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Standard FEC Report

Scheme: Standard Research
Programme: Mathematical Sciences
Call/Type: Standard Research 1F

Document Status: With Owner

EPSRC Reference: EP/E050441/1

Award Holding Organisation

Organisation	The University of Manchester	Research Organisation	R102911 EMZ
Division or Department	Mathematics	Reference:	

Title of Research Project

The Manchester Centre for Interdisciplinary Computational and Dynamical Analysis (CICADA)

Project Details

Start Date	01/11/2007	Duration of Grant (months)	54
End Date	30/04/2012		
Report Due Date	29/07/2012		

Funds Awarded

Summary Fund Heading	Description	Full Economic Cost	EPSRC Contribution	Percentage Contribution by EPSRC
	Funds Awarded	£ 0.00	£ 1,738,869.16	
Directly Incurred	Absence	£ 0.00	£ 0.00	
	Staff	£ 742,019.03	£ 593,615.19	
	Travel and Subsistence	£ 165,614.87	£ 132,491.95	
	Equipment	£ 20,000.00	£ 16,000.00	
Directly Allocated	Investigators	£ 158,934.23	£ 127,147.29	
Directly Incurred	Other Costs	£ 18,750.00	£ 15,000.00	
Directly Allocated	Other Directly Allocated	£ 0.00	£ 0.00	
Indirect Costs	Indirect Costs	£ 675,835.74	£ 540,668.59	
Exceptions	Staff	£ 105,238.79	£ 105,238.79	
	Other Costs	£ 26,117.41	£ 26,117.41	
	Equipment	£ 0.00	£ 0.00	
Directly Allocated	Estate Costs	£ 228,237.40	£ 182,589.94	
	Grant Total	£ 0.00	£ 1,738,869.16	

Beneficiaries

The outcomes of this project will benefit the user community in a number of important ways: * The researchers will gain a deeper and broader domain understanding through the experience of working in an interdisciplinary team at the forefront

of emerging theories, their applications and new technologies. * The industrialists and other end-users will increase their theoretical and practical understanding of hybrid systems; for example, AstraZeneca's real-time, 'high content' biological analytical data at both the 'image' and metabolite levels , or NATS requirement to more accurately model an increasingly busy and complex air traffic environment, in which automation will need to provide intelligent prediction and support to humans in air traffic control . Accompanying this proposal are letters of support from AstraZeneca, BAe, IBM, NATS, Rolls Royce, Unilever, the Centre for Computation Science in Chemistry at University College, London, Tufts University and the North West Development Agency. Another end-user will be the Imaging Science and Biomedical Engineering Group (ISBE) in the Manchester Medical School. * The wider scientific community, both in academia and corporate R&D will have access to a significant new body of knowledge through the scientific literature and the open source repository (see 2.5 of the case for support), and to researchers in the UK with leading-edge expertise in a field of such salient importance.

Objectives

The main objectives of the research [up to 4000 chars] at proposal time

To build a multi-disciplinary Centre with sustainable critical mass to study hybrid systems across the boundaries between Mathematics, Computer Science and Control Theory. This will be a centre of excellence and will be a national resource which will attract leading international researchers. It will also give valuable training to young researchers in this important field and will provide a mechanism to facilitate natural and sustained interactions with Industry. The scientific aims of the Centre may be summarised as follows: * To develop new methods for analysis, abstraction, design and maintenance of hybrid systems and adaptive computational systems which will lead to significantly better formal verification and control of hybrid systems and adaptive hybrid systems. * To develop new mathematics in dynamical systems, numerical analysis and other areas motivated by problems in hybrid and adaptive computational systems. * To apply new mathematical techniques, and other existing techniques we will have identified as being useful and relevant, to problems with continuous and discrete components in both man-made and naturally occurring systems, including system design, verification, analysis, maintenance and control.

The main objectives of the research [up to 4000 chars] at report time

The first sentence should include biological applications:
 To build a multi-disciplinary Centre with sustainable critical mass to study hybrid systems across the boundaries between Mathematics, Computer Science, Biology and Control Theory.

Two notes:

1. The researcher, Dr Younes Chahlaoui, referred to in the Summary was appointed at the same time and on an equal footing with those charged fully to the grant. His appointment was part of the contribution of the University of Manchester to CICADA.
2. The inter-disciplinary nature of research supported by CICADA required a flexible approach to use of funds under directly incurred cost headings excluding the Staff costs. The project has incurred an overspend of more than 20% under the 'Other Costs' funds heading due to various expenses incurred to support activities aimed to encourage inter-disciplinary research. The overspend on the 'Other Costs' heading was compensated by underspend on fund headings of 'Travel and Subsistence' and 'Equipment'.

Investigators

Role	Name	Organisation	Division or Department	Hours/Week
Principal Investigator	Professor Paul Glendinning	The University of Manchester	Mathematics	0
Co-Investigator	Professor Stephen Furber	The University of Manchester	Computer Science	0
Co-Investigator	Dr Jonathan Shapiro	The University of Manchester	Computer Science	0

Co-Investigator	Professor Howard Barringer	The University of Manchester	Computer Science	0
Co-Investigator	Professor Nicholas Higham	The University of Manchester	Mathematics	0
Co-Investigator	Dr John Brooke	The University of Manchester	Research Computing Services	0
Co-Investigator	Professor Hong Wang	The University of Manchester	Electrical and Electronic Engineering	0
Co-Investigator	Dr Mark Muldoon	The University of Manchester	Mathematics	0
Co-Investigator	Dr Martin Brown	The University of Manchester	Electrical and Electronic Engineering	0

Patents

Details	Title	Related Grants	Authors
Reference: 2011/0225097 Date Filed: 23/11/2010 Date Granted: 15/09/2011	Method of Apparatus for Valuation of a Resource		Dr Paul Johnson Professor Sydney Howell Professor P Duck Dr Geoffrey Evatt Dr John Moriarty

Revenue

Please estimate the total value raised from the Intellectual Property generated through the grant (£)

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Publication Summary

	Journal	Refereed Journal	Conference Proceedings	Book	Other
Total	62	60	26	8	29
Number of Reviewed (if different from above)	60	60	21	6	3
Total with Industrial Co-Author	0	0	0	0	0
Total with International Co-Author	29	29	15	6	13

Publications

Type	Title	Author(s)	Reference				Reviewed	International Co-Author	Industrial Co-Author
			Name	Year	Vol.	Page			
Journal	Modelling human balance using switched systems with linear feedback	Dr Piotr Kowalczyk Professor Paul Glendinning Dr Gustavo Medrano-Cerda	Journal of the Royal Society Interface	2012	9	234-245	Yes	No	No

	control	Dr Houman Dallali Dr Jonathan Shapiro Dr Martin Brown							
Journal	Attractors near grazing-sliding bifurcations	Professor Paul Glendinning Dr Piotr Kowalczyk Professor Arne Nordmark	Nonlinearity		2012	to appear	Yes	Yes	No
Journal	CONTROL OF A COMPLIANT HUMANOID ROBOT IN DOUBLE SUPPORT PHASE: A GEOMETRIC APPROACH	Dr Gustavo Medrano-Cerna Dr Houman Dallali Dr Martin Brown	International Journal of Humanoid Robotics	2012	9	1250004	Yes	No	No
Book	Stochastic reachability Analysis of Hybrid Systems	Dr Luminita Bujorianu	Springer Communications and Control Engineering series	2012			Yes	No	No
Other	An algebraic approach to time borrowing	Professor David Broomhead Professor Steve Furber Dr Marianne Johnson	MIMS Eprints	2012	2012.60		No	No	No

Summary

The research described in simple terms in a way that it could be publicised to a general audience. [up to 4000 chars]

Revised Summary

The CICADA project was designed to create critical mass at the University of Manchester to develop mathematical tools to approach such 'hybrid' problems, to bring together different communities so as to understand the commonality of the problems faced, and to train a group of young researchers in the multi-disciplinary aspects of the problems. The extent to

which the large scale ambitions were met can be judged by the fact that over 100 different researchers contributed to the 125 papers or books so far supported by the grant; some 60 CICADA seminars were held, about 25 workshops/conferences in Manchester (the iCub conference was covered in national newspapers!), and over 50 contributions to international conferences were made by members of CICADA. The project developed its own momentum, drawing in biologists and physicists, and attracting further external funding for its activities (e.g. Royal Society and LMS grants, EPSRC Feasibility grant). One patent was part-funded by the grant. In terms of training, the two PhD students who have completed both have post-doctoral positions (Hook, EPSRC (Manchester), and Dallali at IIT, Italy), one other student has just submitted and the other has not yet completed three years and continues at Manchester. Of the five original researchers, two have moved to permanent academic positions, two have further EPSRC postdoctoral funding (one on a fellowship) and one has a permanent position in Russia but is trying to find a fellowship in Europe. The CICADA project also helped Manchester appoint a technology translator in mathematics (Evatt) who has now become a permanent member of staff. CICADA continues to function as an inter-disciplinary centre in Manchester, with a seminar program and reading groups in human balance and in max-plus algebras. Manchester has advertised a full-time lectureship in max-plus algebras as a result of the success of this aspect of the grant.

It is impossible to do justice to the full range of research carried out, but here are some highlights. Bujorianu produced the first book on the reachability problem for stochastic hybrid systems. This book brings together the theory (Markov processes etc) necessary to deal with one of the fundamental problems in computer science. Korovina extended the systems for which rigorous computer verification is possible. Brown and Dallali looked at the interaction between discrete and continuous dynamics in robotics. The work was largely applied to the iCub and CoMan, two humanoid robots which are being developed at the IIT, Genoa. The work investigated the interplay between different (discrete) phases of locomotion, such as single support and double support and the transition between them which is modelled as an impacting system (heel strike). Detailed dynamic models were built in Robotran and these models were used to design constrained controllers and validated on simple test problems. Glendinning and Kowalczyk advanced the description of the dynamics of hybrid systems and, with Nordmark (Sweden) and Jeffrey (Bath) made significant progress on the understanding of the extra complexity introduced by higher dimensional settings. Conversely, Brooke, Chahlaoui and Higham worked on reducing dimensions, with Chahlaoui providing numerical methods for dimensional reduction of hybrid systems and error bounds for these methods. Broomhead, Furber, Hook, Johnson and Kambites collaborated on different aspects of max-plus algebras. As the trend in digital electronics proceeds to yet greater densities, design methods which allow for device variability are needed. The max-plus time borrowing algorithms we have developed have potential application in design tools to meet this new challenge. Wong applied hybrid control in the paper industry. Mixing the expertise of the non-smooth dynamics group and the robotics group created new activity in the understanding of human balance, leading to on-going collaborations with physiologists (Loram, MMU).

Add web address : <http://www.maths.manchester.ac.uk/~pag/reports.html>

Staff

Role Name	Name / Post Identifier	Duration	% FTE	Gender	Qualifications gained on project
Researcher	Piotr Kowalczyk	37	100	Male	
Researcher	Younes Chahlaoui	1	100	Male	
Researcher	Pablo Shmerkin	37	100	Male	
Researcher	Manuela Bujorianu	43	100	Female	
Researcher	Margarita Korovina	45	100	Female	
Researcher	Daniel Tang	12	100	Male	
Researcher	Gareth Jones	8	100	Male	
Project Student	Chris Welshman	31	100	Male	
Project Student	Marios Bujorianu	32	100	Male	
Project Student	James Hook	31	100	Male	
Other	Helen Harper	4	100	Female	
Researcher	Jinliang Ding	2	100	Male	
Researcher	Donal Fellows	3	100	Male	
Researcher	Ruediger Borsdorf	1	100	Male	
Researcher	Marianne Johnson	14	100	Female	
Researcher	Ebrahim Patel	3	100	Male	

Staff Destinations

Name	Organisation details	Employment type
Piotr Kowalczyk	Manchester Metropolitan University Manchester United Kingdom	HigherEducationAcademic
Younes Chahlaoui	King Khalid University PO Box 9004 Abha Saudi Arabia	HigherEducationAcademic
Pablo Shmerkin	University of Surrey Guilford United Kingdom	HigherEducationResearch
Manuela Bujorianu	University of Warwick Coventry United Kingdom	HigherEducationResearch
Margarita Korovina	Organisation Not Given	Not Given
Daniel Tang	Organisation Not Given United Kingdom	SelfEmployed
Gareth Jones	University of Oxford Oxford United Kingdom	HigherEducationResearch
Chris Welshman	The University of Manchester Manchester United Kingdom	HigherEducationResearch
Marios Bujorianu	The University of Manchester Manchester United Kingdom	HigherEducationResearch
James Hook	The University of Manchester Manchester United Kingdom	HigherEducationResearch
Helen Harper	The University of Manchester Manchester United Kingdom	HigherEducationOther
Jinliang Ding	North Eastern University China China	HigherEducationAcademic
Donal Fellows	The University of Manchester United Kingdom	HigherEducationResearch
Ruediger Borsdorf	Organisation Not Given United Kingdom	NotKnown
Marianne Johnson	The University of Manchester School of Mathematics United Kingdom	HigherEducationResearch
Ebrahim Patel	Organisation Not Given United Kingdom	NotKnown