AIMS

EPSRC Centre for Doctoral Training in Autonomous Intelligent Machines & Systems

Annual Review 2014/15

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UNIVERSITY OF OXFORD

In the next decade our economy and society will be revolutionised by ubiquitous Autonomous, Intelligent Machines and Systems, which can learn, adapt, take decisions and act independently of human control.

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Foreword

Welcome to the first annual review highlighting key aspects and activities of staff and students in AIMS during 2014/15. This has been the first full year of the EPSRC Centre for Doctoral Training in Autonomous Intelligent Machines & Systems. Following intakes in 2014 and 2015, the Centre now has 21 full time Ph.D. students engaged in the four-year Ph.D. programme. It's been a busy year, but an enormously rewarding one. The CDT is thriving, with applications escalating at a pace, three new academic faculty coming into the CDT along with five new industry partners. In 2014 we took nine students, all funded via EPSRC or university studentships. In 2015 we were able to take 12 new students, 6 of whom are fully or half funded by industry. This year has seen our first cohort finish their training year and move onto their PhD programmes; they have provided valuable feedback into the course modules, acted as ambassadors for the CDT at events joint with other CDTs and outreach events and have set a bar of excellence. It is truly an exciting time to be involved in autonomous and intelligent systems in the UK.

We would like to say a huge thanks to EPSRC and our industry partners for their continued support of studentships and internships.

Stephen Roberts
Director

Niki Trigoni
co-Director

Why AIMS?

In the next decade our economy and society will be revolutionised by ubiquitous *Autonomous, Intelligent Machines and Systems*, which can learn, adapt, take decisions and act independently of human control. They will work for us and beside us, assist us and interact and communicate with us. The UK has the opportunity to become a world-leader in developing these technologies for sectors as diverse as manufacturing, energy, security, healthcare, assisted living, transport, environment, entertainment and education. AIMS looks to address the present need for smarter, more useful, machines and systems capable of handling intertwined heterogeneous data. We meet this requirement by training student cohorts in the underpinning sciences of robotics, embedded systems, machine learning, wireless networks, control, computer vision, parallel & distributed computing, statistics & data analysis, design and verification. Our students are able to program, embed and design software, to implement established and novel algorithms efficiently and correctly, to develop and apply models and decompositions which allow for them to control, access, leverage, learn from, interpret and distil large volumes of data.

Our research themes

The CDT is underpinned by key skills areas in four interconnected themes, in which Oxford has particular research strengths, led by members of the CDT team and strengthened by industrial contacts.

Robotics, Vision and Perception: The first key skills area is in enabling autonomous systems to identify and interpret complex scenes, from moving vehicles to human activity and form robust situation assessments to enable appropriate action and decision making. For example, robotic systems require such capabilities so that they can navigate in unknown environments; augmented reality systems require methods for scene perception and object identification. Our vision is to train a new generation of researchers that will be able to understand and embed such intelligent machines across sectors, from home health care to driver-less cars. Such applications are particularly challenging because they require autonomous systems to operate in environments that are inherently unpredictable, continually changing, and impossible to directly model. We infuse expertise in Robotics, Vision and Perception in a unique educational curriculum that cuts across theoretical developments in vision and robotics, scene

understanding and perception and state-of-the-art systems research in mobile robot autonomy, navigation and mapping.

Machine Intelligence & Multi-Agent Systems: The second key skills area is in making machine autonomy and intelligence ubiquitous; allowing machines to discreetly pervade the world around us and assist us. Our students are equipped to answer questions like "how can we make machines part of our daily lives without having to continually give them instructions, maintain, repair and look after them?" and "how can machines increasingly learn our objectives, sense our frustration, and help us achieve our goals with minimum interference?" With strong multi-disciplinary expertise in the areas of artificial intelligence, machine learning, crowd-sourcing, participatory systems, language understanding, scalable inference, decentralised information systems, agent-based computing and game theory, the CDT promotes a training foundation for students to inject machine intelligence into real-world applications, such as the critical domains of healthcare, smart grids and energy resources, big data analytics, disaster response, citizen science, human-in-the-loop systems and the environment.

Control & Verification: Our third skills areas lies in developing effective techniques to monitor and control intelligent machines, such as those used in manufacturing, transportation and biosensing/healthcare systems, and to ensure their safety and dependability. For example, how do we ensure that the embedded software controller of the self-driving car does not crash, or that the implantable blood glucose monitor correctly identifies an abnormal range and raises an alarm? Verification via model checking provides automated methods to establish that given requirements are satisfied, but is challenged by the need to consider the complex interplay of discrete, continuous and probabilistic dynamics. This problem is exacerbated in the context of multi-agent systems interacting in uncertain environments. Although there are many new results in the emerging area of hybrid and probabilistic systems, there is a clear gap in developing computational tools that make use of solid theoretical foundations to solve practical problems. Our CDT combines robust control methods with approximate computation methods in stochastic hybrid systems and symbolic model checking & synthesis of embedded software.

Machine-to-Machine (M2M), Secure Sensing & Actuation: The fourth skills area underpins the vision of connecting intelligent devices seamlessly, allowing them to share their sensing, monitoring and actuating capabilities. This is often referred to as "M2M" or the "Internet of Things". Although this vision is not new, there are key technical barriers in the widespread adoption of "intelligent networked" devices. First, machine interaction typically relies on context-awareness (e.g. location) which is problematic in indoor environments. Second, sensors and actuators are inherently

unreliable, often lacking calibration, quality estimation, energy management and fault detection capabilities. This compromises their practical use. Third, most M2M solutions have been designed to meet functional requirements, ignoring security and privacy concerns, both in peer-to-peer ad-hoc networks and cellular networks. By combining expertise in communication and positioning protocols, fault-detection and quality estimation and privacy and security for wireless networks and cloud platforms, the CDT offers a training in M2M systems and the problems they currently face.

To deliver training in these core research themes, we deliver a series of modules in the following areas:

- Data Estimation & Inference
- Machine Learning
- Signal Processing
- Optimization
- Embedded Systems Programming
- Introduction to Modern Control
- Learning from Big Data
- Computer Vision
- Systems Verification
- Security in Wireless and Mobile Networks
- Autonomous Agents & Multi Systems
- Sensor & Actuator Networks
- Computational Linguistics
- Mobile Robotics

Equipment

The CDT was awarded an Equipment grant in October 2014. Our vision for the CDT capital money revolved around the establishment of two major resources. Firstly a lab for training and research in *Autonomous Cyber-physical Systems*, offering the CDT students hands-on, simulation-free, exposure to real systems. Secondly, a large and flexible compute engine to leverage student capability in *intelligent systems, big data problems* and *advanced learning* and *reasoning in autonomous systems*. The latter is a shared resource with the CDT in Statistics (OxWaSP) providing linkage between the two CDTs and allowing for a cost-effective yet highly scalable solution for all users.

Our suite of equipment currently includes a variety of fixed and mobile sensor devices, from portable laser sensors to magnetic, wifi and bluetooth sensors. The lab also includes a variety of mobile devices, such as cameras, smartphones and tablets, as well as wearables (e.g. Google glasses and smart watches). In addition, it includes a variety of aerial vehicles (e.g. Parrot AR drones, Asctec Fireflys) and ground vehicles (e.g. TurtleBots, Huskie kit). A Smart Energy Building System encompassing heat/humidity/CO_2 sensors and new, highly sensitive HVAC actuation, has been installed along with several cameras for a Vicon system.

The high-performance server systems are used very extensively for teaching (particularly modules in computer vision, learning from big data and machine learning), mini-projects, general analysis and research. Students use the computer servers in three blocks of time. In their first six months students use the server to complete the taught modules. About 50% of module time is given over to student-led investigation. In their second six months they use it intensively in their two research projects and finally they will use it to support their research in years 2-4. We have high speed custom-built network links to the university data-centre in which we house this compute server, linked transparently from every desktop. The facility enables students to complete computational research much more rapidly than otherwise.

Skills Training

During the first year the students attended a number of skills training courses, which include writing skills and public engagement. They also attended internal courses on CUDA Programming, Introduction to Unix/Linux and a workshop on Introduction to Finance and Financial Data which was run by the Oxford Man Institute. During the students' 2nd year, they will be expected to attend a number of other training skills courses which are run by the University to help in completing their research degree.

Events, highlights & outreach

- In January 2015 we held a joint CDT workshop with the CDT in Cyber Security looking at the security of driverless cars.

- The CDT students attended the Joint Robotics and Control Workshop hosted by the University of Bristol.

- During the course module on Mobile Robotics, the students built, programmed and tested their robots prior to a finale competition, in which the robots had to autonomously negotiate an obstacle course and navigate a series of waypoints.

- Students attended a number of courses which were run by external companies. There were courses on MATLAB on Simulink run by Mathworks, BP also offered a course on Project Management training The students also attended a one day workshop at YouGov's London office and the Oxford-Man Institute gave a workshop on Autonomy and Intelligent systems in Finance.

- Two of the CDT students attended the "Why Science? Why Maths? at Cheney School (a local secondary school in Oxford). This was attended by over 300 pupils from a number of state schools in Oxford. The students presented a talk on their research interests and also flew one of the CDT's Drones.

- We welcomed this year new CDT partners in Ocado, Mathworks, nVidia, IBM and Network Rail. We look forward to working with you in the coming years.

- We also welcomed three new faculty, Professors Alex Rogers (cyber-physical systems), Pawan Mudigonda (Machine Vision) and Shimon Whiteson (Machine Learning). Welcome to the CDT!

Seminar Series

During the 3rd term in the first year, we had a series of seminars from high-profile academics in the areas of our Research Themes.

These were:

- Dave Parker, University of Birmingham, *"Probabilistic Model Checking and Strategy Synthesis for Robot Navigation"*

- Alex Rogers, University of Southampton, "*Decentralised Coordination of Large-Scale Autonomous Systems through Local Message Passing"*

- Alan Winfield, University of the West of England, *"Towards an ethical Robot: internal models, consequences and ethical action selection"*

- Jeremy Wyatt, University of Birmingham, *"Robots in Our World: Uncertain, Incomplete and Unfamiliar"*

Mini-projects

All students completed two mini-projects during their first year. A list of titles can be found below, and all these mini-projects can be found at the following url:

http://aims.robots.ox.ac.uk/completed-mini-projects/

- Acoustic Signal Processing to Battle Malaria
- Investigating Correlation in point processes
- Information Extraction from Multiple, Asynchronous & Heterogeneous Financial Data Stream
- Text Spotting
- Teach & Repeat with a MARS Rover
- The Use of 77GHz Radar for light Urban Mobility
- Detailed and Comprehensive Understanding of Videos
- Advanced Bayesian Nonparametric Modelling via Probabilistic Programming

- Deep Image Generation
- Long-term energy efficiency experience based localisation
- Optimal FX Market Making Under Inventory Constraints
- Text Spotting : Improving Detection
- Probabilistic Radar Scan Matching for Robot Teach and Repeat
- Deep Learning for Computer Vision
- Mars Robot
- Improving SLAM
- Posterior Server Architecture for Large Scale Bayesian Learning

DPhil Proposals

As the first year is now complete for the 2014 cohort, they now go into their PhD projects. **http://aims.robots.ox.ac.uk/dphil-research-proposals/**

Feedback from Students – Cohort 2014

"Very clear and precise lecture materials, excellent content regarding multi agents and game theory"

"It was a very insightful overview of the field of Computational Linguistics. I especially enjoyed learning about Parsing"

"Excellent practicals; a lot of work went into their design to ensure we got a hands-on sense of the applications of the theory covered in lectures"

"Exceptional breadth of knowledge from the lecturer allowed for deeply insightful parallels and tangents"

"A very good course structure which encouraged direct engagement with the challenges faced in Mobile Robotics"

"The first year of the AIMS CDT has been incredibly useful for me, particularly in strengthening my understanding of topics that I didn't encounter during my undergrad."

"I have enjoyed the first year AIMS course. Being able to discuss ideas in a relaxed setting with the Professors, and to implement them in the afternoon labs helped me to understand the key ideas for each of the courses."

"The first year on the AIMS CDT has been a pedagogical privilege. The sheer breadth of topics covered gives the student a solid, well-rounded foundation for further research. The cohort system provides both a soft landing into the DPhil lifestyle, and a network to draw upon for future interdisciplinary collaborations. I could not have asked for a better start."

"The breadth of material taught has been nothing short of fantastic. The structure of the AIMS program has enabled me to both solidify a research direction and gain an appreciation for many of the disciplines under the remit of AIMS that I may otherwise have not had exposure to."

"This past year has been exhaustingly awesome! The AIMS CDT was a great way to get an overview of a broad range of relevant topics. There range of backgrounds and skills within the cohort meant that we could all bring something different to the table and there was a strong sense of friendship within the group."

"I found the first year extremely valuable. The breadth of the coursework allowed me to get a great overview of the field, while the depth of the mini-projects allowed me to closely explore the subjects I was most interested in."

Student Biographies – Cohort 2014

Samuel Albanie

I did my undergrad in mathematics at Oxford, before doing a Masters in computer science Trinity College, Dublin. I'm interested in AI, particularly computer vision and learning.

Oliver Bartlett

After growing up in New Zealand, Syria and London, my family moved near Banbury in 2004. I did my undergraduate Engineering Science at New College, culminating in my 4th Year Project where I investigated trends in the Afghanistan War using Log-Gaussian Cox Processes. Outside of Engineering I enjoy Windsurfing, Aussie Rules Football, Hockey and Skiing. I look forward to continuing my studies at Worcester College.

Siddartha Ghoshal

I'm British-Indian and grew up in Fontainebleau, a lovely small town on the outskirts of Paris. Halfway through my schooling I moved to the UK, and have spent most of the past 2 decades based in London. Following an undergraduate degree in Mathematics at Imperial College, I began work in debt capital markets at Dresdner Kleinwort Wasserstein in 2002. I subsequently took a year out from investment banking to complete an MSc in Finance and Economics at the LSE to expand my personal knowledge. This opened new and vastly more exciting doors in my sector, so I plunged back in as a trader in commodity exotic derivatives at Deutsche Bank, where I spent much of my twenties. I completed the MSc in Computer Science at Oxford in September 2012 and have ever since been keenly interested in the application of machine learning techniques to pattern recognition in complex datasets.

Ankush Gupta

I am from India but was in the US for my undergraduate work in Electrical Engineering and Computer Science at the University of California, Berkeley. I am interested in computer vision, robotics and machine learning methods. Recently, I have worked on learning robotic manipulation from human demonstrations, specifically, learning surgical suturing. I have also worked on 6DOF tracking system for large-scale demonstration collection. My time at Oxford is being funded by the generous Clarendon Fund and Balliol College Eddie Dinshaw Scholarship.

Jack Hunt

I originate from Kent in southeastern England and conducted my BSc in Computer Science at Goldsmiths College, University of London. During my study for my Batchelor's degree I developed an interest in Machine Learning and Adaptive Systems. This interest has lead to my participation in the CDT in Autonomous Intelligent Machines and Systems. In particular, I am interested in applications of Machine Learning, Computer Vision and Agent Systems to Robotics.
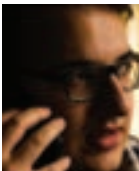
Stefan Saftescu

I am from Romania and moved to the UK to start university. I obtained my Bachelor's Degree in Computer Science from the University of Surrey in 2012 and my Master from University of Oxford in 2013. Having spent a year as Software Engineer in a London-based "big data" start-up, I am now eager to move into Engineering Science throw the CDT in Autonomous Intelligent Machines and Systems.

[1] See the VGGMaxBBNet entries at: http://rrc.cvc.uab.es/?ch=2&com=evaluation

Hillary Shakespeare

I'm from London where I studied Physics (MSci) at Imperial College. I then took a year out to make a micro-budget movie (a long standing hobby) before coming to Oxford for an MSc in Computer Science. Within the MSc I was most interested in Intelligent Systems and Machine Learning and am excited to expand on these and related areas in the CDT.

James Thewlis

I was born in Wales but grew up near Alicante in Spain. I studied MEng Computing at Imperial College London. After graduating I spent some time travelling across North America before starting work at Mirriad, collaborating with Oxford on a TSB funded project using deep learning for video analysis. I am interested in Computer Vision and Machine Learning, especially object recognition and scene understanding.

Stefan Webb

Graduated from the Australian National University in 2013 with a Bachelor of Statistics and Economics with First Class Honours in Statistics, topping his cohort. He received the first and second year economic prizes for the highest overall marks, and was also a recipient, during his studies, of the Statistical Society of Australia's Young Statisticians Award. His research interests lie in the fields of machine learning and Bayesian statistics, and at Oxford he intends to work on developing the next generation of intelligent systems that can understand natural language. Alongside his academic work, Stefan has worked as an ANU teaching assistant in maths, economics, and computer science, as well as supporting outreach and school support work coordinated by the university. Outside of study, his interests include drumming, classical music, and photography. On completion of the DPhil he hopes to either continue work in the field of academia or establish himself as a big data entrepreneur.

Student Biographies – Cohort 2015

Leonard Berrada

I was born and raised in Paris, France, where I have benefitted from a multidisciplinary education: after two years of theoretical mathematics and physics at Lycée Sainte Genevieve, I have studied a broad range of engineering subjects at Ecole Centrale Paris, with an emphasis on computer science and applied mathematics. While there, I also completed a Bachelor of Science degree in Fundamental Physics at University Paris-Sud. I went last year to University of California, Berkeley, for a Master of Engineering in Industrial Engineering and Operations Research. After an internship at Thales Research & Technology, I am now thrilled to join the Autonomous Intelligent Machines and Systems program to further my passion for artificial intelligence and machine learning.

Rowan Border

I'm from the island of Bermuda but have spent the past four years in Scotland where I attended the University of Edinburgh and studied for a BSc in Artificial Intelligence and Computer Science. In my final year at Edinburgh I was able to pursue my interest in robotics for the first time by working on my robot drawing dissertation project, the 'Robot Picasso', with the SLMC robotics group. I have been elected as the Rhodes Scholar from Bermuda for 2015 and will be attending Lincoln College. I am very excited to be starting the CDT in Autonomous Intelligent Machines and Systems and continuing to explore the world of robotics.

Adam Cobb

I completed my undergraduate degree in Engineering Science at Lady Margaret Hall, Oxford. Having particularly enjoyed working on the detection of exoplanets in large data sets for my final year project, I am excited to explore other areas in the field of AIMS. My hobbies include football, running, swimming and golf.

Rob Cornish

I am originally from Australia, and grew up mostly in Melbourne. I began university as a philosophy major at the University of Melbourne before transferring to study pure mathematics and electrical engineering, and then completed an Honours year in applied mathematics at Monash University with a thesis topic in computer vision. Along the way, I also gained some research experience in program analysis at the University of Melbourne, and in robotics with the CSIRO. I am particularly interested in artificial intelligence topics within a robotics context. I also enjoy cycling, hiking, and playing contemporary and classical guitar.

Maximilian Igl

I am from Germany where I have been studying Physics (MSc) and Economics (BSc) in Munich. Over the last two years I also have been quite active at the Centre for Digital Technology and Management, a University program here in Munich dedicated to entrepreneurship. There, and also during my studies of Physics, I've developed a strong interest in Machine Learning and its applications. In my free time I like to go climbing or hiking. The last time I was in England (I was at the University of Warwick for one year) I also did quite a lot of Tango Argentino.

Gregory Farquhar

I'm German-American but have lived in the UK for over ten years now. I studied at Oxford for a Masters in Physics, but am looking forward to shifting my academic focus for the CDT in AIMS. I'm particularly interested in how humans interact with autonomous systems, and in natural language processing. In my spare time I love to play guitar!

Kevin Judd

My name is Kevin Judd, and I live between Baltimore and Washington D.C. in the U.S. with my parents, younger sister, and my dog and cat I graduated from the University of Maryland College Park with degrees in both Electrical Engineering and Computer Science. Outside of class and work, I enjoy the outdoors and being active. I love running and playing sports, as well as cooking and music. I'm always excited by the opportunity to travel to new places and meet new people.

Ivan Kiskin

Originally from Ukraine, I have attended schools in London, Kiev and Germany. I then went on to study Engineering Science at Wadham College, Oxford. In my fourth year project I worked on signal processing and probabilistic machine learning techniques to aid the detection of pulsars. Outside of studies I take an interest in music and guitar. I am looking forward to further expanding and applying my knowledge at AIMS.
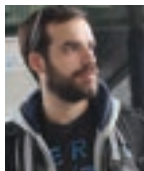
Kyriakos Polymenakos

From Athens, Greece, studied Electrical and Computer Engineering in the NTU of Athens. Took special interest in Power Systems, but soon was more attracted to Control Systems and Machine Intelligence. As part of the CDT in AIMS looks to take part in the research creating a new generation of intelligent systems, propelled by learning from big data and cooperation between multiple agents.
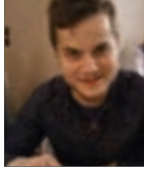
Nikitas Rontsis

I am from Greece, where I studied Electrical & Computer Engineering (5-year Diploma) at Aristotle University of Thessaloniki. During this period, I was an exchange student in EPFL for 2 semesters, where I also made my diploma thesis in controlling kites for energy harvesting. I am excited about modern control methodologies, including, but not limited to, data driven techniques.

Timothy Seabrook

I graduated in MEng Intelligent & Robotic Systems at Lancaster University in 2014 and co-founded a Sharing Economy limited partnership in the same year. I am interested in exploring and developing collaborative AI agents reflecting the social roles of humans, as well as pushing the bleeding edge of autonomous complex systems modelling and prediction.

I am a keen entrepreneur, and hope to discover new applications for Artificial Intelligence to benefit humankind.
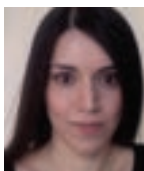
Jaleh Zand

I completed my MSc in mathematics at Imperial College London in 2014. Previous to that I was a structured trader, followed by a quant strategist in Fixed Income division at UBS investment bank, where I started to be fascinated and intrigued with machine learning methods. I further have a keen interest in Bayesian statistics, neural networks, and complex systems.

AIMS Contacts

The AIMS administration team comprises the Director, the co-Director and the Centre Administrator.

Stephen Roberts
Director

Niki Trigoni
co-Director

Wendy Adams
Centre
Administrator

Academic Supervisors

A full list of academic supervisors can be found at:
http://aims.robots.ox.ac.uk/academics-and-staff/

AIMS

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