UNCERTAINTY, VISIONS AND EVERYTHING

JOINT CCT DSERC AND ISERC MEETING

Dr Fabio Cuzzolin
Artificial Intelligence and Vision research group
OVERVIEW OF PROPOSED PROJECTS

- Project A: **Machine Learning for Recognition**
  - Online action detection and recognition -> Suman Saha
  - Human-Robot Interaction (with Nigel) -> 150th Scholarship
  - MAGNA collaboration (with Torr and Nigel)
  - Vehicle counting (with CA Traffic)
  - Semantic video browsing (with Oxford Uni)
  - AVATAR project (with Nigel and Malta University)
  - Gait analysis for dementia diagnosis (with Helen Dawes)
  - Towards guessing future intentions
OVERVIEW OF PROPOSED PROJECTS

- Project B: **Mathematics of Uncertainty**
  - Survey of 50 years of belief functions -> into Springer monograph + upcoming IJAR review papers
  - BELIEF 2014 and networking
  - The Total Belief Theorem
  - Exterior algebra/spinors and belief functions
  - Climate change predictions
  - Pose estimation using Belief Regression
  - Random Set Random Trees/Forests for multilabel classification
MACHINE LEARNING FOR RECOGNITION

IN ONLINE ACTION RECOGNITION, HUMAN-ROBOT INTERACTION, VIDEO BROWSING
ACTION RECOGNITION

RATIONALE

- Recognising the action(s) performed in a video
- Applications: video browsing, surveillance, automotive, human-robot interaction, medical ..
- From both traditional (RGB) and depth (Kinect-like) cameras
- It is a **classification problem**: need to train a classifier which produces the label of a new video, given the labels of training videos
- Typically batch (as in browsing) -> moving towards online
- New trend: **guessing future actions**
ONLINE ACTION LOCALISATION AND RECOGNITION
OUTLINE OF OUR APPROACH

Based on recent advances on convolutional neural networks for object recognition AND our own multi-year work on part-based, discriminative action recognition

1. we need to segment the video and localise the regions of interest to both
   • Boost recognition performance
   • Localise and detect (multiple) events/actions of interest
2. need to represent video regions in a discriminative way
3. Need to update the model online, frame by frame
ONLINE ACTION LOCALISATION AND RECOGNITION
STEP 1 – SEGMENTING EACH FRAME INTO REGION PROPOSALS

- Example: temporally consistent “superpixels”
- [http://www.mvdblive.org/seeds/](http://www.mvdblive.org/seeds/)
We need to efficiently associate region proposals in time, in order to generate “action tubes.”
Task: computing for each action tube a feature vector able to discriminate action categories

To encode appearance we use Convolutional Neural Networks

Achieved state of the art on ImageNet classification tests
(http://www.cs.toronto.edu/~fritz/absps/imagenet.pdf)

Output is a feature vector, each output neuron scoring a class

A lot of exciting work here, cutting edge
HUMAN-ROBOT INTERACTION
VIA GESTURE RECOGNITION FROM DEPTH CAMERAS

- Using the in-built Kinect for online gesture recognition
- Real-time demo prepared by Rocco and Luis
- [http://homes.di.unimi.it/cesa-bianchi/Pubblicazioni/bmvc_final.pdf](http://homes.di.unimi.it/cesa-bianchi/Pubblicazioni/bmvc_final.pdf)
- Ongoing, robot interaction still to implement
LEVERHULME AVATAR PROPOSAL
EMOTION RECOGNITION FOR THE CREATION OF ROBOTIC SURROGATES

- Emotion are recognised via EEG sensors..
- (data from U Malta)

- New form of telepresence and assisted living for the disabled
  - Based on novel multilinear classifiers we are developing
  - Need to get results from Malta’s collected data

- .. and sent to a robot who can then express them via facial expression and body poses
Early diagnosis of dementia signs is difficult

Another challenge is the discrimination of different types of conditions (PD, Alzheimer)

.. and the continuous monitoring of disease progression

With Prof Helen Dawes we proposed a machine learning pathway to dementia diagnosis and monitoring

- Based on both analysing smartphone’s accelerometer recordings while people go about their daily activities, and in-lab gait measures of people with conditions

Former EPSRC submission, ongoing project, papers and proposals to write
Semantic Video Browsing
Combining Probabilistic Ontologies with Part-based Discriminative Models

- complex Google video queries deliver mostly irrelevant results
- develop a novel class of search engines, able to:
  - automatically (without human intervention) extract semantic content from videos (e.g., what happens in the video, who is involved and where), and:
  - use this content for semantic video search and querying

- Leverhulme full proposal
- With Oxford’s T Lukasiewicz
- Dataset, efficient coding
**Vehicle Class Counting**

**A KTP in the Making with CA Traffic**

- Agencies and councils need stats on the number of vehicles of each class passing on a certain road.
- That can be done via cameras mounted under overpasses.
- CA Traffic has developed new pairs of IR/RGB cameras to cope with various weather conditions.

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**Vehicle Specifications**

- **12. Gigaliner:** A road train with a length of max 25.25 m and a gross weight of max. 80 tonnes. There are several configurations of a road train as illustrated to the right.
  
  - MVT type 1, truck-dolly-semi-trailer (60 tonnes)
  - MVT type 2, truck-semi-trailer-cart (60 tonnes)
  - MVT type 3, truck-link-trailer-semi-trailer (60 tonnes)
  - MVT type 4, truck-trailer (48 tonnes)

- **13. Special purpose road motor vehicle:** A road motor vehicle designed for purposes other than carriage of passengers or goods. It includes e.g., bulldozers, tankers, fire brigade vehicles, and mobile cranes. No differentiation is made between the different types of special purpose road motor vehicles.

**Table 1: Specification of Vehicle Classes**

<table>
<thead>
<tr>
<th>Vehicle Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gigaliner</td>
<td>A road train with a length of max 25.25 m and a gross weight of max. 80 tonnes.</td>
</tr>
</tbody>
</table>
POTENTIAL COLLABORATION WITH MAGNA
ON FULL BODY COCKPIT MONITORING AND OUTDOOR SCENE UNDERSTANDING

- Focused on developing smart sensors for this car component company, for:
  - Outdoor scene understanding
  - In-cockpit monitoring
  - New datasets to collect
  - A lot of coding to do
**Towards Guessing Future Actions**

**Guessing Intentions**

- In the automotive scenario it is crucial to guess future intention of pedestrians. A pedestrian is approaching a zebra crossing: what is their likely future behaviour?
- Very few papers have appeared on the subject so far
- **Next step in action recognition!**
THE MATHEMATICS OF UNCERTAINTY
IN REAL-WORLD PROBLEMS
BELIEF FUNCTIONS
AS GENERALISED PROBABILITIES

- Probabilities do not represent well ignorance and lack of data.
- Evidence is normally limited, rather than infinite as assumed by probability.
  Sometimes expert knowledge needs to be combined with hard evidence.
- In extreme cases (rare events or far-future predictions) very little data.
- Belief functions proposed by Dempster and Shafer in late Sixties.
- Idea: evidence is typically available in support of events/propositions directly, and can be translated into a distribution over all events (a random set).
- Can be fused by Dempster’s rule, a generalisation of Bayes’ rule.

![Diagram of belief functions and belief masses](image)
**Belief 2014**

Networking to expand the community

- Chaired the 3rd International Conference on Belief Functions last September

- Still a lot of work to do:
  - Expanding the community via a [moderated mailing list](#)
  - Organising special issues on IJAR and IEEE Fuzzy Systems
  - Linking up with wider AI, UAI and FUSION conferences
  - Targeting real-world problems (CC, policy making)
**The Geometry of Uncertainty**
*Treating Uncertainty Measures as Geometric Entities*

- Belief functions can be seen as a point of a simplex
- Probabilities are part of the border of this simplex
- Possibility and fuzzy measures too -> unified geometric approach to uncertainty
- Problems can be approaches there:
  - Conditioning belief functions (IEEE TFS to revise)
  - Decision making with belief functions (AIJ to revise)
  - **Lots of open problems**
UPCOMING SURVEY PAPERS ON 50 YEARS OF BF
THEORY AND APPLICATIONS

Papers invited by IJAR’s editor in chief, a lot of work to do to compile references and abstracts of thousands of papers.
THE TOTAL BELIEF THEOREM
COMPLETING THE THEORY OF BELIEF FUNCTIONS

- Given an a-priori belief function.. $b_0 : 2^\Omega \rightarrow [0, 1]$
- ..and a set of conditional functions .. $\omega_i$
- .. find the total belief function(s) meeting these constraints

$\Pi_i = \rho(\{\omega_i\})$

- $\rho$
- $\Theta$
- $\Omega$

Fundamental methodological contribution
BELIEF MODELLING REGRESSION
FOR EXAMPLE-BASED POSE ESTIMATION

- IEEE Transaction on Fuzzy Systems paper to revise
MODELING CLIMATIC CHANGE IN THE FRAMEWORK OF THE THEORY OF BELIEF FUNCTIONS

- Possible collaboration with Oxford’s Jim Hall, lots of work to do
In many classification problems, items are denoted by more than one label. Example: when browsing for images one wants to use more than one label to describe them. Computational requirements are very strict -> random forest are fast and effective. However, need to split nodes according to entropy of sets of label values. Belief decision trees. Interest from Microsoft Research India on this topic.