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Making Machines See

Roberto Cipolla
Department of Engineering

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

Cognitive Systems Engineering

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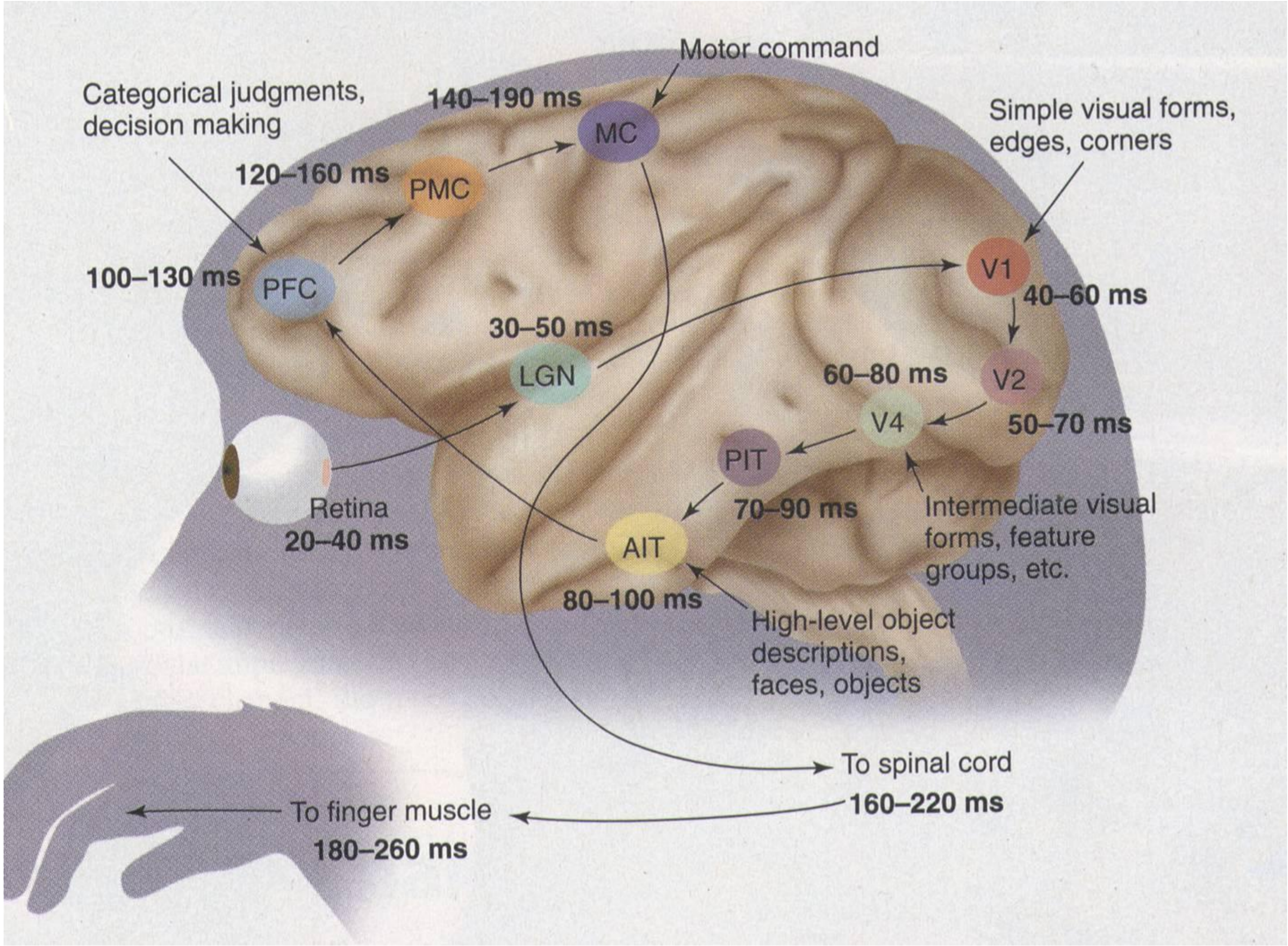

Making machines see

- Vision: What, Why and How?
- 3Rs of computer vision:
  - Reconstruction
  - Registration
  - Recognition

Registration?

Target detection and pose estimation

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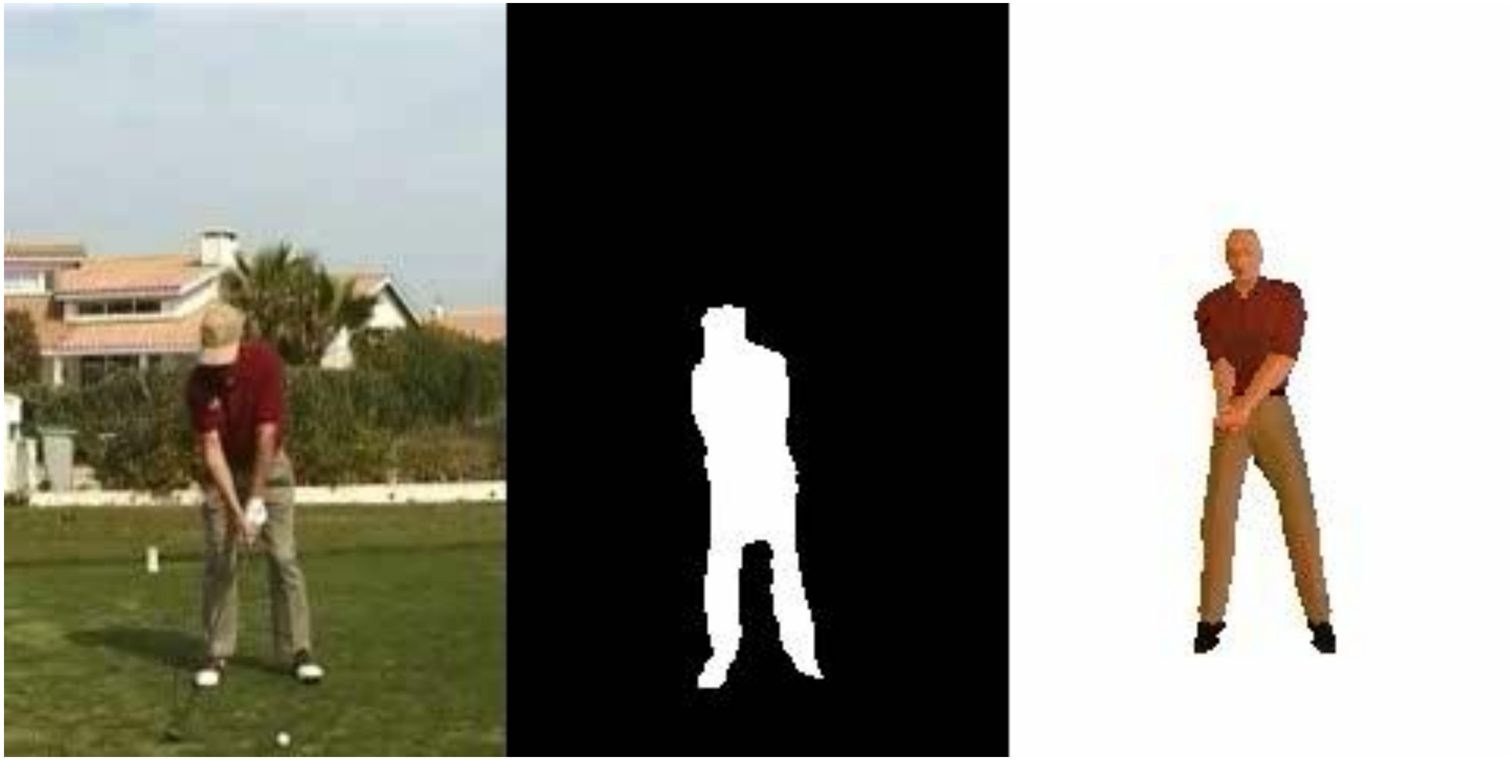
Registration

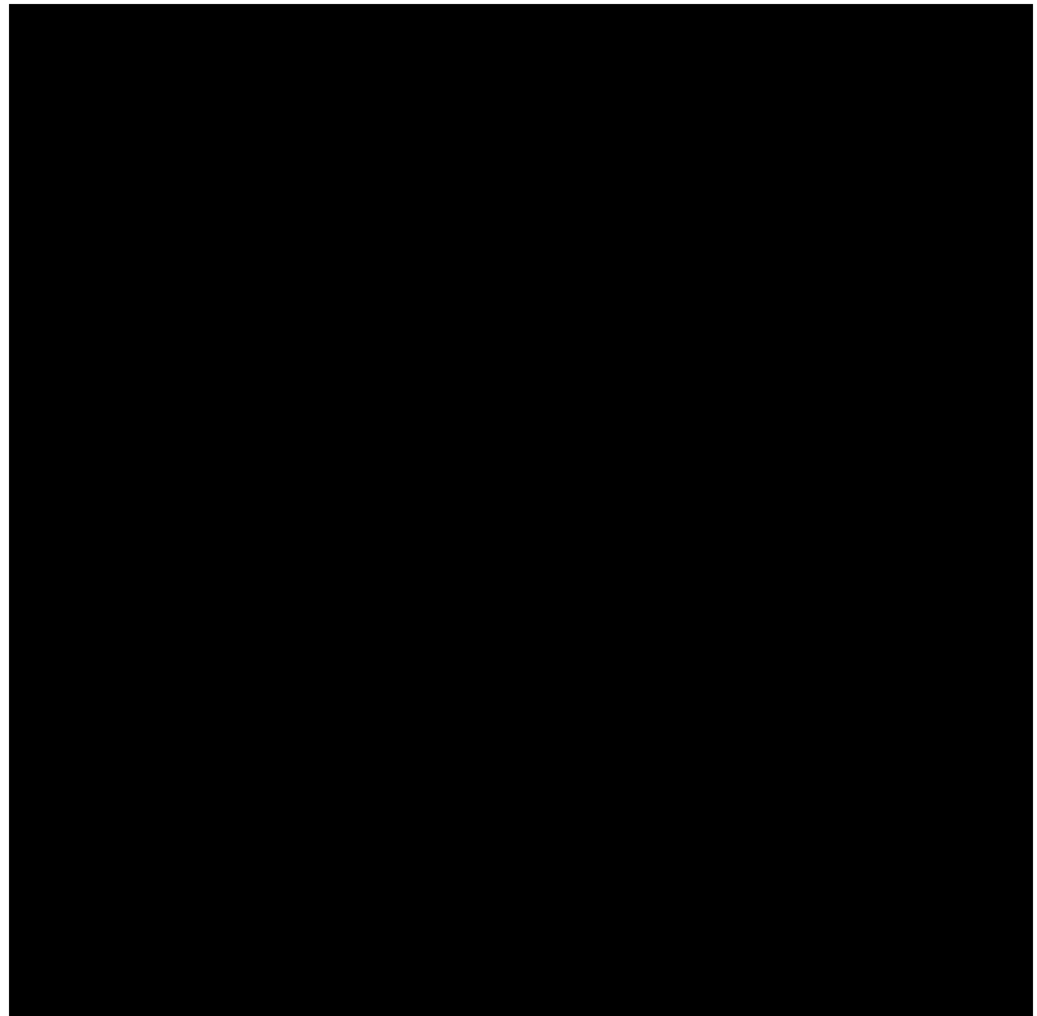


Registration

Reconstruction?

Recovery of 3D shape from images

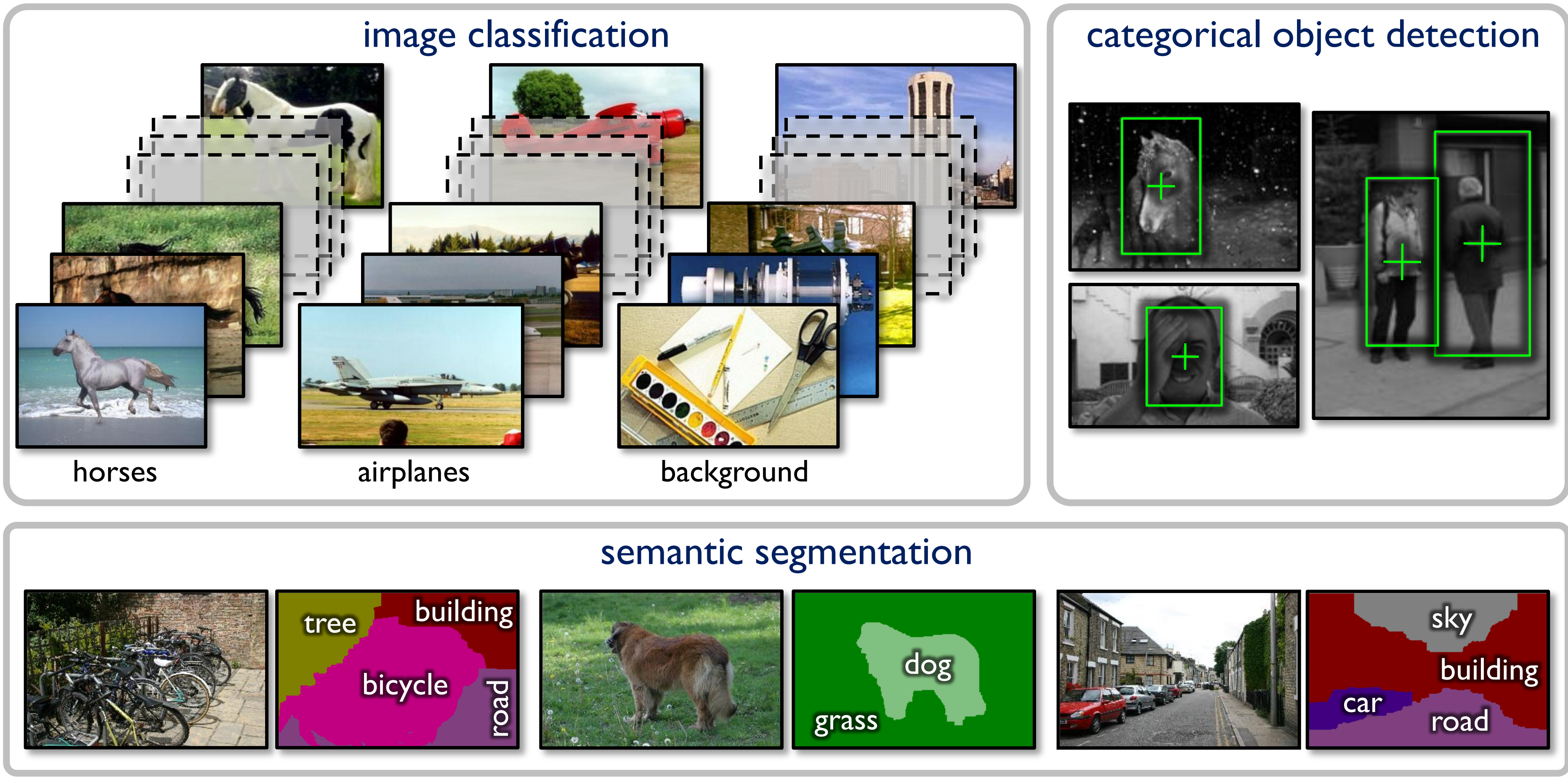
Reconstruction



3D models

Recognition?

Recognition



Pedestrian detection

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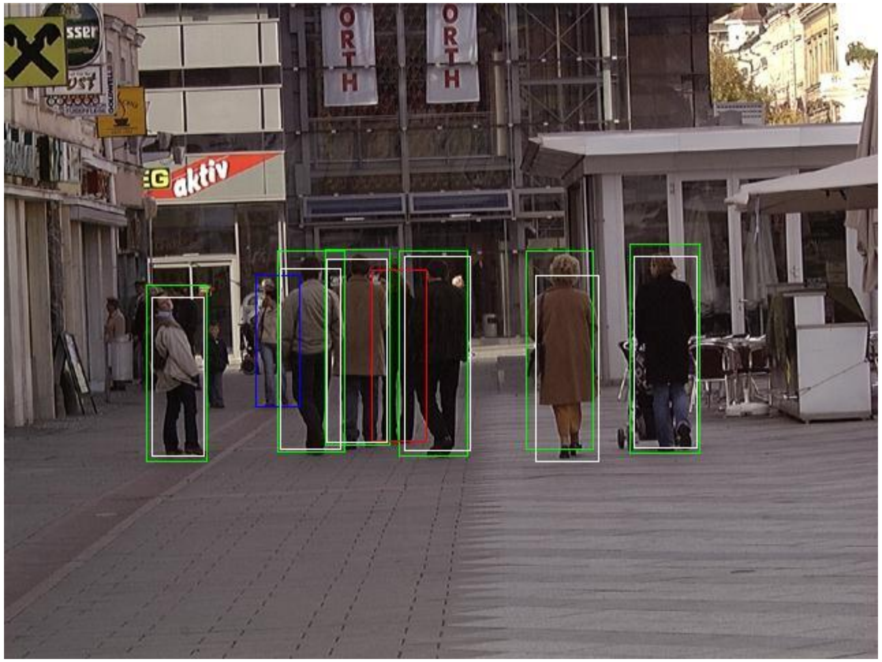

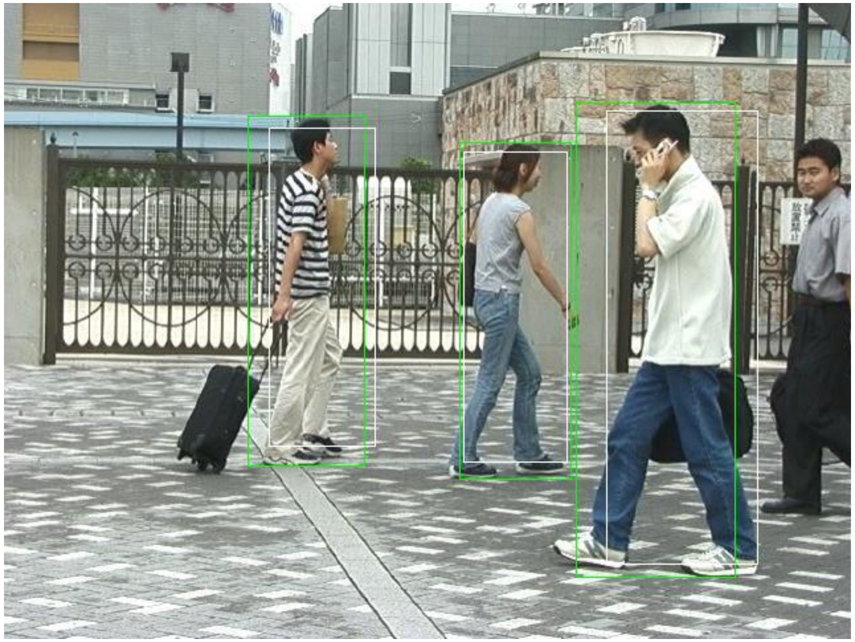

Existing applications

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Traditional research in Computer vision developed for:

- Visual inspection
- Medical imaging
- Remote sensing
- Surveillance and biometrics
- Target detection and tracking

New applications

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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How to make machines that see?

Why not study biology?

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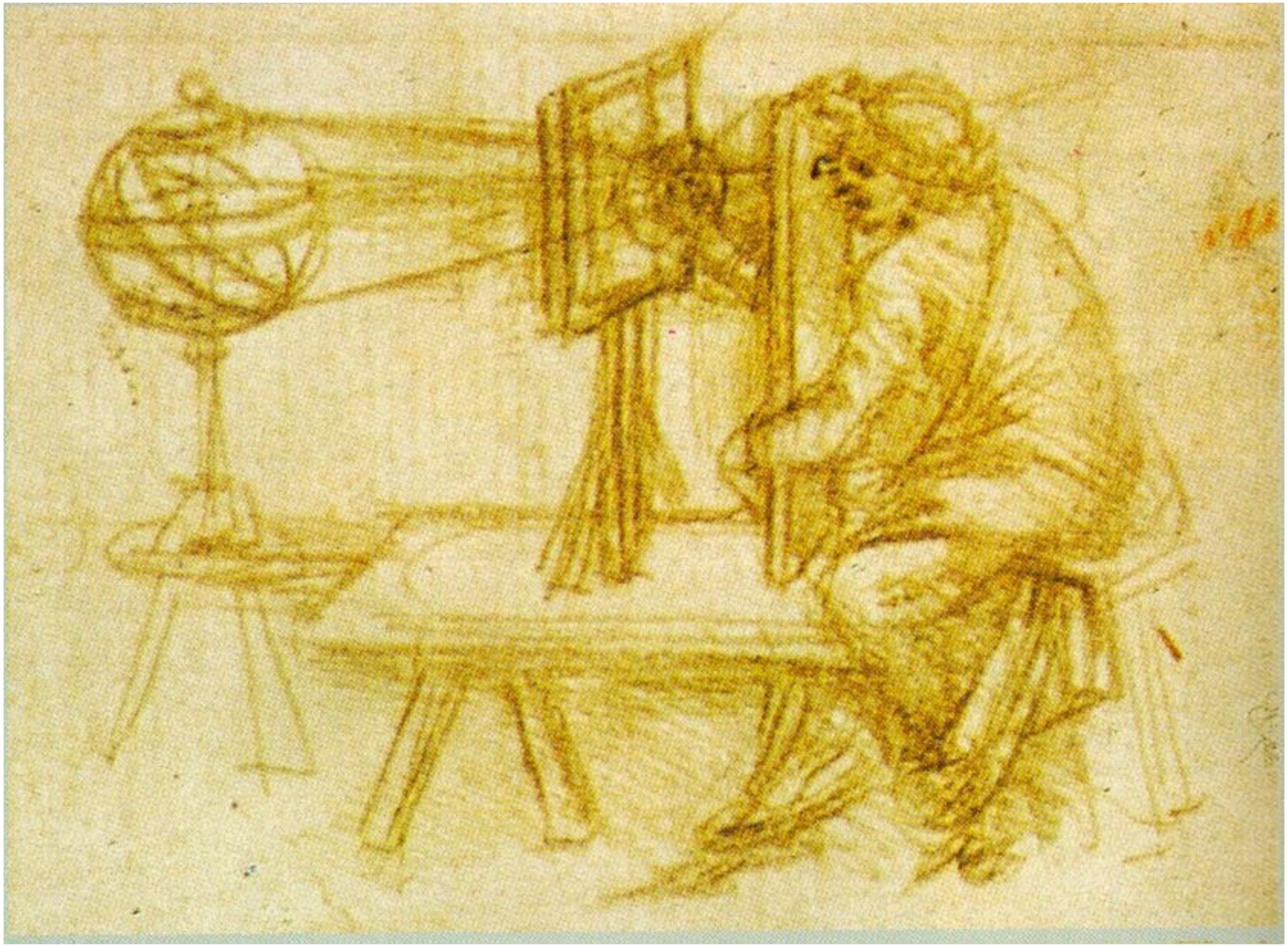
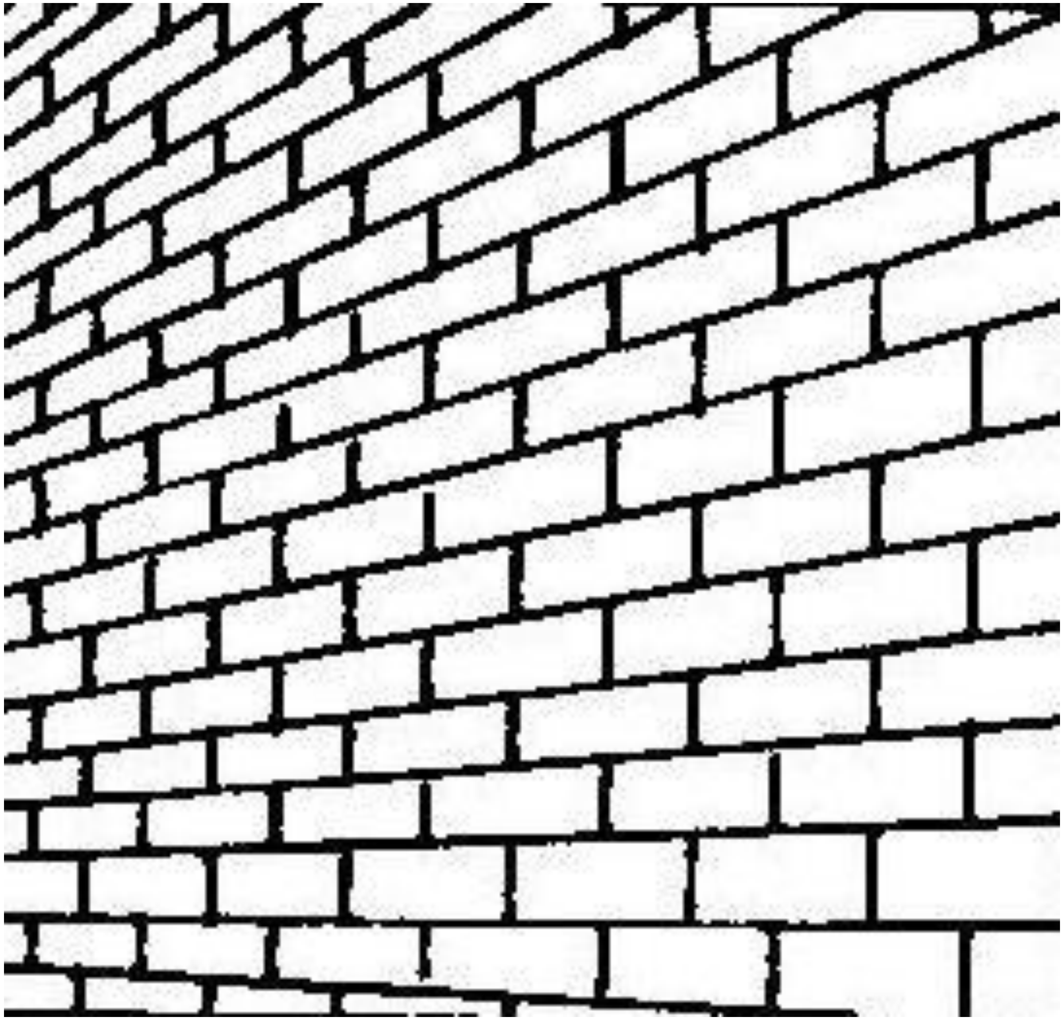
Perspective



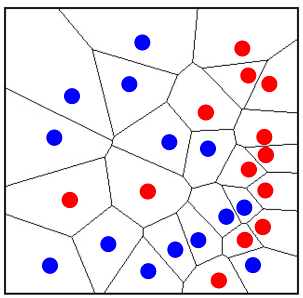
Transformations

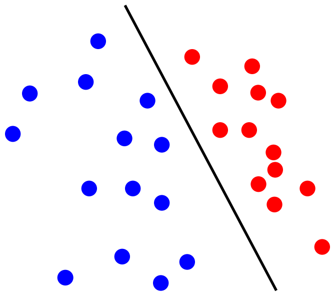


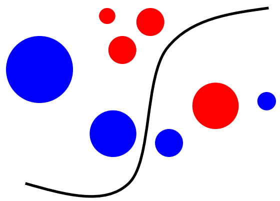
Shape

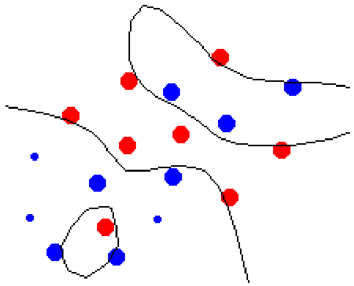
Machine Learning

Machine Learning









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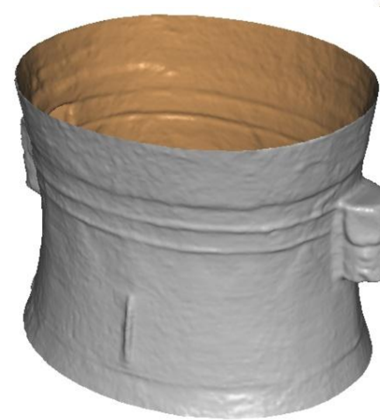
I. Reconstruction:

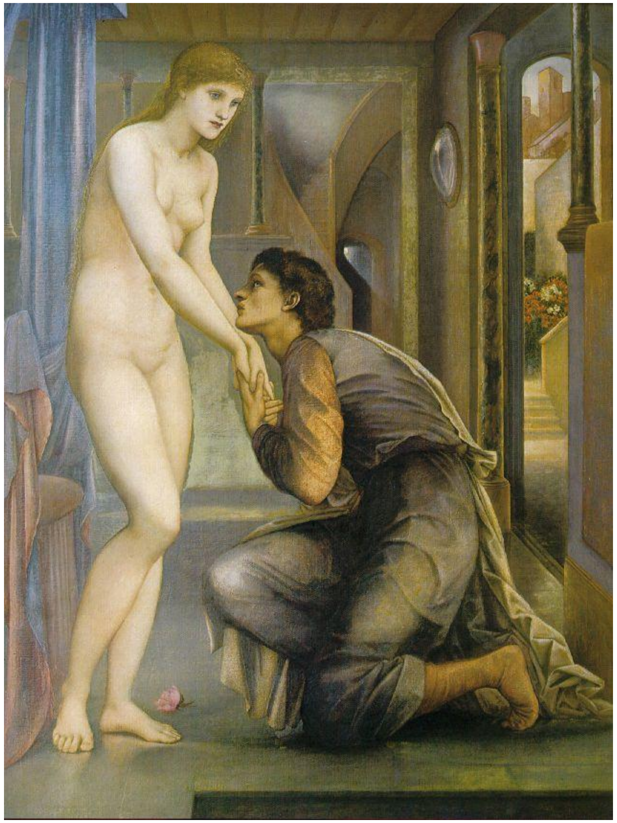
Recovery of accurate 3D shape from uncalibrated images

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

Digital Pygmalion Project

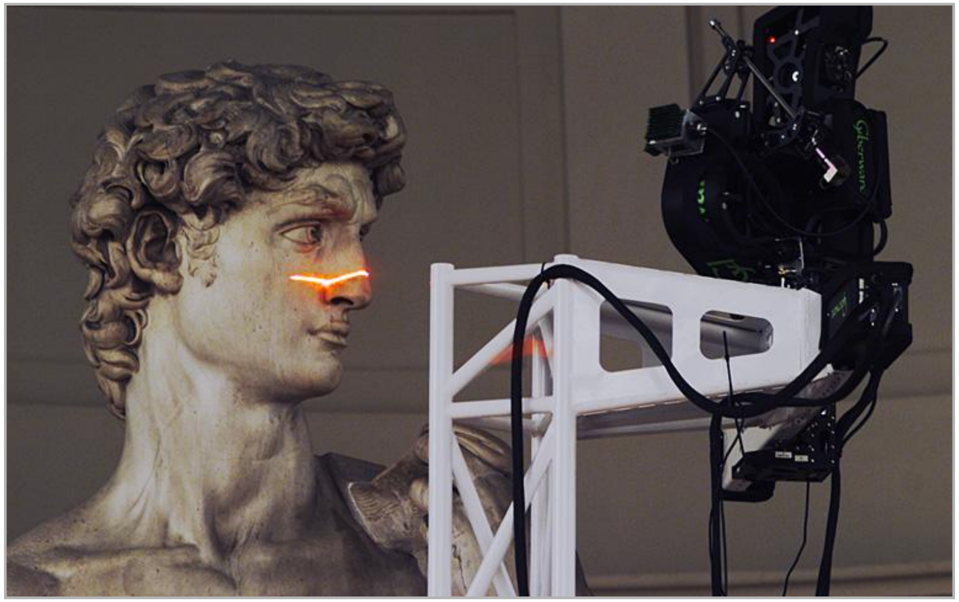


Digital Pygmalion – the myth



Scanning technologies

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



3D models

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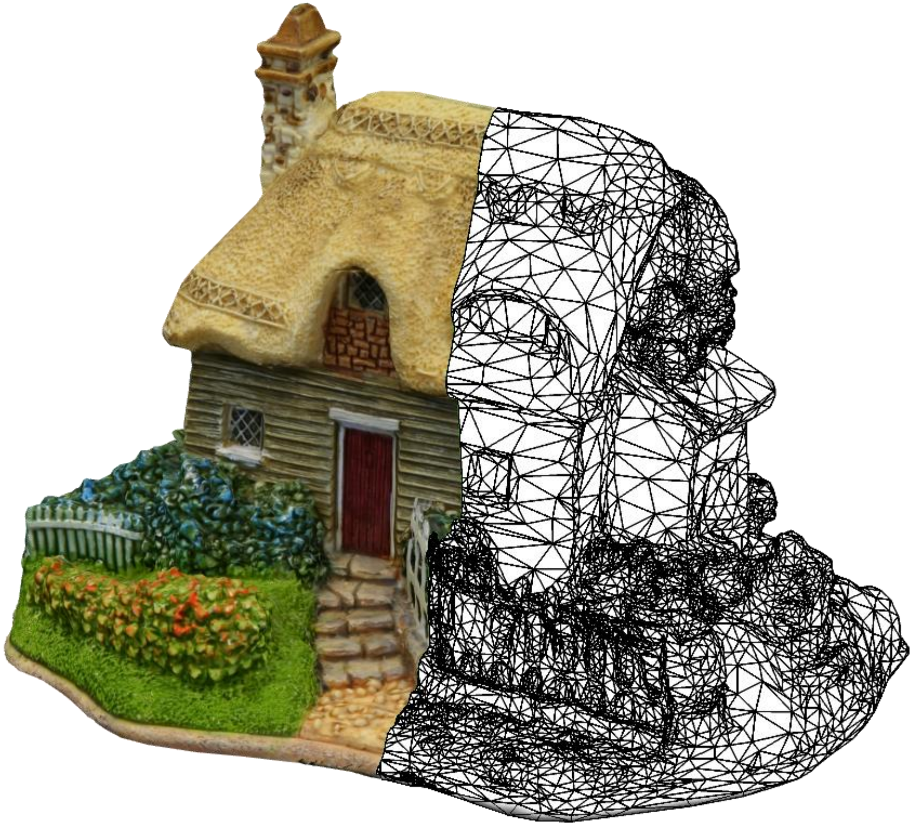
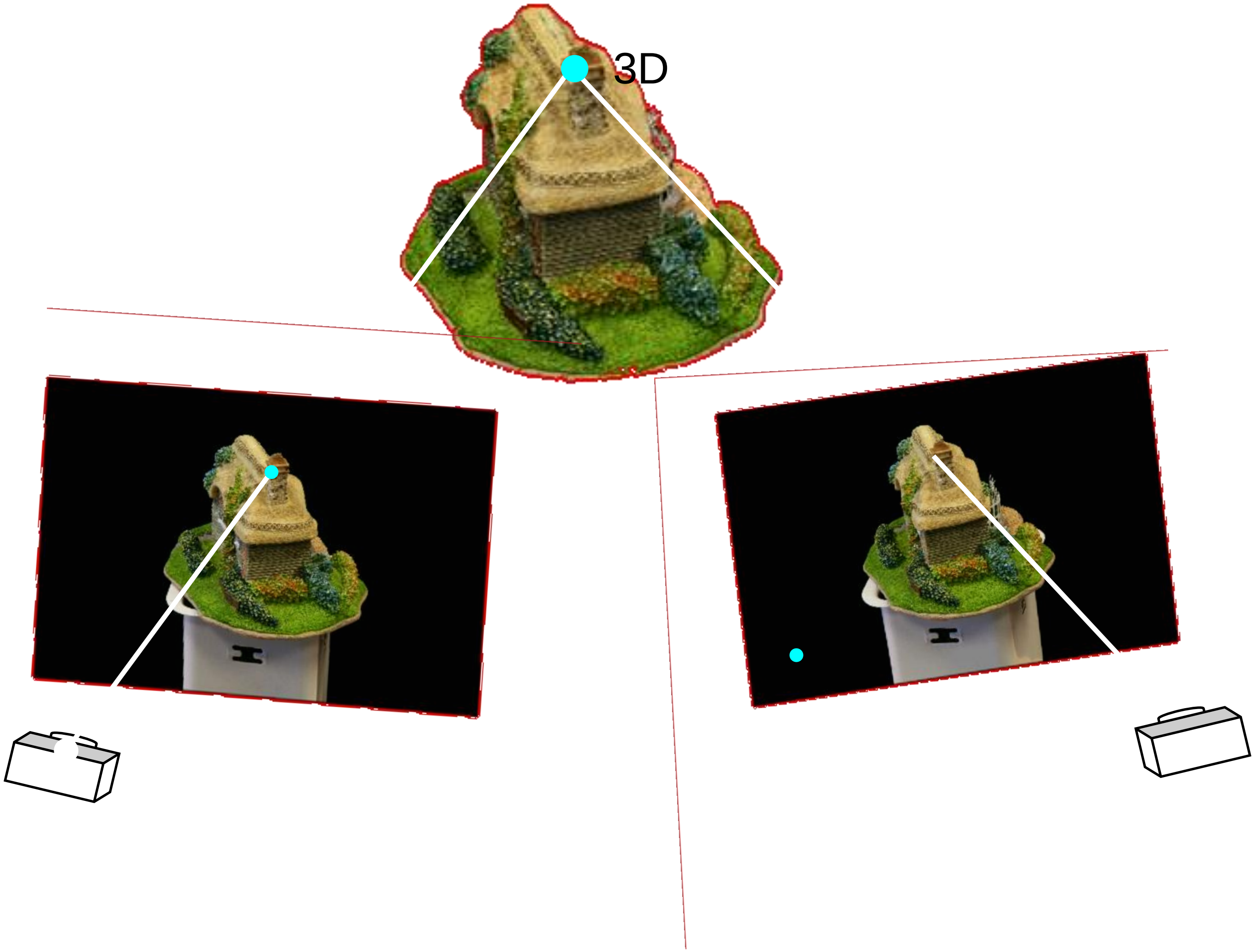
- We need a way to get them that is
  - practical
  - fast
  - non-intrusive
  - low cost



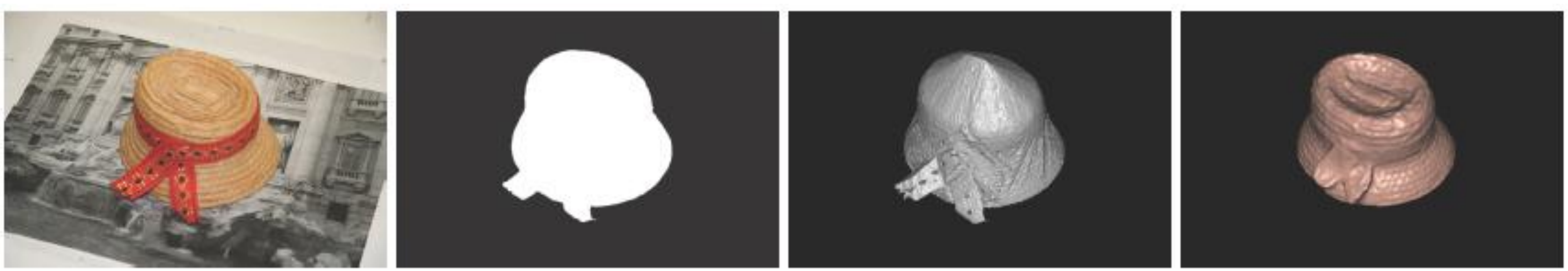
Stereo vision



Automatic 3d modeller

- Camera motion
- Segmentation of object outline
- Multi-view volumetric stereo
- 3D segmentation

input images → silhouettes → visual hull → 3D model



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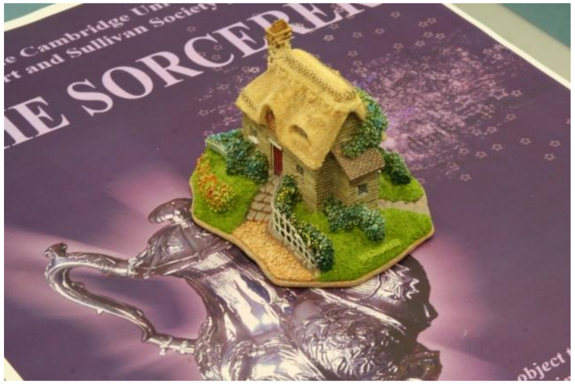
From images to model

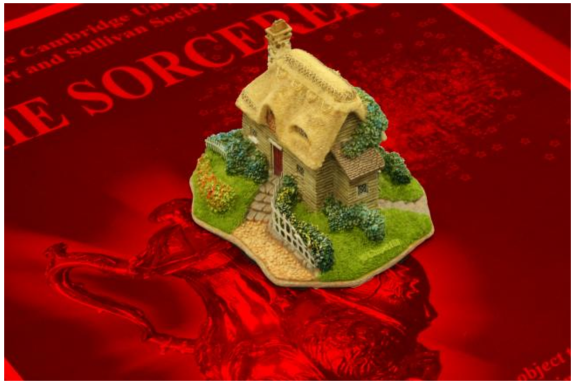


- capture images of object on top of a coloured sheet

From images to model

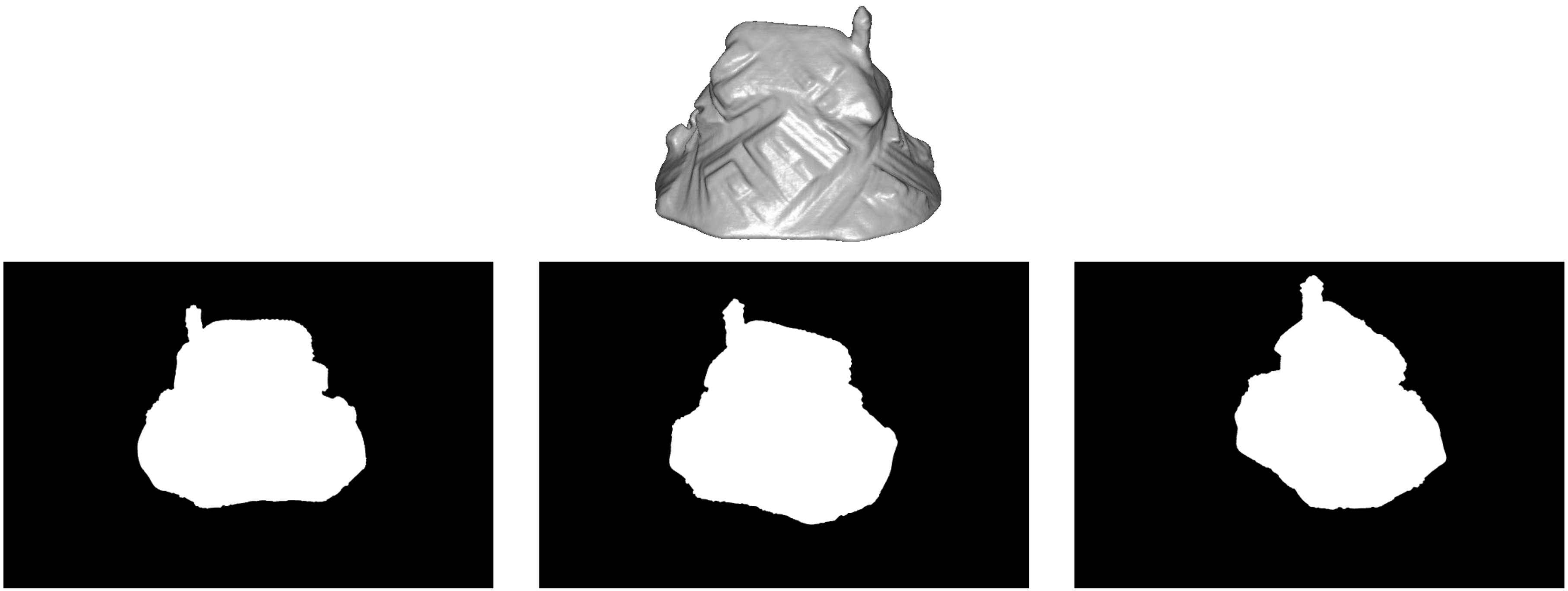
- calibrate cameras (i.e. estimate position, pose and focal length of camera in each photo) using pattern on sheet

From images to model



- identify object of interest by using *fixation constraint* and simultaneous 3D

From images to model



- construct visuall hull (largest object that can fit inside silhouettes)

Photo-consistency

Non-photo-consistent point

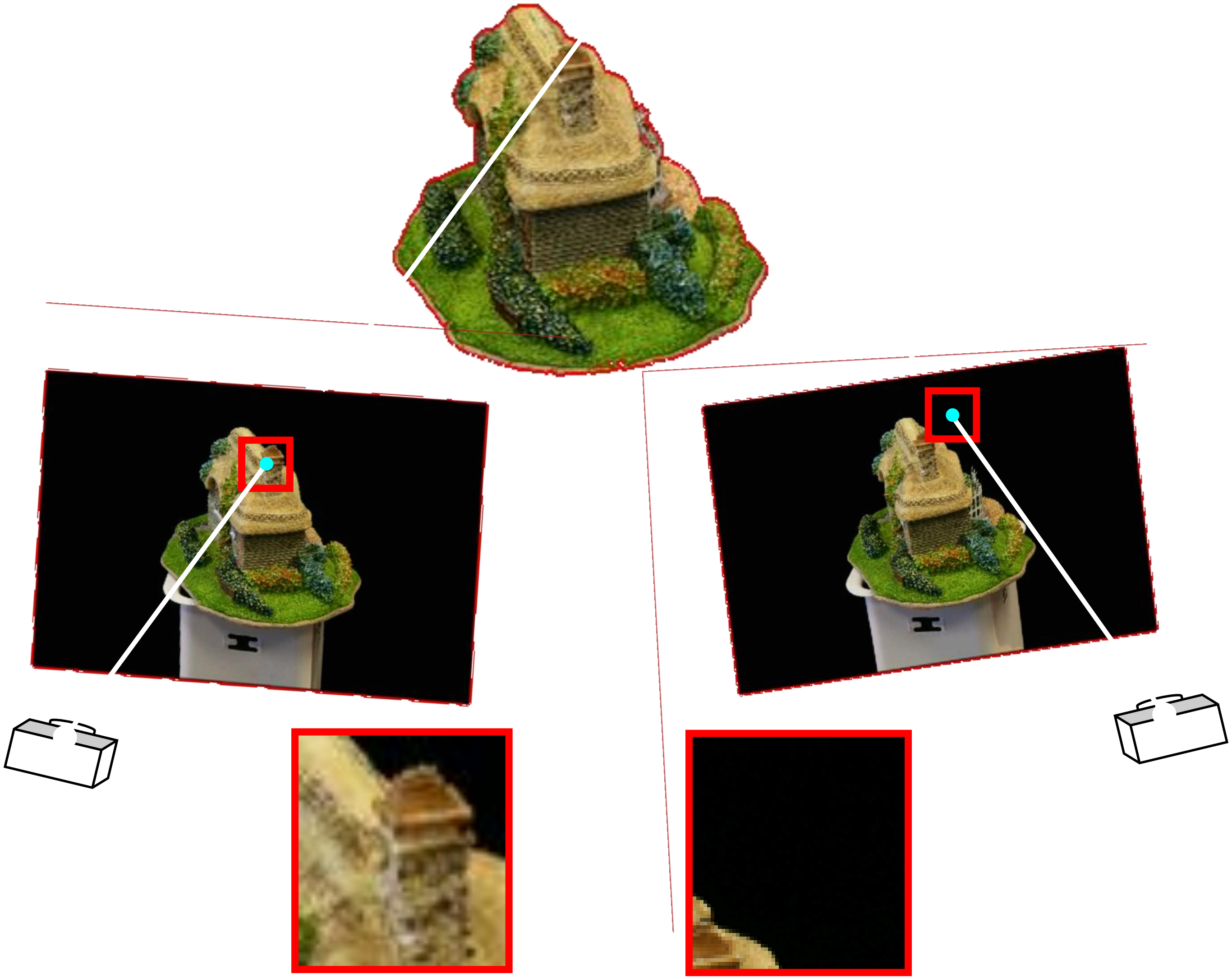
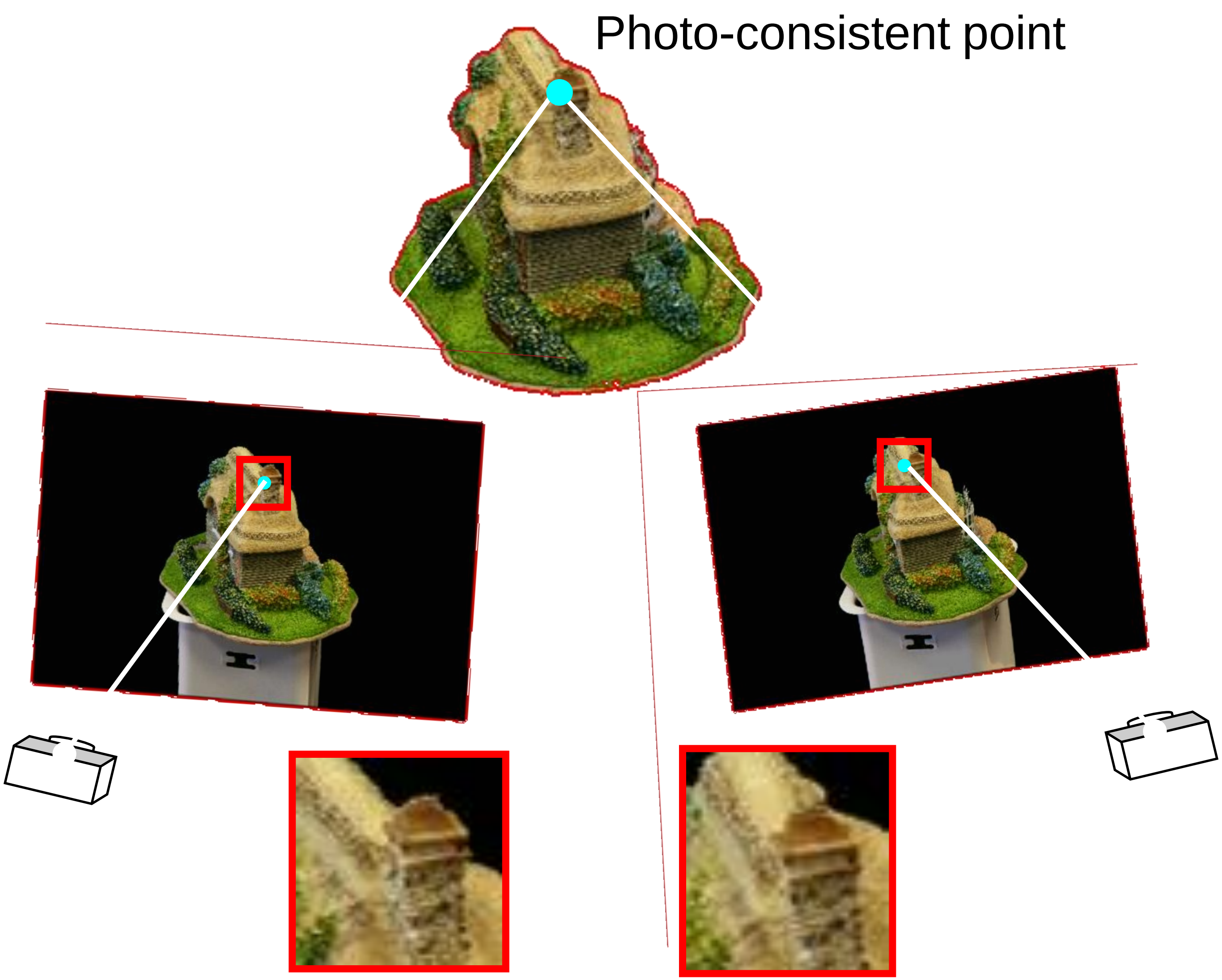
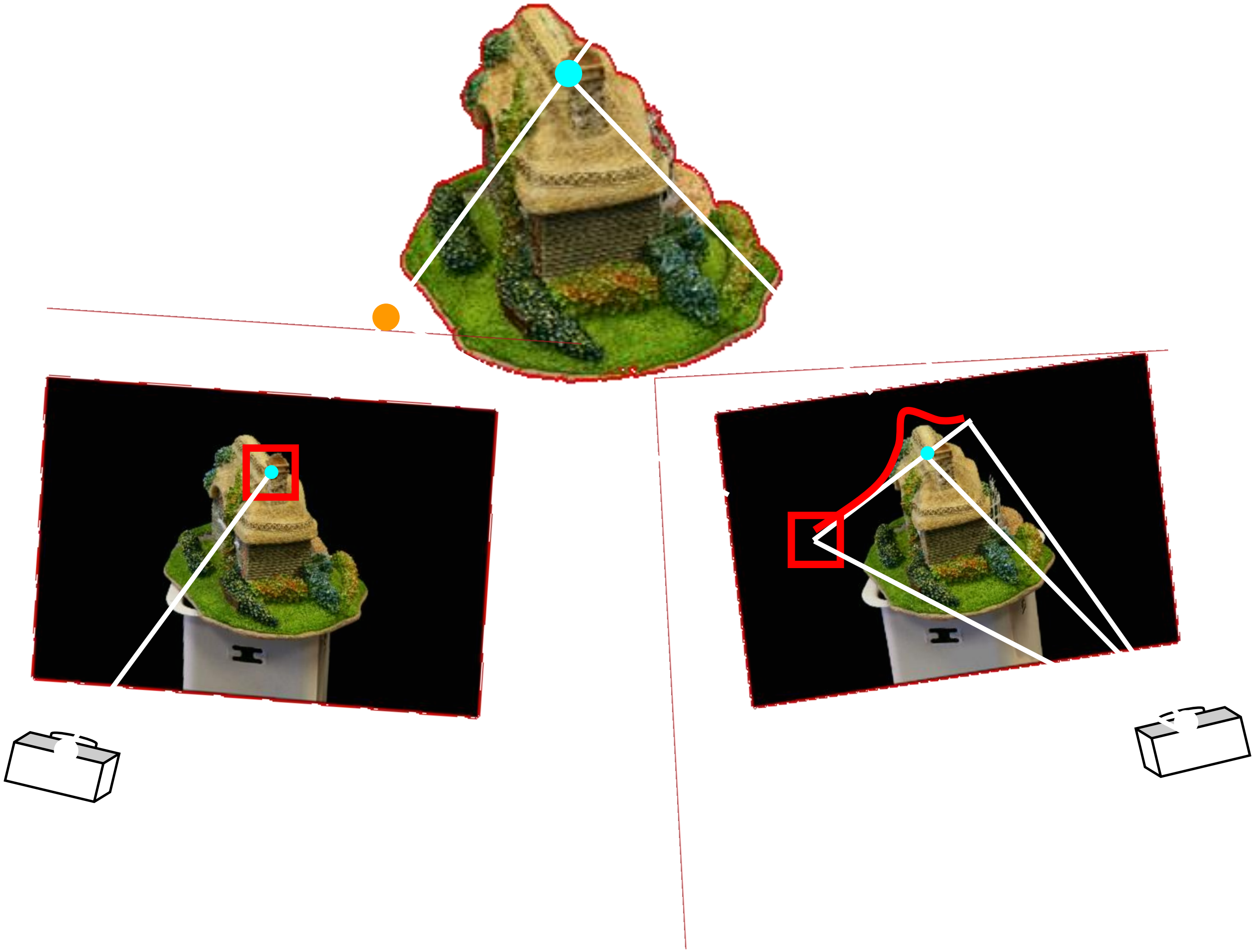


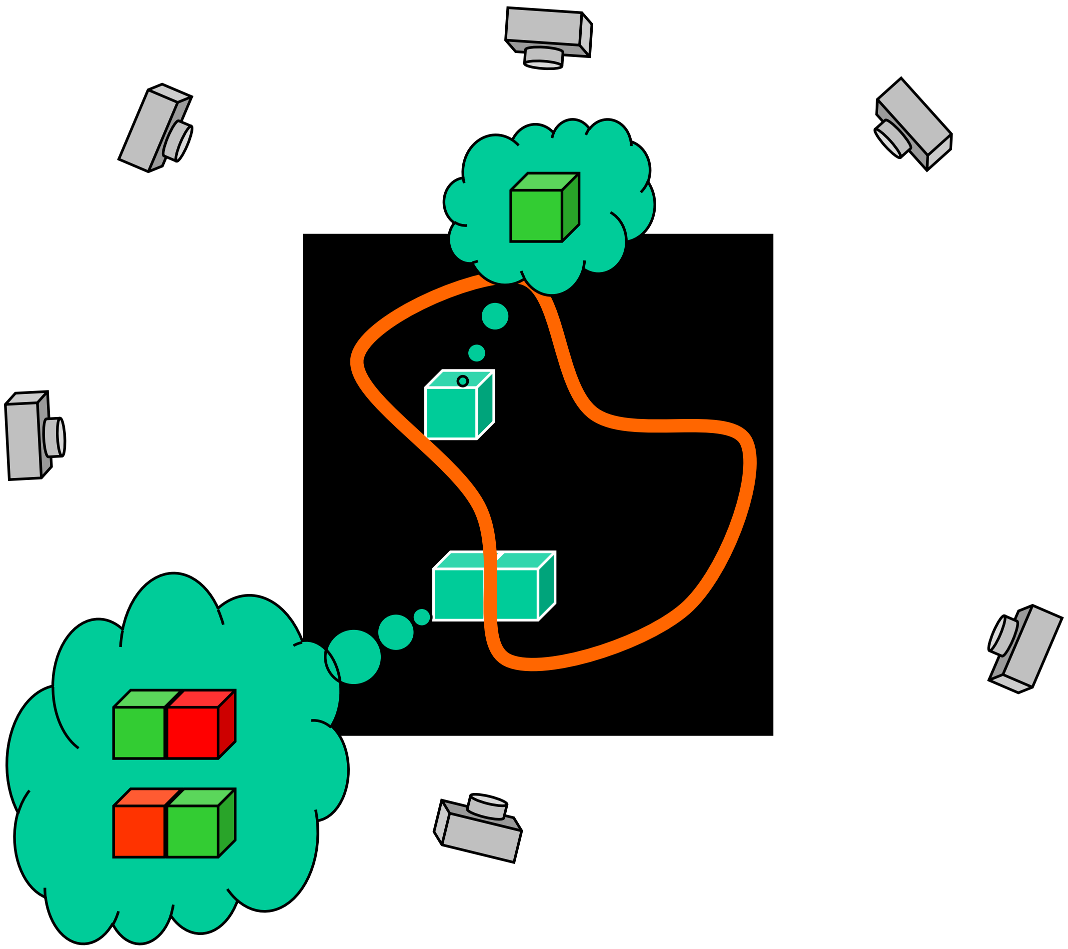
Photo-consistency



Finding the surface



3D segmentation

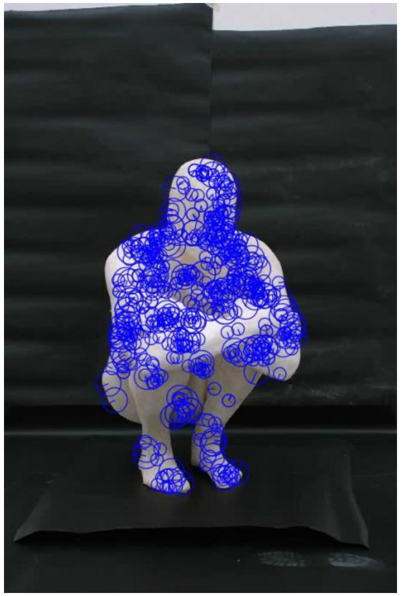


3D Models

Gormley - input Images

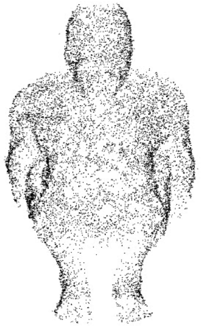
Recovery of camera motion

Input images



Feature extraction

Feature matching



Bundle adjustment

Probabilistic 3D segmentation

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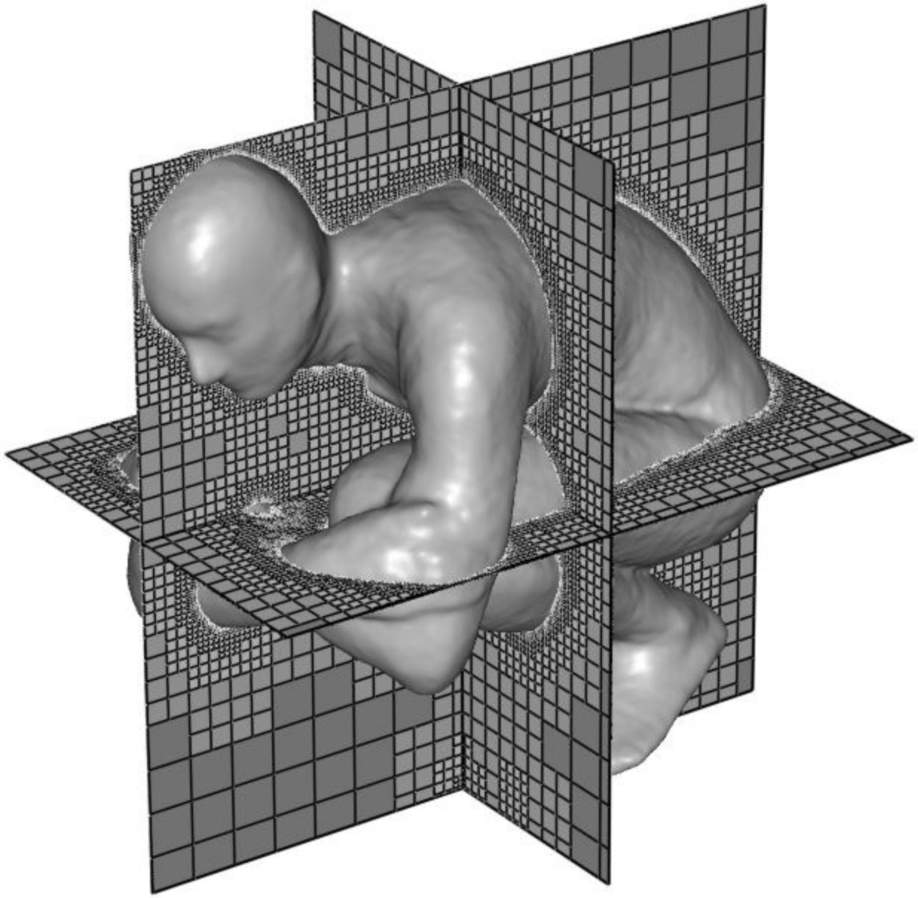

3D Models

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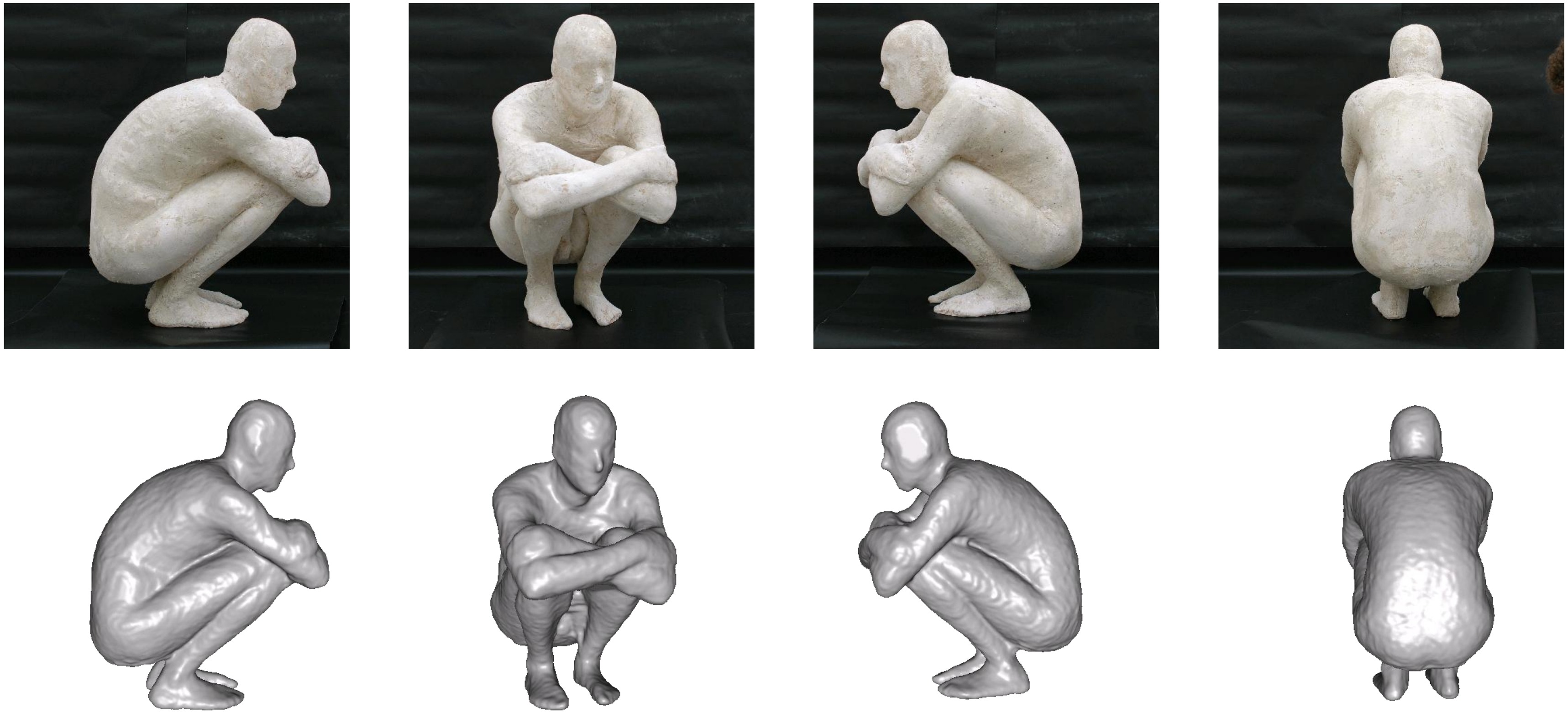

Final installation

3D models

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Multiview photometric stereo

Vogiatzis, Hernandez and Cipolla 2006 and 2008

Untextured objects

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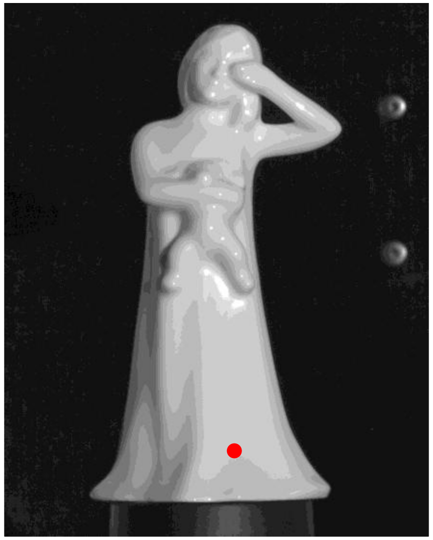
- Almost impossible to establish correspondence



Use shading cue

Untextured objects

Changing lighting uncovers fine geometric detail

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

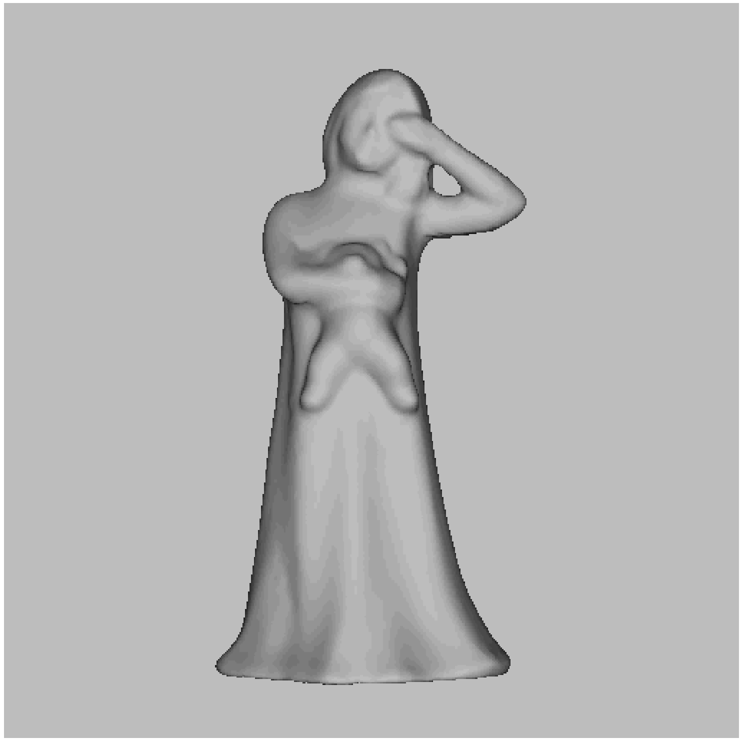


Image acquisition setup

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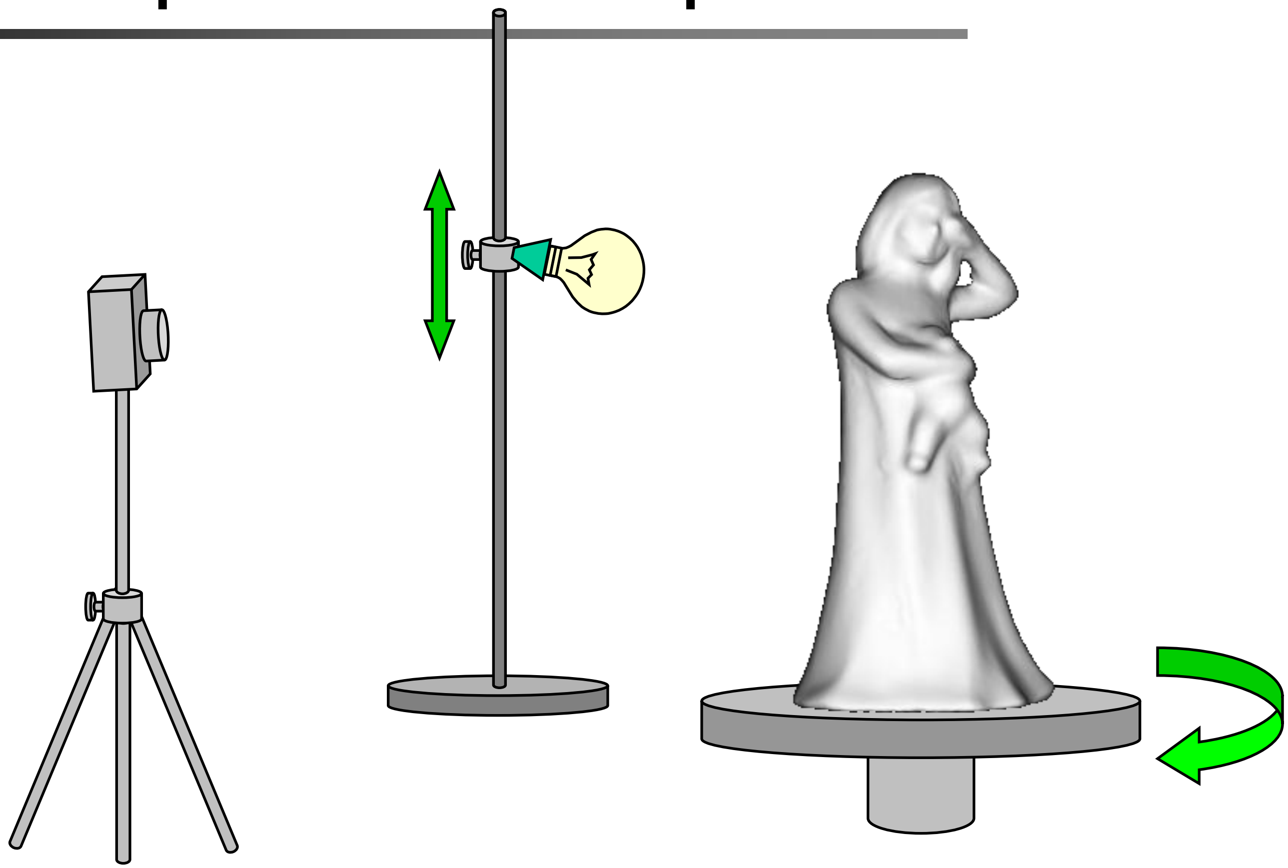
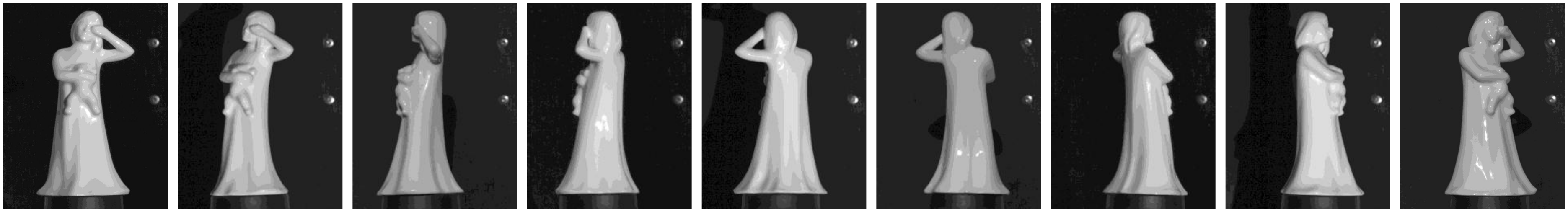
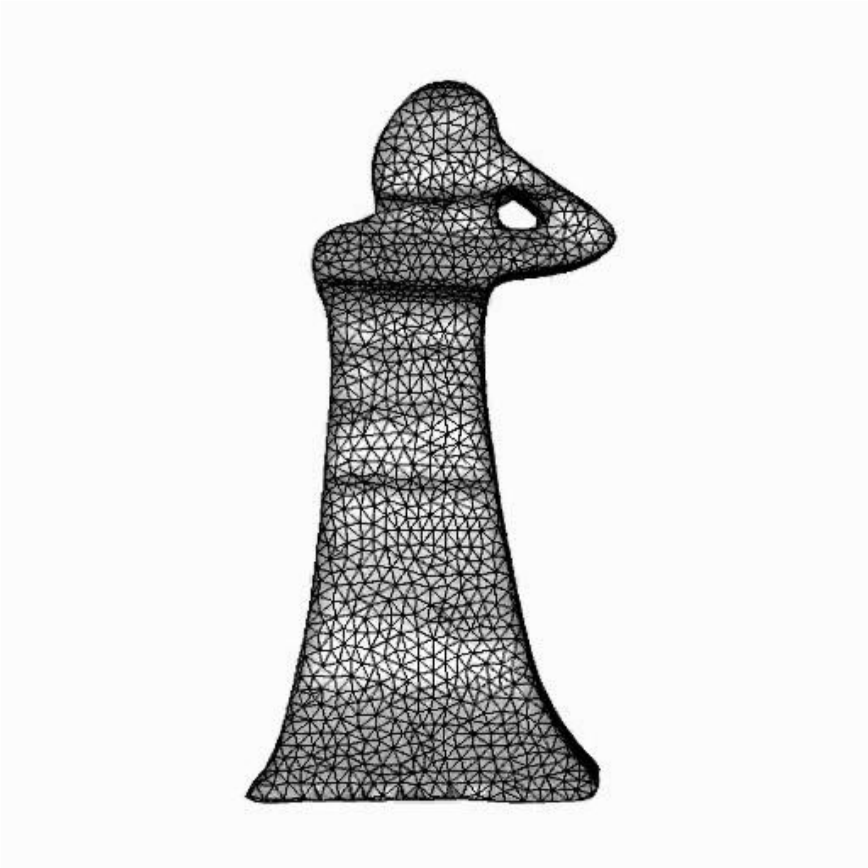




Surface Evolution of 3D Mesh



3D Models

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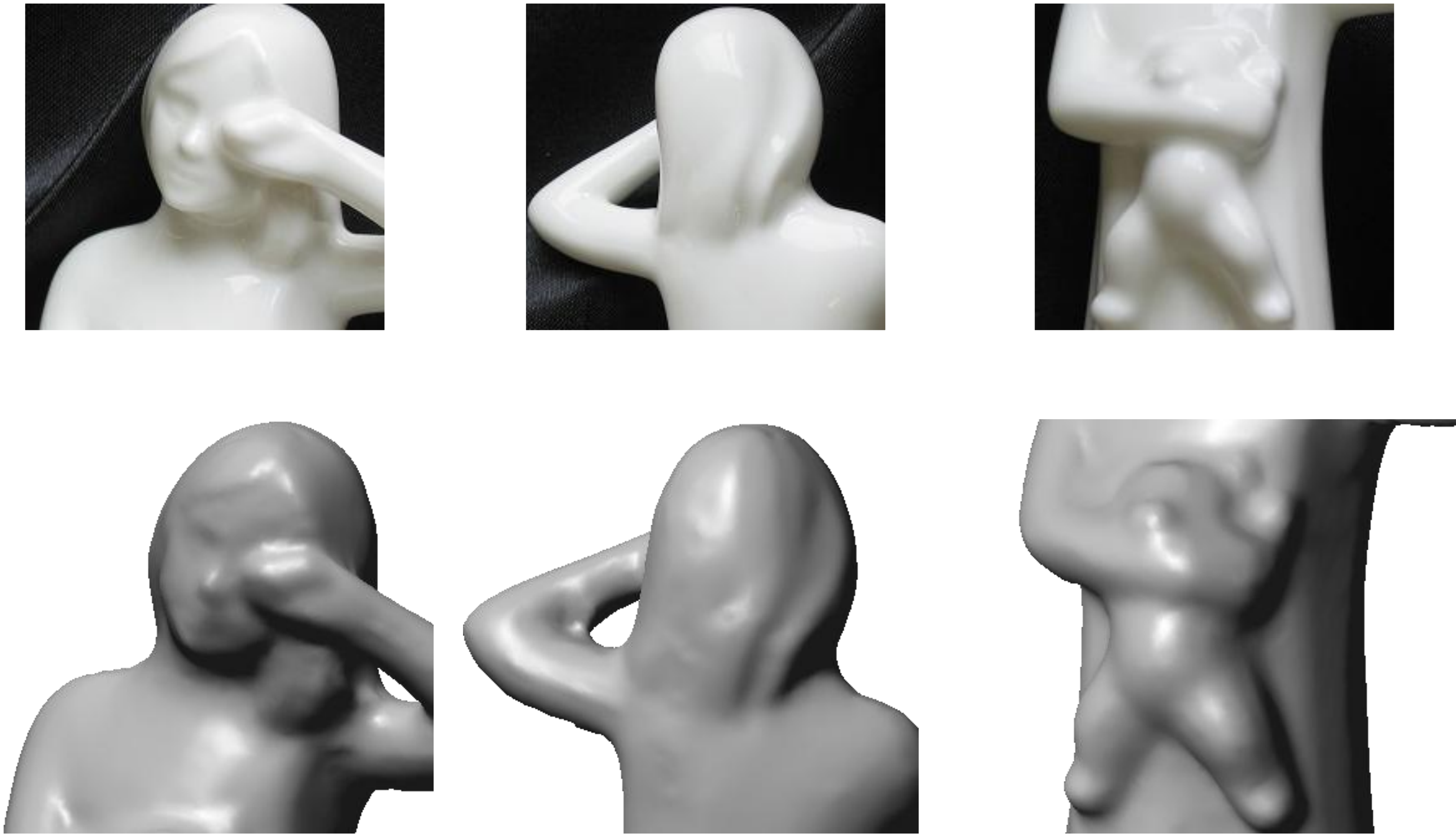
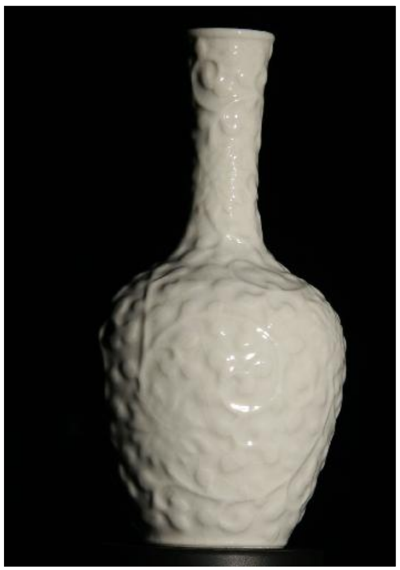
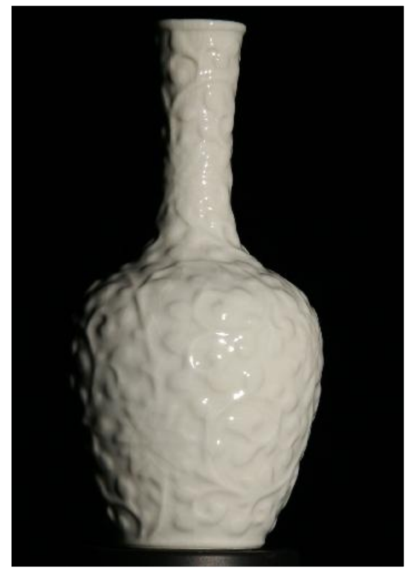


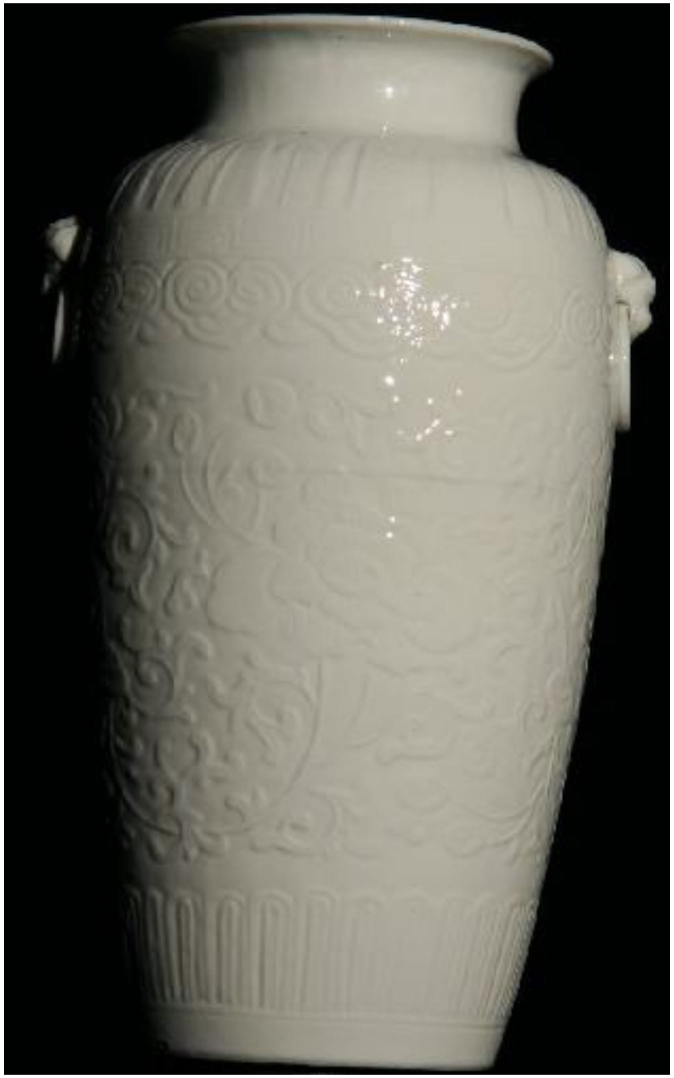
Making physical copies

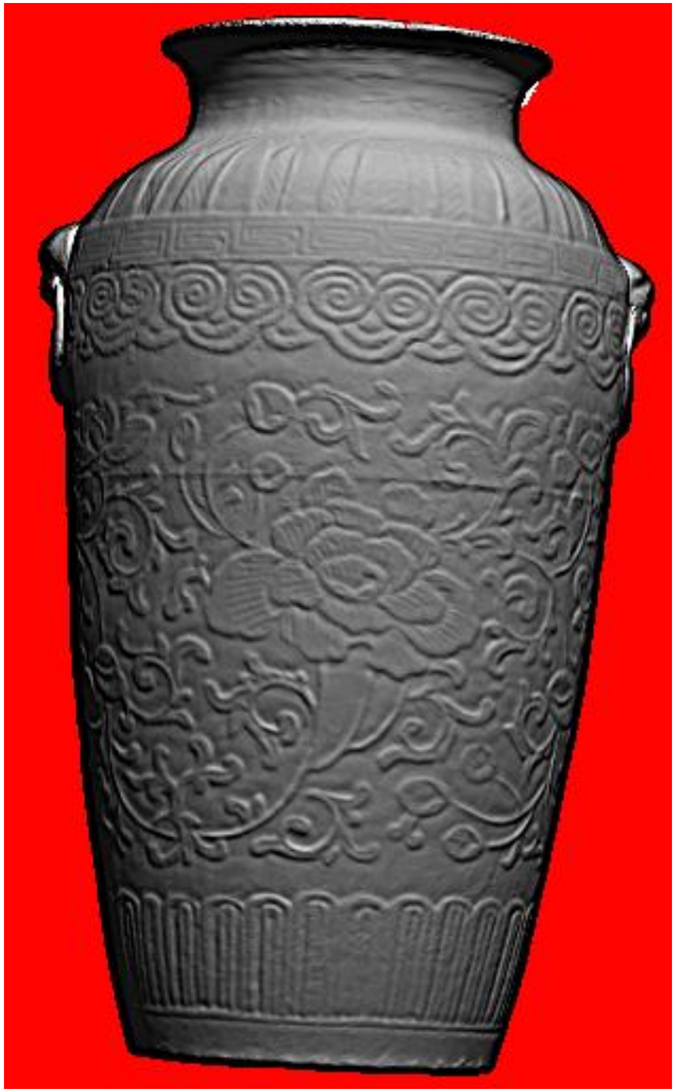
3D Models





3D Models

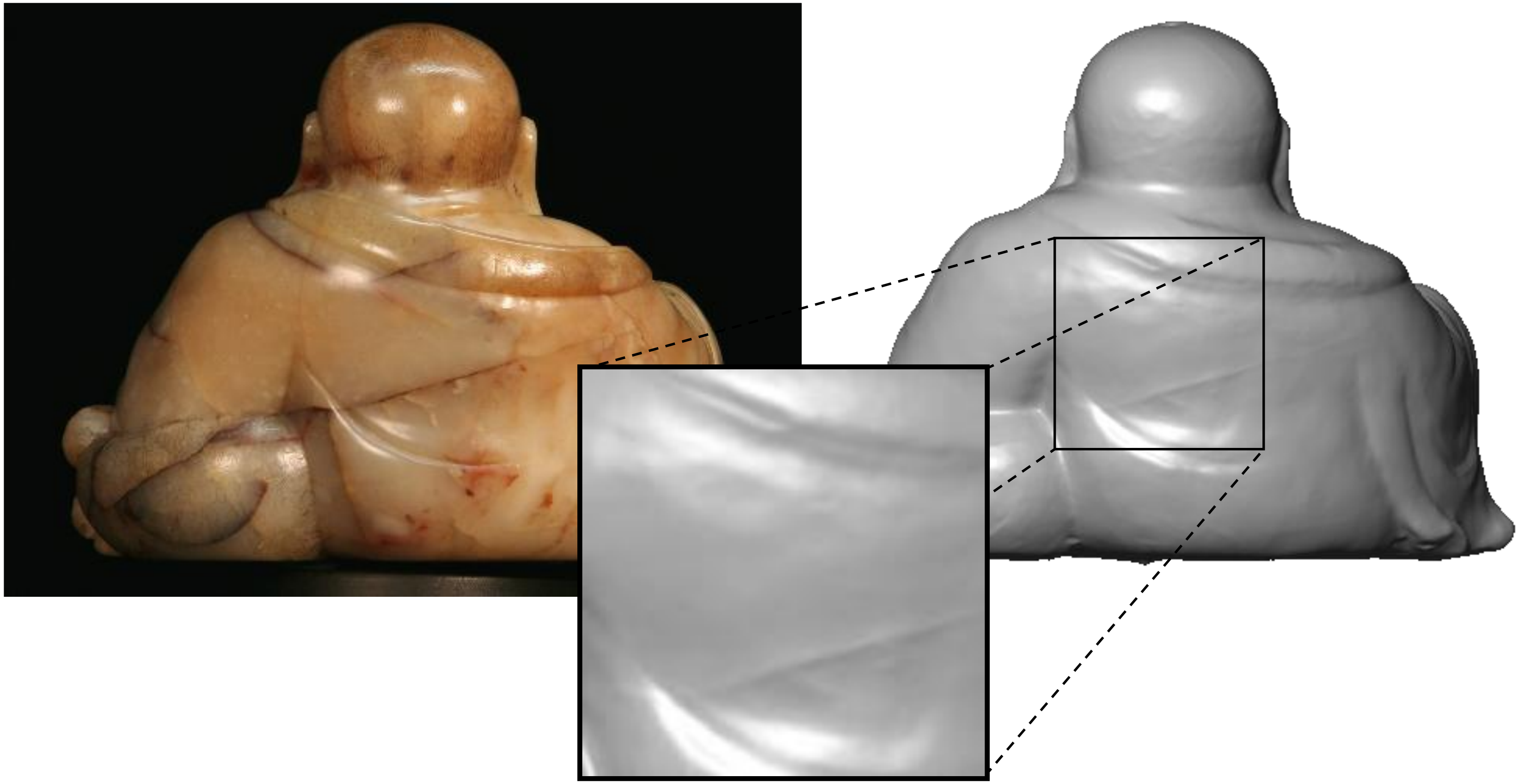




3D Models

3D Models

3D Models



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Deformable objects:

Real-time photometric stereo using colour lighting

Hernandez et al 2007

Photometric stereo with colour

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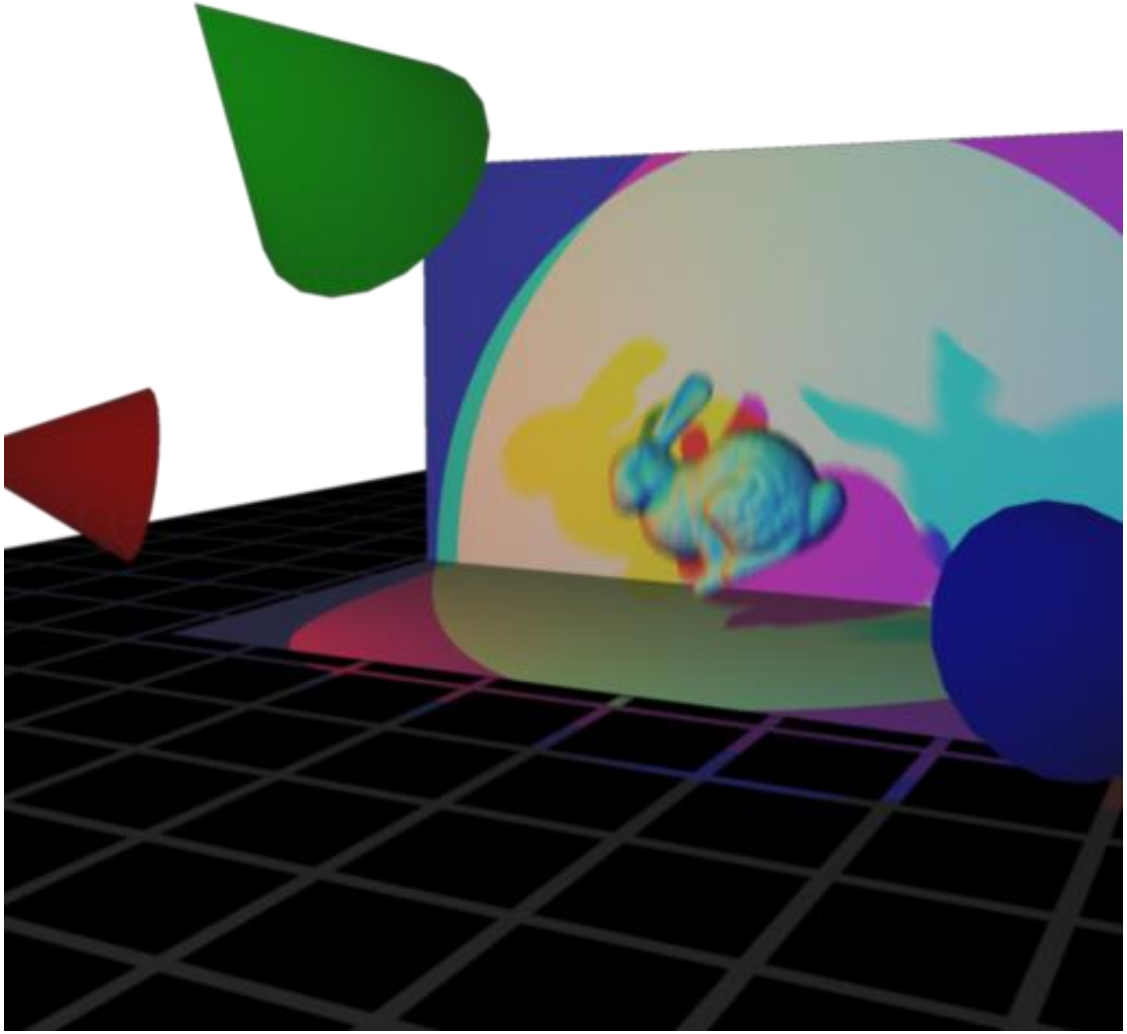
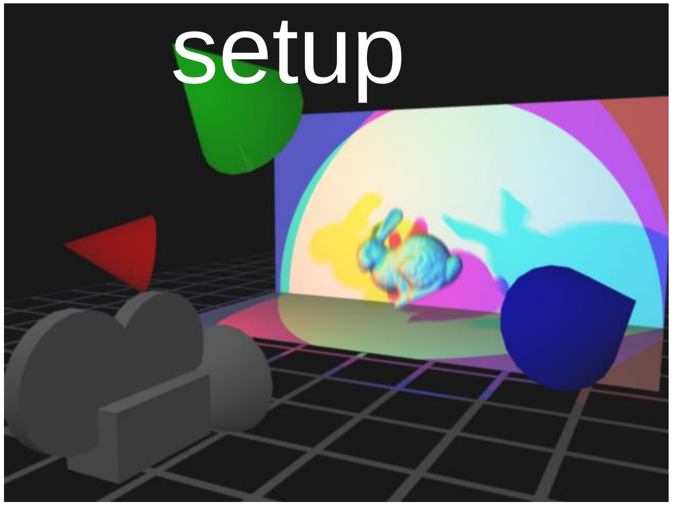
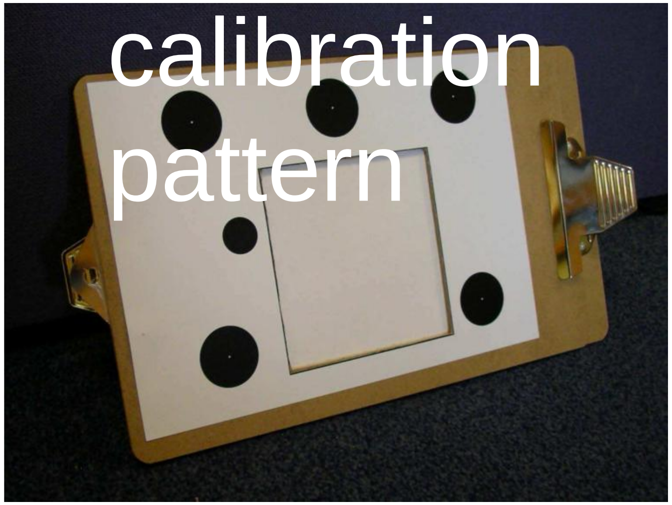


Deformable objects?

- a method for reconstructing a textureless *deforming* object in 2.5d





Shape from colour

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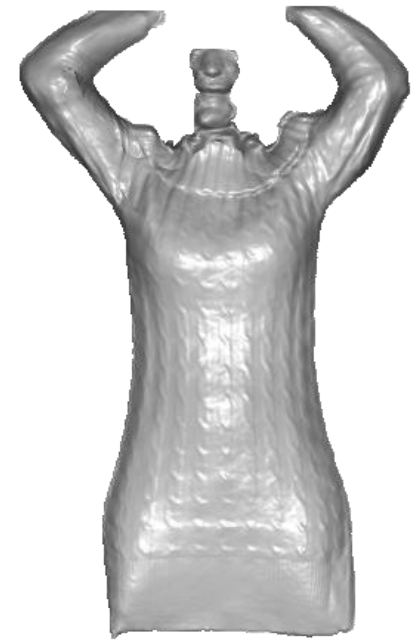
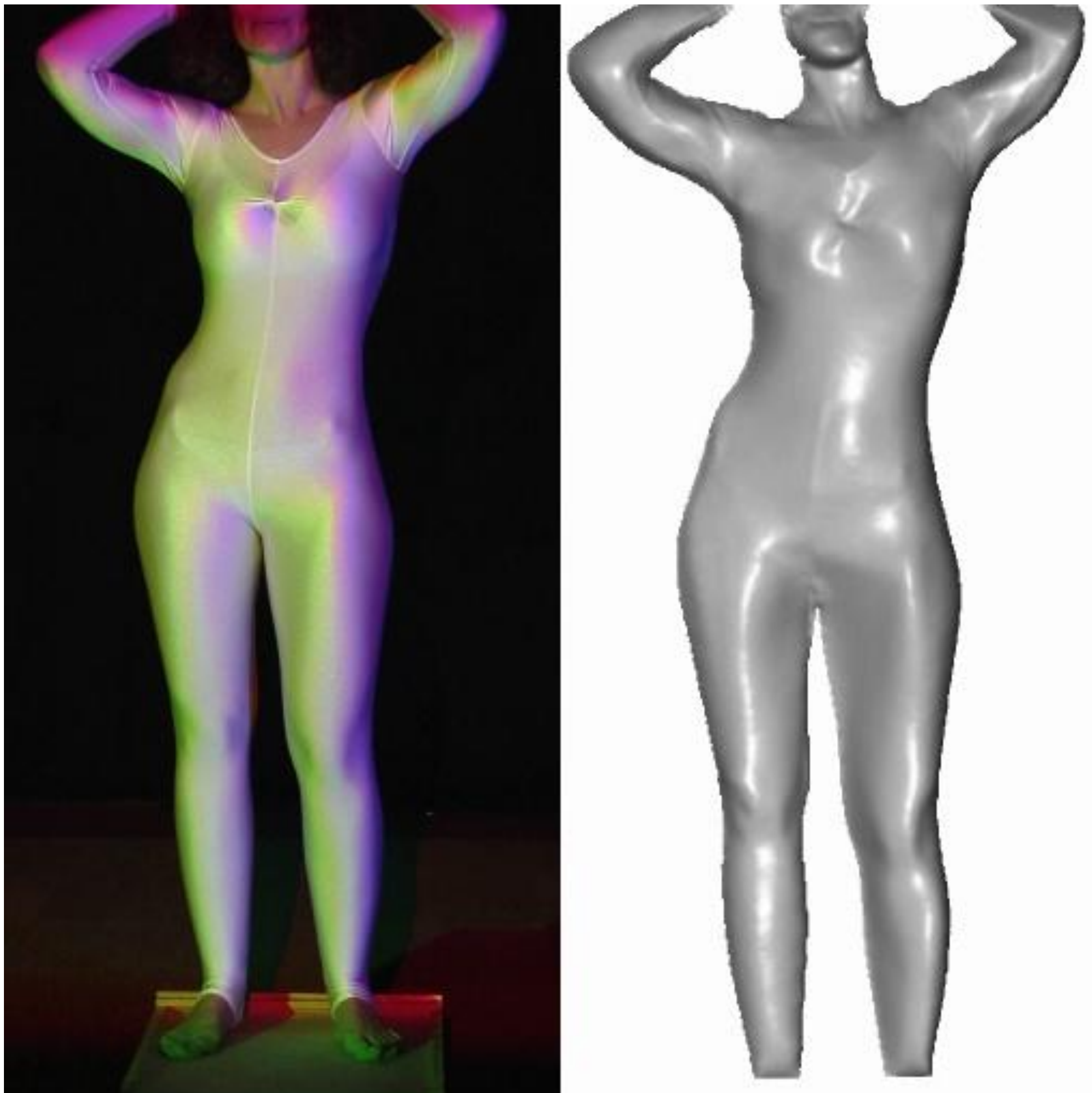
- observation: **1-1 mapping between colour and surface orientation**

- get map of surface orientations from colour image
- integrate orientations to get depth map

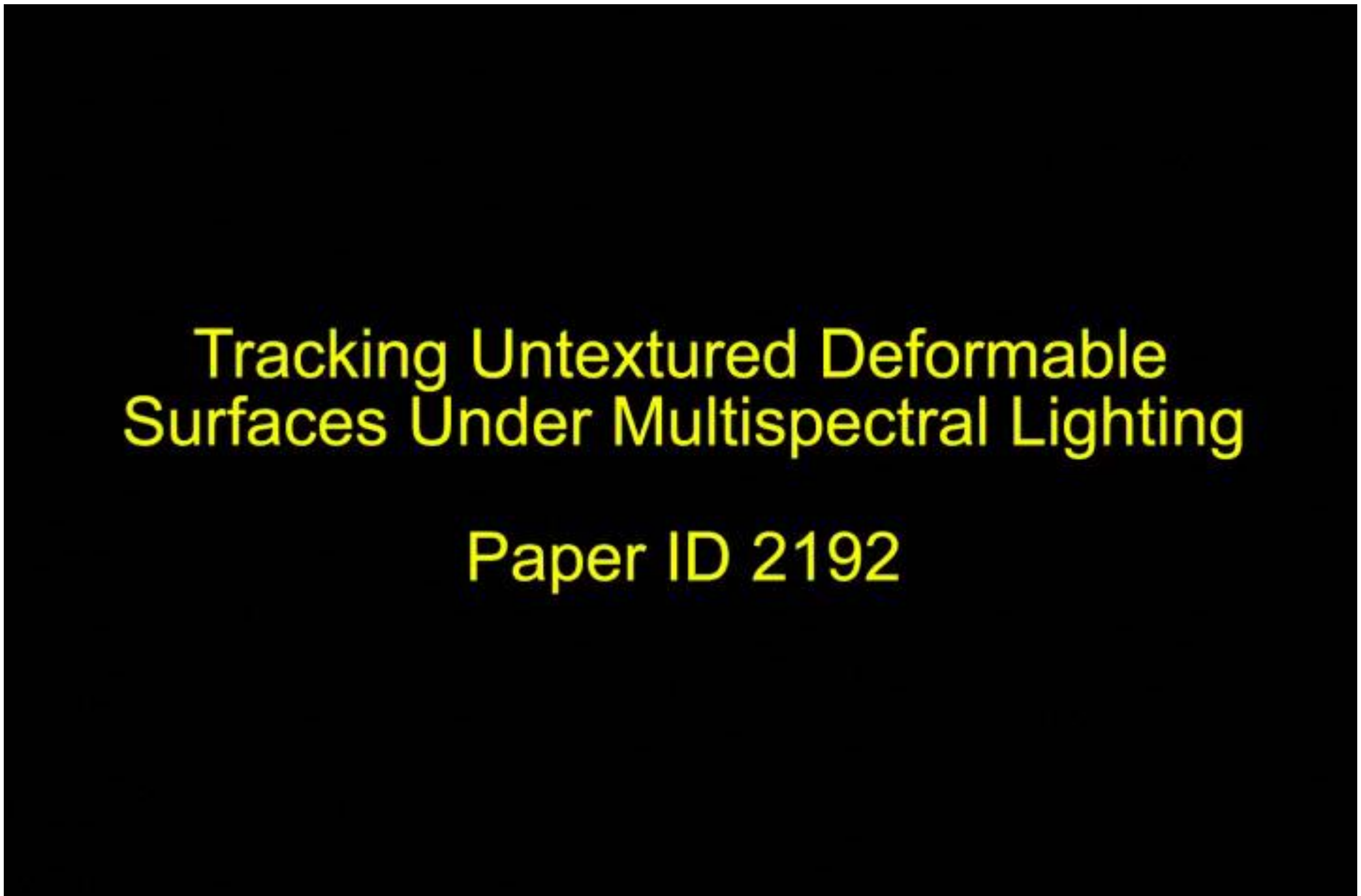
- do this for colour video to get 2.5d reconstruction of deforming object!



Photometric stereo with colour



shape from colour



II. Registration:

Target detection and pose estimation

Image matching

Registration:

Where am I?
What am I looking at?

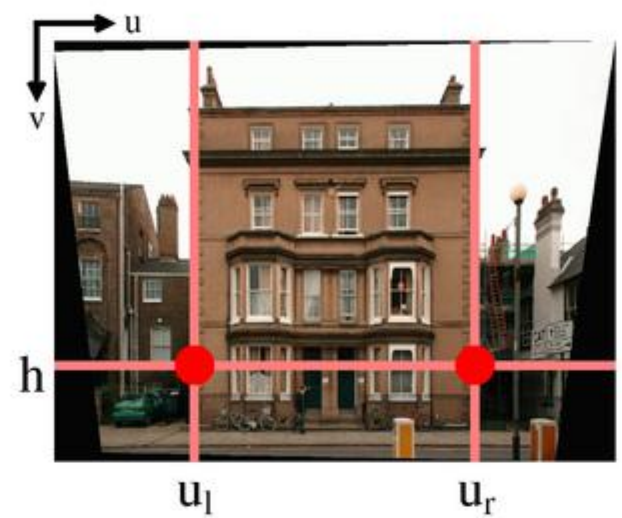
Johansson and Cipolla 2002
Robertson and Cipolla 2004
Cipolla et al 2004

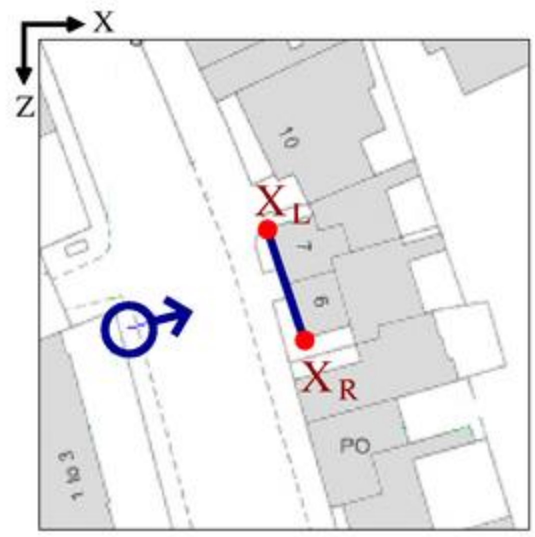
Where I am?

Determine pose from single image by matching

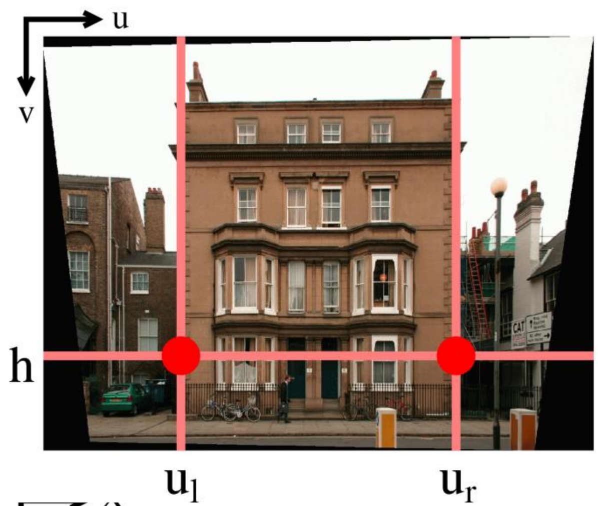
Register database view

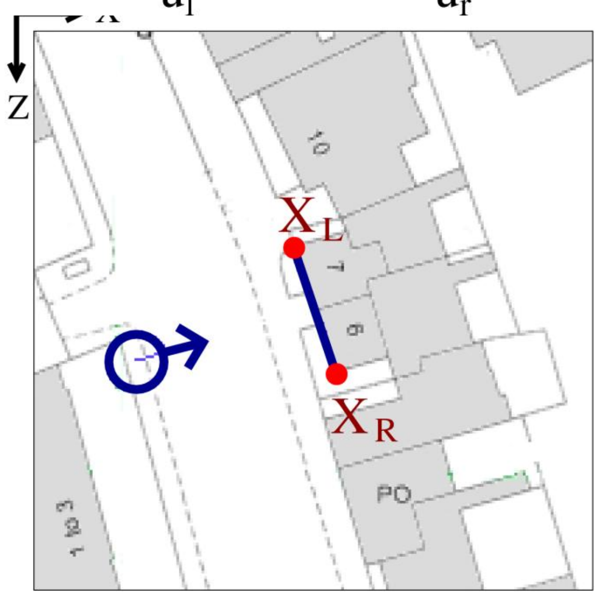
First align database view to map





Localisation of query view





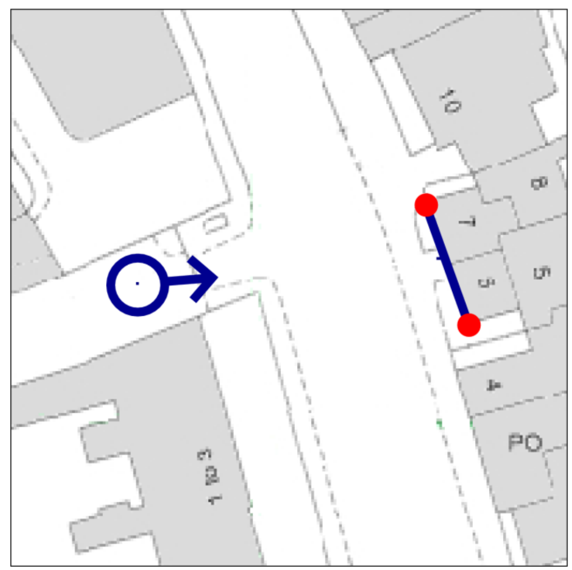


Image-based localisation

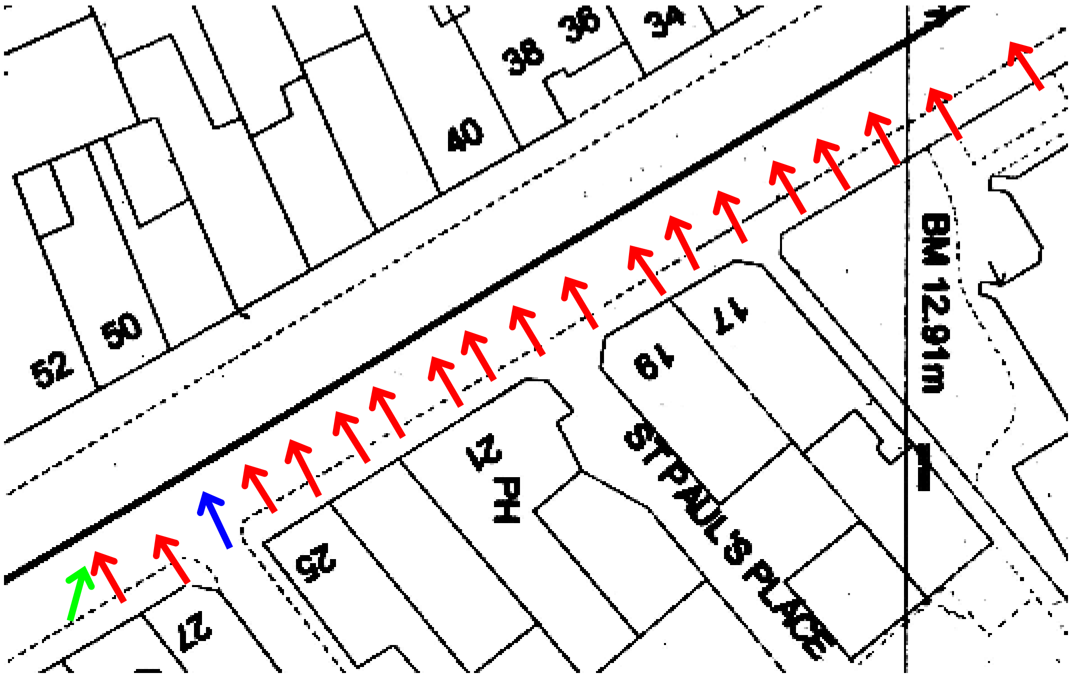


Image-based localisation

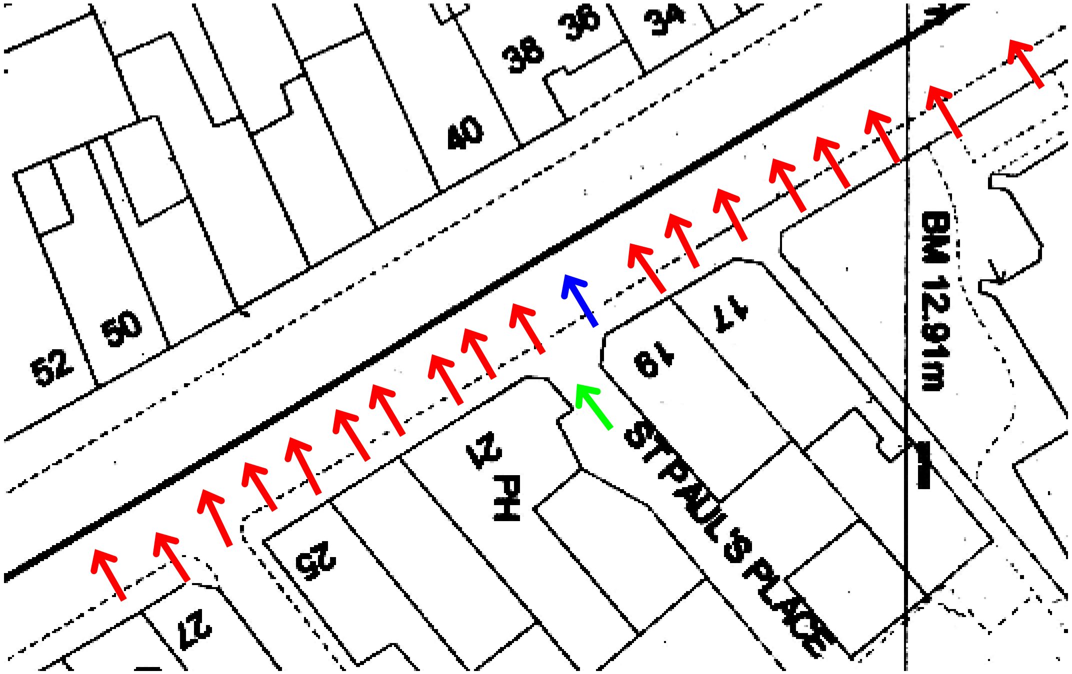
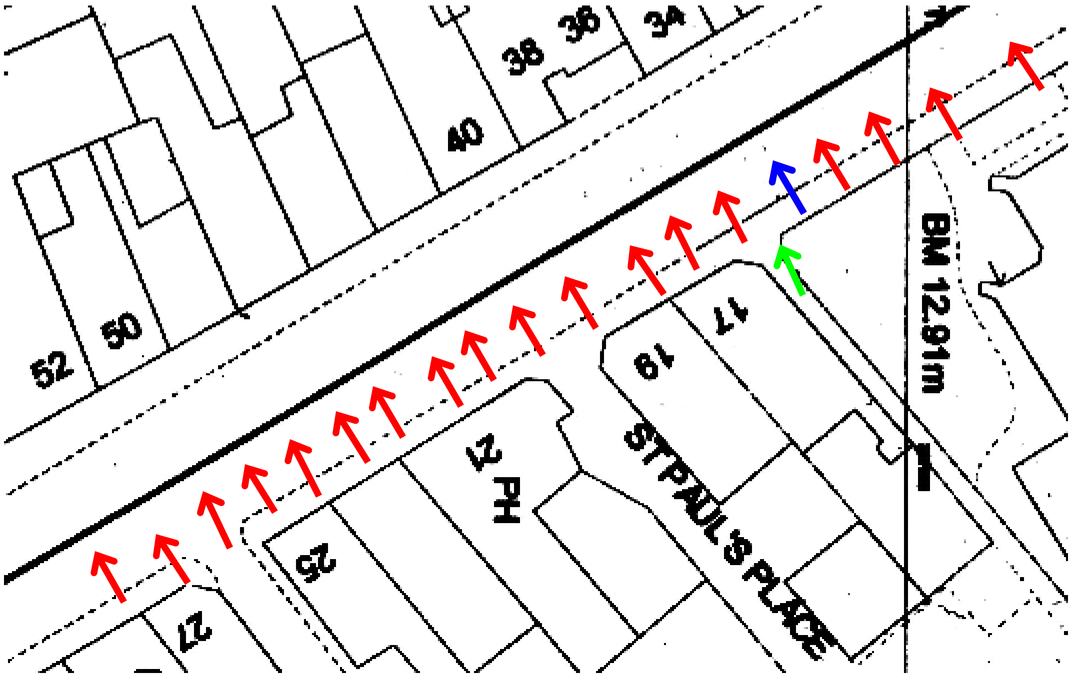


Image-based localisation

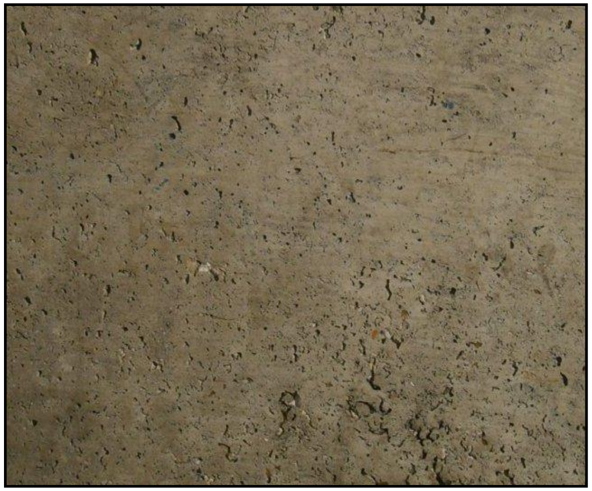


Registration:

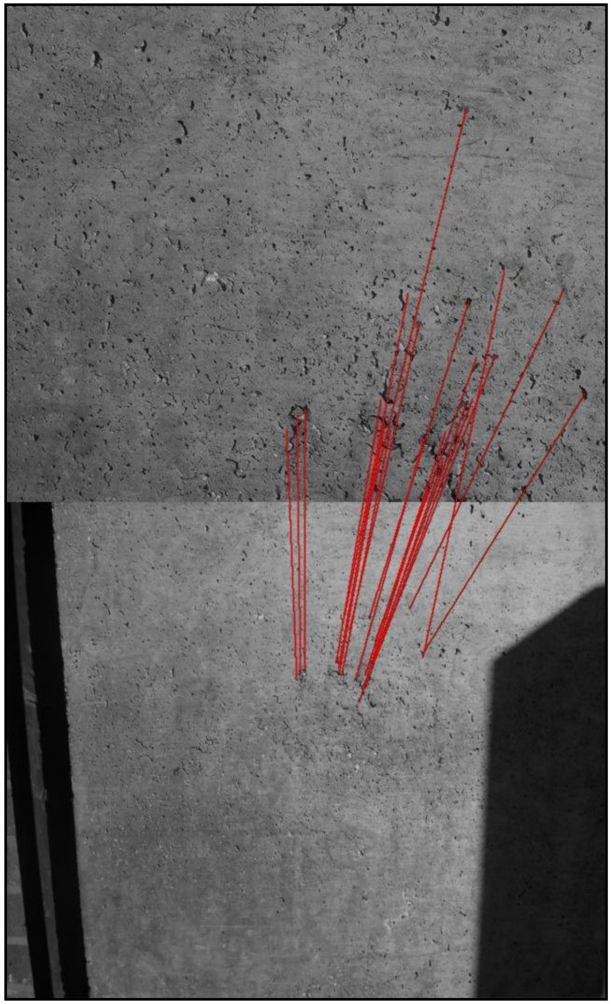
Ageing infrastructure inspection

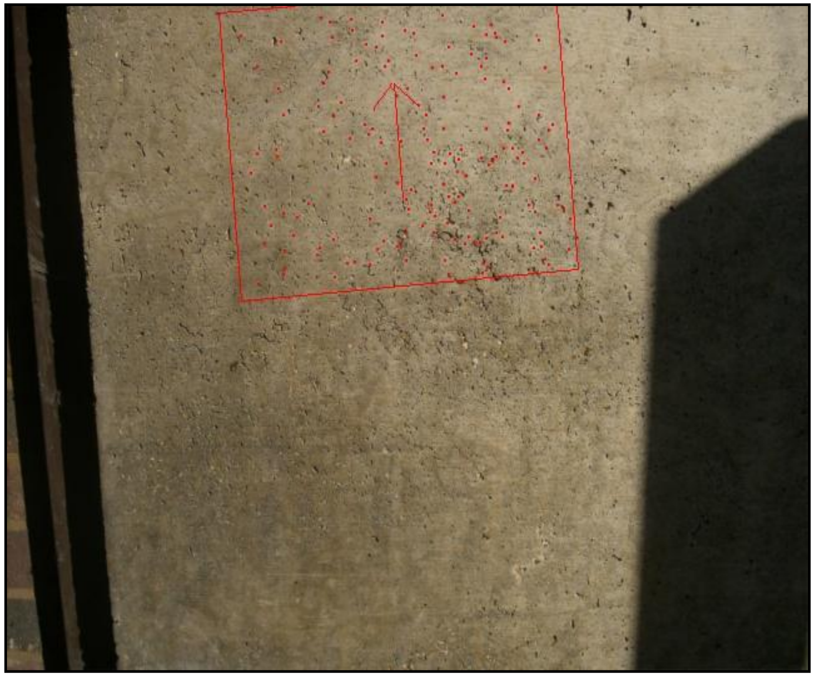
Registration with concrete

- Can appear very repetitive to the eye
- However, plenty of distinguished features can be extracted
- Very accurate matching is possible



Registration with concrete





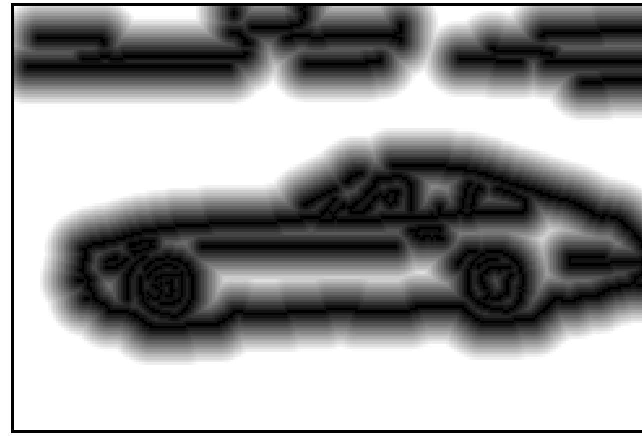
Finding 2D shapes and applications to HCI

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

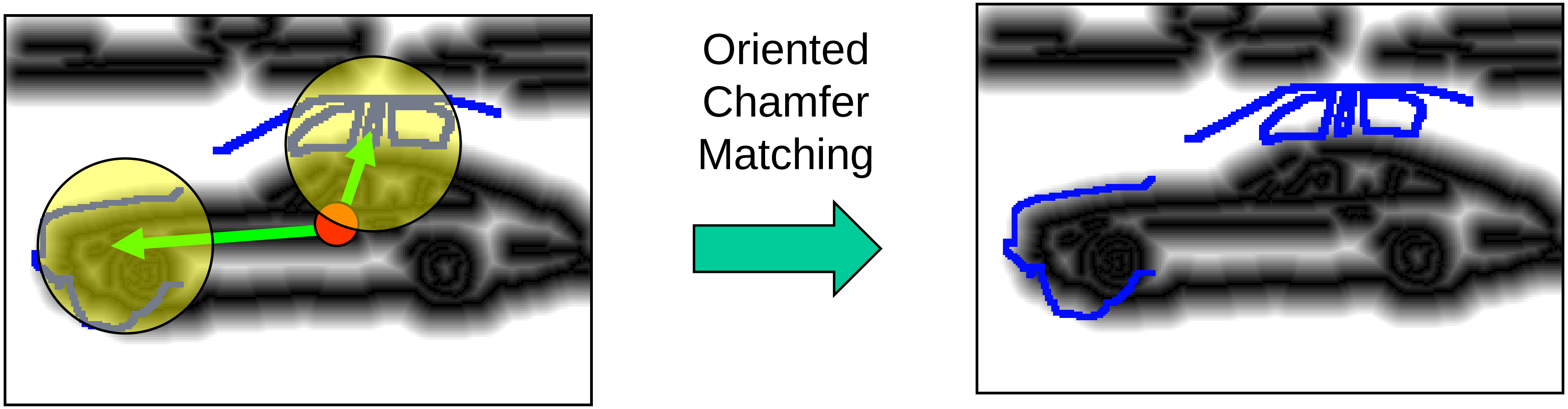
Matching shape templates

Oriented
Canny
Edge
Detector

Oriented
Distance
Transform



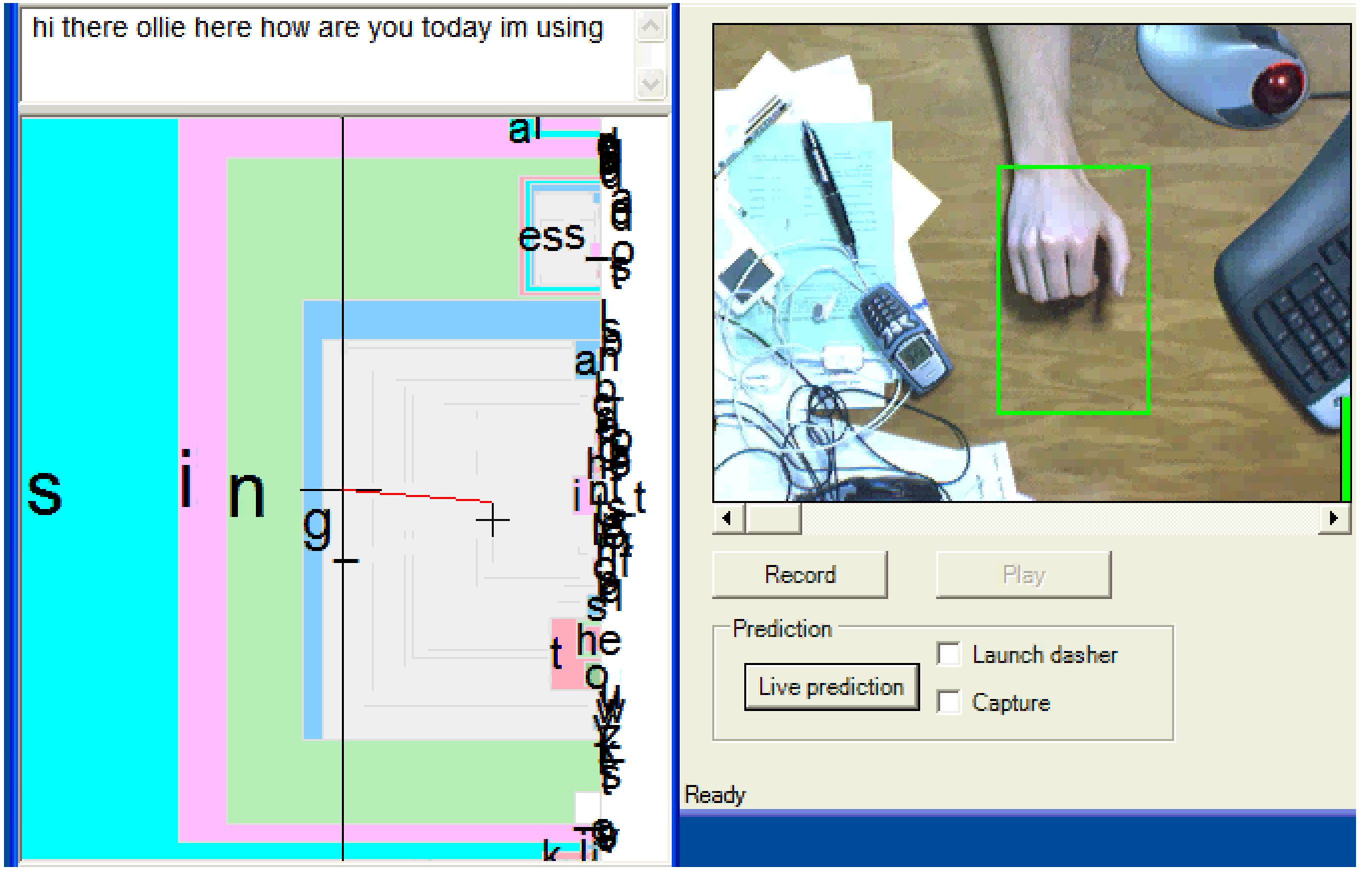
Matching shape templates



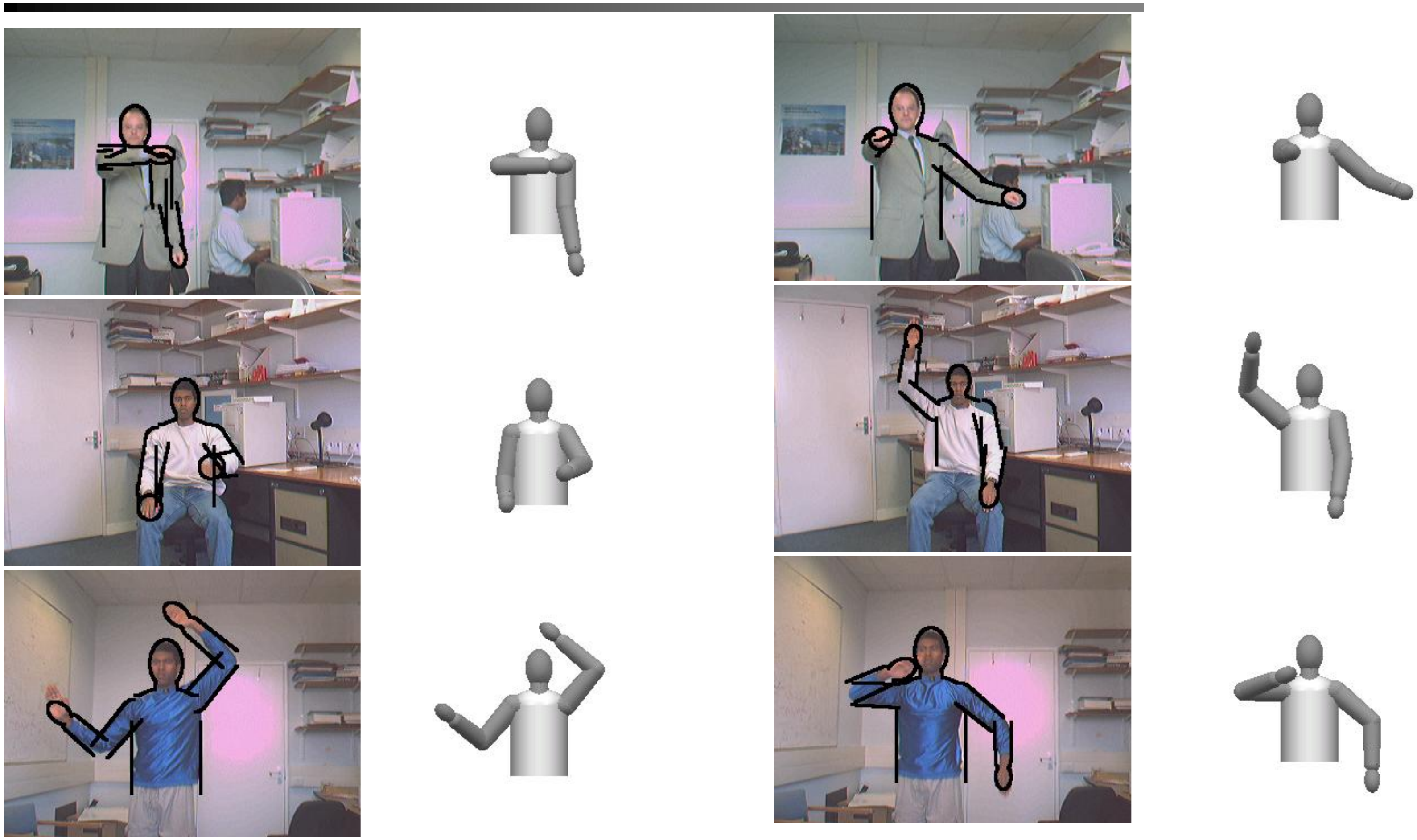
Hand detection system

Tracking - 3D mouse

Real-time visual controller for Dasher



People and pose detection



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

Wong and Cipolla 2007

Overview

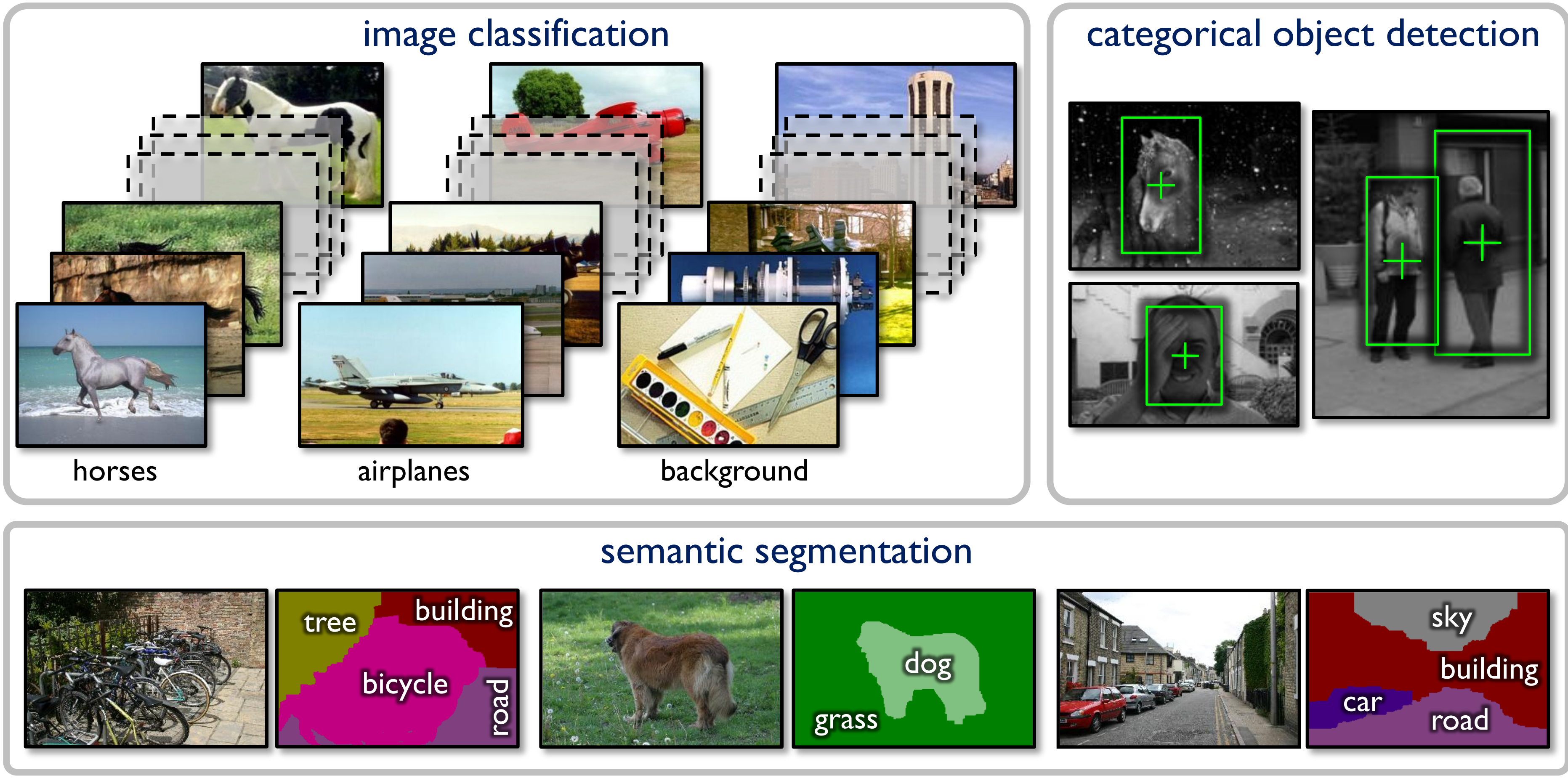

image classification
horses
airplanes
background
categorical object detection
semantic segmentation
tree
building
bicycle
road
dog
grass
sky
building
car
road

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Using interest points and visual words

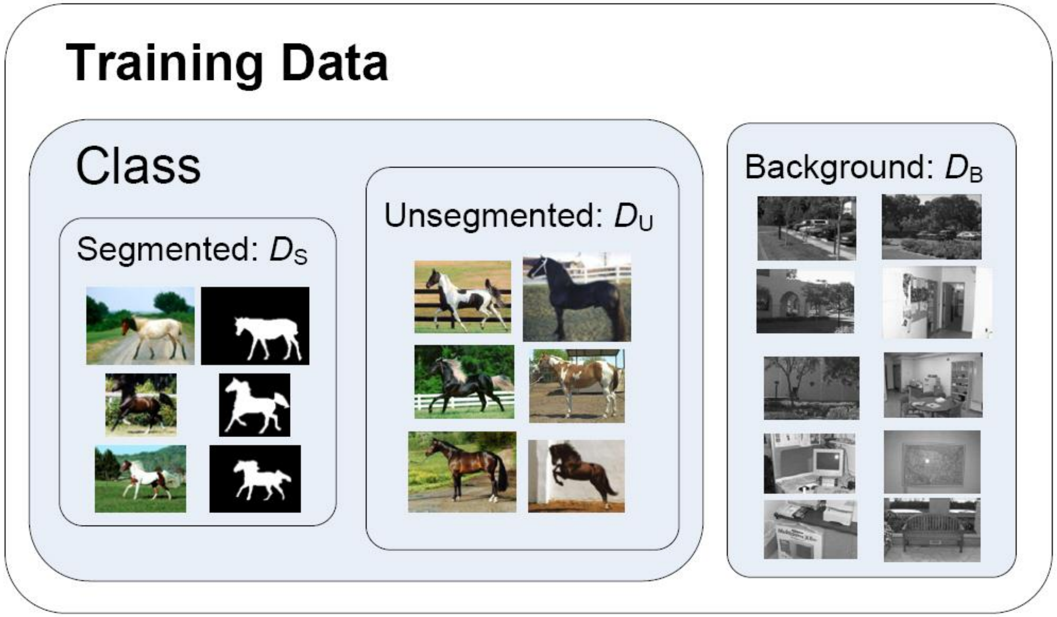
Johnson and Cipolla

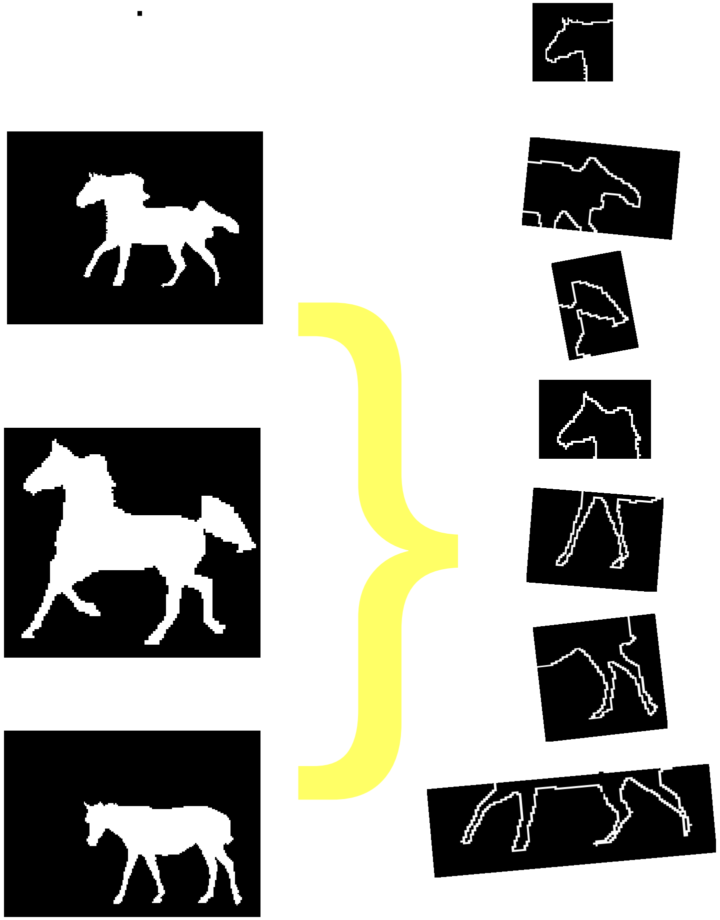
Image matching

Using contour and shape

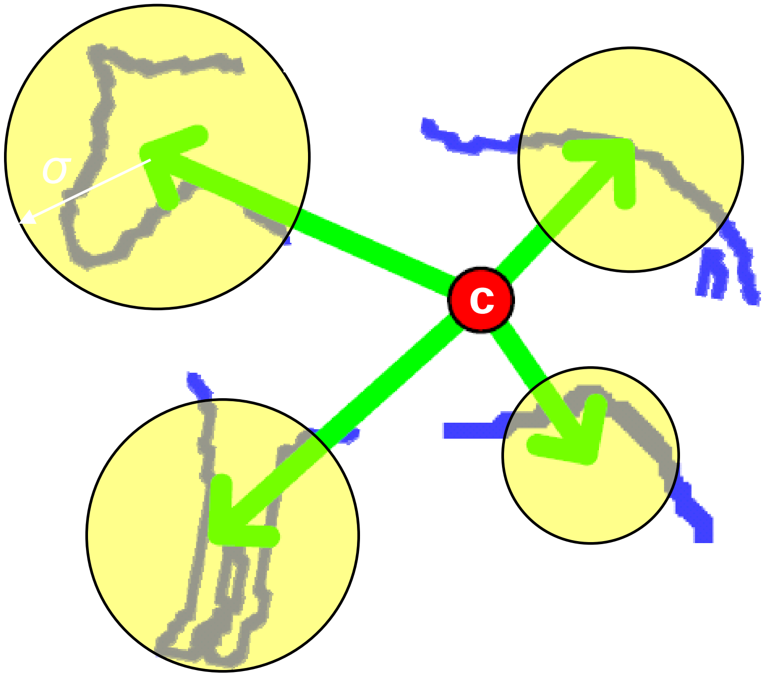
Shotton, Blake and Cipolla 2005-2007

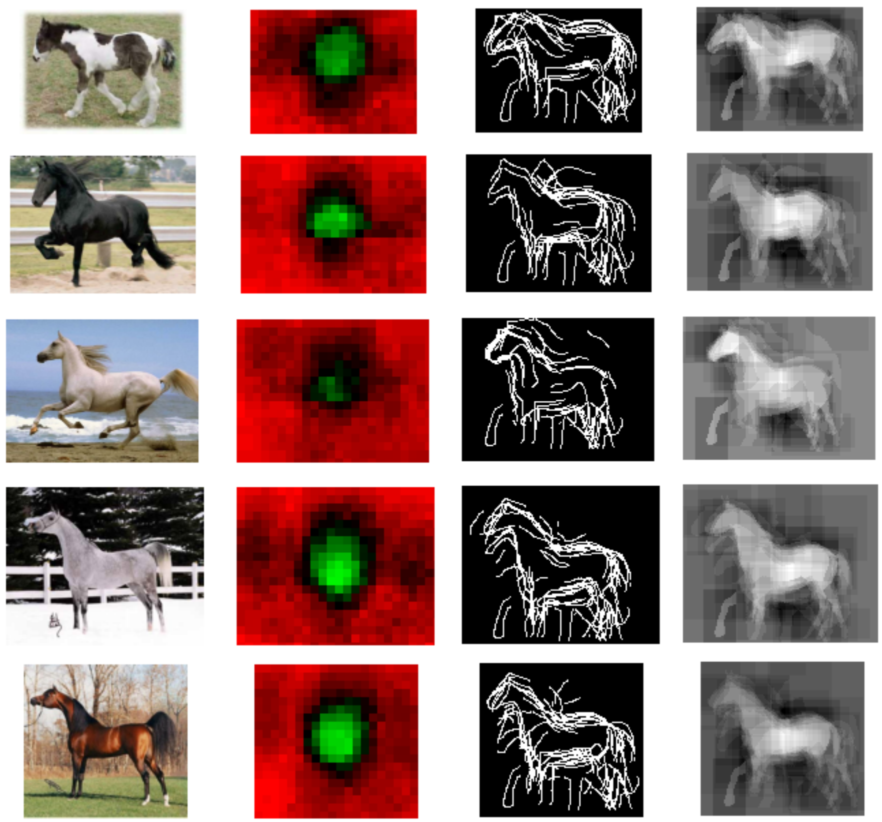
Learning and Adaptability



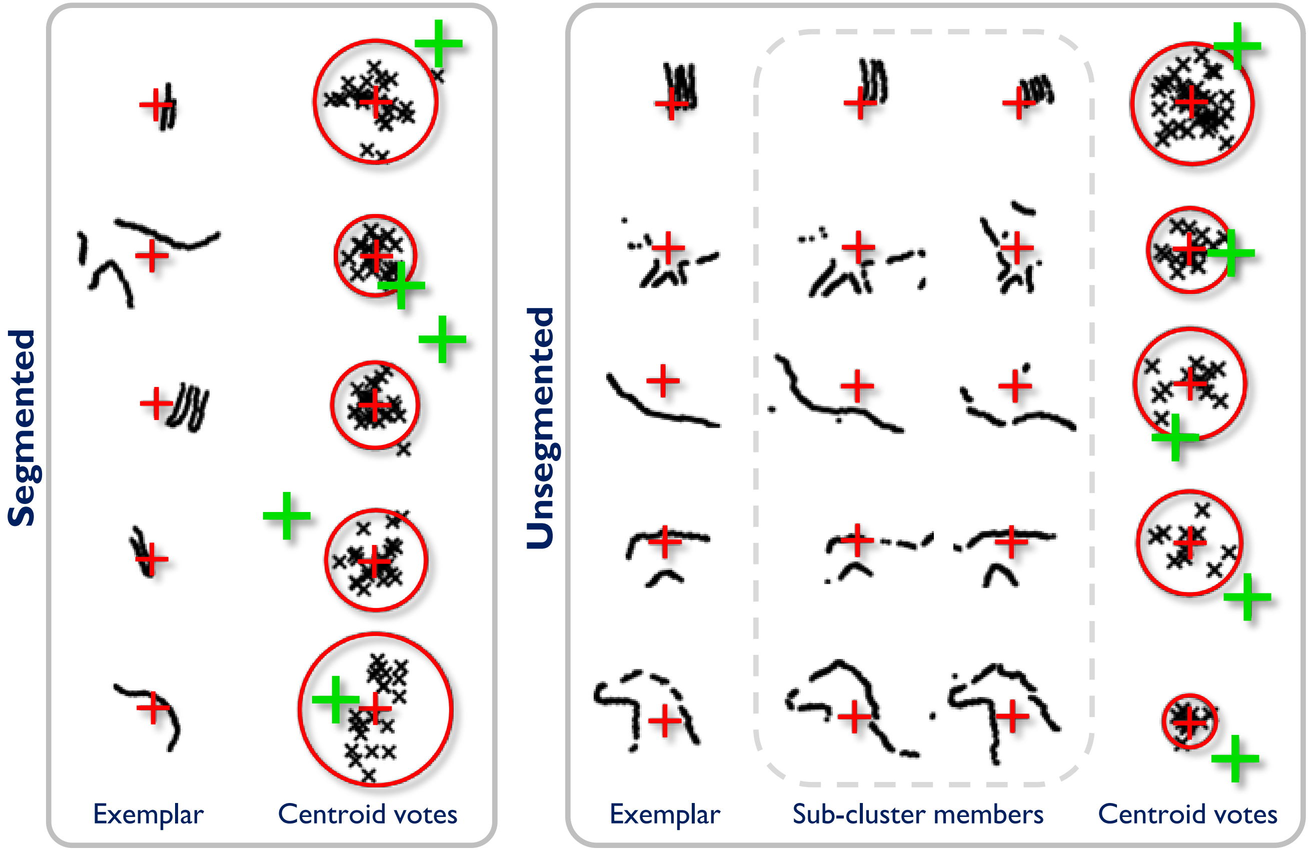


Object Model

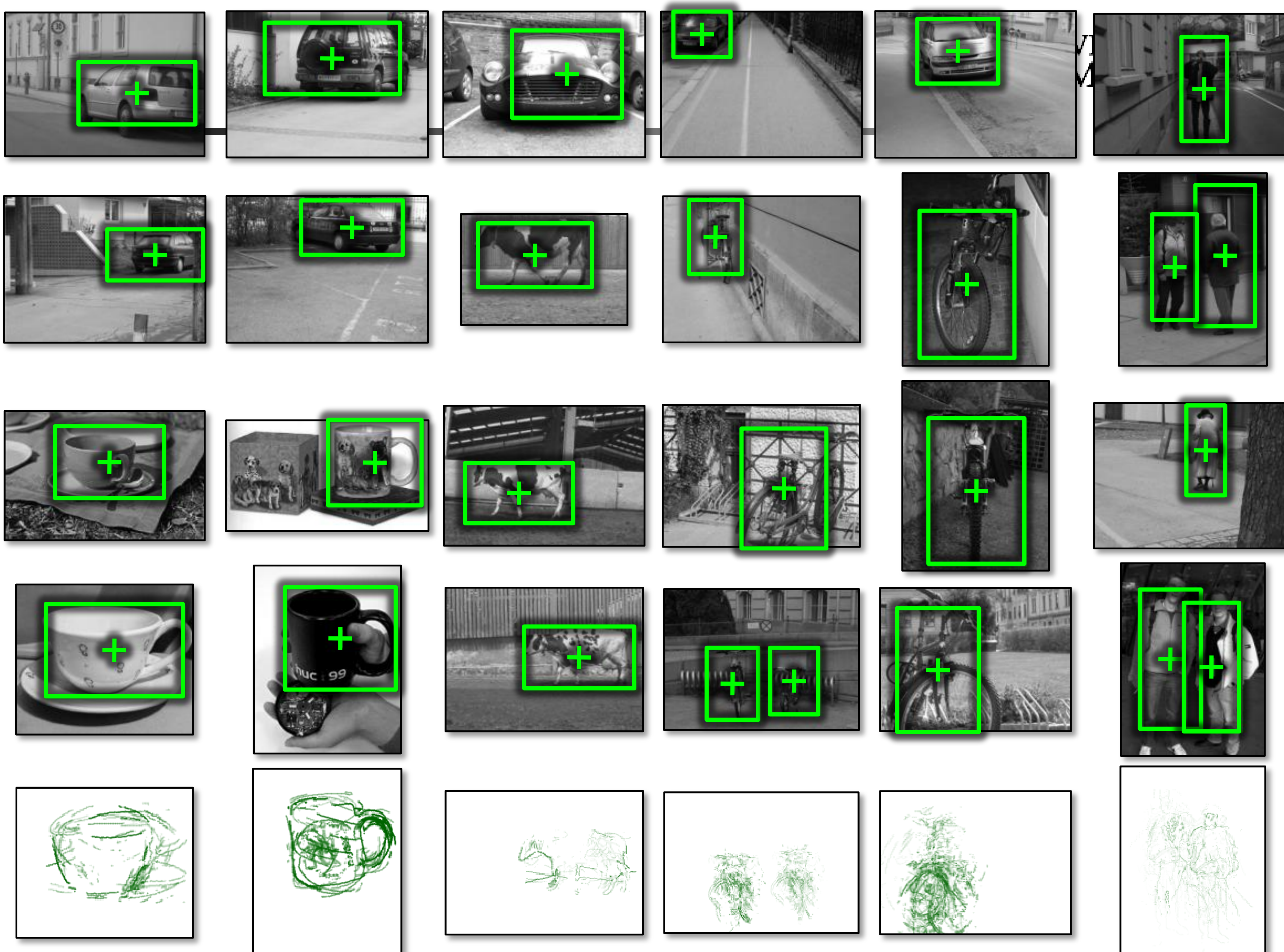




Shape



Segmented
Exemplar
Centroid votes
Unsegmented
Exemplar
Sub-cluster members
Centroid votes


huc 99

Recognition in video

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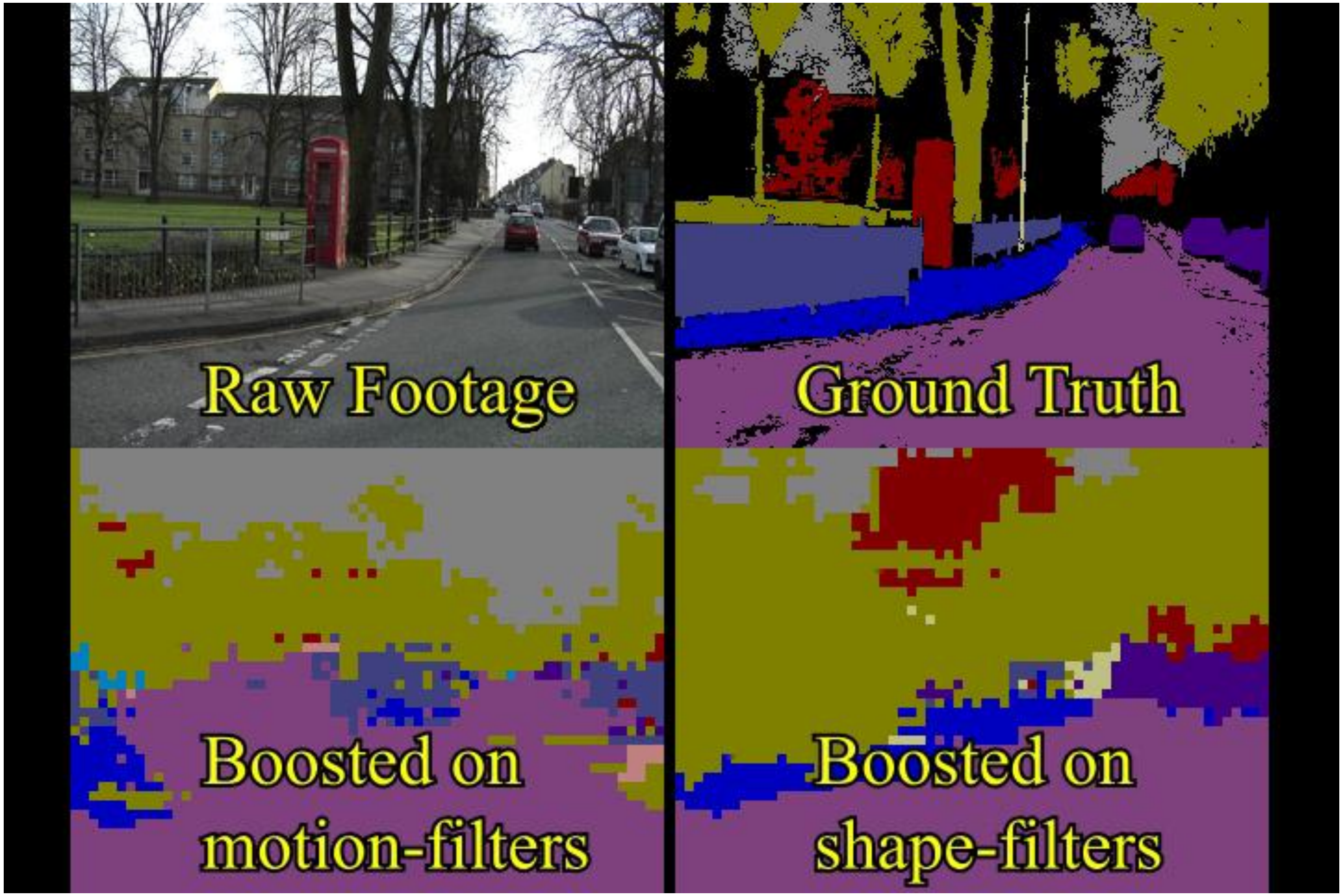

Making machines see

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- What is vision and how to duplicate it?
- 3D shape: making digital copies of sculpture from photographs from multiple viewpoints
- Recognition of a painting/picture from a single photo using a mobile (camera) phone
- Detection of objects: hands, faces and people and use in novel man-machine interfaces

Summary

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