

<p>Institution: Liverpool Hope University, Liverpool</p>
<p>Unit of Assessment: Computer Science and Informatics</p>
<p>a. Context: The research scope of the Centre for Applicable Mathematics and Systems Science (CAMSS), which is based in the Department of Mathematics and Computer Science (M&CS), covers a broad range of activities including, for example, developing tools and techniques for teaching science and mathematics to visually impaired school children, the development of computational methods for medical imaging and watermarking for use by medical professionals, and applications of mathematics to medical and biological problems. These wide ranging and broad activities are, as such, also reflected in the types of impacts from these research activities which are similarly broad in reach, but with a focus predominately in the areas where system-interaction-design, modelling and simulation, and technological development have a key role, or where particularly strong public-engagement and outreach play a major role.</p> <p>Within CAMSS, the research with the strongest impact is from the researchers working on themes of 'Human Computer/System Interaction-Design' (HCI, e.g. the MAGIC2VIP project reported as one of the case studies), 'Medical Informatics and e-Health', and with a burgeoning impact profile from 'Simulation, Modelling and Software Engineering' in design of system software. The remaining research in the CAMSS focuses more on the fundamental/theoretical aspects of mathematics and computer science but these are applicable to the areas of robotics, applicable mathematics, applications of control systems theory, communication systems, embedded systems and advances, which will have research impact in the future. Some of the on-going work in applied and applicable mathematics shows great promise in delivering significant impact on a 5-year time-scale, with the stated ambition of moving this work out into the real world. For example: Dr Foulkes' work is on applications of spiral waves for modelling the activity observed in the brain to look at how migraines, and in particular their associated aura, affect the functionality and performance of human vision before, during and after the human has experienced a migraine; this has potential applications and impact, for example in the aviation industry, where migraines can restrict what medical certificate a pilot, or potential pilot, can be awarded; Nagar and Reid's work in a control systems approach to Petroleum Well optimisation (PhD project of Nwankwor who is due to submit the thesis after revisions - viva was held in September 2013; a publication in Computational Geoscience is being submitted as one of Reid's outputs - this work is primarily industrial facing in relation to petroleum and technology companies).</p> <p>The establishment of CAMSS, and its interdisciplinary membership which draws from across the university (e.g. from Psychology and Health Sciences) as well as from industrial professionals and visiting academics (e.g. Drs Anya from IBM; Mammon from CMC (India); Dr Thamburaj from MCC; Prof Arumugam from n-CARDMATH (India); Dr Patterson from St Vincent's: a (Liverpool based) specialist school for sensory impairment and other needs) provides an opportunity to engage more with users and industry, and thus strengthen the impact potential.</p>
<p>b. Approach to impact: The impacts attained by the work of the CAMSS have been achieved within the context of the University's mission of engaging with the world beyond academia, to '<i>be the critic and conscience of society</i>' and to '<i>make a difference</i>' (and MAGIC2VIP is an example of one such project in the latter category). This is mirrored in various strategies of the Faculty of Sciences and Social Sciences of which the M&CS and its CAMSS centre are a part. This highly distinctive University environment conditions the activities of CAMSS and of individuals within it as there is clear expectation of wider contribution, clearly articulated in staff recruitment, annual monitoring and promotion policies, in which individuals are required to demonstrate their contributions to academia within and beyond the University and beyond the academic world. The work of the CAMSS, therefore, nests into this environment, and draws on contacts and expertise from elsewhere in the University, for example the Research Facilitator, and over the years it has nurtured extensive, and in several cases, deep, external associations. As such, over recent years we are taking a more active role in the development and encouragement of impact realisation and there has also been the creation of synergetic, research based relationships through the work of our partner HEIs such as the Madras Christian College (MCC) and Christian Medical College (CMC) in India. The University and the CAMSS continue to facilitate staff (including funding e.g. HEIF grant) in the pursuance of innovation and other new, sometimes serendipitously emerging, research areas, and to expedite production of research output and engagement with research users as the work develops. The types of impact realised from the CAMSS are predominately technology, quality of life, or service based, with economic impact through engaging with</p>

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education, business and industry, and provision of consultancy and training (e.g. the KTP on Nuclear Skills passport during 2010-12). This is achieved either directly through prototyping, computational and modelling work or by working with partners outside of the CAMSS. Outreach and impact through public engagement are also important activities across CAMSS, specifically within the areas of mathematics, and the activities are held up as examples of good practice within the University. This includes summer schools where local/national schools are invited, and engagement with media on the latest research topics.

The University has a Business Gateway with the aim to focus impact strategy to ensure opportunities come to fruition. In addition the members of the CAMSS have taken advantage of a number of key steps the University has implemented that have aided in the realisation of the impact in the presented case studies, and will continue to ensure the delivery of future impact from current research. There is recognition that the underpinning Computer Science and Mathematics research is often best demonstrated in collaboration with academics from other disciplines. One example of that is CAMSS's involvement in the recently established 'Dementia Centre' in the university, and collaboration between Liverpool Hope and its partner HEIs in India (MAGIC2VIP is an e.g. of one such project). The CAMSS, in conjunction with the University's Business Gateway team, have held research open days and summer schools to show case on-going research within the centre (e.g. recently the Engineering and Medical Informatics (EMI) 2013 symposium had an industrial track and an exhibition/poster session to show case applications; a dedicated summer school in July 2010 on 'teaching of science and mathematics to visually impaired students' in which students from specialist Blind schools were active participants and Prof Toriyama and Dr Thamburaj delivered sessions jointly with Prof Nagar).

The CAMSS has taken a number of different approaches to ensure impact from its research, ranging from a broad sweeping approach to raise the impact awareness of all its researchers, to specific and targeted impact activities focused around research themes/clusters and individuals that have the potential to achieve significant impact. Briefly various approaches taken by CAMSS to enable impact from its research activities are as follows: (1) **Interactions with Users/Industry** play a major role in the impact realisation of the CAMSS, and these interactions have been aided and facilitated by the Business Gateway, providing supporting services such as drafting non-disclosure/confidentiality agreements, advising on IP agreements, and providing training, together with business breakfast opportunities to engage with businesses and industry. There are a number of industrial engagements across the research activities within CAMSS, covering a wide range of research topics (e.g. visual cryptography (VC) based secure sharing and information encryption project and on-going discussions with the Barclays Plc.). To further enhance interactions with industry, the CAMSS and the M&CS have established an industrial liaison panel which meets two to three times in an academic year and has industrial advisors on it (e.g. colleagues from EADS Innovation Works). (2) The CAMSS realises that impact is more readily achieved in themes that are applications focused, and as a result there have been **targeted efforts to establish and develop research themes and activities** that are more industrial focusing but still delivering innovative and excellent research and science; often these activities bring researchers with multidisciplinary backgrounds together. CAMSS has been established as a vibrant interdisciplinary centre with the following in mind: to further forge strengths between Mathematics and Computer Science, and as a route to bring advances in research through to application and these actions are very likely to result in significant impact in the near future. (3) **To fund and support impact potential** of research, the University has established funding opportunities and the CAMSS has been pro-active in utilising these opportunities. Of particular success has been the HEIF grants and research committee funding. (4) **The role of public engagement and outreach** is something in which CAMSS is particularly active and it aims to inform widely the importance of research from within the CAMSS (e.g. the workshop, for blind schools, on teaching of science and mathematics to the visually impaired).

c. Strategy and plans:

CAMSS's key goals will be (i) to increase the overall impact of research by introducing M&CS and CAMSS-wide strategies, (ii) to identify key research areas where there is significant impact potential, and (iii) to target these areas with a focused impact plan, enabling the development of impact with the highest reach and greatest significance.

The vision of the CAMSS is aligned to the University's mission and vision of engaging with the world beyond academia, to 'be the critic and conscience of society' and to 'make a difference'. The

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CAMSS is actively developing its impact strategy to ensure that current and future research will achieve its full impact potential and will continue to develop a range of measures to raise the overall level of impact awareness across all research themes and members, as well as identifying and supporting key themes and individuals **through strategic targeting including resource and specific research strands identification**. The CAMSS will also target IP protection in specific areas, with the aim of building up patent portfolios in key areas that will be used to **attract industrial engagement and investment**. This strategy is already starting to happen in the recent work on the visual cryptography based banking solution.

Impact awareness (including staff development and mentoring): Research themes in CAMSS such as e-Health and Systems Biology, Applied Mathematics, HCI, have research activities that are very much impact focused, either through developing technologies with direct commercial relevance, or working with users and companies to solve important problems. However, there is a broad range of research activities within the CAMSS that are less inclined to short-term impacts of reach and significance, but nevertheless would benefit from engaging more in impact activities. The CAMSS places importance on the ability of every researcher to identify and pursue the impact potential of their research activities. As such, the CAMSS will set in place a range of strategies to engage the broader community (e.g. industrial partners /users as mentors for researchers; attendance at the enterprise sessions, business breakfast organised by the Business Gateway). The CAMSS will encourage the development of impact for every researcher by increasing the importance of impact awareness within performance review and staff development opportunities. This approach will also aid in monitoring the impact activities of researchers, and will be an invaluable tool in assessing the impact awareness of the CAMSS. This will require assessment of potential impact opportunities and development of an impact strategy for each of the research themes.

Enhancing interaction with Industry/Users: To enhance interactions with industry, the CAMSS will continue to host an Open Day as 'Industrial Showcase Event' and as a networking opportunity to engage local industry with both the research community within the CAMSS, but also the final year undergraduate and postgraduate community. Further networking events will link in with Daresbury Laboratory (at Warrington in Cheshire) and Liverpool Science park with which the members are already collaborating. This will encourage interactions with the technology business community. To continue to build research links to other academic disciplines as a step towards impact the CAMSS is planning to hold a series of themed research match making/pairing sessions to create new opportunities.

Targeted impact: Raising the impact awareness of the CAMSS is important. However, certain research areas are more likely to realise impact of significance and reach on shorter time-scales, and as such these research areas will be targeted for additional impact related support. The CAMSS is already employing this strategy, with its establishment as a recognised centre in the University. The University has invested in the research laboratories and equipment of the department, where CAMSS is based, in procuring cutting-edge equipment (such as 3D Printer, HPC machine, robotic equipment, Matlab software etc.).

Recruitment of staff: The CAMSS will also target key academic appointments in areas that strengthen industrial collaborations, including areas of Health Informatics and Energy.

d. Relationship to case studies: The various approaches taken by the CAMSS are reflected in the make-up of the submitted impact case studies. User engagement is a key aspect of the impact of the research within the CAMSS, and the MAGIC2VIP and Medical Image Segmentation and Watermarking case studies are two examples where strong user engagement has enhanced the reach and significance of the impact. In particular, the research reported in the case studies has developed and demonstrated this relationship in the following way: (1) the **MAGIC2VIP impact case study** (Nagar and Thamburaj) is directly linked to providing services to Blind Schools in the remote and difficult to reach villages in Chennai area (India) and thus has an impact on enhancing the learning experience and quality of life of the blind pupils; and (2) crossing disciplines and achieving impact through engagement with medical professionals has been a key aspect the impact of the **medical imaging and watermarking project** (Nagar and Thamburaj) by the development of a procedure that is being deployed in the medical wing of the CMC Vellore (India) to support the work process of haematologists, and raise awareness of a new way of archiving the smear images.