COSIPRA Lab:
An Introduction

UNIVERSITY OF STIRLING

Presentation Outline

- Introduction to COSIPRA Lab at Stirling University
  - Overview of COSIPRA Lab Projects

- Effective Clinical Risk Assessment Using Ontology Driven and Machine Learning Approach

Presentation - Overview

- Overview of University
- Overview of Department:
    - Research Groups: CI, C&S, CARET
    - Commercial Exploitation & Technology transfer

- Overview of COSIPRA Lab Projects

Presentation - Overview

THE SUNDAY TIMES
Scottish University of the Year
2009/2010

- Overview of University
- Overview of Department:
    - ☐ Research Groups: CI, C&S, CARET
    - ☐ Commercial Exploitation & Technology transfer

- Overview of COSIPRA Lab Projects

Stirling University - Overview

THE SUNDAY TIMES
Scottish University of the Year
— 2009/2010 —

- Medium-sized (10,000+ students), Campus-based University – located in 310 acres of stunning countryside!
- Stirling is proud of its diverse international community, with over 80 countries represented on campus
- Named **Scottish University of the Year 2009/10** by the Sunday Times newspaper, in recognition of the University's "outstanding student experience and record for **innovation** & high quality teaching"
- Ranked 32 in the Sunday Times University League Table 2009
- Aim to shape & improve life in Scotland & the world through our research

In the Research Success Rankings (Research Fortnight, 2006/07) Stirling was ranked 1st in Scotland and 9th in UK based on the ratio of applications to awards.

Chi

Computing Science Dept - Overview

- Department of Computing Science at Stirling (with 20 academic staff) currently holds over £3m in external research grants
- There are 3 Main **'inter-disciplinary'** Research Groups in the Dept
  - ☐ Computational Intelligence (CI)
  - ☐ (Tele)Communications & Services (C&S)
  - ☐ Care Technologies (CARET)

- The primary 'intelligent and cognitive signal and image processing' areas are within the CI group, including:
  - ☐ Speech & Natural Language processing (including multimodal SP)
  - ☐ Neural signal processing / Neuroinformatics
  - ☐ Machine Learning for challenging real-world applications
  - ☐ Theoretical, computational & practical aspects of ISIP techniques
- There is also SP related work in CARET and C&S, as well as in development of a commercial USB board for signal input to Linux systems

USB-DUX
www.linux-usb-daq.com

CI Research Group - Overview

Senior Staff:

- Leslie Smith, Personal Chair (Head of CI Group)
- Amir Hussain, Professor Personal Chair (Head of COSIPRA Lab – 12 PhD Students ,4 Post Docs and Research Fellows)
- Tariq Durrani, Honorary Professor, IEEE President Elect 2014 (Co-Head of COSIPRA)

Aims:

- To develop better (more intelligent) computational techniques and systems through incorporating biologically based, naturally occurring and cognitive signal and image processing techniques
- To improve understanding of neural systems by modelling them both in software and in hardware

CI Techniques:

- CI covers biologically inspired, natural and cognitive signal and image processing, as well as modern optimization techniques such as genetic algorithms, particle swarm optimization & self-organizing multi-agent systems.

CI Group - Application Areas - I

- **Assistive Technology & Telecomms Services**
  - ☐ Multi-modal signal processing, multi-lingual (including Arabic) ASRs & natural multi-modal HCIs

- **Neuroinformatics**
  - ☐ Signal processing for neurophysiological signals

- **Intelligent Control for Autonomous Systems**
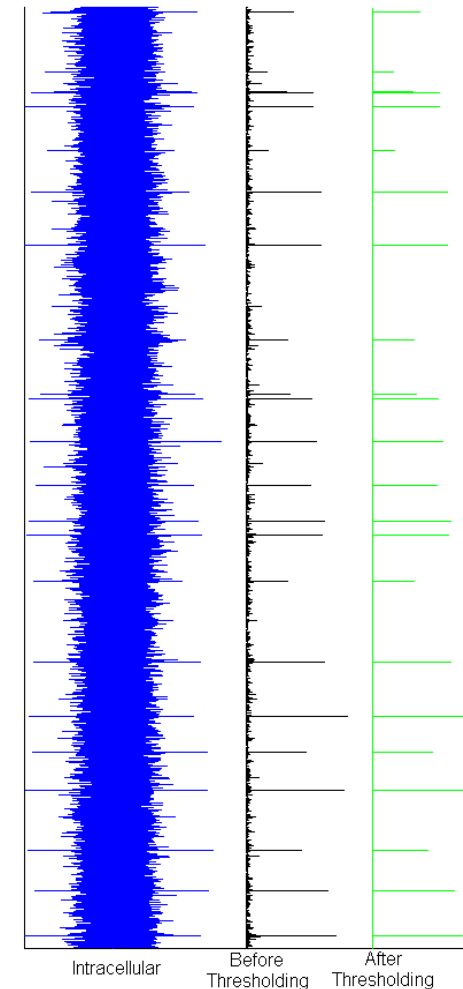 - ☐ e.g. driving tasks for autonomous vehicle control

- **Aquaculture**
  - ☐ e.g. aquatic parasite discrimination (to prevent disease spread)

- **Data/Semantic Web Mining & Optimisation**
  - ☐ Treatment Schedules & time intervention
  - ☐ (Bi)clustering in health/cancer care

- **Hardware** (intelligent DSP and FPGA implementations)

Intracellular   Before Thresholding   After Thresholding

CI Group - Application Areas - II

- **Intelligent Decision Support**
  - □ Clinical decision support systems for primary (e.g. cardiovascular) care
  - □ Analysis/Differential diagnosis of breast cancer, dementia etc.
  - □ Business decision support in financial & telecommunications industries
- **Mobile (Tele)communications**
  - □ mobile location determination, blind equalization, co-channel interference suppression, smart antenna arrays, self-organization in mobile & P2P networks
- **Modelling of biological systems**
  - □ Models of the immune system; Agent based modeling & simulation of self-organizing systems e.g. tumour growth, HIV, disease spread etc.
- **Community support systems** (CI to support field work in archaeology..)
- **Looking for new application areas through NLPR-CASIA collaboration!**
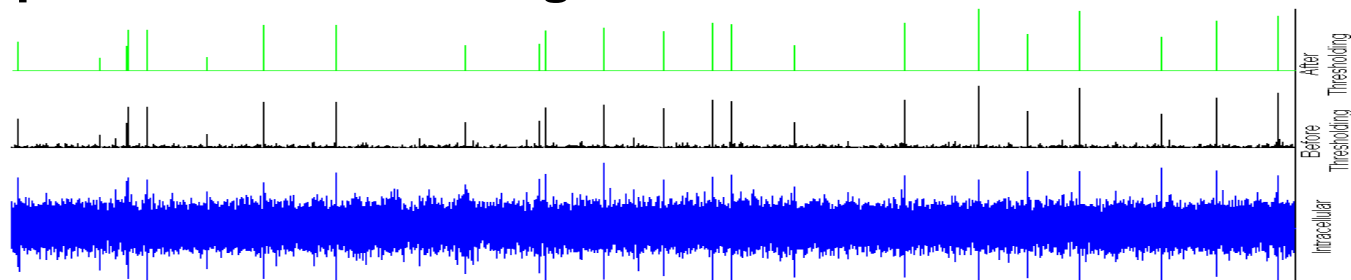
CI Group – Example Current Projects

☐ CARMEN (Code analysis, repository & modeling for e-Neuroscience) - large ~£4.5m EPSRC e-Science project involving 11 Universities

☐ European Research Network ~£400k (Stirling Principal Investigator (PI) Hussain) on advanced speech and natural language processing, including cognitive multi-modal signal processing – funded by European Science Foundation

☐ Semantic Web Mining and Decision Support for e-Healthcare (PI: Hussain) - 2 EPSRC & industry funded PhD projects (~£170k) **joint with Sitekit Labs, MIT Media Lab & Harvard Medical School**

☐ Immunology Imaging & Modeling: New Signal Image Processing based Models & Applications–funded by BBSRC (Stirling PI: Hussain)

☐ NEW: Cognitive Control of Complex Autonomous Systems (Stirling PI: Hussain, ~£350k) joint with Sheffield,ISC & SciSys Ltd, EPSRC funded (2011-14)

CI - funding, collaborations and papers

- The CI group is funded primarily by UK research councils, EU & industry
- Work in conjunction with other larger Scottish University Depts.
  - □ Electronics and Electrical Engineering (EEE) at Glasgow & Edinburgh
  - □ Cambridge, Sheffield & Strathclyde's EEE & Industrial Control Centre
- Papers are **regularly published** in a wide range of **top journals** including:
  - □ **IEEE Transactions** on: Neural Networks, on Acoustics, Speech and Signal Processing, Biomedical Engineering, Communications
  - □ (**Elsevier**) Neural Networks, Neurocomputing, Neuroscience, Physiology
  - □ (**MIT**) Neural Computation, (**Springer**) Computational Neuroscience
  - □ **IEE/IET** Proceedings & Electronics Letters etc.
- **Hussain: founding general co-Chair** of biennial Intern.Conf.Series: Brain Inspired Cognitive Systems (**BICS**'04,06,08,10, with **forthcoming IEEE SSCI 2014 in Florida, Orlando, US** http://ieee-ssci.org/.

CI Group – Journal & Book Editing Examples

- Hussain: founding **Editor-in-Chief of "Cognitive Computation" journal (Springer, NY, USA) - www.springer.com/12551**

- Hussain: Associate Editor for several journals including the IEEE Transactions on Neural Networks (one of world's top 10 journals in EEE) & Robotics & Automation

- Hussain: Guest Editor for 12 Special Issues of international journals

Book Editing Examples:

- Hussain,Smith,Aleksander et al."*Biologically Inspired Cognitive Systems*" Springer"Adv. in Experimental Medicine & Biol."Series,Vol.657,310p,2009

- Cutsuridis, Hussain, Taylor (Eds.) "*Perception-Action Cycle",* Springer "Cognitive and Neural Systems" Series, Vol.1, in press, 2010

- Chetouani, Hussain, et al. "*Advances in Non-linear Speech Processing*", LNCS (Springer), Vol.4885, 24 ch., 281p, 2007

Commercial Exploitation & Technology Transfer

The Dept actively promotes commercial exploitation & technology transfer using Stirling University Research & Enterprise (SURE) Office

The Dept has two Knowledge Transfer Partnership (KTP) funded projects, one with Think Analytics Ltd. and another with SysNet Ltd.

Two EPSRC funded industrial PhD projects (£170k) (PI: Hussain) in:
cognitive signal processing for semantic web mining - co-funded by Sitekit Labs & joint with MIT Media Lab (USA)– 2009-12

cognitive decision support for primary (e)healthcare - co-funded by Sitekit Labs & joint with MIT & Harvard (USA)- 2010-13

Hussain is IEEE (UK & Ireland) Chapter Chair of Industry Applications Society which aims to exploit industrial applications of EEE
Two CI members are directors of a spin-out technology transfer company (ITL) - wholly owned by the University

Overview of COSIPRA Lab Projects

People:

Professor Amir Hussain (Head)
Professor Tariq Durrani, IEEE President Elect 2014 (co-Head)

Post-doctoral & PhD Researchers (14):
Hicham Attassi, Thomas Mazzocco, Rozniza Ali, Andrew Abel, Kamran Farooq, Liaquat Ali, Omair Albakistani, Summrina Wajad, Usman Zakir, Muhammad Ilyas, David Vidal, Zeeshan Malik,Saliha Minhas, Hani Alharbi

Collaborators:
Academic: MIT Media Lab, Harvard Medical School, Sheffield, Strathclyde, Chinese Academy of Sciences, Brno University of Technology, Anhui University, University of Windsor, National University of Singapore
Industry: Sitekit Labs, Industrial Systems Control, SciSys Ltd.

Overview of COSIPRA Lab Projects

Key Research Areas:

Area 1: Cognitive Agent based Modelling and Simulation of Self-Organizing Complex Systems

Area 2: Intelligent Signal Processing for Communications Applications

Area 3: Cognitive Modeling & Control of Complex Autonomous Systems

Area 4: Multimodal Signal Processing (CMSP) for Next Generation Communications & Assistive Technology

Area 5: Cognitive Signal Image Processing for Real-world Applications

Area 6: **Cognitive Signal Processing for Intelligent healthcare Applications-FOCUS OF THIS PRESENTATION – next**!

Overview of COSIPRA Lab Projects

Area #1: Cognitive Agent based Modeling and Simulation of Self-Organizing Complex Systems

- Formal agent based modeling and simulation framework to better model and simulate self-organizing complex adaptive systems in a range of domains, including wireless and ad hoc networks (Niazi & Hussain, IEEE Comms Mag. 2009)
- Recently, a formal Agent based framework has been used for developing a simulation model for wireless sensor networks for monitoring complex adaptive environments
    - Case Study: used a boids model of self-organized flocking of animals monitored by a random deployment of proximity sensors (IEEE Sensors Jour. 2010)
- Current work is focussing on demonstrating the application of the agent based modeling&simulation framework in a range of domains
    - Including for modeling and sensing of different types of physical and virtual complex adaptive environments & complex networks such as Citation Networks, Biological Networks (including cancer tumour growth & disease spread) and Fault-Sensing in Distributed Systems.

..

Overview of COSIPRA Lab Projects

Area #2: Intelligent Signal Processing for Communications Applications

Topic: "Novel Machine Learning Techniques for Multi-Target Tracking in Challenging Environments"

Aims two-fold:

High resolution detection & localization of multiple (non-stationary moving) targets (with time-varying DoAs)

Broadband signal separation

These technologies are essential in communications systems, e.g. SDMA schemes for terrestrial & satellite mobile communication systems. Other applications of direction finding include smart antennas & telemetry..

Area #2: Intelligent Signal Processing for Communications Applications
Proposed Multiple-Target Tracking Framework
(Hussain & Durrani)
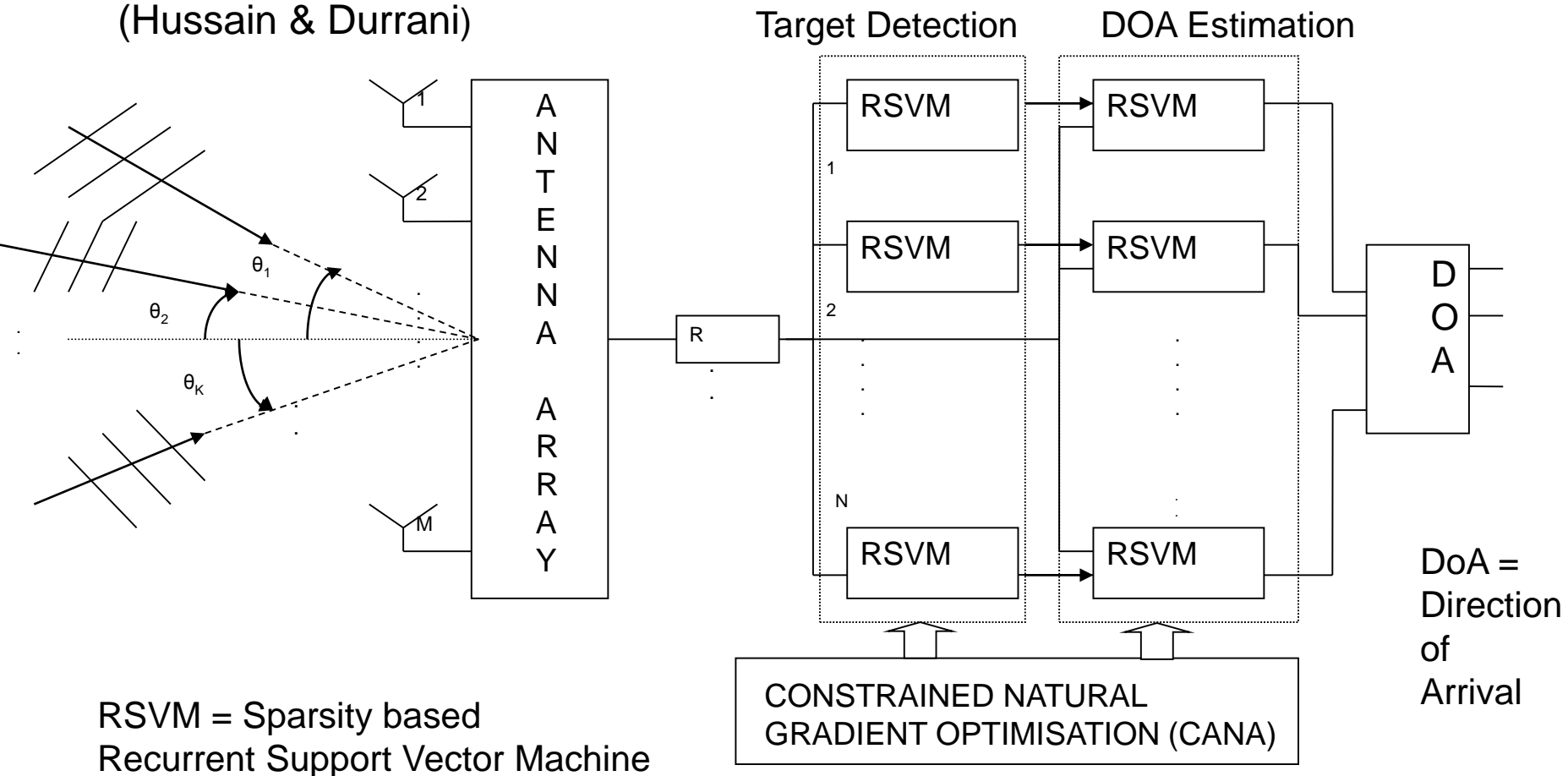
RSVM = Sparsity based
Recurrent Support Vector Machine

DoA = Direction of Arrival

Area #2: Intelligent Signal Processing for Communications Applications

Topic: "Novel Machine Learning Techniques for Multi-Target Tracking in Challenging Environments"

Aim to overcome some key limitations of existing approaches e.g[1]
by exploiting generalization, real-time learning & fault-tolerance capabilities of Recurrent SVM[2] that is further optimised using CANA[3]

The receiving antenna field of view is spatially sectored
dramatic reduction in the training set
detection & DoA estimation to within an arbitrary angular resolution
no requirement for a priori knowledge of the number of targets
can locate targets that are greater in no. than array/sensor elements

Comparative performance assessment with measured radar data
including challenging low-angle tracking radar environments

[1]Zooghby & Christodoulou, IEEE TAP'00
[2]Olivier & Hussain, SPWC'03; [3]Shah & Durrani, EUSIPCO'09

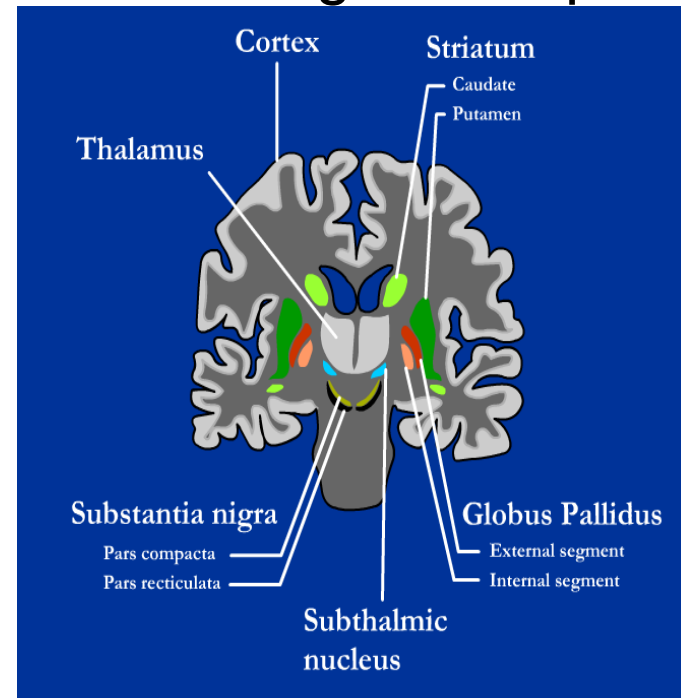# Area #3: Cognitive Modeling & Control of Complex Autonomous Systems

Topic: Exploiting links between neuroscience, psychology and engineering/machine learning to build more intelligent adaptive controllers for autonomous vehicles

Collaborators: K. Gurney (Sheffield),K.Warwick (Strathclyde) & Industrial Control

Systems Ltd. & SciSys Ltd.

Funded by UK EPSRC (Erfu Yang (Post Doc, 2011-14)

Approach:

- Review neuroscience of habit vs. goal-driven
- Explore utility of Brain's central switch: Basal (action) selection properties
- Explore commonalities with & inform future engineering/machine learning based
- approaches for autonomous vehicle control
- (AVC)

Area #3: Cognitive Modeling & Control of Complex Autonomous Systems

Autonomous vehicle control (AVC)

(Abdullah, Hussain, Warwick et al., (Elsevier) Neurocomputing'2008)

- Smart cars
  - ☐ Follow the leader, Overtake
  - ☐ Avoid obstacles
  - ☐ Automated Highway/Transportation Systems
- **Task:** To simultaneously control:
  - ☐ Steering, Throttle
  - ☐ & Braking (subsystems)
- Human drivers use both behavioural modes (habit/automatic and controlled/executive)
- Do/Can autonomous vehicles?

NEXT GENERATION EMOTION-SENSITIVE DOCUMENT ANALYSIS AND SEMANTIC WEB MINING TECHNIQUES

Background:

- **This joint PhD project represents a new partnership between the COSIPRA Lab of the University of Stirling (Scotland) and NLPR, CASIA, Beijing, China.**

- **The project was jointly funded by the Royal Society of Edinburgh and CAS**

- **The original/approved joint-project proposal aimed to build on two complementary strands of research in the partner Labs:**
  - an ongoing (EPSRC & industry/Sitekit Labs funded) PhD project at Stirling in the areas of common sense computing, sentiment and opinion mining for auto-categorisation/analysis of documents and development of multimodal affective HCI for intelligent web applications (in partnership with MIT Media Lab)
  - related ongoing research at NLPR in the general area of document analysis & sentimental document classification techniques and applications.
  - FUSION of above strands of work will lead to:

http://cs.stir.ac.uk/~eca/research

Area #5: CMSP for Next Generation Communications/Assistive Technology

- (K. Farooq's) work aims to exploit and build on the above kind of multi-modal emotion sensitive conversational agents as part of future clinical decision support systems for e-healthcare applications where the aim will be to enhance the doctor-patient relationship
  - ☐ Developed a clinical prototype for cardiovascular preventative care - to lower long waiting NHS lists

- (H. Atassi's) work also links with the above two works in that it is aimed at recognizing emotions from speech and also exploiting additional modalities
  - ☐ currently looking at combining EEG information with the speech in order to detect some neurological diseases.