the system

Systems Engineering Innovation Centre

Integrating people, processes, tools and technology to create tomorrow's business and product solutions.

NEWS FOR SYSTEMS ENGINEERS

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If a picture paints a thousand words…

it helps if you can see it clearly

When you take a photo with a digital camera you (or the camera on automatic mode) select a combination of settings – flash, focus, aperture, shutter speed and so on – to get the best result according to the surrounding conditions and the subject. You also choose the file size for the resulting image in pixels depending on how or where you plan to use the photo – a web site or a holiday snap or a piece of forensic evidence. The same choices can be made for video recordings.

Vision sensors on unmanned or remotely controlled vehicles are becoming increasingly important for gathering vital data about the context and status of their operating environment, whether a battle zone or the surface of Mars, and transmitting it back to base or to another vehicle. The intelligence value of both the still and the moving images is in direct proportion to their quality – and good quality almost inevitably means large file sizes.

When competition for bandwidth is fierce or when stealth is required for the transmission of data – for example in sensitive situations, hostile environments or over insecure networks – then no time can be wasted sending file sizes which are larger than necessary. Streaming data in real time significantly reduces the need for on-board storage and thereby the associated payload but rapid transmission to prevent interception or corruption is still essential. The inherent conflict between the objectives of quality and speed can be mitigated with visual data compression. But the key question remains: How much compression confers the optimal transmission rate over low bandwidth channels without losing the value of the image? Also the compression method used for one application or sensor type may not necessarily be suitable for another application.

It is the trade-off between these objectives of speed and quality that interests the researchers in the Advanced Virtual Reality Research Centre at Loughborough and integral to their study are the tricky questions: What does 'quality' mean? What does 'good' look like?

Even though we can all judge the quality of an image or video subjectively in its context, a decision about levels of compression requires an objective, quantitative measure of visual quality. Because of this the research has two strands:

- Firstly the creation of an objective measurement of visual quality based on the human visual system and using five categories of image attribute.

- And subsequently the creation of look up tables for each five categories to answer the question: What is the optimum amount of compression to obtain best visual quality for known bandwidths?

The visual measurement system[1] supplied the project with fitness ratings for each of the five categories against which compressed videos could be assessed.

Creating the look up tables was the next step. Firstly, all possible combinations of compression levels and system performance attributes needed to be tested and this was done using a multi-objective evolutionary algorithm, (MOEA). This technique is sometimes criticised for being too complex in computational terms and not selective enough. However, it does ensure completeness and allowed the researchers to generate the population of all possible pairs of compression parameters, or in genetic algorithm terms, 'chromosomes'. The fitness of each chromosome was measured separately and formed the basis of the evolution process.

This is an intensive, iterative process and the results which it produces are mapped into the search space for each combination of parameters to reveal the Pareto optimum and the Pareto Front which embodies the look up table (see Figure 1 – back page). The study created five separate look up tables in this way which were then integrated as sub-systems of the whole process.

[1]This is the subject of separate paper. For details contact the author

continues on back page

For Good Measure

Multi-scale Metrology makes an appearance

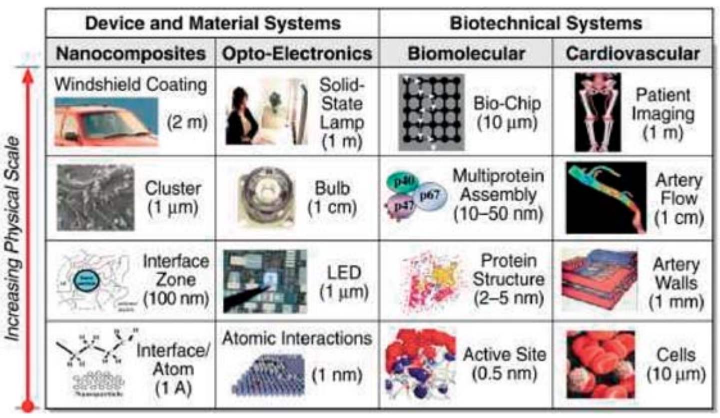
Measurement and the representation of its findings are central to many (if not all) applications in systems engineering. We work in a discipline that covers the very big and the very small, with perhaps a 10^{15}m gap between the two: nanoscale structures combine to form microscale conglomerates; these compounds are mixed together to provide structure and organisation at even higher scales, until a final functional entity is formed.

An engineering specialist may not ever need to think beyond one appropriate level of measurement, but a systems engineer who requires a holistic view of a system, must simultaneously visualise and synthesise the different scales of measurement being used. Needless to say this can be a complex task for which there are few tools available.

A good example of connections between subsystems at different levels of scale creating the need for multi-scale metrology is in the field of medicine. Here systematic analysis is a tradition that is embodied in the training of medical students. Whereas a GP is the closest to a systems engineer in terms of looking at a system as a whole, those who choose to specialise study physiology at different scales: molecular biologists might be interested in the functionality of gene networks (atomic level – 10^{-12}m) and the use of pathway models for protein synthesis and protein-protein interactions (10^{-9}m); cell biologists and histopathologists may investigate cellular activity (10^{-6}m); pathologists may view tissues (10^{-3}m) and organs (10^{0}m) along with those clinicians who dedicate themselves to specific organ specialties (cardiologists for heart function, orthopaedics for skeletal disorders etc.).

However, medicine could be on the verge of a paradigm change – from identification of illness and its treatment, to identification of genetic risk factors to prevent illness and promote the concept of wellness. An example of this phenomenon is the known locations on chromosome 6 that encode for asthma; should genetic screening become widespread (as it surely will do), then those people in the population who are more susceptible to asthma can be identified before they present with the disease and therapeutic intervention started to ward off the onset of the condition. This cannot be done without making those vital connections between each level of scale – from genomic information (genotype) through to the multiple ways that this information can be expressed in the human body (phenotype). The predisposition of an individual human being to asthma is just one example of many diseases and metabolic conditions whose genotype to phenotype interactions have been identified. Crucially, only a systemic standpoint can accommodate and facilitate the change necessary for this paradigm shift.

Work is now underway at Loughborough on multiscale systems engineering that not only aims to provide a framework to answer the health system requirements posed above, but also to translate the challenges it presents to other physical systems. In principle, multiscale systems measurement and modelling can be performed on any type of physical system, as demonstrated by the work of Mark Shephard and his team at Rensselaer Polytechnic Institute in the USA (see figure below).



Outline view of multiscale systems applications (Shephard et al., 2007)

One of the definitions of metrology concerns the development of new measurement methods, realisation of measurement standards and the transfer of traceability of those standards to end-users. It is these aspects that are of concern in multiscale modelling, which itself can be defined as the field of solving physical problems which have important features at multiple scales, whether these be multiple time or multiple spatial scales. In systems engineering applications, both may be of importance although, for the purposes of this article, we deal only with multiscale spatial concepts.

Using Shephard's figure to represent work at Loughborough, the first column represents micro-nano technology measurement at four spatial scales (at 10^{-10}m, 10^{-7}m, 10^{-6}m 10^{0}m); the second demonstrates an opto-electronic system that could represent the optical sub-system of the imaging system being developed in the Biophotonics and Health Technologies Laboratory of the Department of Electronic and Electrical Engineering; the third column shows a typical biotechnological application where the active site of the protein is identified at the smallest scale, through to the bio-chip itself at 10^{-5}m; and the fourth column indicates the spatial scales used in the imaging of human organ systems, again an interest of the Biophotonics and Health Technologies Research Group.

A unique aspect of the work underway at Loughborough is the use of ontological models to provide the information structure necessary for a holistic understanding of these multiscale systems. Recursive ontological models describe not only the functional relationships between entities within one level of scale, but also provide the essential information links between the levels of scale. The model required for the latter is a novel concept and a feature of the traceability function of the multiscale method. Its inspiration was Stafford Beer's Viable Systems Model, which is used to either diagnose faults in existing organisational systems or design these systems *ab initio*.

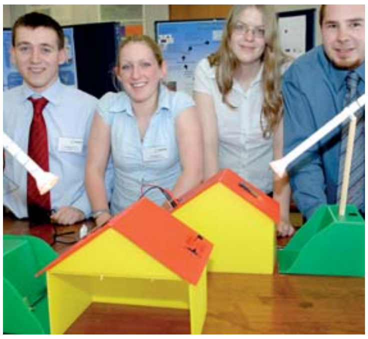
Work in Loughborough is currently at the level of identifying the theoretical challenges in the validation of multiscale models (e.g. how are errors propagated through the different levels of scale?) and the technical challenges of how to represent information at different levels of scale concurrently. When there are solutions to these research questions and multiscale metrology can be applied as a systems engineering tool, a systemic (rather than a systematic) understanding of structure, function and organisation connecting each level of scale will be attainable. The potential offered by access to this new dimensional analysis is set to be huge, with pervasive applications in all physical systems. Whereas the first application relates to optical imaging, research and development in other physical applications are actively being sought.

For further information contact Professor Ron Summers (r.summers@lboro.ac.uk)

Project Performance

The undergraduate group projects this summer showed yet again how systems engineering can be applied to any aspect of human endeavour. Between them, the fascinating array of projects covered crime detection, health, sport, education and renewable energy. To add an extra fillip there was a £500 prize at stake, offered by Qinetiq to the group demonstrating the best handling of that delicate trade-off between risk and innovation.

Hands-on kit



The winning group designed, developed and produced a prototype test suite to be used by Key Stage 4 pupils (14-16 years) at a local High School for studying renewable and sustainable energy resources, a requirement of the Science National Curriculum. Currently available commercial kits demonstrate single aspects only and besides being costly – one set per class! – and sometimes unreliable, they are also not integrated. The Loughborough students' solution provided affordable modular sets of equipment to demonstrate each form of renewable energy (e.g. solar panel, wind turbine, hydroelectric, fuel cell, etc.) on a small scale, with a common user interface for planning, setting up, and logging data for experiments. The teacher was delighted!

Howzatt!

All of the approaches to modern electronic means of making sports decisions have been driven to date by the available technologies. Working with the university's wireless systems engineering and sports technology experts, this group investigated not only the complex technical problems in electronic cricket umpiring of discriminating a bat-ball from a pad-ball impact, but the personal, social and political requirements of the umpires, the players - during training as well as competition, and the National Governing Bodies.

Fair cop

Copper cable theft is a serious issue for many industries, but particularly for the railways which use large amounts laid on trackside for signalling. The failsafe signalling system means that any cut cable turns all signals in the area to red and brings any nearby train to a halt. The scrap value rewards are high enough for thieves to risk cutting through live high-voltage cable, stealing up to 800m in a night's work and leaving passengers massively inconvenienced by delays. The cost to the industry through disruption, compensation, replacement and repair is huge and rising rapidly. Network Rail estimates such thefts landed the organisation with an £8m bill in 2007. Since the start of 2008, British Transport Police has already recorded over 1000 thefts and 235 arrests for this offence.

Amey Infrastructure Services posed this challenge: develop a post-installation monitoring system which can detect when a cable is moved, cut or tampered with and its precise location to catch thieves in the act.

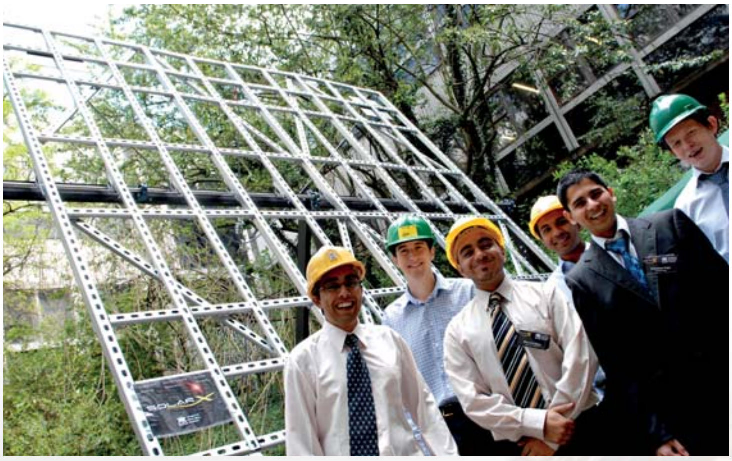
Robot-assisted orthopaedic surgery

When pinning a long bone to mend a fracture, minimally invasive surgery techniques which reduce the amount of tissue trauma and speed recovery time are now common. However it may require several 2-D X-ray images before the surgeon has enough 3-D placement information for a successful drill hole. Inevitably this exposes both the patient but more importantly the surgeon, who may do several operations daily, to potentially dangerous doses of radiation. Working closely with orthopaedic consultants from the University Hospitals of Leicester to ensure customer/user satisfaction and robotics experts from the Wolfson School of Mechanical and Manufacturing Engineering, this group integrated the different working components into a modular solution which could be used in any combination according to need.

Follow the sun!

Working with the Control Systems Group and the Applied Photovoltaics group of the Centre for Renewable Energy Systems Technology (CREST), this group designed and built a weather-tight tracker rig which could be used as part of an existing suite making detailed characterisations of photovoltaic modules and for studying their operation and performance.

The university's research group who had previously used a smaller, somewhat temperamental rig were delighted with the functionality of the new system.



If your company would like to know more about sponsorship of this innovative undergraduate programme, contact Amanda Pearce (a.v.pearce@lboro.ac.uk)

In the News

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The resulting novel process in action

When an unmanned vehicle is sent to collect video intelligence, firstly the onboard sensors collect data about the subject, the context and the environment. All the sensory inputs are then analysed using the intelligent algorithm and the results fed to the appropriate look-up tables. The combination of results from the look-up tables are further synthesised to select the optimum compression and then filming can begin using coder-decoder (CODEC) in the knowledge that the best transmission result has been guaranteed.

This capability to automatically and instantly assess the most effective compression level can be used in any send and receive combination, making the applications of this novel technique extremely broad.

Future work is currently planned on low dynamic range videos captured by infrared or night vision sensors and on developing the ability to selectively compress parts of an image using object based recognition techniques. Medical imaging is another field of interest in order to facilitate, for example, remote diagnosis or even surgery. Outside news broadcasts, sporting events, environmental emergencies, security monitoring, even home videos through our mobile phones are all examples of potential applications for this novel advance.

For technical information about this project, contact
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or Professor Roy Kalawsky (r.s.kalawsky@lboro.ac.uk)

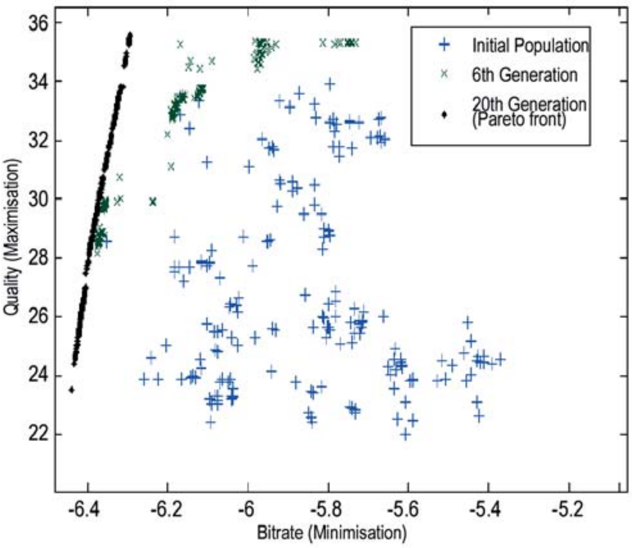

Figure 1: Convergence of solutions towards the Pareto front

The SEIC hosted a visit from Mike Wilkinson, Strategic Development Manager of WS Atkins. Mike has a mainly technical role across much of Atkins' defence business and also co-chairs the INCOSE Architecture Working Groups, at both UK and International levels. The meeting reviewed several opportunities for collaboration and planned a joint workshop later in the year on Innovation Management, one of Atkins' key themes.

The SEIC led two working groups at a major NATO workshop held in Norway on Applied Vehicle Technologies and participated with contributions on health monitoring and technologies for unmanned autonomous vehicles. This bi-annual workshop attracts over 200 participants from across NATO with the objective of developing a strategic plans for NATO's capabilities in this field.

A 1-day event on Technology Lifecycle Management was held in association with INCOSE, the UK's Integrated Products Manufacturing Knowledge Transfer Network (IPMKTN) and the Centre of Excellence in Metrology for Micro and Nano Technologies (CEMMNT). The event attracted presentations from various industrial sectors, including aerospace, life sciences and defence all addressing the issue of technology transition, integration and evolution.

Professor Neil Lindsay of DSTL gave a fascinating talk on the role of Systems Engineering in Counter Terrorism. The Ministry of Defence is adopting a more systematic approach to solving many of the complex problems it currently faces. This approach ranges from enterprise-level systems to acquire more effectively the new capabilities it needs, right down to detailed technical solutions to defeat specific threats. Spanning this broad problem space lies the pervasive threat from terrorism and insurgent activities, in particular faced by UK forces whilst deployed on operations abroad.

Norman Hyde, the MOD's new DE&S Director for Systems Engineering and Integration Group (SEIG) and his Systems Engineering Skills Development Team Leader, Dave Hawken visited the SEIC.

The Royal Academy of Engineering (RAE) held an event on the professional recognition of systems engineering – an issue the SEIC is keen to support. The event was attended by professional institutions including the Institution of Engineering and Technology (IET), the Institute of Mechanical Engineering (IMechE) and the International Council on Systems Engineering (INCOSE). The evolution of systems engineering as a recognised profession is, clearly, key to both the competency and the industries it serves.

The SEIC coordinated, hosted and facilitated an international Experts workshop on the topic of "design-for-purpose". Sponsored by the EU, this workshop attracted 25 acknowledged experts from industry and academia. The output will be articulated into a strategy document to help the EU develop their future FP7 calls in this field.

Systems Skills are of increasing importance to the UK Ministry of Defence (MOD) to meet the challenges of delivering capability in a holistic way. The Defence Science and Technology Laboratory (Dstl) recently held a symposium, involving systems experts from government, industry and academia, to share best practice in the application of systems skills and to compare how such skills are being developed. A follow-up Systems Skills workshop, co-hosted with the SEIC, and attended by 10 HEIs, sought to identify practical steps to collectively advance the development of systems skills in the current and future workforce. Providers of systems skills education in its widest and most inclusive context are all welcome to contribute. Contact Amanda Pearce for more information. (a.v.pearce@lboro.ac.uk)

A workshop on Architecting for Capability was attended by members of SEIG, Dstl, INCOSE Architectures Working Group, Loughborough University and SEIC. The output will provide a contribution to the NECTISE Conference, RNEC08, in October this year. For details of the conference, see www.nectise.com.

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FEEDBACK

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