Particle Physics and Astronomy Research Council

Identifying relevant future technological developments

1 What relevant technology trends are likely to impact on health and healthcare in the next ten to fifteen years?

As the resolution of medical images advance, the resultant data files increase in size. These files need to be stored securely on data-servers, with capacities large enough to accommodate the 31 million images produced per annum through x-rays, CT, MRI, ultrasound, radio-isotopes and fluoroscopy. This figure does not include imaging technologies such as SPECT and PET which account for a further 120,000 images per annum. The electronic storage of such images will allow the sharing of the data between remote institutions – a potential that poses its own set of problems.

From the PPARC perspective, the technology trends applicable to this call for evidence can be divided into three categories: image analysis, data storage and data networking. Examples of PPARC enabling science is discussed below.

1. Image analysis

Mike Hobson of the Cavendish Laboratory in Cambridge, who holds a PPARC Advanced Fellowship, has been developing algorithms that can separate out images of the cosmic microwave background (CMB) – the tepid radiation left over from the birth of the Universe – from the unwanted 'noise' arising from other astronomical sources and from contaminated data. The CMB signals are very weak, so observations need to undergo a certain amount of 'reconstruction' in order to recover the clearest possible images from often complicated and noisy data. Dr Hobson uses a statistical technique called Bayesian inversion which maximises the probability of the image from the information available. The image is converted from its pixel (picture element) basis into a mathematical representation which can be more accurately optimised and then converted back to pixels. This picture enhancement approach was first developed and applied to astronomical images by Professor Stephen Gull at Cambridge in the 1980s. The idea quickly transferred to more everyday uses such as reconstructing fuzzy police photos of car number plates. Dr Hobson's work has already been applied successfully to deblurring images of pollen grains obtained using confocal microscopy and is currently looking at other biological applications, such as improving CT and PET images to give a greater image definition to improve diagnosis and indicate a suitable treatment regimen.

http://www.metropolis-data.co.uk

2. Data storage

Industry is increasingly looking for simpler ways of storing and accessing larger and larger collections of enterprise data. The emergence of Enterprise Resource Planning (ERP) systems represents a major breakthrough for enterprises and their means for conducting business. However, issues remain in the integration of such ERP systems in the operation of the enterprise which can only be resolved through an extensive, systematic and integrated approach to business process modeling and automation, that potentially impacts on every aspect of enterprise activities and organization. CRISTAL has been developed for the high-energy physics community to cope with very large scale and complex production problems. However it has been designed to be sufficiently generic to be applicable to be customized for use in healthcare, manufacturing, telecommunications, scientific and engineering domains.

To give an indication of the amount of data CRISTAL can handle; the AstroGrid and GridPP projects, supported by PPARC, handle many Petabytes (1 petabyte = 1 x 10^9 megabytes) of data across a 100-node Grid. This is a live system with several nodes in the UK, including at the NeSC in Edinburgh and the Tier 1 centre at RAL. The data produced by the next generation of physics experiments is expected to be of the order of 5-15 Petabytes per year. This quantity of data may seem irrelevant to healthcare at present, but past experience indicates that demands in data storage in the healthcare community will eventually catch up.

The handling of complex data management at the Terabyte level allows:

- The flow management of multiple versions of design and productions specifications;
- The traceability of products and workflows over extended timescales;
- The integration of the many islands of information with insurance of local quality control for the individual tasks;
- The management of local current activities;
- The management of complex system descriptions including devices configuration and layout;
- The sharing of data across multiple users and domains.

CRISTAL supplements the Grid technologies (discussed below) to provide the ability to track activities across multiple sites. It could be used in healthcare to monitor the functions and efficiencies of many remote sites and allow the extraction of data in a variety of formats. For example, it could be constructed to monitor bed utilisation across a Health Authority, comparative surgical success rates, A&E throughput metrics, etc.

http://dbnetra01.cern.ch:9000/pls/ttdatabase/display.item?itemtable=technology&item_id=37

3. Data networking

PPARC was awarded 27% (£57.6million) of the total UK e-science budget 2001-2006, to establish two out of the three flagship Grid projects for the promotion of networking within the UK and into Europe (source – Science budget 2003/4-2005/6 DTI (OST)). These two programmes, GridPP (particle physics) and AstroGrid have been established successfully and developed further into more applications, outside of the physics domain. The ultimate aims of these grids are to support and enable collaborative research and provide a system-architecture to manage large volumes of data. For example, the data generated by the large hadron collider at CERN is in the order of 15 petabytes per year (1 petabyte = 1 x 10^9 megabytes) and is shared through the GridPP. Two healthcare applications of Grid technology, at different stages of development, are discussed below: MammoGrid and CancerGrid.

MammoGrid

MammoGrid is an EU FP5 project that uses the emerging Grid technologies to develop a European-wide database of mammograms that will be used to investigate a set of important healthcare applications and to support effective co-working between healthcare professionals throughout the EU. The project aims specifically to apply these existing technologies rather than merely focusing on their further development. Medical conditions such as breast cancer, and mammograms as images, are extremely complex with many dimensions of variability across the population.

The objectives of the programme were set to:

1. Evaluate current Grids technologies and determine the requirements for Grid-compliance in a pan-European mammography database
2. Implement the MammoGrid database, using novel Grid-compliant and Federated-DB technologies to provide improved access to distributed data and allow rapid deployment of software packages to operate on locally stored information
3. Deploy enhanced versions of a standardisation system to enable comparison of mammograms in terms of intrinsic tissue properties independently of scanner settings, and to explore its place in the context of medical image formats (DICOM)
4. Develop software tools to automatically extract image information that can be used to perform quality controls on the acquisition process of participating centres (e.g. average brightness, contrast)
5. Develop software tools to automatically extract tissue information to be used in clinical studies (e.g. breast density, presence, number and location of micro-calcifications), for increasing the performance of breast cancer screening
6. Use the annotated information and the images in the database to benchmark the performance of the software described in points 3, 4 and 5
7. Exploit the MammoGrid database and the algorithms to propose initial pan-European quality controls on mammographic acquisition and ultimately to provide a benchmarking system to third party algorithms.

Current pilot applications are aimed at addressing two main problems:

- Image variability, due to differences in the acquisition processes carried out in the diverse centres scattered throughout Europe, and to differences in the software packages (and underlying algorithms) used for their processing;
- Population variability, which causes regional differences affecting the various criteria used for the screening and treatment of breast cancer.

CancerGrid

Built upon PPARC architecture, the CancerGrid project aims to deliver modular, distributed software solutions for the key problems of clinical cancer informatics: clinical trial patient entry, randomisation and follow-up; storage and analysis of complex datasets; linking trial and epidemiology data with profiling information. It will facilitate trials management and future collaboration across international boundaries.

CancerGrid will deliver a working services-based Grid infrastructure for cancer clinical trials, to implement established trial protocols as network services. XML documents containing trial protocol metadata will provide a basis for computation across trials, automating meta-analysis and the integration of trials and bioinformatics information. CancerGrid also aims to ensure the consistent use of clinical terminology through the establishment of a consensus regarding domain-specific vocabularies and data items, thereby allowing automatic linking of entries.

A necessary requirement for developing open standards for clinical cancer informatics is the development of collaborative environments to allow researchers to quickly and transparently locate data and to communicate with colleagues at remote sites. CancerGrid will promote the use of Telemedicine to co-ordinate clinical trials between the five distributed sites; Cambridge, Oxford, London, Birmingham, and Belfast.

Assessing the potential positive and negative impacts of relevant future technological developments

2 What areas in the provision of health and healthcare could be positively or negatively affected by these developments?

A wide variety of disease states could be positively affected by the technologies discussed above. The main advances would be improved diagnoses, through clearer imaging, and the sharing of high resolution images to provide clinicians with information on other cases to improve clinical research. Furthermore, centres of expertise may become national facilities because, for example, specialist medical image diagnostic teams could serve the whole of the UK whilst being located remotely from the patient.

Potential negatives of the Information System technologies discussed are security concerns and risk to patient confidentiality.

3 What actions should be undertaken now to maximise positive impacts, or to prevent or minimise adverse effects?

To maximize positive impacts:

1. Image analysis

Encourage clinical researchers to work in collaboration with PPARC scientists to transfer knowledge from the astronomical community into the healthcare domain. Advances in the production of medical images should be cleared through any regulatory obligations as a priority and, once proven, adopted as a standard across the whole of the NHS imaging community.

2. Data storage

Develop a national strategy for the access, storage and retrieval of diagnostic image data

3. Data networking

Investigate the feasibility of networking specialist facilities across the country to enable the construction of more “healthcare GRIDS”. The hardware infrastructure for this project should be regarded as a national facility and would benefit from central funding and project management to ensure adequate control and resourcing.

To minimize negative impacts:

Employ current, standard IT security measures.

Evaluating the wider implications of relevant future technological developments

Questions 4, 5, 6, 9, 11 and 13 are outside of PPARC’s area of expertise.

7 What infrastructure would be required to allow any new technologies to be used effectively?

The Grid infrastructure is currently in place covering the main research institutions in the UK. These could potentially act as hubs to distribute data down to another tier at the hospital level. Broadband access would be needed into all of the clinical centres who would use this system.

8 What are the most likely promoters and barriers to the take up of new ICT devices and systems?

Promoters: The technologies discussed above will become the state of the art in clinical treatment and these are areas where the UK can lead the world. The adoption of novel image analysis techniques by leading specialist centres will naturally pull other institutions along as the clinical benefits become more apparent. Similarly, the use of a more extensive systems architecture would be adopted in a two phase timeframe – larger teaching institutions first to initially populate the databases with case studies, followed by a further rollout into other centres.

Barriers: The realization of the benefits of deploying these technologies may require a significant change in the ways of working for both clinicians and their diagnostic teams. Deploying pilots would provide an indication of the benefits, however the full deployment of the networking and information systems required for these technologies would require significant funding.

10 How are professional roles and responsibilities likely to be affected by the increasing use of ICT?

The technologies discussed above are unlikely to have a significant impact on professional roles and responsibilities as such; rather they would have an enabling impact on the clinicians and their diagnostic teams. This impact would allow for improved diagnosis and the sharing of clinical case data.

12 What are the potential impacts of the costs of any of these new technologies?

It could be argued that any increase in costs could be exacerbated by improved diagnosis and hence reduced costs due to inappropriate treatment regimes. It is otherwise difficult to quantify what the costs would be and we are not in a position to comment on how these costs would impact.

Are there any other important issues that have not been addressed by the questions above and that you think the working group should address?

There are no other issues that PPARC wishes to raise.