Characterizing shapes and motions

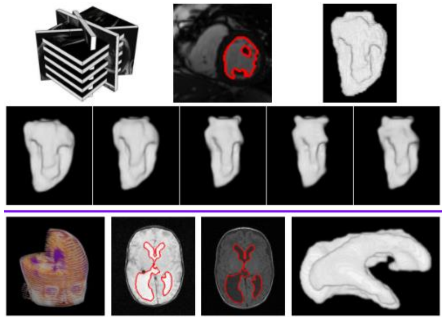
How can computer vision and deep learning help with astronomy image analysis?

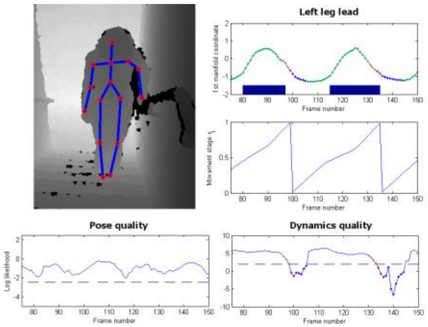
Adeline Paiement

Large scale visual data analysis

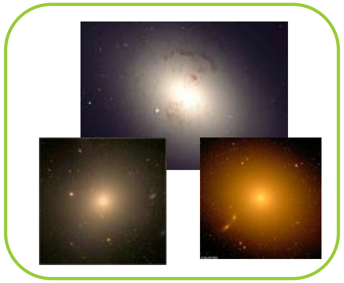
Computer vision, machine learning and deep learning

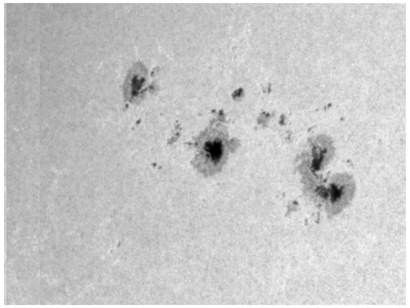
Healthcare applications
- Medical image analysis
- Looking at people and their activities
- Diagnosis & assistive technologies





Astrophysics applications
- Catalogue generation from grand surveys
- Detection, monitoring, and prediction of transient events and dynamic objects

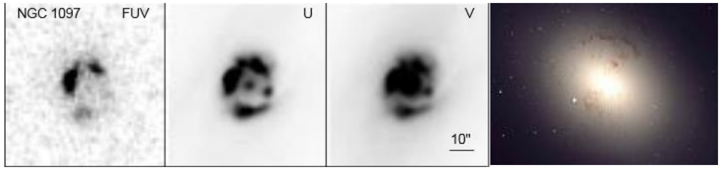


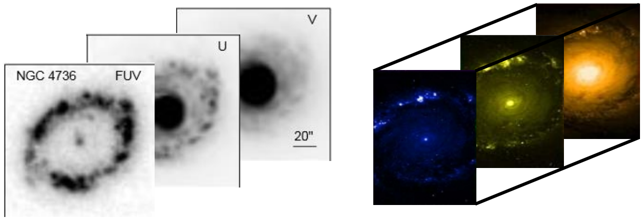


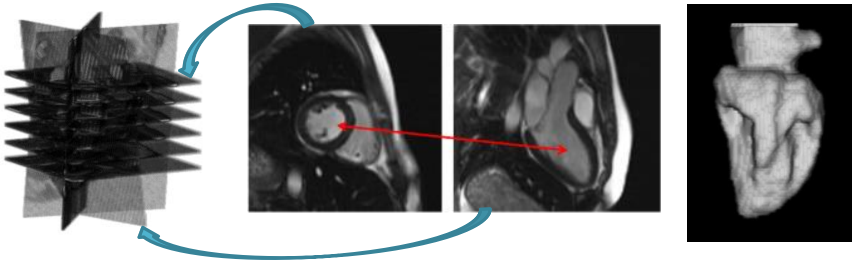
Similar tasks

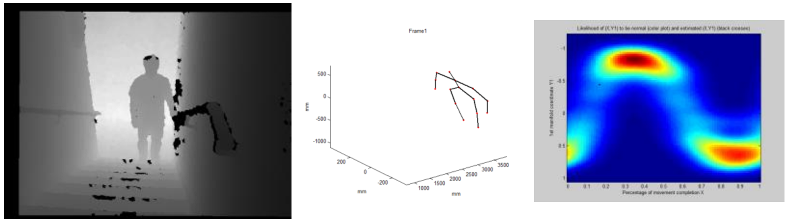
Characterising shapes

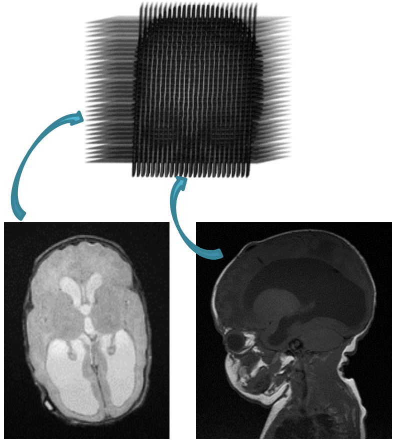
Characterising motions

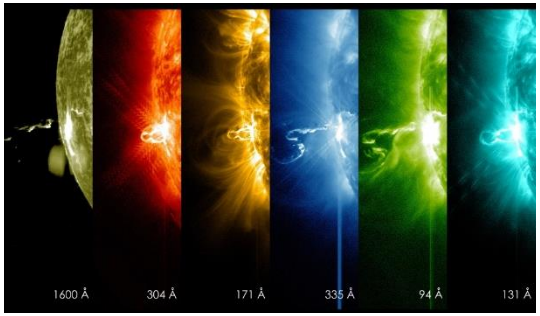


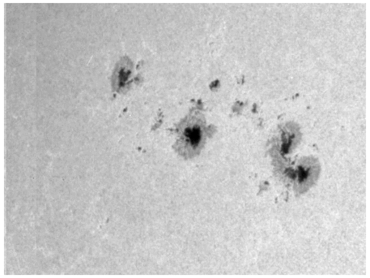








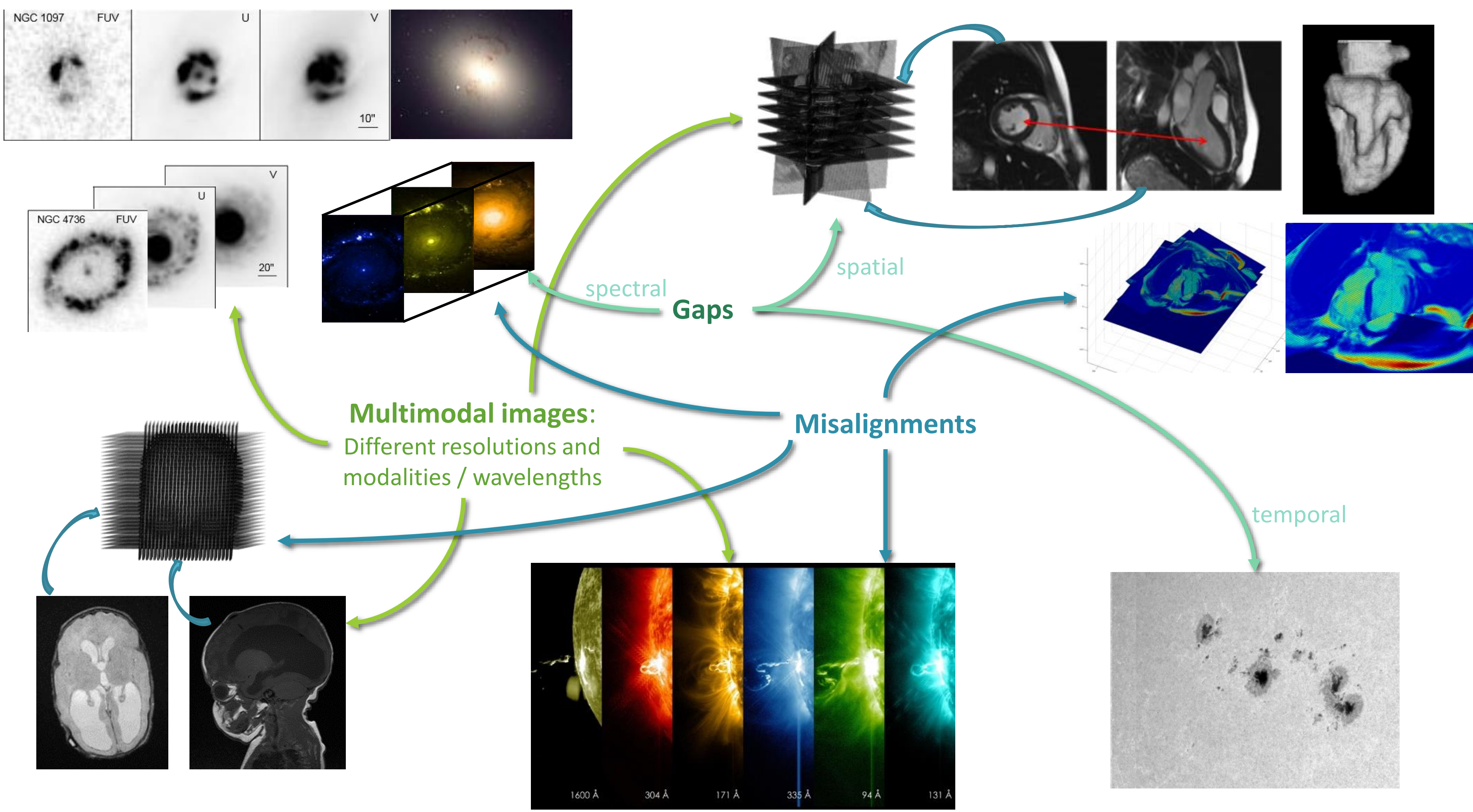




Similar challenges

Big data

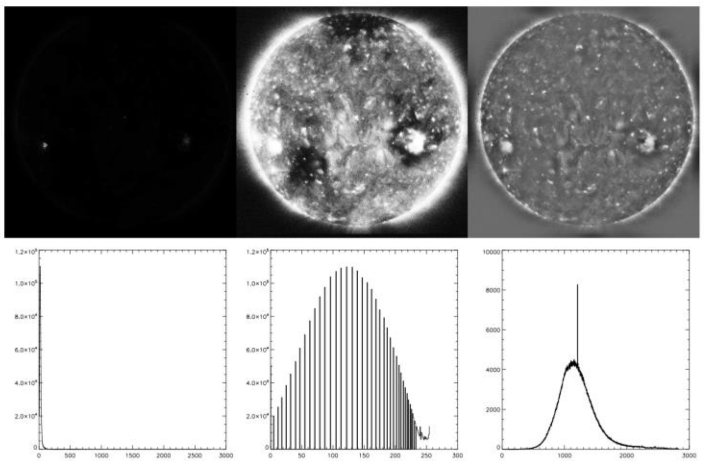
Interpretability



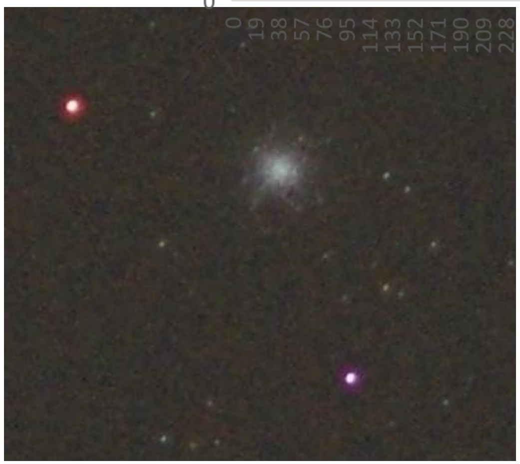
Scientific image properties

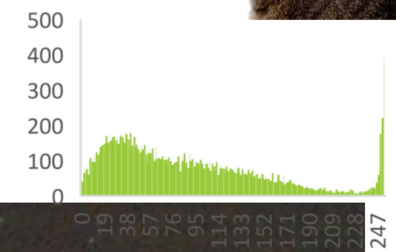
Scientific vs natural images

- High dynamic ranges, low contrasts

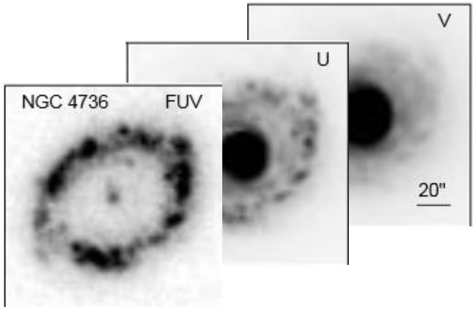


- Noise





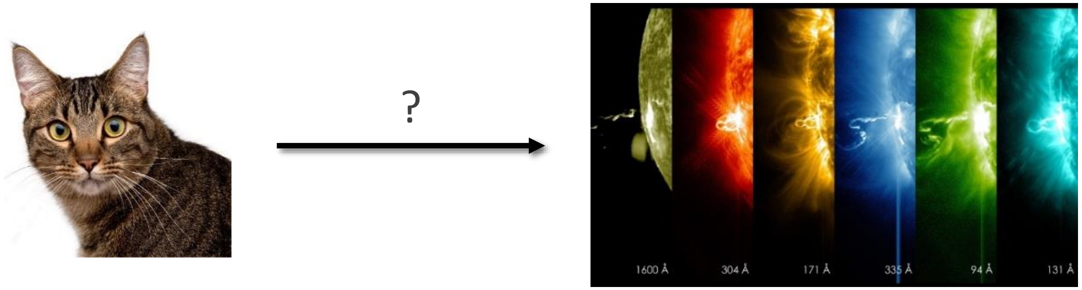
- Meaning of the intensity value



➢ Need specifically designed algorithms

Some more challenges

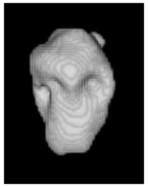
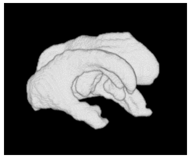
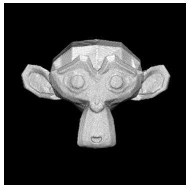
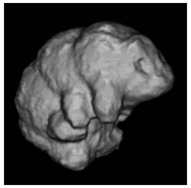
- Lack of ground-truth → semi-supervised learning, transfer learning
- *Can* we transfer learnt models?



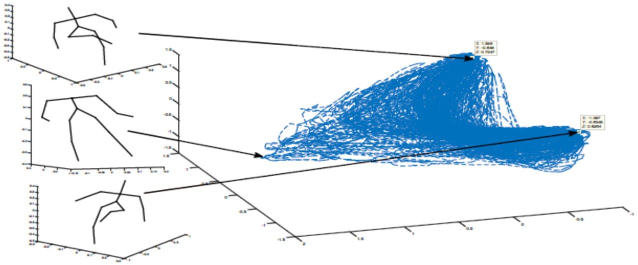
- *Meaning* of the systems and results?
  - Integrating **knowledge**
  - **Explaining** models and results

Overview: Characterising shapes and motions

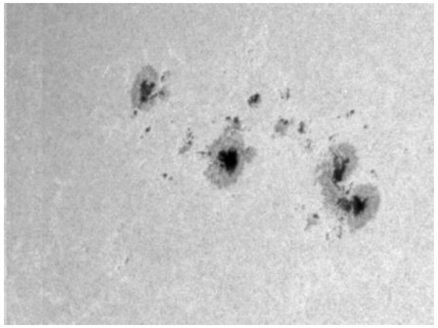
Shape reconstruction

Shape analysis

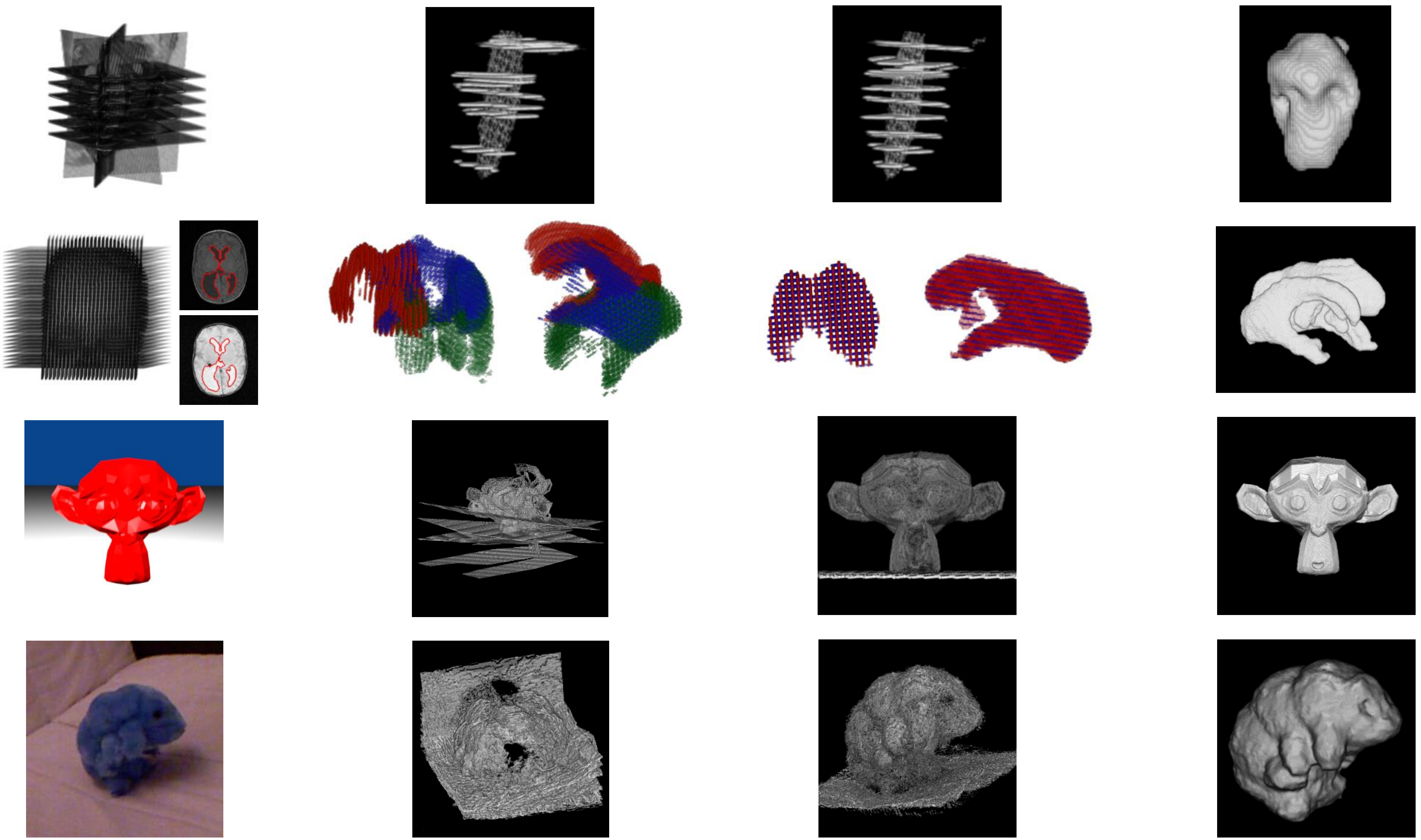


Motion analysis

IReSISD: shape modelling for multimodal data

Modelling from multimodal data with heterogeneous resolutions, misalignments, and gaps



[1] Adeline Paiement, Majid Mirmehdi, Xianghua Xie, Mark Hamilton: **Registration and Modeling from Spaced and Misaligned Image Volumes**. *IEEE Transactions on Image Processing*, Vol. 25, Issue 9, 2016

[2] Adeline Paiement, Majid Mirmehdi, Xianghua Xie, Mark Hamilton: **Integrated Segmentation and Interpolation of Sparse Data**. *IEEE Transactions on Image Processing*, Vol. 23, Issue 1, 2014

[3] Adeline Paiement, Majid Mirmehdi, Xianghua Xie, Mark Hamilton: **Simultaneous Level Set interpolation and segmentation of short- and long-axis MRI**. *MIUA*, pp. 267-272, 2010

IReSISD: shape modelling for multimodal data

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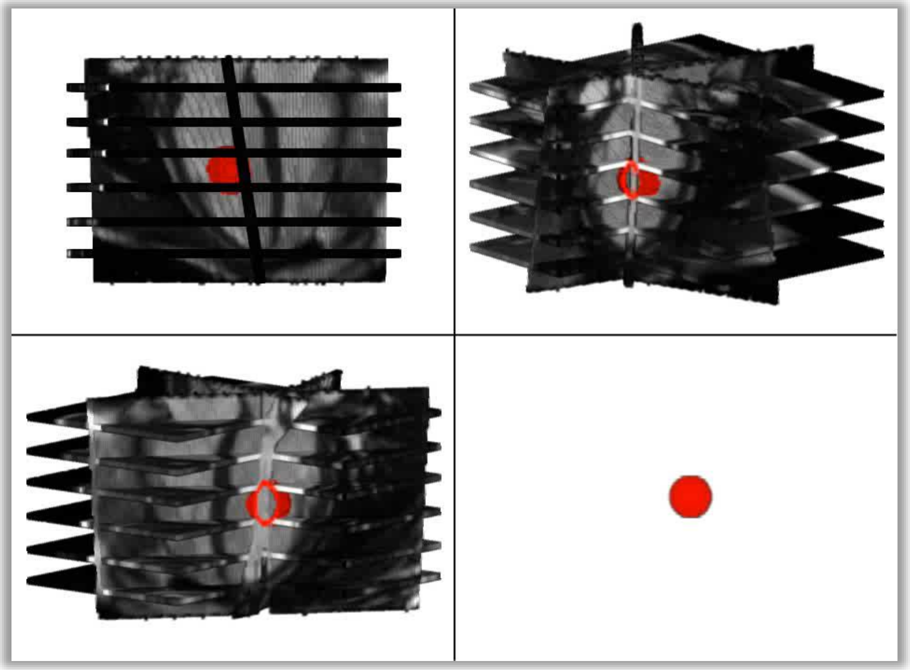

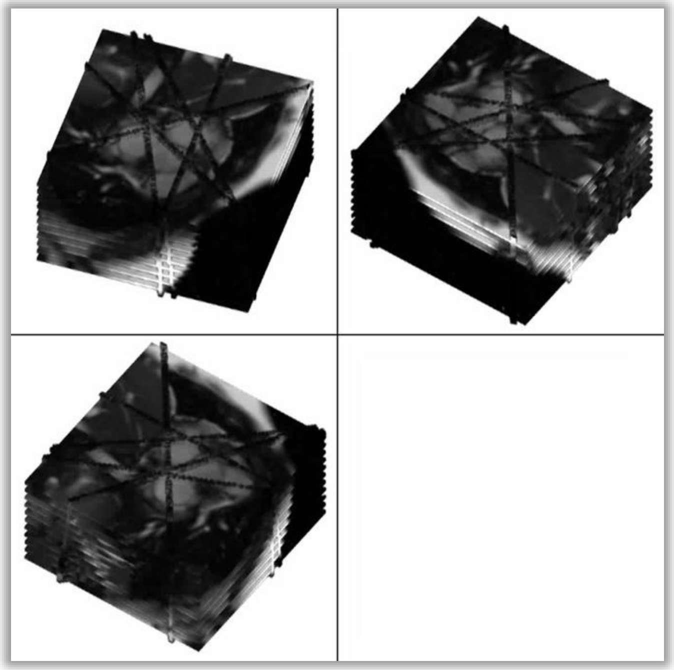

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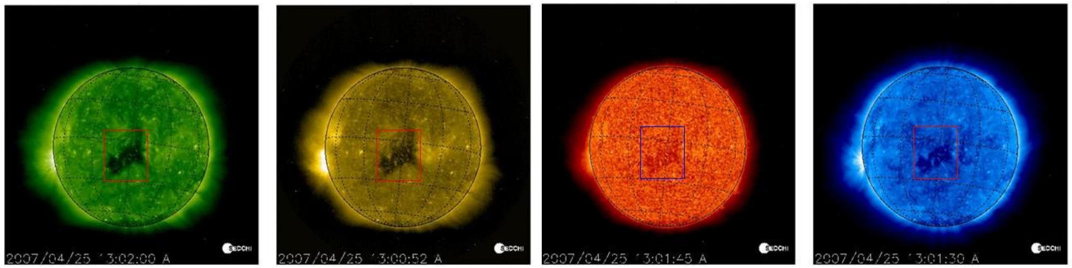
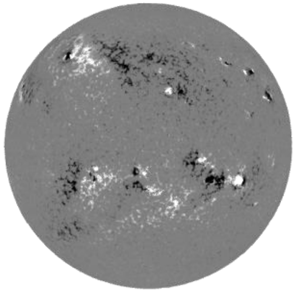
Some examples of application in astronomy

- Reconstruction of solar active regions from multispectral images





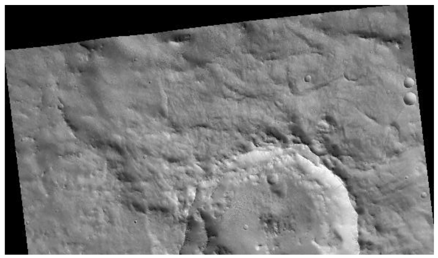
Goals:

- 3D/4D reconstruction of active regions
- Studying the mechanisms of solar activity
- Prediction of solar activity

Collaboration with Jean Aboudarham, Paris-Meudon Observatory

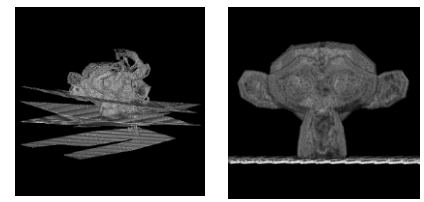
Some examples of application in astronomy

- Modelling of the Martian terrain from orbital multispectral images
  1. 3D point cloud: stereoscopic photometry

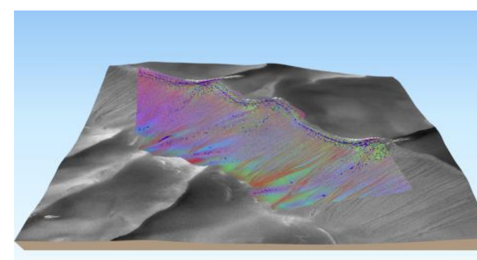


Stereoscopic photometry – [Wikipedia]

  2. Fusion of point clouds and modelling by IReSISD



  3. Deep learning-based segmentation of terrain types and unmixing of compositions



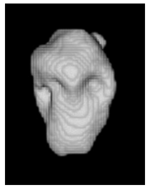
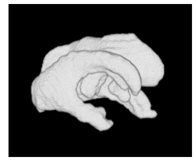
Goal:

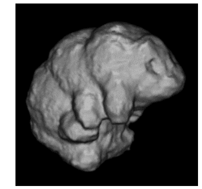
- Identification of typical and abnormal geological properties

Collaboration with Sylvain Douté, Institut de Planétologie et d'Astrophysique de Grenoble

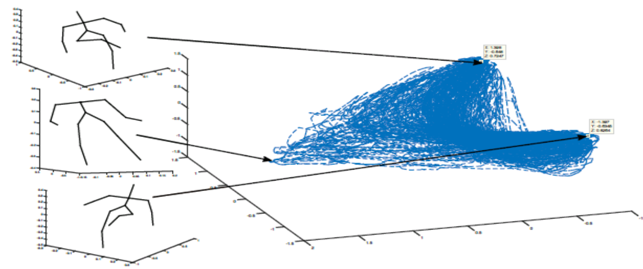
Overview: Characterising shapes and motions

Shape reconstruction

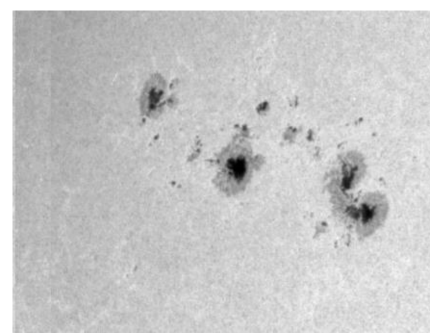





Shape analysis



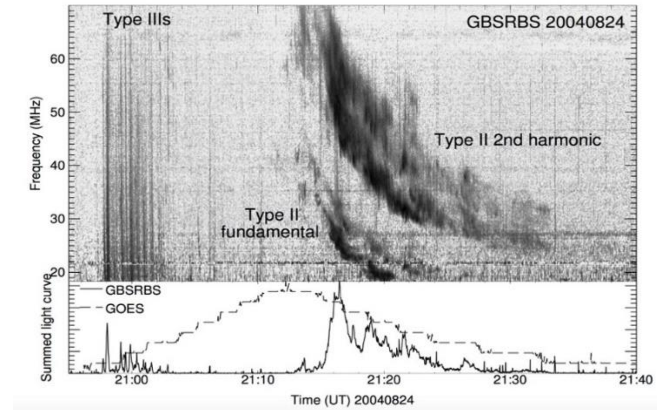
Motion analysis

Characterising shapes: solar radio bursts

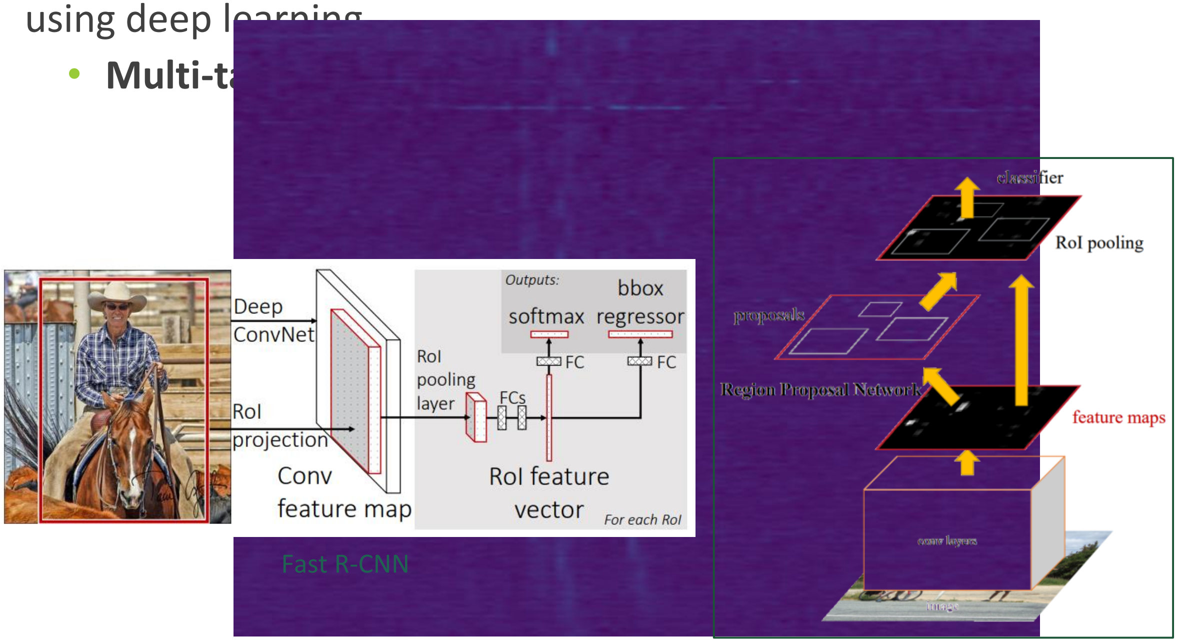
Joint solving of interdependent tasks

- **Detection**
- **Classification** (types II and III)
- **Regression** of properties (duration, decrease rate, harmonic)

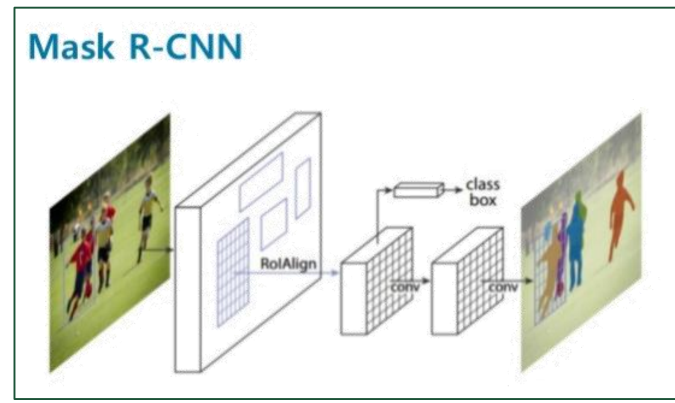


using deep learning

- **Multi-t**



Faster R-CNN

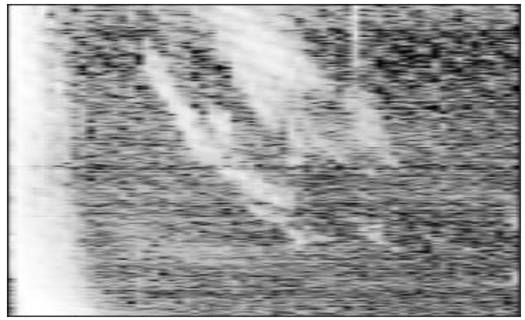


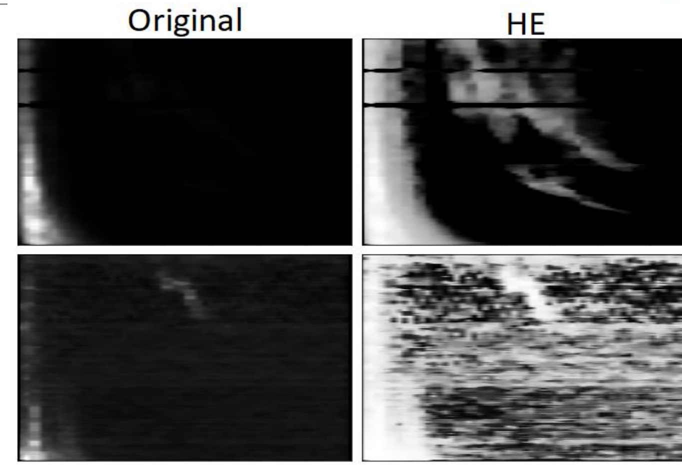
Collaboration with Jean Aboudarham, Paris-Meudon Observatory

Adapting deep learning models to spectrograms

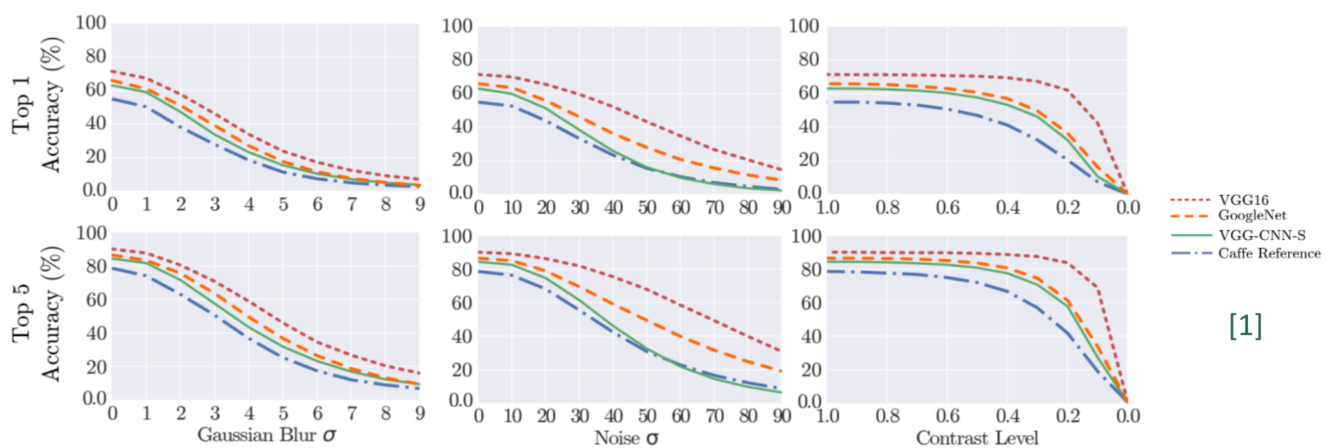
Challenges to transfer learning:

- Noise
- High dynamic range
- Low contrast





Classification results suffer from low image quality

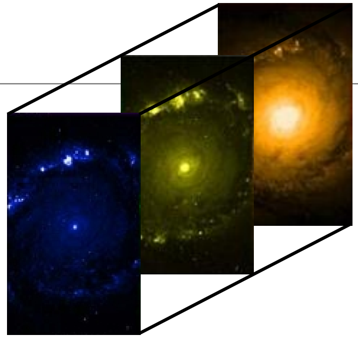


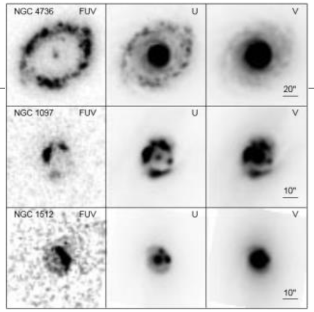
[1]

➢ Image enhancement? Adaptive transfer learning?

[1] Dodge and Karam: **Understanding How Image Quality Affects Deep Neural Networks**. In *Quality of Multimedia Experience (QoMEX)*, 2016

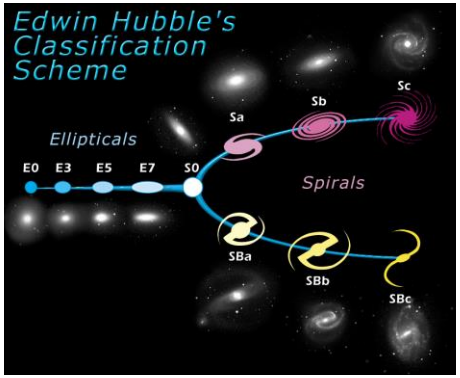
Galaxy morphology

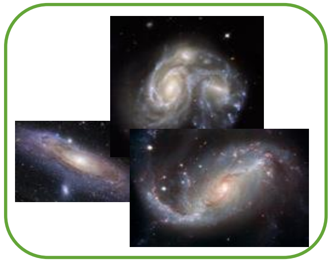


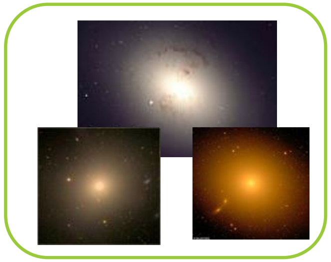


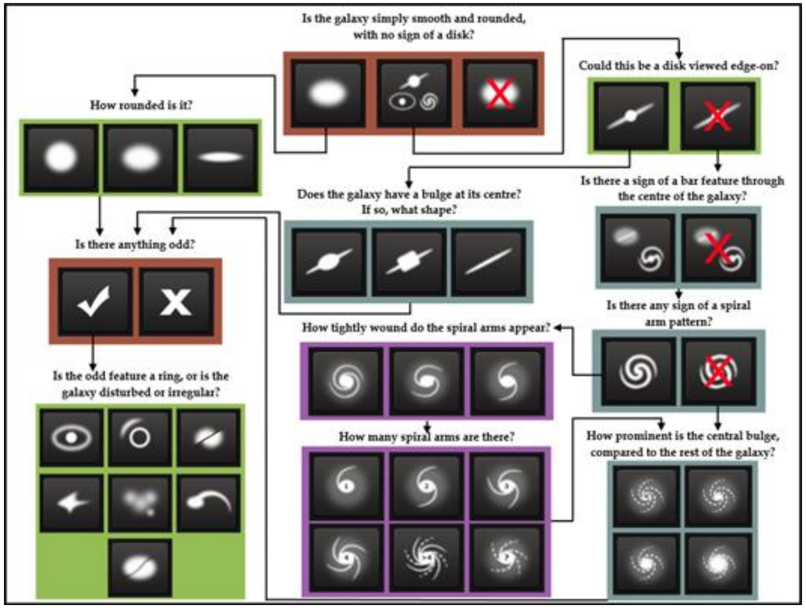
Joint solving of interdependent tasks:

- Classification of morphology types
- Regression of morphology parameters







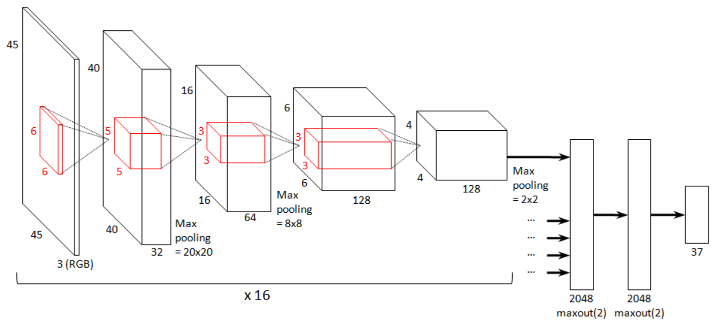


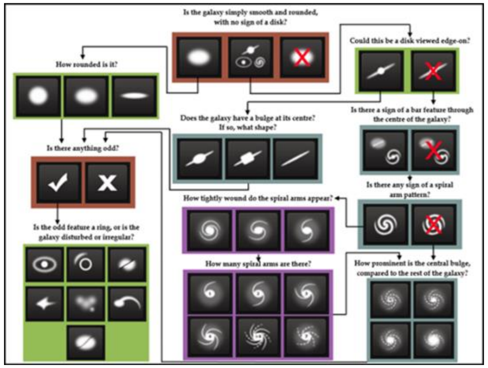
Galaxy Zoo model

Collaboration with Pierre-Alain Duc, Strasbourg Observatory

Structured analysis that integrates prior knowledge

- Multi-label classification task [1]
  - Rough estimation of numerical attributes
  - Does not account for relations between parameters

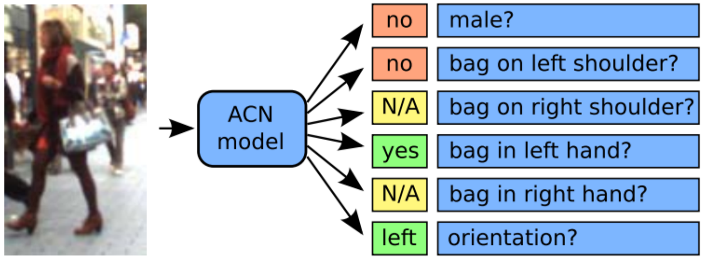




- Hierarchical loss function [2]

$$p(\mathrm{A},\mathrm{B}) = p(\mathrm{B|A}) \cdot p(\mathrm{A})$$

Visible Value Value term Visibility term

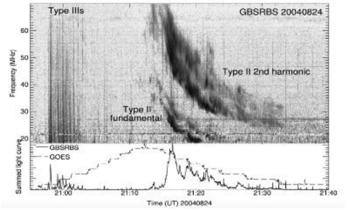


- Structured loss for galaxy morphology characterisation (on-going work)
  - Combines classification and regression
  - Deeper hierarchy, integrate knowledge of correlated attributes

[1] S. Dieleman: **My solution for the Galaxy Zoo challenge**, 5 April 2014. [Online]
[2] P. Sudowe, H. Spitzer, B. Leibe: **Person Attribute Recognition with a Jointly-Trained Holistic CNN Model**. ICCV-W, 2015

The question of representation

- Parametric representation
  - Radio burst: duration, decrease rate, thickness…



  - Galaxy morphology: number and angle of arms, size of bar…

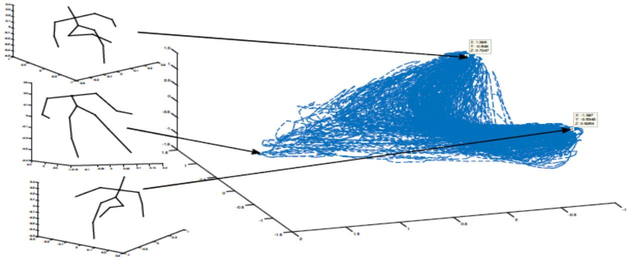
- Learned representation
  - Comets:

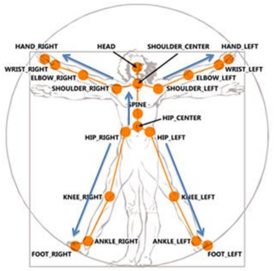
  Parametric representation hard to define

  - Body pose:

  Skeleton (e.g. Kinect) may be more complex than needed

Robust Diffusion Map Manifold

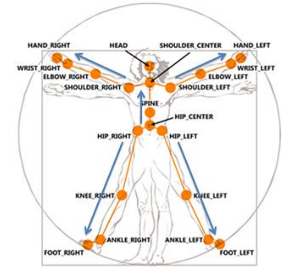




Kinect skeleton

The body poses of a (single) movement

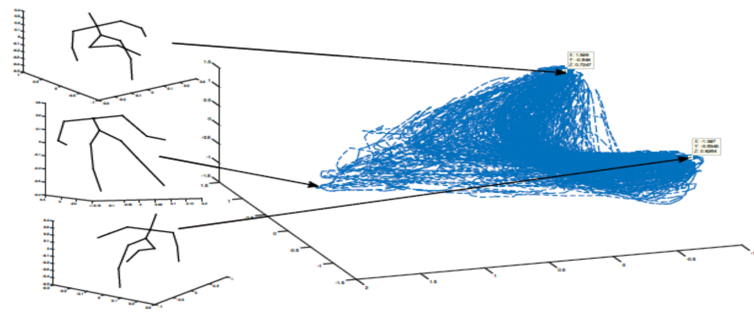
Skeleton representation: redundant and complex



Kinect skeleton

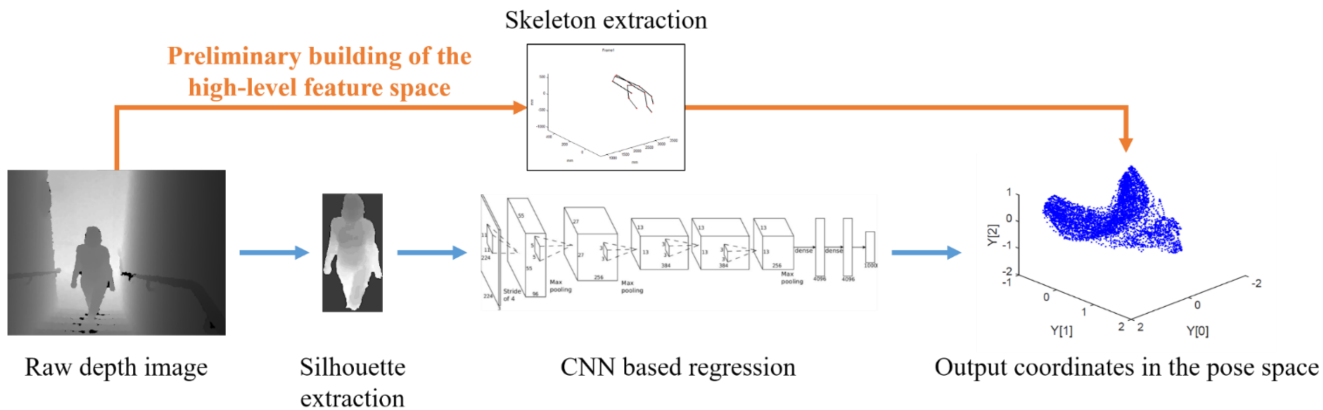
Manifold representation of body pose [1]:

- Capture relevant pose variations



Robust Diffusion Map Manifold

Using the manifold representation:



[1] A. Paiement, L. Tao, S. Hannuna, M. Camplani, D. Damen, M. Mirmehdi: **Online quality assessment of human movement from skeleton data**. *BMVC*, 2014
[2] B. Crabbe, A. Paiement, S. Hannuna, M. Mirmehdi: **Skeleton-free body pose estimation from depth images for movement analysis**. *ChaLearn Looking at People workshop at ICCV*, 2015

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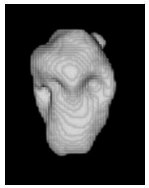
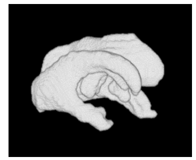
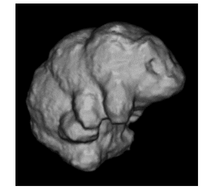
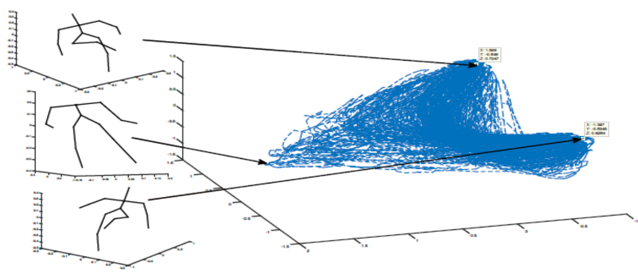
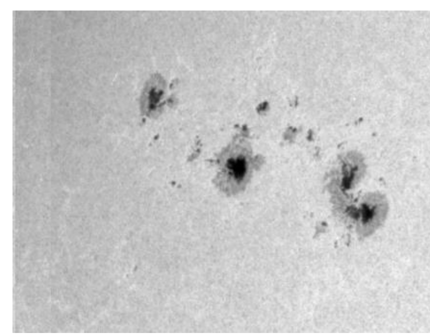





Shape analysis

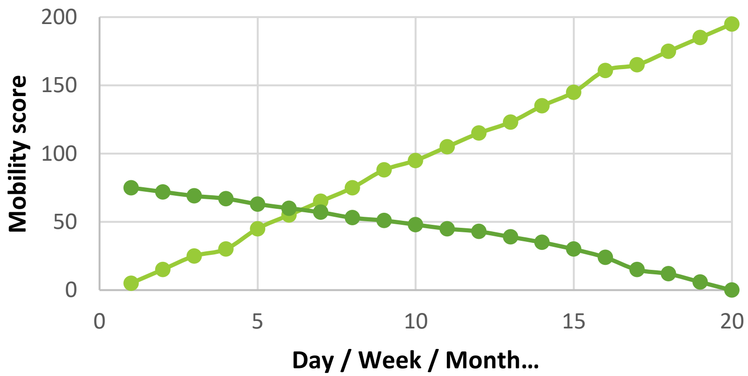


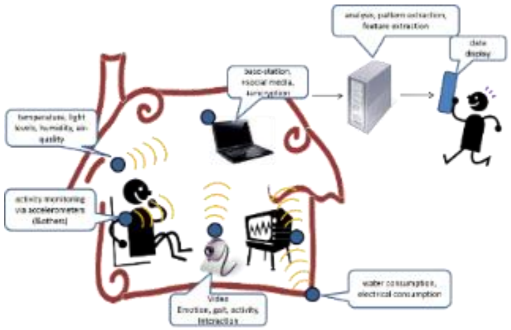
Motion analysis

Mobility assessment from Kinect data

Aim: Continuous **score** for movement quality

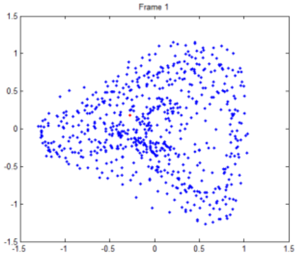




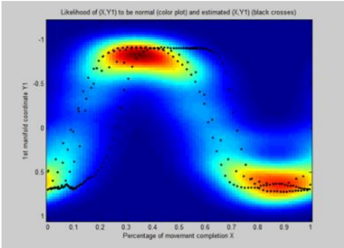
Quantifying deviations to a model of “normal” movement:

Kinect skeleton data

Pose representation



Statistical model of kinematics



Measure of kinematics’ quality

Statistical model of pose

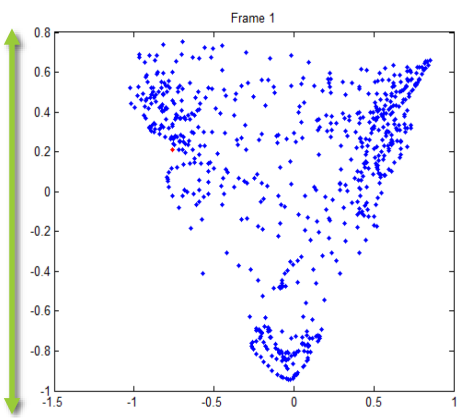
Measure of pose’s quality

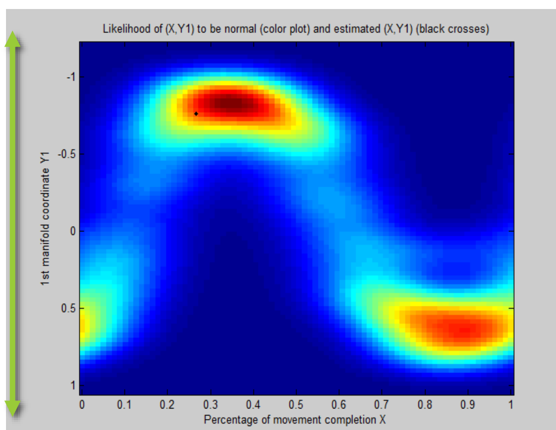
[1] A. Paiement, L. Tao, S. Hannuna, M. Camplani, D. Damen, M. Mirmehdi: **Online quality assessment of human movement from skeleton data**. *BMVC*, 2014

[2] L. Tao, A. Paiement, D. Damen, M. Mirmehdi, S. Hannuna, M. Camplani, T. Burghardt, I. Craddock: **A Comparative Study of Pose Representation and Dynamics Modelling for Online Motion Quality Assessment**. *Computer Vision and Image Understanding - SI: Assistive Computer Vision and Robotics*, Vol. 148, 2016

Mobility assessment from Kinect data

Example of normal movement:



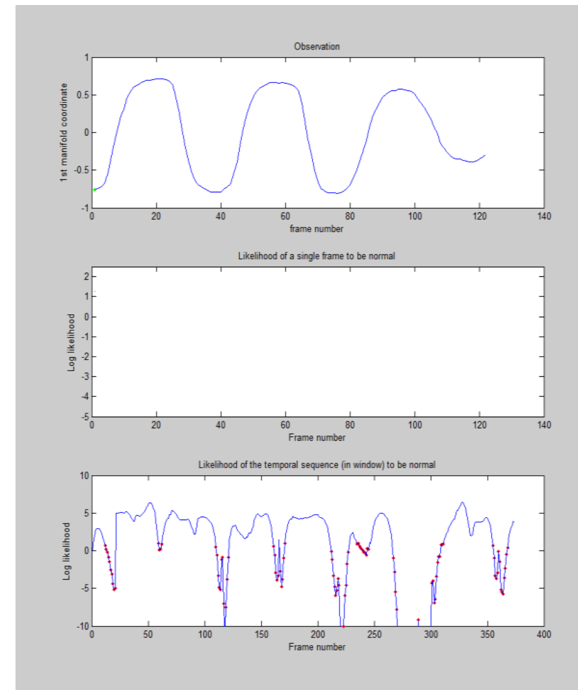


Hidden state **x**

First manifold coordinate

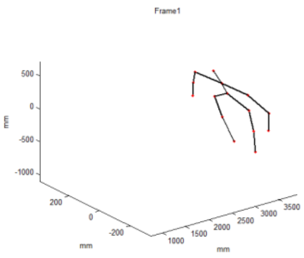
Pose score

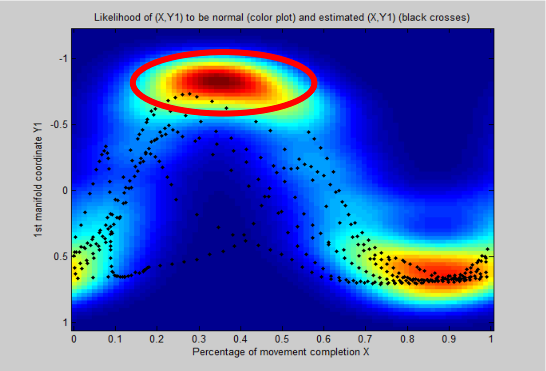
Kinematics score

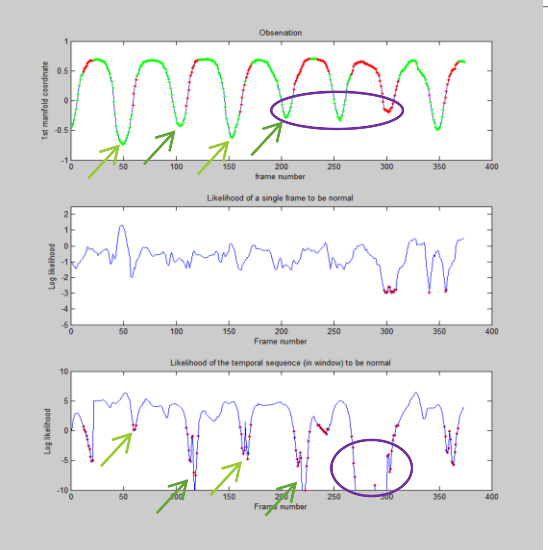


Some abnormal movements

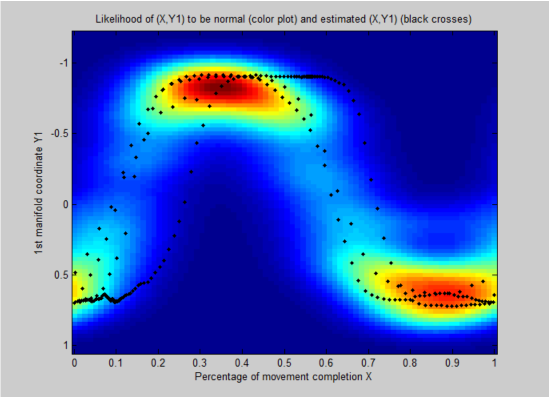
- Left leg lead

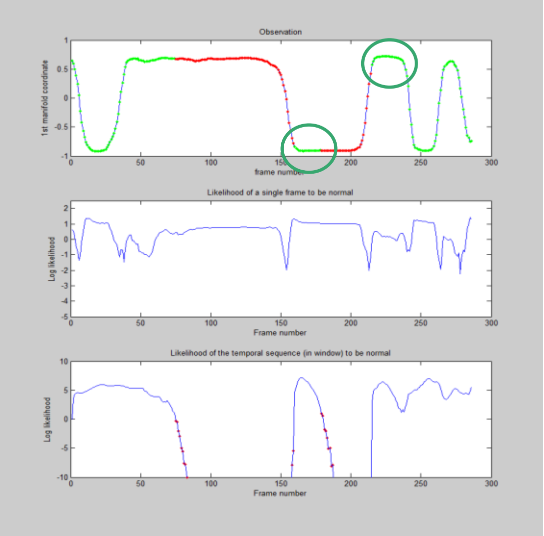






- Freeze

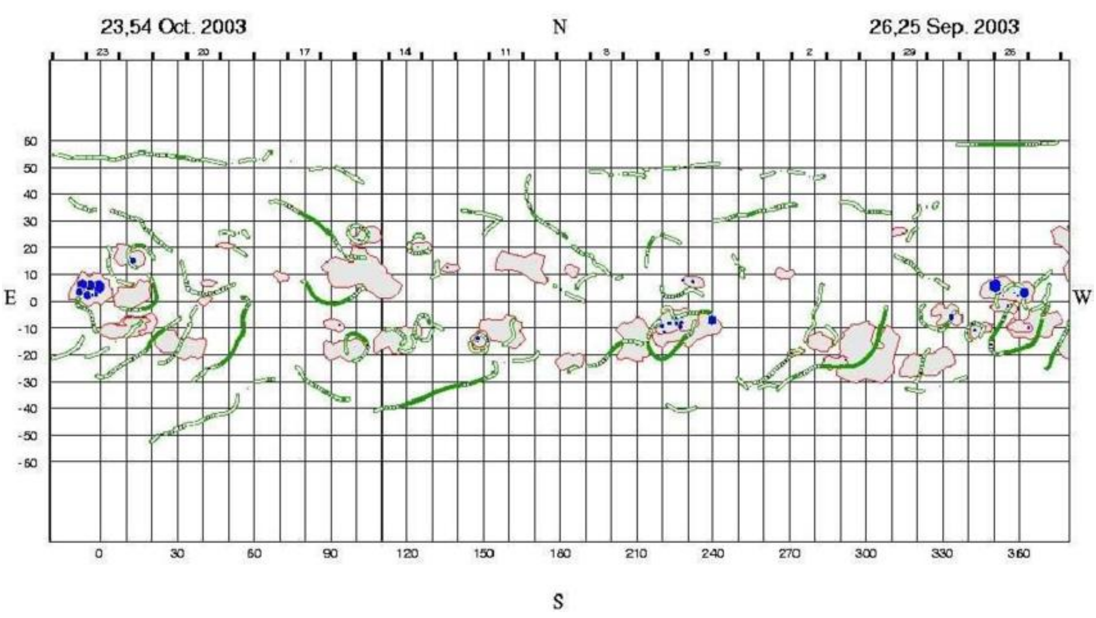


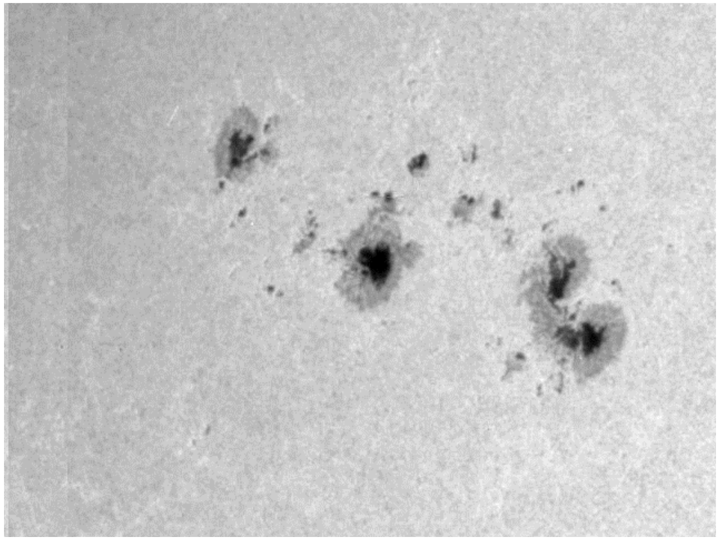


Other application of modelling motions

- Behaviours of solar features
  - Discovering families of behaviours?

ROTATION 2008

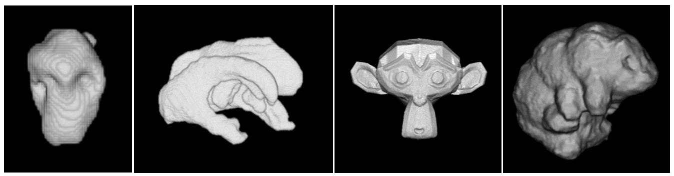
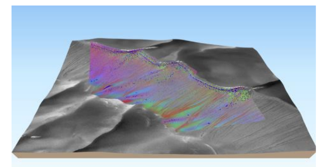
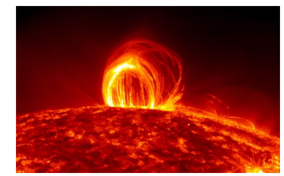




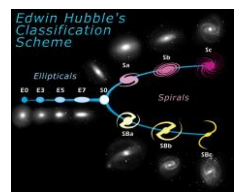
Quick summary

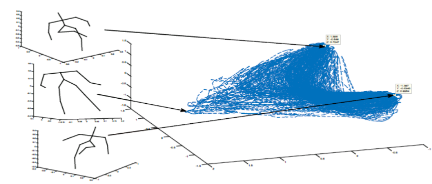
Characterising shapes and motions

Shape reconstruction

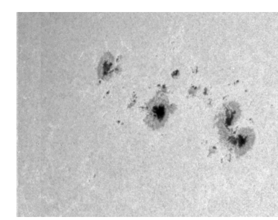
Shape analysis

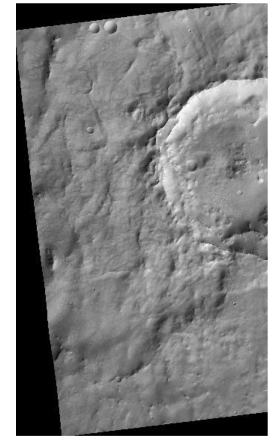



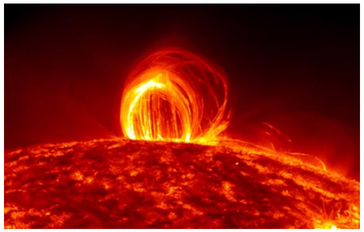


Motion analysis

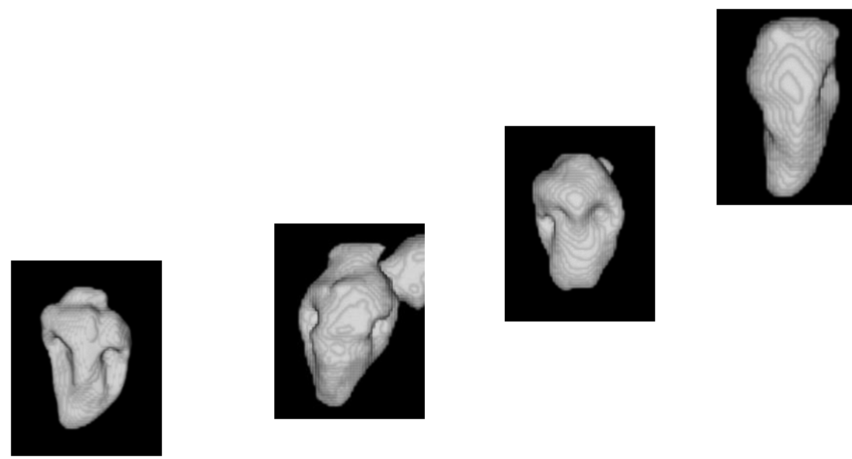








Thank you



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