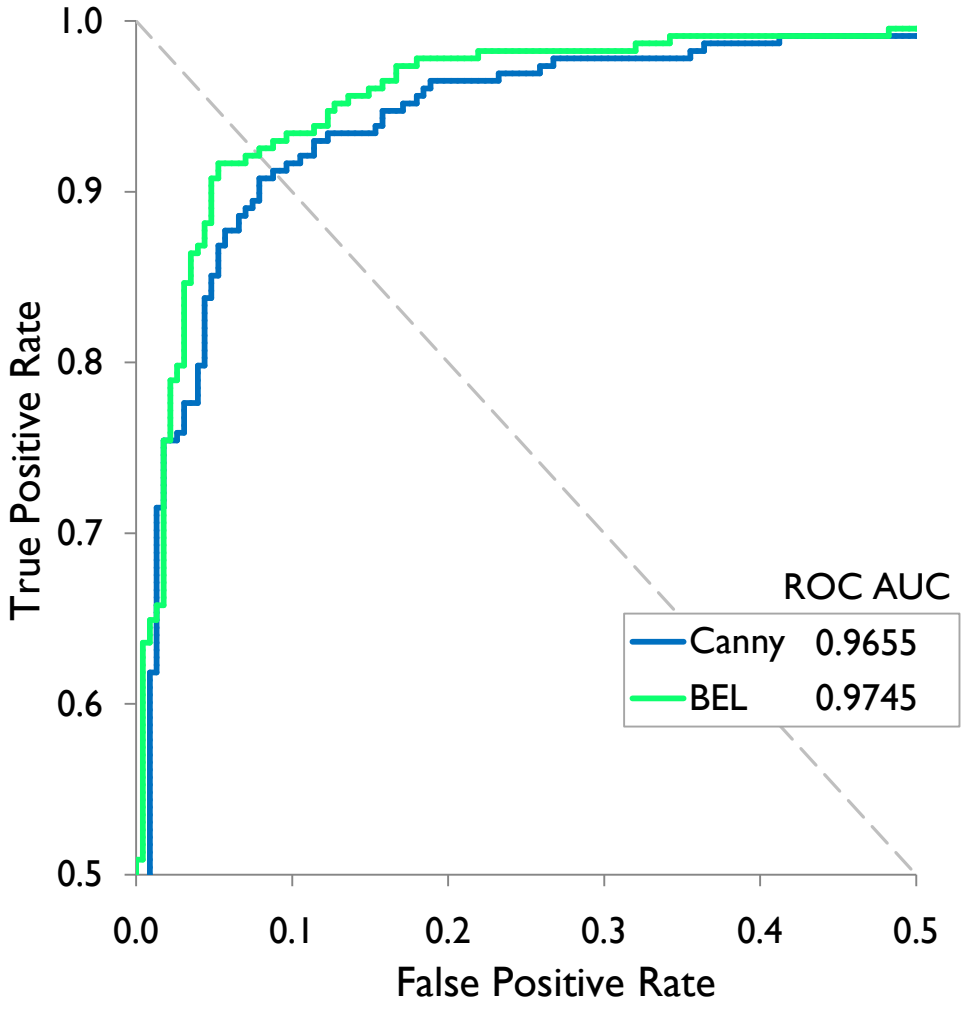
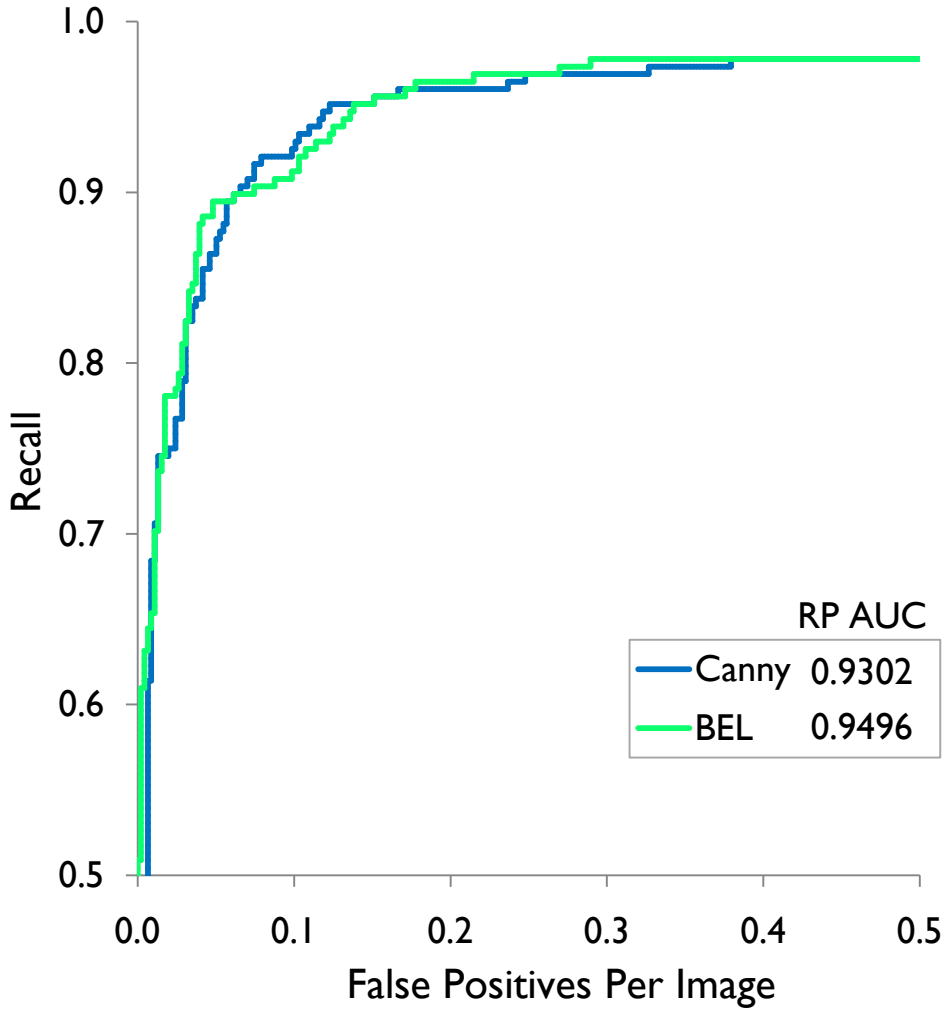


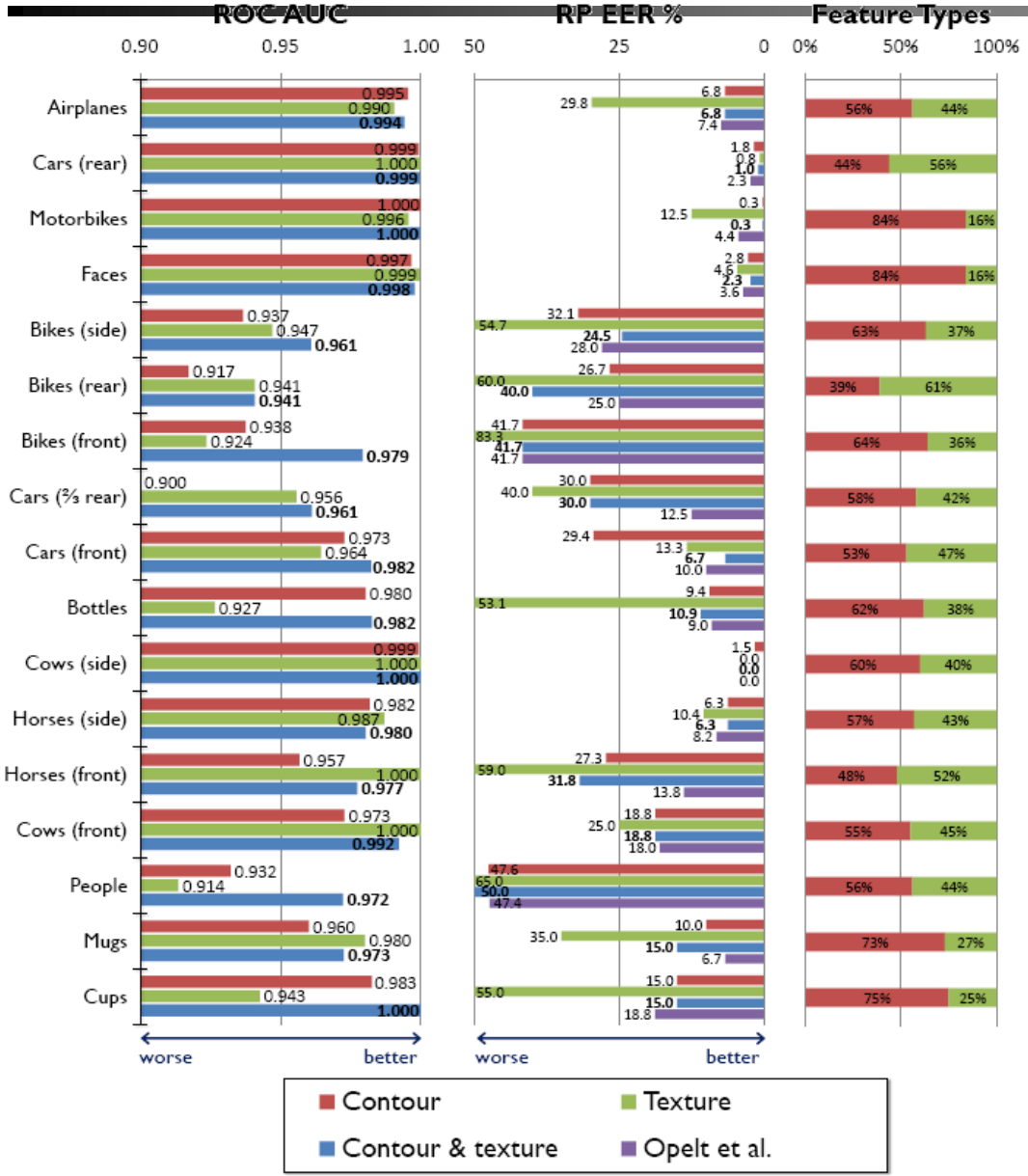
Performance

UNIVERSITY OF CAMBRIDGE



Performance

UNIVERSITY OF CAMBRIDGE



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9. Detection and tracking of people

Brostow and Cipolla 2006

Bucciarelli and Cipolla 2007

Pedestrian detection

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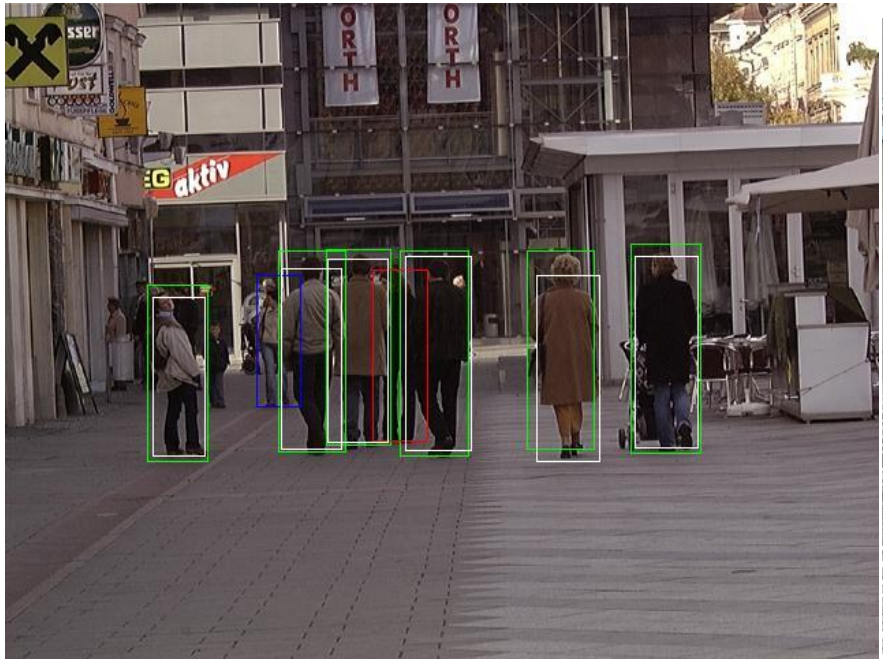

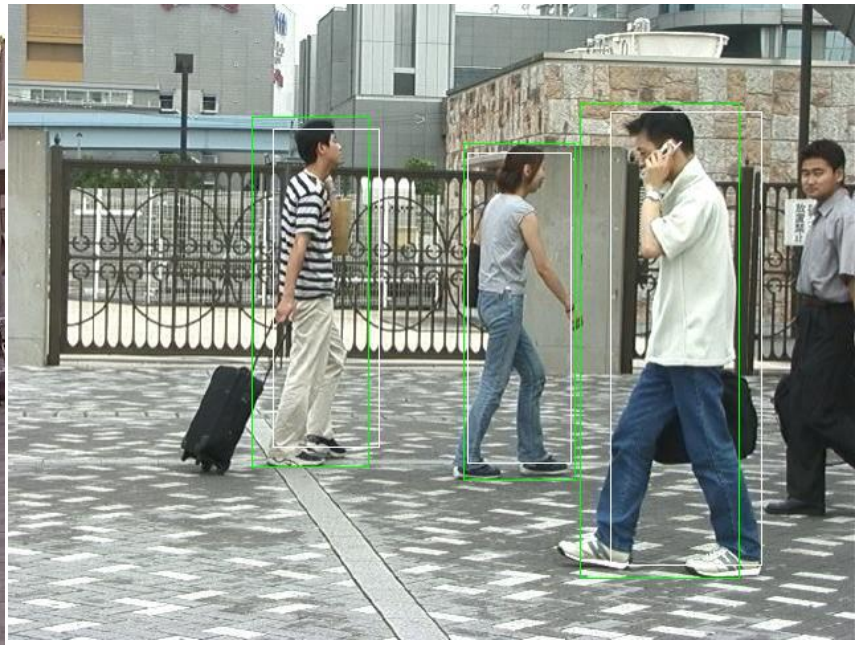

Tracking people in crowds

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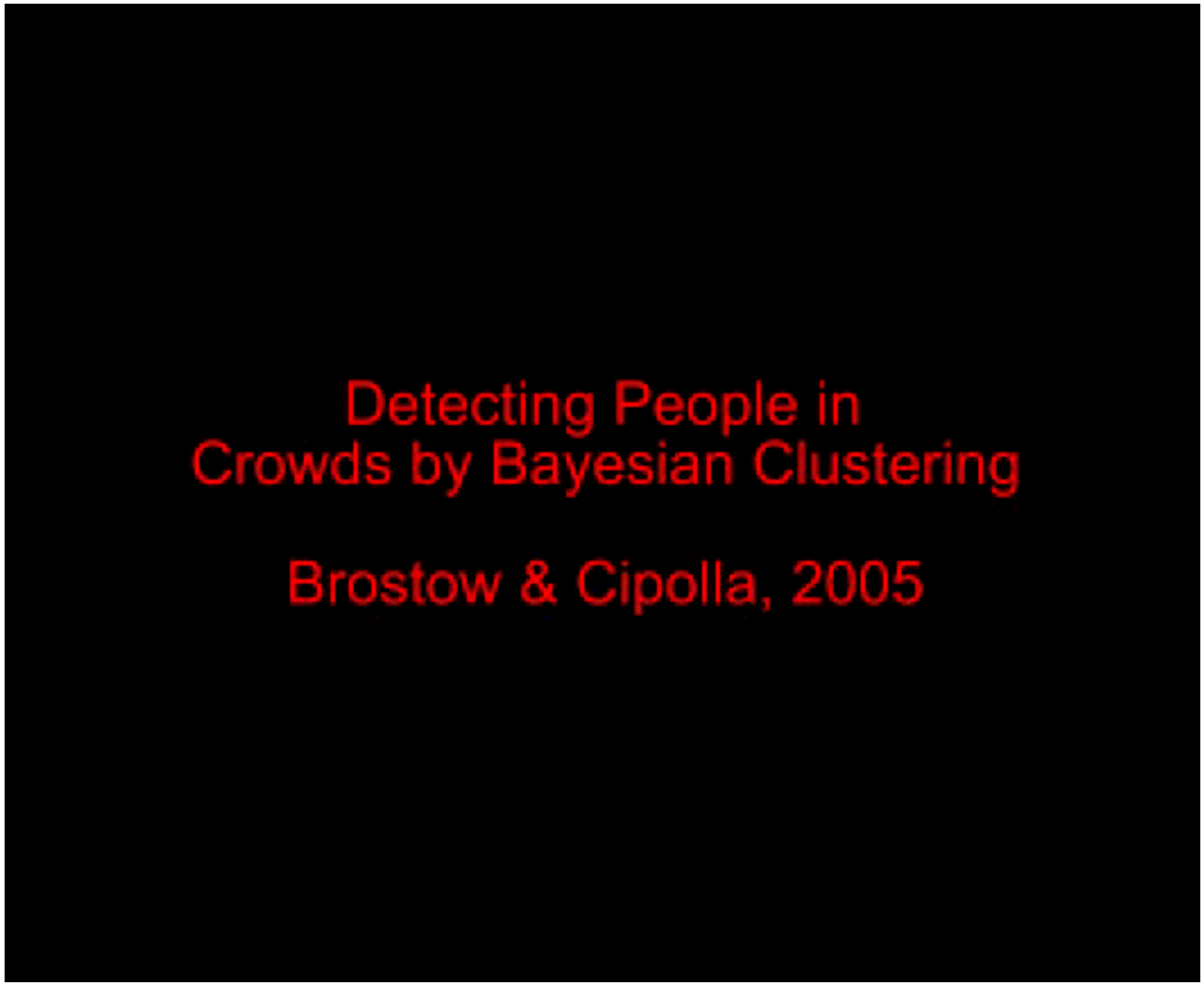

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10. Recognition in video using CCA

Arandjelovic and Cipolla 2006

Kim, Wong and Cipolla 2006-2007

Face recognition

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Overcome appearance variations due to:

Lighting condition

Scale, pose, motion pattern

Automatic cast listing

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Problem difficulties

Automatic cast listing

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"Simple clustering" results

Action recognition

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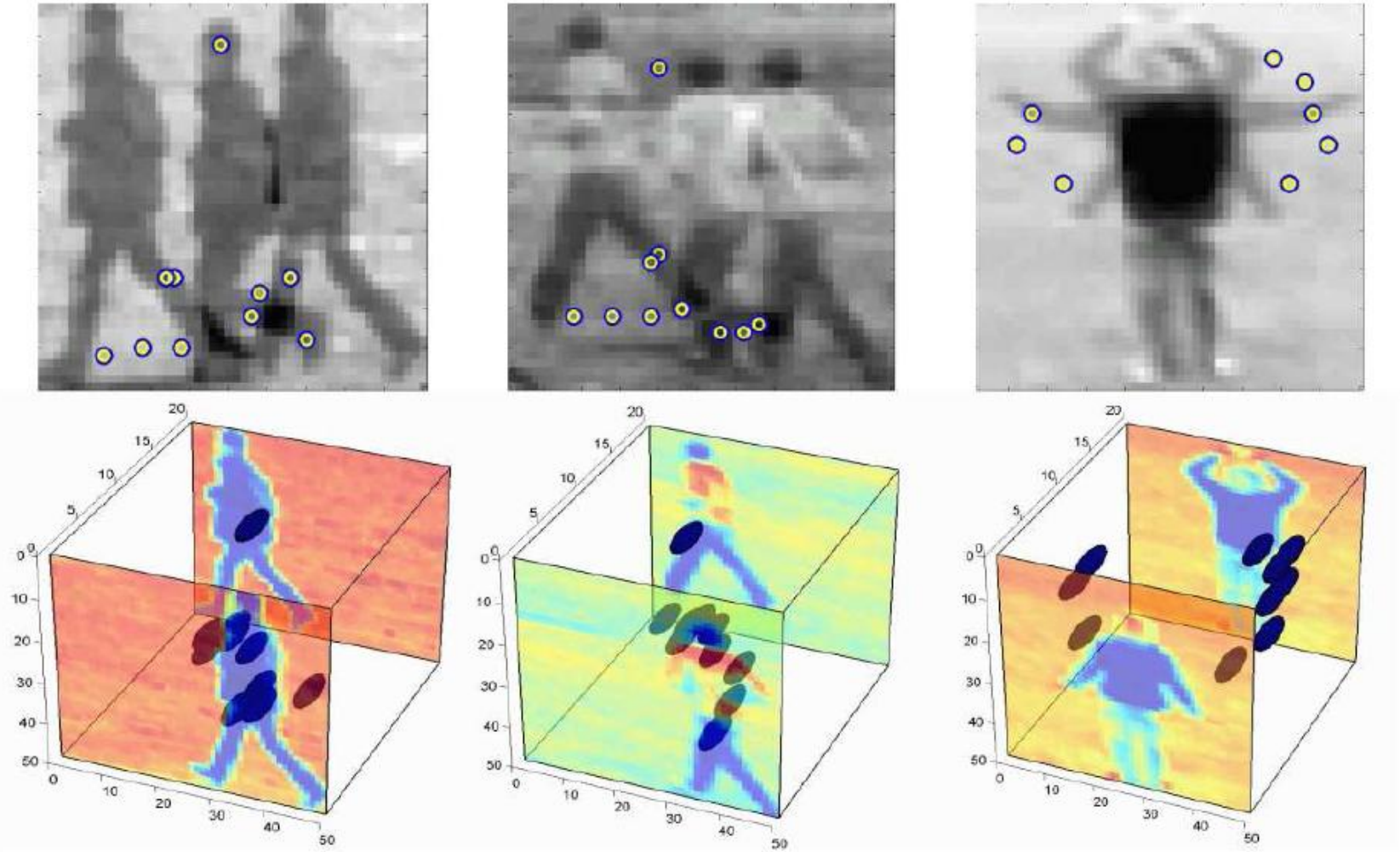

Action recognition

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Boxing

Hand clapping

Hand waving

Jogging

Running

Walking

Summary

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- Image registration and matching
- 3D shape from uncalibrated images.
- Object detection and tracking