Institution: **Middlesex University**

Unit of Assessment: **Computer Science and Informatics**

a. Context

The computer science research submitted here is largely collaborative, involving a wide range of user communities, industries and organisations as well as academic partners, and is frequently initiated as a result of specific problem-based funding opportunities. Much of our research activity is also multi-disciplinary, as real problems rarely respect disciplinary boundaries. We engage with a range of user groups and beneficiaries broadly summarized as follows:

1. Communities where classical command and control situations involve the use of distributed decision making with rapid integration and analysis of complex, heterogeneous data sets such as social and geophysical data. Typical beneficiaries include the US Department of Homeland Security, who have responsibility for managing natural disasters such as flooding and also anti-terrorism measures, police and security forces, and NASA, who require autonomous control structures that can be verified and certified.
2. The medical sector, both UK and overseas, where our research into investigating instrumentation and measurement, medical-imaging, telemedicine and rehabilitation robotics is undertaken with clinicians, developers of medical instrumentation and partners such as the hospitals, the NHS and Ministry of Defence (DSTL).
3. Agencies responsible for managing the equality and ethical aspects of technology use through policy formulation and legislation at national and international levels. These include government departments responsible for policy and deployment, the European Commission, industrial sectors producing technology and those funding research into technology.

We also engage with other communities on individual projects, and the groups above clearly overlap in places, but they provide a context for what follows.

b. Approach to impact

Engagement with industry, users and the wider community is part of the culture for all of our work in computer science. Many of our programmes of study include a sandwich component or are based upon close links with industry and the use of 'real' industrially led projects. For example, the Cabinet Office noted that we were 'leading the way in recognising Building Information Modelling' with the recent launch of a new MSc in BIM, a programme evolving from our research in virtual realities and visualisation as applied to the built environment. Thus we combine the practice base with research-informed teaching at all levels, leading to on-going opportunities for technology transfer and the development of relationships between our staff and relevant companies and organisations.

We believe that interactions between people are essential for genuine impact, and, in 2008, we recognised that the school needed to invest in, and manage, these human processes, rather than assume that ad hoc interactions would be sufficient for the emerging impact agenda. We identified that key actions included developing and supporting networks and relationships with sets of research users, involving users throughout research processes in co-development, and establishing excellent infrastructure and management support for the enterprise. Our decision to build strength in computer science across all levels, including appointing ECRs also meant that we needed to support not only mature research areas, but also to embed the culture in new areas. To support this process, the School took the decision to invest heavily in various initiatives.

We developed a business model that recognises external engagement has an implicit value as well as explicit costs and ensured that appropriate engagement is recognised as valuable. This has enabled us to invest in activities without needing to see immediate financial returns. For example, in 2008 the School funded two senior staff to visit the National Visualisation Centre (established by the Department of Homeland Security at Pacific North-West National Laboratory) for two weeks, and subsequently hosted and funded a one week symposium within the UK to bring together the US and UK agencies with other interested parties (more than 40 participants from academia, industry and governments). This resulted directly in the formation of the United Kingdom Visual Analytics Consortium, with a specific mission to create transatlantic pathways to exploitation for research in visual analytics, led by Middlesex and includes the universities of Oxford, Imperial, UCL and Bangor. We are following a similar approach in the area of Sensor Networks, and have recently organised our first workshop around our successful EU bid (610840

POSEIDON project) on the same topic.

More locally, in 2010 we invested £500,000 is establishing a fully staffed Innovation Centre (http://www.redloopdesign.co.uk/), in new purpose-designed premises embedded in a local business area. The mission of this centre is improving access to the intellectual property from the University, supporting small companies in developing new ideas by adding value from our research base and bringing together co-creators of research from academia and business. The centre has already managed many technology transfer initiatives such as a European Development Fund Project for local businesses and a competition project for Enfield Council to identify potential start-up companies. It also works internationally, helping communities in Africa, for example, to develop sustainable approaches to the design of energy-efficient systems and as a consultant to Macy's of New York on interaction design in retail, channelling research expertise from the interaction design centre into a global arena. Currently the centre is working with Hendon Royal Air Force Museum on the Dornier WW2 aircraft recovery project creating the exhibition, interpretation and development of virtual visitor experiences. The creation of the centre, has enabled us to be highly agile in responding to such opportunities. Staff do not have to demonstrate immediate returns or make a business case for each avenue explored, and they are able to call upon expertise across the whole of the school whilst being free to respond in timescales expected by those in industry. The centre also provides intern opportunities for our students, some of whom have now started their own businesses and subsequently work with us collaboratively, expanding our reach, others have embarked on research degrees here after being exposed to research teams and seeing real areas of application, maintaining the industrial links as part of their research.

Our recognition of value in these activities per se also means that support is usually readily available for physical resources that carry impact into the wider arena, without the need for complex bids or competition for resources. For example, we have invested £50,000 in ten TurtleBots and the design and construction of a Stewart Platform, capable of supporting 200kg, with a sophisticated ROS integrated control system. This provides a low-cost, portable, vehicle for exploring synergies between robotics, sensors, haptics, interaction design and games technologies. It has attracted interest from FESTO and National Instruments, who are keen to see us exhibit this nationally and internationally, but also museums, who see the potential for creating interactive exhibits (such as experiencing flight in a WW1 plane). Technologies such as this have offered us the opportunity to take our work into events such as the final of WorldSkills at the ExCeL centre, where 240,000 visitors were able to visit our exhibition and engage with our researchers. Not all of our impact is based on technically sophisticated research. For example we constructed the 5m delta robot recently displayed in the Tate Modern, microprocessor controlled costumes for the closing ceremony of the Olympics, and the LED jackets for Take-That at Wembley. Through such activities, however, we have developed a reputation as an institution that delivers technology on time and to budget, and are increasingly invited to join research consortia where that skill is highly valued alongside our research.

The School is supported in this by a team of professional staff in our Research and Knowledge Transfer Office, with specialist knowledge in knowledge transfer, industrial partnerships provision of relevant training such as legal requirements, managing innovation and contracts. This office will also assist with taking out patents (with 7 being lodged by the School since 2008), and takes a proactive role in identifying opportunities (both home and abroad) for exploitation. We are also well supported by marketing, outreach and public engagement teams within the institution, who also understand the value in what we are doing. We have a dedicated public relations manager, with significant experience in a similar role for a professional body, working with the School to publicise the impact of our research and track stories as they flow around the world, alerting us to new opportunities and potential partners.

c. Strategy and plans

There are two key aspects of our strategy for impact that underpin everything we do and also underpin our research strategy generally: we value collaboration very highly and we do not make forced distinctions between research and knowledge transfer.

We view computer science as a global, collaborative, enterprise and research, not as enclosed within academic boundaries waiting to be transferred to industry. The emphasis on collaboration rather than competition (developed more fully in the environment section) enables us to build communities including various stakeholders in our research: manufacturers,

legislators, infrastructure providers as well as end users of artefacts and services. This rich environment facilitates interesting crossovers between communities: work with the elderly and low-literacy users of technology, for example, provide insights into ways that multi-national security teams, working in contexts where sensory information may be inhibited, will react to complex decision making. Thus communities frequently transcend individual projects, and provide long-standing relationships. Another example of this is our work with clinicians. The TIME project enabled us to build a community of practice in the area of telemedicine, including clinicians from Greece, Russia and China. This has developed into a more specific project (WIDTH: 269124) working with clinicians in medical imaging in five major hospitals in China, but these projects also created opportunities to work closely with our internal colleagues in biomedical sciences (submitted to unit 3), sharing laboratory infrastructure and befitting from their close links with local hospitals and the NHS, and that in turn has brought our medical physicists closer together with those working on algorithms.

The research programme around visual analytics has enabled us to build international communities across organisations including universities, government agencies, specialist tool providers, banks and the legal profession. The School has recognised and accepts that any impact mechanism, such as establishing networks and building communities for co-development, cannot be guaranteed to deliver, and that risk must be accepted.

The strategic decision to regard research and knowledge transfer as inseparable and mutually supporting is, we believe, fundamental in computer science. There is rarely a simple process from research to application, implementation and impact. We accept that there are few clear distinctions between producers and consumers in research at an organisational level, for many computer science led companies have strong R&D divisions, often leading the field.

The benefits of combining knowledge transfer and research and avoiding boundaries between them are easily illustrated by recent examples. Our research in visualization and human computer interaction has led to close cooperation and knowledge transfer with various industry sectors including security, finance and publishing through the UK Visual Analytics Summer School programme that has been running for several years. Our research in languages for enterprise architecture (EA) has resulted in us working closely with Tata Consultancy Services via short sabbaticals. Research and current practice in enterprise architecture is thus tightly interwoven. Similarly, our case study on model checking in multi-agent systems illustrates how our research is influencing research undertaken at NASA. Amalgamating these activities into a strand of integrated activity means that researchers have a consistent set of targets where external engagement is clearly valued.

To support our strategy, the Dean, Deputy Dean and Heads of Computer Science (all included in this submission) meet regularly with senior colleagues within the school to discuss research and knowledge exchange activities in a single executive forum. Thus issues such as staffing, grant applications, infrastructure and impact are constantly reviewed, with necessary investments and actions agreed and acted upon. Our decision to develop robotics as an area across the school, for example, arose from recognition that we had areas of significant strength in learning systems, image analysis, interaction design, sensor networks and haptics, and also major outreach activities, including running the UKSkills mobile robotics and eurobot UK competitions. This led to the decision to invest in staffing and resources, which immediately paid off with opportunities for impact in collaboration with DSTL in tackling the problems of phantom limb pain amongst amputees.

One implication of this strategy is that resources need to be found to engage with activities even though there may be no associated funding. For example, members of staff are fully supported to work with the British Computer Society and EU in areas such as ethics, standards and policy relating to equal opportunities where we have substantial track record and publications. Our broader research strategy reflects the fact that the value of such activities on our curriculum, staff development and general environment makes them valuable. Mutual support, trust and external interaction is rewarded, and not seen as the dissipation of resources or a loss of focus. Our investment in staff development, the mentoring of ECRs by senior colleagues and the ways in which we use technical training events to build teams also ensure that all staff understand the importance we place in these activities.

Our commitment to working with a range of non-academic research users is reflected in our funding sources. In addition to securing funding from RCUK, we have sources such as

EuroControl, the Department of Homeland Security, the Home Office, DSTL, BAe Systems, JISC and the Nominet Trust. Such relations ensure that an emphasis on impact is integral to our research culture.

The School is also deliberately integrating activities across its three REF units of assessment as part of our STEM agenda. Many of our external partners are involved in enterprises that integrate aspects of biosciences, environmental sciences and computer sciences (such as managing complex data sets, sensor networks, imaging and visualization). Historically, these areas were managed as distinct, with synergies arising primarily through 'collaboration'. We are using ways of achieving deep integration so that we can help address many of the challenges facing our external partners and offer an integrated solution through research and knowledge transfer collaborations across these domains, along with extensive external collaborations, such as the visualisation of complex data for flood management.

d. Relationship to case studies

The unit has submitted six case studies that demonstrate different forms of impact and engagement at different levels whilst addressing the needs of our three major user groups. They are all underpinned by excellent, continuing, research and demonstrate how different routes to impact are being constructed in this unit. The bio-imaging case study focuses on developing algorithms that enable the use of electrical impedance tomography (EIT) for imaging of brain and lung functions; this work is located in broader collaborative research in areas such as telemedicine, and content based retrieval of 3d medical images.

The two case studies addressing digital inclusion and ethics related issues are focused on policy making at professional, national and EU levels. The case studies represent a range of impacts including in relation to professional standards, tools and methods and policy making. The feedback and evaluation from this impact continues to inform current funded research that is specifically addressing the technological needs of marginalized young people in the youth justice system, bringing both digital inclusion, ethics and the need for multidisciplinary collaborations to bear on current real problems.

The visual analytics and complex user interface design case studies build upon research into critical and complex decision-making in information rich environments. These are both the results of projects involving close collaboration between academics and the wider community. The visual analytics case study is an excellent example of our strategy to ensure key impact determinants such as the need to establish networks and relationships with research users are managed within our processes.

The user groups associated with case studies have been developed and sustained as part of our impact strategy. Our medical practice partners include organisations from UK, China and EU countries. The user groups contributing to HCI related impact case studies have been developed by our policy of engaging in speculative knowledge transfer, sometimes without specific sources of funding in mind. The success of this approach encouraged us to consider further speculative activities to allow us to more concretely embed our research with knowledge transfer leading to the two visits to Indian software research labs to develop relationships for future collaboration.

The Model-checking case study illustrates impact arising from relatively early stages of relationship building with NASA, a long term goal. The case study has arisen through sabbatical visits and exemplifies our strategy of collaborations with research users and our desire to blur the distinction between research and knowledge transfer. Thus several of the case studies have arisen from contract research while others are based on more conventional research grant funding. The complex user interface design case study was partially funded by the Korean Atomic Energy Institute and illustrates how ideas transfer between projects, as it incorporates the Variable Uncertainty Framework developed within the centre. Similarly, the design for all impact case study was partly funded by ANEC (the European Association for the Co-ordination of Consumer Representation in Standardisation).

The case studies address a range of subject areas, and the needs of different user communities, within the broad discipline of computer science and collectively illustrate our commitment to engage with research user communities to ensure impact and reach.