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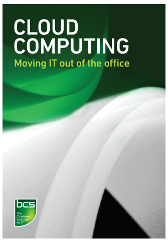

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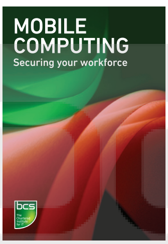

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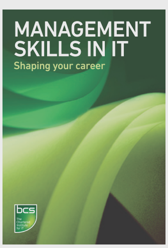

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INTRODUCTION

Health care is very much an information business. Administering health care was the subject of many early systems. It was not long after the first computers appeared that they were being used to support the finance function at the London Hospital. Things have come a long way since those days and still have far to go. Use of computers to support the clinical care of patients is a more recent phenomenon, but one that is obvious if you think about it. Much of health care deals with the collection of symptoms and results of tests to form a diagnosis. The formulation of a plan and its implementation involves the collection and recording of much information.

The recent Health and Social Care Act 2012 initiates major changes to the NHS, giving responsibility for commissioning health services for local populations largely to GPs in Commissioning Care Groups. These changes aim to create productivity improvements in the health and care of populations by ensuring more integrated care across a range of settings from home to hospital care, where different providers contribute to the overall integrated pathway of care for a patient. This can only be achieved satisfactorily by using information and information systems to transform the productivity and economics of the NHS; improving the quality of care, its outcomes and the health of the population.

This briefing is aimed at presenting just a few of the many innovative ways in which information systems and technology are being used to support health care. Matthew Swindells, Chair of BCS Health, points out in the first article that 'the challenge is to IT-enable the whole system, not just the silos: stepping out of our narrow institutional interests and finding a way to deliver benefits for the population, the patient, the NHS and its staff.' He describes the five pillars on which this should be based to achieve success.

You will find articles on robotic surgery and radiotherapy targeting showing how informatics is being applied in leading-edge clinical treatment of patients. 'Telehealth: for better patient care' and 'Smart textiles' focus on how technology can support people in their own homes and avoid the need for expensive hospital care.

It is well documented that patients are harmed and killed by medical errors with about 1 in 10 patients being affected in some way. In 'Safety first', Dr Paul Shannon explains how 'electronic systems, wisely designed and implemented, can help reduce risks in a variety of ways.'

As the number of different providers of health care to individual patients increases, the need to integrate care and information from different sources also increases. This risks greater fragmentation, potentially leading to more, rather than less, medical errors. Researchers William Buchanan and Christoph Thuemmler of Edinburgh Napier University talk about their approach to this complex problem using the latest innovations in cloud computing.

Janet Sampson from the Welsh Blood Service describes how other areas of health care computing can learn from the strict validation procedures they must apply for new computing systems. This becomes increasingly important where information is crossing organisational boundaries in order to provide a complete picture for a patient.

If you need any convincing of how exciting health informatics can be and want to be inspired, read Justin Richards' interview with Dr Julie Greensmith: 'A real rollercoaster ride'. Part of the Intelligent Modelling and Analysis Group in the School of Computer Science at the University of Nottingham, she describes how she got into this domain and what she is working on.

The line up is completed by Andy Savvides describing the NHS Infrastructure Maturity Model; Margaret Cosens and Keith Richardson on the application of speech recognition and digital dictation; Paul Chapman on how the implementation of an electronic patient record at NHS Rotherham has led to shorter waiting lists and productivity; and Carol Bond on how the internet has transformed information for patients, the public and health care professionals.

While we cannot hope to cover the sheer variety of areas in health care where information technology is already making an impact or the complex and exciting areas still to be tackled, we hope that these articles give you some insight into the domain. They are aimed at an audience that does not require detailed understanding of health care or health informatics.

Sheila Bullas
Vice Chair Publications
BCS Health

1 USING IT TO IMPROVE POPULATION HEALTH MANAGEMENT

At the annual conference of the Primary Health Care Specialist Group, Matthew Swindells, Chair, BCS Health, talked about the changes that have been brought in by the recent Health and Social Care Act 2012 and the implications this has for informatics.

The Health and Social Care Act 2012 hands commissioning of health services over to 'clinical commissioning groups' largely run by GPs. As the Chair of the NHS Commission Board, Malcolm Grant, said: 'The best clinical commissioning groups will be those with the best information systems.' There is, therefore, an obligation on those who work in the area of health informatics in general and those in primary care informatics in particular to step up to this challenge.

Traditionally health care has stood out as the one industry where the perceived wisdom is that spending and quality are inextricably linked. It is held by many to be self-evident that, if you reduce cost, you must by default increase how long people wait for care and reduce the quality of the service.

No other industry can get away with this simplistic view, and the evidence shows that in health care the perceived wisdom isn't true either. There are innumerable studies around the world to show that variations in quality are frequently nothing to do with the amount of money spent. Whether you look at the Dartmouth Health Atlas showing the failure of higher spending to correlate with better outcomes in the USA or at the fact that many of England's hospitals with the best clinical outcomes also have the lowest reference costs, you see that money can be spent wisely to get great outcomes at lower costs or badly to get poor outcomes at high cost.

The challenge for informaticians is to show that they can break the perceived wisdom, that they can reliably and repeatedly reduce cost while improving access, quality and outcomes through the application of information and technology.

There are only two ways to drive cost reductions and quality improvement:

- One is to make individual health care institutions and services such as hospitals, community clinics and home nursing more productive.
- The other is to make the whole health and care system more productive.

The former is critically important and the NHS should not be distracted from the important task of driving waste and inefficiency out of its services. I have previously written a number of papers and given several talks on the potential for productivity improvement in hospitals through process redesign and the application of evidence-based care, supported by information and technology. In my talk I focused on the whole system and opportunity to transform the economics of health and care by placing the patient at the centre of system design and using information and technology to improve their health and reduce their cost demand on the health care system.

The challenge is to IT-enable the whole system, not just the silos: stepping out of our narrow institutional interests and finding a way to deliver benefits for the population, the patient, the NHS and its staff. This needs to be based on five pillars:

1. Strong electronic health record (EHR) foundations in hospital care, primary care, community care and homecare: without good, real-time clinical information, very little else is possible.

There is a question about whether the purchaser or commissioner of care should worry about the EHR systems being used by their providers or even whether they have a right to have an opinion. I would argue that if they are serious about managing quality and developing benefits through system integration, they should insist that their providers have a digitised health record and are able to share this data in real time.

The next generation of health care information technology will apply knowledge algorithms, such as prompts on the appropriateness of admission or the identification of patients at risk of being readmitted as an emergency, as the data is collected so that, for instance, preparation for managing their discharge can start as they come into hospital.

These, and the hundreds of other intelligent support algorithms that it would be possible to build and run to support staff and protect patients, are dependent on comprehensive EHRs, gathering data on patients as it is known, not two days after discharge.

Furthermore, commissioners should insist on the digitisation of the whole care pathway because it will support the elimination of 'memory-based care' and the distribution of clinical decision support to propagate the application of best practice. It is well known that one of the keys to better, safer, lower cost care is the application of evidence, but it is also understood that the adoption of new knowledge into routine practice is painfully slow: one study showing that it takes 17 years for a new piece of knowledge to be adopted into practice by half the physicians.

This is not because doctors are difficult and refuse to use the evidence in front of them. It reflects the fact that the volume of new evidence being produced, the complexity of care pathways and the number of professionals involved in providing care makes 'memory-based care' a defunct approach to modern medicine. Einstein did not clutter his mind with 'facts' he could find in a book. He devoted his efforts to interpretation. The average clinic appointment doesn't provide the time for a doctor to refer to a pile of clinical text books, so we expect them to provide care based on what they can remember.

The consequences are seen in the waste and harm that is caused by prescribing errors: three to five per cent of all hospital admissions, £500 million unnecessary costs; and the myriad of examples of where best practice care can deliver low cost, higher quality, but is patchily adopted.

This is why, when commissioners think about redesigning a health system, they need to require their providers to use EHR technology effectively, and then apply the 'closed loop' principle to quality management beyond the hospital and integrated care pathway processes.

2. Using a health information exchange (HIE) to link the care system together, so that we don't have silos of information, but clinicians can have access to all the relevant information at the moment of decision.
Digitising the health care silos is not enough to transform health care as a whole. HIEs allow organisations to connect and exchange information across an entire health system. In Oklahoma, for example, a publicly managed health information exchange called SMRTNET (Secure Medical Records Transfer Network) captures data on more than 2.6 million people or 72 per cent of the state's population.

There are a growing number of published studies that support the clinical and economic benefits of this integration. One recent study showed that HIE access achieved a 230 per cent return on investment by reducing admissions through A & E; another showed increased efficiency in primary care from improved access to test results and less staff time handling referrals; and a third showed that 70 per cent of outpatient doctors forecast that an HIE would reduce costs, 86 per cent that it would improve quality and 76 per cent that it would save time.

The technology exists to allow hospital doctors to see relevant patient data directly from the GP system and the GP to see data directly from the hospital electronic medical record (EMR), allowing clinicians to share their knowledge about a patient in real time.

3. Gathering data together, outside of individual systems and organisations, to give a comprehensive view of the health of a population.
Clinical integration through an HIE will improve quality and productivity in operational practice, but designing the health system of the future requires more than this. Advances in technology mean that system-wide information design, which is the legitimate interest of commissioners, can move beyond retrospective reporting into real-time patient and quality management. This requires us to lift data out of the institutions and bring it together at a higher level, in the cloud, to enable:

- pain-free health system reporting and benchmarking to drive process improvement, reduce bureaucracy and insurance income retrieval;
- real-time patient and system tracking to optimise the patient experience;
- predictive modelling to plan future interventions;
- whole pathway decision support that is not encumbered by organisational boundaries.

This liberation of data allows the health system to maximise value by addressing the needs of the whole population and, within that: to identify patients with long-term conditions and ensure that they receive locally agreed pathways of care, personalised to their own needs; to ensure that episodic care is applied according to best-practice evidence and that quality and cost are monitored; to ensure that specialist care is supported by the appropriate experts and advanced decision-support tools.

4. Support the direct management of patient care, so that community services address the correct patients, in a timely way, supported by the information and evidence that they need.

In an EHR-enabled health system, population level information analysis isn't simply for information and reporting: it needs to be integrated directly into front-line patient care to drive changes in population health.

The data from risk stratification and tracking the clinical data collected in hospital, community, primary and home care, as well as by patients themselves, can be used to prioritise cases for a case manager, telephone-based health coach or home nurse's schedule. It can then guide the conversation that they have and the vital signs that they need to collect, applying decision-support algorithms in the background to prompt advice to the patient or decisions to refer to another professional. It can alert the hospital or primary care clinician if a patient is deviating from their expected recovery or disease management pathway to provoke an intervention. It can ensure that patients, their carers and the clinical team are kept informed about decisions made in other parts of the care pathways.

5. Use technology to support the patient in being a partner in maintaining their own health.

There is considerable experience around the world to suggest that simply giving patients access to their clinical record adds little value. Some highly motivated patients are interested and access it frequently, but most look once and then very rarely. To make a personal health record (PHR) compelling it needs to be interactive and supportive.

The PHR should provide a simple and user-friendly record of the patient's notes in different organisations for them to view. Most patients have GP records and several hospital records. The PHR should bring these together in one place, not being tethered to a single institution or software vendor.

It should prompt the health maintenance activities that patients should be undertaking, such as exercise or taking their own measurements. It should integrate to home monitoring devices such as scales, pedometers and blood pressure cuffs.

Through its interface to the cloud-based population health platform it should link with data captured at home and with data captured in primary care or the hospital, and provide real-time alerts with advice on what to do next (such as an online, evisit questionnaire) and share this data with the GP, case manager or practice nurse.

IN CONCLUSION

Population health improvement requires more than retrospective public health analysis. It requires:

- Platforms of EHRs in all parts of the health system so that data can be accurately captured, shared and used to provide decision-support prompts that encourage application of best practice. These platforms need to be integrated through an HIE to allow clinicians to share information and gather the data to support analytical tools.
- An information infrastructure that allows:
  - automated retrospective reporting and submissions;
  - real-time patient tracking;
  - predictive modelling, risk assessment and population segmentation;
  - patient prioritisation;
  - the application of evidence-based decision-support algorithms.
- Care management tools that support the management of patients in all settings and proactive intervention to support health.
- Tools to assist patients in managing their own health and engage them in decision making.

The NHS will not deliver 20 per cent productivity savings without this investment in information and technology. The challenge is whether we have the skills and the courage to change the way medicine is practised, with the help of information and technology.

2 SAFETY FIRST

While IT is transforming health care practices and procedures throughout the UK, a significant proportion of the NHS relies on outdated paper-based processes. These are not just wasteful and inefficient; they are putting lives at risk. Dr Paul Shannon FRCA MBA, Consultant Anaesthetist, Doncaster and Bassetlaw Hospitals NHS Foundation Trust and Medical Director, CSC UK Healthcare, examines a flawed approach to patient safety and the solutions that should be adopted.

'Staggering numbers of people are harmed and killed by medical errors,' the World Health Organisation (WHO) said recently, with mistakes having an impact on 1 in 10 patients. Little wonder that the organisation is warning that patient safety is an 'endemic concern'. This is not new.

In 2004, the National Patient Safety Agency described the risks that arise from our complex health care system, warning that 'evidence shows that things will and do go wrong in the NHS; that patients are sometimes harmed no matter how dedicated and professional the staff.'

But while individual errors might be found to be due to the mistakes of one or more person (e.g. the tired doctor, the overworked nurse), it's invidious to blame health care staff for the WHO's 'endemic concern'. Why blame humans when we deny them the tools that can help cut the risks of error and improve patient safety?

Why tell staff they have to pull their socks up when there are solutions already out there that can improve their working lives and make the care they provide that bit better? Electronic systems, wisely designed and implemented, can help reduce risks in a variety of ways. Here's how.

CONSTRAINING HUMAN ERROR

'To err is human,' as the poet and essayist Alexander Pope said almost exactly three centuries ago. We can see examples of this every single day in every single health care setting.

The common types of individual human error are lapses and slips; that is, errors of omission (I forgot to do something I should have done) and commission (I did something I didn't mean to do). The root causes are many, including such contributing factors as fatigue, distraction, lack of knowledge, poor communication and even deliberate wrongdoing.

Electronic systems don't suffer from many of the frailties of humans. Where they can replace tedious, repetitive, high-speed and complex tasks currently performed by people, they can improve safety. Electronic systems are logical. Steps can be made compulsory: no cutting corners or skipping items by mistake. Think of buying an airline ticket; you must follow the prescribed sequence or else you can't complete the task.

There are many examples where there is evidence to show improvement in patient safety. Here are just a few: electronic cross-match of blood; electronic monitoring and voice prompts to enhance hand-washing, thereby reducing nosocomial infections; prompts and pauses.

A prompt reminds the user to do something, for example vital signs monitoring. A pause introduces time for reflection or confirmation: 'Do you really want to do this?' Cutting out that human element, or even prompting us to think a moment, can and does save lives.

HARDWIRING QUALITY

With the best will in the world no doctor or nurse can know everything. They'll have strong and weak points in their knowledge and skills. They have good days and bad days, like the rest of us.

Health IT can help direct care and ensure that the patient stays on the right track, that they receive all the appropriate care in a timely manner: right thing, right way, right time. Again, illustrations are plentiful. Enhanced communication across care boundaries, for example, can provide integrated care (vital for things like safeguarding) and also helps to overcome the fragmentation of care delivery.

Formal clinical decision support is also hugely useful, for example, with systems such as ePrescribing improving the quality and safety of patient care. Informal support, such as Medline and even Google, is also proving its worth.

Electronic systems are great for tracking patients along pathways of care, improving hospital care planning from well before admission to long after they return home. They can also help to implement care bundles (groups of interventions that, when implemented together, have a synergistic effect on a disease pathway or patient outcome).

IMPROVED DECISION MAKING FOR CLINICIANS AND PATIENTS

Having the necessary information about a patient is essential to good clinical care. Having that information at your fingertips when you need it and easily accessible helps avoid pitfalls and promotes bespoke decisions: forewarned is forearmed.

The patient feels valued, listened to and at the centre of attention. The full recording of clinical observations (such as vital signs and early warning scores) facilitates medicines reconciliation and enhances continuity of care. After all, if the notes are consistent and trustworthy, then they will be trusted by the next clinician who treats the patient.

AND WHEN THINGS GO WRONG

Electronic systems are terrific at discovering the source of problems because they allow data to be captured automatically. Coding systems, such as SNOMED CT and ICD11, aim to overcome ambiguity in language by providing terms that have defined meaning.

If information is captured, it can be investigated, analysed and presented in meaningful ways. This provides the possibility for remembering and learning from mistakes (retrospective analysis), providing a real-time picture of how things are (current status, dashboards) and how things are likely to be in the future (prediction).

Here are just a few examples of how this is working in practice:

- Automated adverse event detection can spot medication errors and infection risk.
- Automated critical incident reporting makes it easier to flag when things go wrong.
- Data mining can identify complex correlations and novel associations that would otherwise never be seen.
- Population surveillance can aid with establishing the safety of products or interventions (such as vaccine safety) and also monitors the spread of infection or progress of epidemics.

There are many more examples benefiting all aspects of health care. These range from supply chain management (e.g. ordering the right stuff on time and without unnecessary duplication) to making sure patient information is recorded properly to save the same questions being asked over and over again.

IT ALL ADDS UP

The use of electronic systems in health care is already embedded into everyday practice. It would be inconceivable to contemplate providing modern health care without such essentials as patient administration systems (PAS), picture archiving and communication systems (PACS) and theatre management systems (TMS).

In many parts of the NHS, however, paper-based and manual processes still dominate, and it is in this area that most patient safety issues occur. The time is now ripe to exploit health care IT fully in the NHS in order to reap the patient safety benefits. These systems, properly implemented, can provide the step change in patient safety that everyone knows we need, but which has proved extremely difficult to bring about in practice.

Simply encouraging health workers to pull up their socks doesn't work, and why should it? There's only so much longer that we can make excuses for not implementing these changes.

I quoted Pope earlier in this article, but perhaps we should look instead to Seneca, whose words were probably Pope's inspiration. A couple of millennia ago, he is believed to have said: 'Errare humanum est; perseverare diabolicum.' This translates roughly as 'making mistakes is human, but carrying on with them is devilish' – and not in a good way. We know that people make mistakes; we know that in health care these mistakes can have serious, even fatal, consequences. We also know that judicious use of IT can reduce the risks. Can we really afford to carry on regardless?

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3 VALUABLE LESSONS IN VALIDATION

The UK Blood Services are unique NHS organisations regulated in a similar way to the pharmaceutical manufacturing industry. Together with hospital blood banks they must comply with EU and UK legislation and are inspected by the Medicines and Healthcare products Regulatory Agency (MHRA). One legislative requirement is that equipment and IT systems are properly validated. With this in mind Janet Sampson, Validation Manager, Welsh Blood Service, explains how computer systems validation in blood establishments can provide valuable lessons for the wider IT community.

WHAT IS VALIDATION?

Validation is much more extensive than testing. It is the part of an organisation's quality management system that ensures that computer systems, equipment and processes work as expected (i.e. they do what they are required to do).

Validation applies to all activities in the life cycle of a system: from the initial requirement and specification through supplier audit and procurement, system design build and test, user system acceptance, training, installation and contingency plans to maintaining the validated state once a system is in operational use.

Effective change control procedures are required to handle project deviations and to ensure that, once accepted for operational use, the validated state is not compromised by ongoing maintenance.

THE VALIDATION PROCESS

Validation commences with the development of the validation master plan (VMP), which states the high-level validation strategy for the life of the system (or multiple systems, for example within a laboratory).

The VMP is a living document defining the requirements for qualification, acceptance, implementation and ongoing operational use. The validation strategy is further broken down into validation plans that define the scope, roles and responsibilities, and the acceptance criteria for elements such as:

- system infrastructure;
- data migration;

- application (including configuration settings);
- interfaces to laboratory equipment and other computer systems;
- legacy system decommissioning.

VALIDATION STAGES

Validation may be performed either prospectively or retrospectively, depending on the position in the system's life cycle. Periodic revalidation is also required. Senior management approval of validation deliverables is required at control points to authorise continuation of the project.

DEMONSTRATING COMPLIANCE

The MHRA expect a robust and effective validation strategy prior to installation and operation of systems. Inspectors demand evidence of adequate control through appropriate project management arrangements accompanied by approval of all relevant documentation.

The focus is on ensuring patient and product safety, and data integrity. Staff are interviewed by inspectors and must present evidence to demonstrate the correct functioning of critical aspects of the system (e.g. test results handling, donors' eligibility, products' labelling and issuing).

The MHRA has been tolerant of hospital blood banks' existing IT systems, but for new IT systems, such as the Welsh Blood Service's replacement blood management system, and major change programmes they expect to see plans in advance.

A failure to satisfy the regulatory requirement for validation will result in the system not being approved for operational use. Critical non-compliances must be addressed urgently following an inspection. Importantly, the MHRA have the power to issue a 'cease and desist' notice to blood banks and blood establishments.

CHALLENGES

Validation must be carried out by suitably qualified staff with records retained for 30 years. A governance framework is required that satisfies Caldicott principles (i.e. no use of identifiable patient/donor data), clinical and corporate governance.

Compliance to standard operating procedures is verified by quality assurance that has the authority to halt work if procedures have not been followed and to prevent the system being used if it is not considered to be fit for purpose. Some technical considerations include the need for:

- a validation environment separate from the operational environment;
- the application to be in a steady state (frozen) to verify functionality;
- simulation of equipment that is in constant operational use.

The challenges of performing validation were first addressed by the pharmaceutical industry from which the internationally recognised Good Automated Manufacturing Practice (GAMP) methodology has originated.

In addition to the inherent constraints on time, resourcing projects may be difficult. In hospital blood banks, especially, validation staff may be scarce, plus there may be an initial failure to comprehend the need to perform additional, complex work.

Organisations must always be prepared to respond to changes in legislation. GAMP® 5 addresses the latest regulatory requirements for validation strategy (aligning validation stages with: product and process knowledge; systems life cycle; leveraging supplier involvement; quality risk management and scalable activities) while being relevant for advances in software development such as Agile.[1]

Challenges such as these have been addressed by the wider blood community. The European Blood Alliance is promoting a collaborative approach to validation, having a workgroup tasked with producing standard validation protocols and proposing collaborative solutions. The International Society for Blood Transfusion has also published validation guidelines.

WHAT OTHER HEALTH ORGANISATIONS CAN LEARN

The need to demonstrate control throughout the process, beyond standard project planning, is an important aspect. Validation requires multi-disciplinary trained teams of IT, validation and quality assurance experts, and users.

Projects are challenging: each system is unique, therefore lateral thinking is needed to devise the correct strategy. Risk assessments are used to identify the critical functionality of the system while focusing always on protecting patient safety, ensuring product quality and mitigating clinical risk.

The benefits of validation to a health care organisation exceed the requirement to achieve regulatory compliance, for example:

- process and system knowledge transfer from multi-disciplinary teams to systems support at go-live;
- optimising use of scarce resources through collaboration with other organisations;
- ensuring suppliers' commitment to validation and support through clearly defined roles and responsibilities;
- good documentation management procedures.

An organisation that is held up to regulatory scrutiny must be reflective. It is forced to examine how it will achieve its aims and objectives and must develop efficient and effective working practices. The process of validation contributes significantly to this.

Finally, validation should not be perceived as a painful, bureaucratic overhead, but as a quality mark that, through a focus on patient safety, product safety and data integrity, accompanied by a commitment to continuous improvement, adds value to the health care organisation.

NOTES

1. *GAMP® 5 A risk-based approach to compliant GxP computerized systems*, ISPE (2008).

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4 THE INTERNET AND PATIENT INFORMATION

Although the internet has only been around for a relatively short period of time, its influence on both clinicians and patients is growing rapidly. Carol Bond, Senior Lecturer in Health Informatics at Bournemouth University, examines the internet and its relationship with patient information.

I find it hard to talk about the internet historically because, although it often feels as if it's been around forever, it's only been available to the public for the last 20 years. The Office of National Statistics didn't start asking about internet use in the General Household Survey until 2000, when only a third of households had home access to the internet.

Among students starting preregistration nurse education at a university in the south of England that year, only 41 per cent had year-round access to a computer with an internet connection.

In the intervening 10 years not only has internet availability changed enormously, with 93 per cent of students having a computer and internet connection, the internet itself has also changed considerably. It has developed from being a mainly static information-giving medium to a dynamic, interactive communication tool.

In spite of the high level of computer ownership among nursing students, nurses have been slow adopters of IT, seeing computers as something that gets in the way of patient care rather than something that supports it. A recent clinical nurse lead for the Connecting for Health programme is quoted as saying: 'If articles are branded as IT it's unlikely that nurses will pick them up, let alone engage with them.'

As patients turn to the internet, however, they might lead a change in this attitude. At the moment many nurses don't understand enough about the internet and its role in patient information to be able to work effectively with their patients.

Historically health professionals have been concerned about patient use of online health information. Two worries are around the quality of the information being assessed and that patients will use it to self-diagnose. The worry around the quality of health websites is to some extent unjustified.

RESEARCH UNDERTAKEN

While there are undoubtedly some poor quality websites in existence, research into cancer-related websites found a low incidence of inaccurate information.

Research undertaken with online breast cancer support groups found that only 0.22 per cent of posts contained wrong or misleading information and that other contributors corrected this within an average of four and a half hours.

Various attempts at establishing some type of quality kitemark for health websites have been made. The most enduring is HONcode and the NHS has attempted to introduce its own schemes. The NHS's most recent attempt is the Information Standard, however this is expensive to obtain and the number of organisations that are listed on the website as having signed up is small.

People looking for online health information have been found to have poor awareness of these quality marks and the schemes have been criticised for being of limited use to the lay end user.

ONLINE HEALTH INFORMATION USERS

The concern about self diagnosis is not borne out by research; many users of online health information are seeking to understand better a health problem they or a family member have. Rather than seeking to self-diagnose, people living with long-term conditions tend to use information found on the internet to help them prepare for consultations.

Users are very supportive of the NHS drive to see people living with long-term conditions as active participants in their own care, working in partnership with professionals rather than being passive recipients of care. Online health information users have the expectation that their use of online resources will improve their interaction with health care professionals.

The health care field, however, is struggling to keep up with the leading-edge patients. Two factors considered in most quality schemes are the authority of the website and the evidence base of information.

When considering interactive web 2.0 sites, however, where peers are sharing information, the authority is that of someone living with a condition and the evidence base is their experience, which may include significant co-morbidities. Condition-specific websites often struggle to deal with this.

The question of what constitutes good quality information is also open to debate, especially as research has found that many patients using online health information were seeking points of view not associated with mainstream medical thinking.

PATIENTS RATING GPs

The internet is developing so quickly that it is difficult to know what its patients (and health care professionals) want from it and from health services. Some attempts to encourage patient participation haven't been well received by the medical community, such as the ability for patients to rate their GPs on the NHS Choices website. Patients don't appear particularly to want this facility either.

Checking my local area, half of the closest 20 GP practices haven't been rated at all. The most rated practice only has three ratings. With such low levels of participation the ratings and comments are in danger of lacking balance.

It is also worth questioning if the NHS should play a general role in patient information or if it should focus on ensuring that patients are aware of what they are entitled to under NHS care. The internet does not operate within country boundaries and it is easy for patients to find out about treatment options in other countries, which opens practical and ethical problems that need discussion.

DEFINING INFORMATICS

Information systems in health care tend to underpin financial management. Certainly in the NHS in recent years, the focus has been on the development of large-scale computer systems. The IMIA NI definition of nursing informatics (agreed in 2009) is wider than this narrow technology focus:

'Nursing informatics science and practice integrate nursing, its information and knowledge and their management with information and communication technologies to promote the health of people, families and communities worldwide.'

Perhaps for too long the focus has been on the T in IT rather than the I. Instead of talking about IT (information technology), we need to make a subtle shift and talk about information **and** technology. Patients deserve health care professionals who understand their information needs and work with them in a new relationship that acknowledges that professionals are no longer the sole source of that information.

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www.bcs.org/content/conWebDoc/38308

5 HEALTH IN THE CLOUD

The health domain has to face problems with fragmentation of information and legacy systems. BCS, The Chartered Institute for IT's Brian Runciman MBCS spoke to William Buchanan and Christoph Thuemmler of Edinburgh Napier University, finalists in the BCS IT Awards 2011, about their approach to a complex information problem.

Over the next few years the amount of data held in hospitals should go down, but only at the cost of further fragmentation as different kinds of carers, therapists, nurses and the like deliver health care in patient's homes and nursing homes.

This will cause even greater information problems in the long term because these disparate information sources will still need to adhere to the requirements of good governance: security, scalability and trustworthiness.

Researchers at Edinburgh Napier University and Imperial College, along with clinicians from Chelsea and Westminster Hospital, London, have created a new, next-generation ehealth platform that overcomes many of the existing problems with usage of electronic patient records.

Called PatientCloud, it uses new security methods to integrate assisted living with primary and secondary health care and aims to create a completely integrated environment for the capture, storage and delivery of clinical services, to create an integrated approach to patient care.

'This new ehealth architecture will allow data to be stored with its context, such as where it was captured, and then used in whatever way is necessary, through well-managed clinical services,' says William Buchanan of the School of Computing at Edinburgh Napier University. 'Within this we have integrated security in every single transaction and, as it is hosted in a UK-based cloud, it is scalable and robust.'

The system has a service-oriented infrastructure with role integration. Key clinical services can then be accessed from a range of devices, including from web pages and mobile phones. A key focus is on the identification of the role of the clinical person, typically using multiple identification methods, in order to gain the rights to certain services. This integrates with a new governance policy, which defines the overall rights of clinicians to the access to clinical services.

The work has also created a unique patient simulator that can create vital clinical measures for a wide range of patient illness, such as for health conditions and infection-related illness, feeding these into the data buckets, so that the clinical services can be observed.

This is currently being used for clinical training and also to assess how the platform copes with large-scale patient integration (with a simulation of millions of patients with different clinical conditions, and with rapid sampling of their clinical measures, such as blood pressure, temperature, SpO2 and so on).

The platform also allows assisted living and primary/secondary care integration. To enhance security the work uses a novel governance policy that applies role-based security within a formal health care infrastructure (such as with primary and secondary health care), and then defines a circle-of-trust policy within assisted living.

The platform then maps the unique identities from the circle-of-trust into primary/secondary health care, and also maps the security policy, so that patients can go between the home and hospitals, and the data and access rights can follow them.

The platform works with a wide range of identity providers and is now integrated with u-Prove, which uses enhanced encryption to link to identity providers such as PayPal and Facebook, but which hides the actual reasons for the access, so that the user's privacy is protected.

PatientCloud is one of the first to integrate primary and secondary health care with assisted living, using a unique governance policy infrastructure. As the UK is faced with future challenges, such as those related to a population that is becoming older, it is important that an integrated health care platform can be created that is secure and can be scaled to the home environment.

The work has received a great deal of dissemination and great credit in applying new security principles, such as with a new architecture and governance policy in a platform that could enhance the quality of life of patients, no matter if they are at home or in the formal health care infrastructure.

Overall the work is patient-centric, where the data is ultimately owned by the patient and the rights of access to the services that use the data are defined by the trust the user has in their care, no matter if the services are carers, in assisted living or in the primary and secondary health care system.

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www.bcs.org/content/conWebDoc/42840

6 TELEHEALTH: FOR BETTER PATIENT CARE

With the words telehealth, telecare and telemedicine being bandied about so much these days, it was apt that Dr Nicholas Robinson, Associate Clinical Director, Long-Term Conditions and Telehealth, NHS Direct, gave a talk about telehealth to the BCS Health (Northern) Group. Tom Sharpe reports.

As well as holding the post of Associate Director for Long-Term Conditions and Telehealth, Dr Nick Robinson continues to work as a GP two days a week, so he is aware of the reality of conditions in the NHS. His seminar set out to describe current developments in telehealth and to discuss the motivation for using these methods to improve care for patients.

Telehealth simply means 'looking after patients remotely' (from the Greek 'tele', meaning 'at a distance'). Dr Robinson revealed that the first known use of telehealth was described in *The Lancet* in 1879. Instances of remote consultation occurred throughout the 20th century, leading to the emergence of nurse call centres in the 1970s and culminating in the UK with the setting up of NHS Direct and NHS Direct Online.

The case for considering techniques like telehealth is driven firstly by the changing demographic profile of the population. It is no longer uncommon for a patient, who might be 100 years old, to receive care from their children who might themselves be 80 years old.

Another factor associated with longer survival is the existence of complex long-term conditions like hypertension, chronic obstructive pulmonary disease (COPD), arthritis and mental health problems, which together affect 30 per cent of the population. A third factor is the reduced availability of health professionals, as both doctors and nurses take early retirement and are currently not recruited in sufficient numbers to fill the gap.

The so-called Kaiser Permanente Triangle (or 'pyramid of doom') in the USA is a model for long-term care in which patients are grouped into three levels. Level-three patients are the five per cent with multiple and complex conditions and very limited mobility, who need expensive treatment under case management. Level-two patients are the 15 per cent who are at high risk and suffer from diseases like COPD, but who can be managed at home with substantial professional support. Level-one patients are the remaining 80 per cent who may be starting to suffer from problems like hypertension: these are potentially serious, but can be managed by self-care with minimal professional support.

Outside of the triangle are those in the general population who are not yet ill. However, it is very important to encourage them (by initiatives like the NHS Health Check Programme) to follow a lifestyle that promotes 'better health'. This, along with regular health monitoring and early intervention, should keep them out of the triangle for as long as possible.

Long-term conditions are those that are progressive, incurable and need ongoing care. They include arthritis, diabetes, heart failure, COPD, mental health problems, dementia, renal failure, cancer, HIV/AIDS and certain other conditions, accounting in total for 65 per cent of deaths worldwide.

Patients, especially those suffering from these conditions, want to feel that they are safe in their own homes and that someone will notice if they need help. They want information about their illness and the medication they are taking to control it. They now also expect to be able to contact NHS services at home or at work, at any time of the day or night.

One way the NHS can improve the patient experience is to offer better pathways, for example to ensure continuity of care from hospital admission to discharge and care at home. The '30-day support-after-discharge for planned admissions' is now mandatory for all admissions.

The need for long-term support in times where resources are limited opens up the possibility of using telehealth techniques. There is a good evidence base for using them to support chronic-care management, involving patients in their own care and supporting them by giving them the means to learn about and monitor their own condition.

Perhaps surprisingly, there is less evidence for case management, evidence-based care pathways and sharing data between organisations. The evidence comes from a number of sources, but is underpinned by results from the King's Fund Whole Systems Demonstrator Action Research Network (WSDAN[1]).

Although virtually unchanged in the last 20 years, telehealth monitoring equipment is able to monitor blood pressure, pulse rate, blood-oxygen levels and temperature. Thus, if a COPD patient has increased heart rate and temperature and reduced blood oxygen, a message can be sent electronically to a call centre for evaluation. The call centre may then refer the problem to nurses to handle and the GP will later be informed that an intervention has taken place.

Currently 10,000 patients are being monitored by telehealth where the focus is on congestive cardiac failure (CCF) and COPD. Some of the challenges to the success of the project so far are that it does not operate 24/7; patients with various disabilities are excluded; patients are only covered in the home; and clinical engagement has been limited.

Telehealth does seem to offer clear benefits to patients by helping them to stay healthy and to know more about their own illness. The data collected is potentially valuable for research, although the volume of data generated (e.g. by continuous PO_2 monitoring) is challenging.

Telecare has also proven its value and could be even more useful if integrated with telehealth. However, it will be necessary to convince both doctors and patients that telehealth offers focused services based on patient needs and is not just a cost-saving exercise.

Costs are a major issue. It is estimated that it costs £500 to call an ambulance, £25 for a patient to visit their GP, £20 to call NHS Direct, £10 to call the new 111 service, £1 for a telehealth 'consultation', but a web- or app-based assessment of a symptom costs 13p. The patient uses the same decision-support tools as the nurse to achieve a final disposition: less waiting, and cheaper!

This means that telehealth would be affordable for a condition like CCF, which affects one per cent of the population, but not for diabetes, which affects eight per cent. There are practical issues about exactly how connectivity would be achieved, for example would it be through a mobile device or through a broadband hub? If the latter, would it be through an existing domestic hub or would a separate one need to be installed?

Results from a questionnaire given by North Yorkshire and York Primary Care Trust to patients in their telehealth project were positive, with three-quarters of patients saying that it gave them peace of mind and nearly two-thirds saying there was nothing they disliked about it. Perhaps surprisingly, only one per cent said they would prefer a nurse to visit.

ISSUES AND DISCUSSION

There was concern that the routine use of telehealth might reduce the amount of personal contact between the GP and their patient and damage the relationship between the two parties. As a GP, Dr Robinson felt that the concept of the doctor providing personal care was a thing of the past. Only with the help of technology would the GP be able to provide more focused care for the patient.

What can we learn from experience outside England? Telehealth has been very successful in Scotland, although it must be remembered that the population is smaller (six million) and more scattered, so conditions are somewhat different.

Also in Japan much use has been made of robotics to help care for an ageing population. It will be a challenge to introduce telehealth on a large scale in England because funding will be limited and, in the short term at least, it will have to be run in parallel with existing systems.

Standards are likely to be another issue: four incompatible telehealth systems are known to be in use, though provided by a single supplier. It may be that standards will have to be imposed for telehealth in the same way that SNOMED CT is to become mandatory for health records.

So it does seem very likely that many, if not most, of us will be able to evaluate telehealth on a personal basis at some time in the not too distant future.

NOTES

1. WSDAN is managed by the King's Fund with DoH support and with the objective of evaluating telehealth in a practical context. It is claimed to be the largest randomised controlled trial of its type ever carried out.

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www.bcs.org/content/conWebDoc/43669

7 ROBOTIC SURGERY

Brian Davies, Professor of Medical Robotics, Imperial College of Science, Technology and Medicine, London, gave a talk on robotic surgery for BCS Health Northern. Phil Paterson reports.

Robotics is part of the study of mechatronics and robotic surgery started about 20 years ago. Although it has come a long way since it is still not widely adopted in the clinical environment. The first medical robot to be described and illustrated by Professor Davies was the Imperial College Probot for prostate surgery, from April 1991. It was experimental and was used by a leading London-based urologist. Early laboratory trials using an industrial robot were described as having eight degrees of freedom, but the safety of robots with multiple degrees of freedom was an issue so a safety ring was designed.[1]

The robot had a camera on the end so that the surgeon could see what it was doing. The surgeon had to put the robot in position and then leave it to run autonomously. But an autonomous robot is not ideal: surgeons prefer a hands-on approach. Professor Davies' subsequent designs of medical robots therefore used this hands-on approach.

The next example was ROBODOC for hip surgery (another autonomous robot). The surgeon would 'lock down' the patient, put the robot in place and start it; the surgeon just had a safety stop button. ROBODOC was used in a large number of German clinics. Unfortunately, fear of litigation by patients and their lawyers put a stop to the use of medical robots in Europe, but Japan and Korea carried on and developed more advanced products.

ARE MEDICAL ROBOTS COST EFFECTIVE?

It depends on how we measure cost effectiveness. To be effective they must make a clinical difference. The cost must be acceptable within the framework of a viable business model. Overall cost reduction is one of the factors in getting robots accepted. Methods of reducing costs include transferring capital costs to a cost-per-patient, and using an operating room assistant to set up the robot in advance to save the expensive time of a surgeon.

Whether a robot makes a clinical difference is not always easy to assess. How good is conventional surgery? It is not easy to get reliable evidence. It is often one person's opinion against another.

Davies explained how master/slave telemanipulation is now used in surgery. It is ideal for soft tissue surgery. Generally the master is positioned near the patient in the operating room and high-quality 3D imaging is used to guide the surgeon in the use of the equipment. In one example, the master console controls a tool, 1 cm in diameter, which has a cable-driven endowrist, which can be used up to 12 times before it has to be discarded in case it breaks.

One such robot is now frequently used for radical prostatectomy. Sales are now driven by patients starting to demand the robot. It costs about $1.5 million plus about $100,000 p.a. maintenance, plus about $20,000 disposables (e.g. replacing the arms) per procedure. There are about 14 robots in the UK now, although not all are used heavily.

WHY WOULD ANYBODY BUY A ROBOT?

The argument is that it does a better job, but the problem is to prove it. It is often very difficult to get good evidence of orthopaedic effectiveness: measures are often subjective, coarse and lacking in comprehensiveness with surgeon's performance being the greatest variable.

The solution has to be simpler, lower-cost robotic systems. They have to be regarded as intelligent tools in the hands of the surgeon. They should be minimally invasive and, for example, use smaller prostheses that cannot be implanted conventionally.

The ACROBOT sculptor for orthopaedic surgeons was described next. A video of an early version, developed at Imperial College, London, was shown as an example. The display shows the surgeon where he is in the body and what is going on.

In controlled clinical trials, with 13 control operations and 13 robotic operations, all the robotic cases were within the target range and all the patients are doing well, whereas only 40 per cent of the controls were within range and two were so far out that they had to be re-done!

WHAT IS THE FUTURE FOR ROBOTICS?

The culture is changing. Patient demand for the best treatment is driving demand for more robotic surgery, but there must be real benefits. Surgeon reluctance needs to be overcome. This requires hands-on intelligent tools, not autonomous robots, and it must be simple to train users, set up the robots and use them.

Lower-cost systems are required. Robots are used for procedures that are difficult conventionally and where they provide clear benefits compared with the alternatives.

In summary, robotic systems are integrated systems that require teamwork and still need funding to be further developed.

In the questions and discussion that followed the talk, it was highlighted that one of the big problems is that many patents have been bought up in the USA. Hence few companies will take on the threat of litigation by developing ideas into new robotic products that are likely to be challenged by US patent lawyers.

The UK has its own interpretation of the legal position, which is more restrictive than in other countries. In the UK, the same legal entity that does the research, must get the robots made and supply them. This is driving collaboration out of the UK into other European countries.

NOTES

1. A safety ring is a mechanical device that limits the movement of the robot, constraining it for safety reasons.

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www.bcs.org/content/conWebDoc/36556

8 RADIOTHERAPY TARGETING

Radiotherapy technologies and their use were discussed at a meeting in Manchester that featured speakers Professor Chris Moore from Northern Western Medical Physics (NWMP) at the Christie Hospital, and Professor Dave Burton from the General Engineering Research Institute at Liverpool John Moores University. Phil Paterson, who chaired the proceedings, reports.

Chris Moore began by giving a brief history of how imaging and therapy parted ways for some time following W. K. Roentgen's popularised discovery of X-rays in 1895. Indeed photography and X-ray parlours gave the public the chance to acquire pictures of themselves inside and out! Radiotherapy treatments were reported on from 1896 onwards.

CANCER CELLS

Chris then started to talk about cancer cells, explaining that they are not 'programmed' properly and do not behave like other cells. One characteristic is that some kinds die much more easily than healthy cells when they are exposed to radiation.

Normal cells can be likened to prize fighters; they will recover time and again, whereas repeated blows will kill off cancer cells. This difference between cancerous and normal cells provides what is termed a 'therapeutic window'.

Single CAT scans have been used for planning radiotherapy since the late 1970s. Algorithms to determine the radiation dose distribution to be delivered to a tumour require the body surface, the target position and the shape of the tumour to be explicitly defined as graphical constructs.

Similarly, organs at risk in the vicinity of the tumour need to be defined as graphical structures. However, despite this exquisite computerised planning detail, it is still common simply to mark the patient's body-surface with indelible ink to indicate to the radiographers where to direct the therapy beams once the patient is in the treatment room.

In the last few years, image-guided radiation therapy (IGRT) has finally taken X-ray imaging directly into the treatment room. Various imaging methods have been deployed to get better images to help the delivery of radiation to the patient. With each new method it seems that more and more data is being generated.

A typical breast cancer patient can have 15 visits during a course of treatment, which has the potential to produce huge amounts of data.

A few figures put things into perspective: A 100-slice CT scan produces 39 MB of raw data and 53 MB of reconstructed data.

CAT SCANS

Cone-beam CT reconstruction, invented in 1984, produces contiguous volumes of image data. Two decades on it is now being widely deployed for cancer treatments. The technique begins with rotation fluoroscopy to form a 2D projection sequence.

The desired image quality for a 1024 × 1024 × 1024 3D reconstruction requires around 768 1024 × 1024 X-ray projections. That's 0.81 GB of 16-bit raw projection data and 2.14 GB of reconstructed volumetric data each time cone-beam scanning is used.

The installed Christie computer systems could not handle this amount of data so the team had to build their own system while waiting for viable commercial solutions. At the moment this technique is only used for a small proportion of the thousands of patients seen annually at The Christie, but this will inevitably grow.

The whole point is to target more accurately the area to receive the radiation and to limit the surrounding healthy tissue to unnecessary radiation.

CAT scanning and treatment planning calculations are not done in the treatment room and are not dynamic. They are performed prior to the arrival of the patient in the treatment room itself. However, during treatment, the tumour is constantly in motion. The patient has physiological motion: they breathe, have heartbeats and so on, so there is no such thing as the patient remaining perfectly still during treatment even with immobilisation devices. All of which makes it hard to set up the patient and aim the treatment beams at the tumour target.

Ideally, imaging should be dynamic and performed during both patient set up and treatment. With X-ray imaging, the therapy radiographers cannot, of course, be with the patient in the treatment room.

The clinical needs of an imaging tool, complementary to X-ray imaging, are that it should:

- show 3D body shape and position;
- provide images on demand;
- be radiation-free;
- work before, during and after irradiation;
- be dynamic, even having a real-time capability;
- have millimetre accuracy.

In 1993, Professors Moore and Burton concluded that there was an optical solution.

OPTICAL SOLUTION

Dave Burton took the floor and began to tell the meeting about how they went about tackling the problem that Chris had described.

It was agreed that something was needed that could measure the shape and position of the patient on the bed. The constraints were:

- there must be no contact;
- it must not interfere with the treatment itself;
- it must be relatively easy to use;
- it must be robust.

The team decided to employ an approach known as ‘structured light’. A highly structured light pattern is projected onto the patient’s body surface and it is viewed off-axis with a digital camera. The patient’s body shape will modulate the structured light as observed by the camera. As the original structure is known and the modulated image can be captured, it is possible to work out the modulating function: the patient’s shape.

The Mark 1 Sensor was based on a laser twin-fibre interferometer. The two professors used a helium-neon optical laser and split the laser beam into a stripy (venetian-blind type) pattern. To overcome the uneven intensity of the light beam (it is brightest in the centre and diminishes at the fringes) they used a piezo actuator, which moves the stripes of light back and forth very fast.

They solved the problem of reconstructing all the parts of a 3D sliced model of a body using a technique called Fourier transform profilometry. An important step in this process is the so-called ‘phase unwrapping’, in which they became world leaders.

The team tested the sensor on a student and they were able to create a 3D model of the student’s back from the stripy pattern of light. From here, in the mid-1990s, they were able to move to testing it on real patients. NWMP then developed a method to dynamically reconstruct the live body surface accurately enough to see the patient breathing and even reveal the heartbeat.

The sensor was used in clinical studies at The Christie, specifically on breast patients, and it lead to some extremely interesting results. At this point it was the fastest, most accurate sensor in use in radiotherapy. However, the team felt that things could still be pushed further. In particular they wondered if they could do it in real time while the patient was being treated, but that would require more coverage and more speed. It would require at least a 270 degrees arc of view with a 40 cm^3 field and something approaching a video frame-rate (about 25 frames per second) with a start/stop button.

The only way to achieve the 270 degrees arc would be to have more than one camera with overlapping fields of view. In fact they would need three cameras and they would need three sensors.

These multiple channels would have to be optically separated and the sensors would have to be networked and operate synchronised and in cooperation, so that each sensor only saw its own stripy pattern. The multi-sensor images would then have to 'snap together' into a 3D model. Given the enormous complexity of one sensor, this was going to be a tall order. Three years ago they set out to build such a system.

GUIDED RADIATION THERAPY

Dave then handed the floor back to Chris for an overview of the use of optical surface sensing for image-guided radiation therapy.

Early testing suggests that the triple optical sensor system is accurate to a millimetre or so, which is comparable with the accuracy of patient cone-beam CT scans. The system is now generating up to 270 GB of data per patient for five minutes of use. Since a course of treatment can easily be 15 daily fractions, the challenge to future networking and data storage problems is obvious.

NWMP at The Christie is now using custom-built terabyte computers on a special network, but it is necessary to find a way to rationalise the amount of data produced. The Christie currently cannot handle this volume of data over its established NHS PACS network. Government advisors have said that image-guided adaptive radiotherapy should become a national standard of care, which of course has huge implications for IT infrastructure.

Funding and support is still needed to continue working with optical sensors before they can become universally available with anything like the performance achieved in the studies by Liverpool John Moores University and The Christie. Inside out, live, and while the patient is being treated, is the goal.

For more information about radiotherapy go to: www.radiotherapy.in/mssd/

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www.bcs.org/content/conWebDoc/35283

9 SMART TEXTILES

According to Professor Tilak Dias, Professor of Knitting, School of Art and Design, Nottingham Trent University, the current generation of textiles, including technical textiles, are passive. However the next generation of textiles will have the ability to monitor their environment and interact accordingly in order to accomplish a pre-programmed functionality. Rita Arafa reports.

Environmentally aware textiles can be considered as truly smart textiles and they would consist of three basic elements:

- sensing and measuring capability;
- activation capability;
- intelligence (programming capability).

One of the solutions for incorporating the above components into a textile material is to create electrically active zones within the structure, whose electrical characteristics can change due to an environmental change or whose structural properties would change due to the application of an electrical signal; for example, change of electrical characteristics due to the deformation of the textile structure.

Generally textiles are made out of materials of very high electrical resistance and can therefore be considered as materials with good electrical insulating properties. However, modern fabric manufacturing machines can be used to create textile structures with localised, electrically active zones, in order to create textile sensors and actuators.

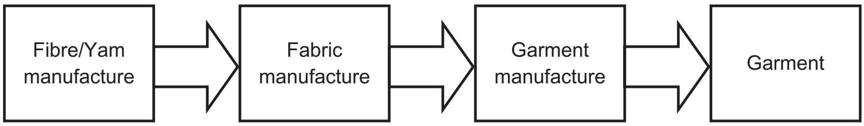
TEXTILES: THE FUTURE

The three core elements in smart and intelligent fibre structures are:

- transducers;
- intelligent signal processes;
- actuators.

The key steps in the integration of electronic devices within apparel during the manufacturing process interface can be seen in Figure 1.

Figure 1 The integration of electronic devices within apparel



The first generation of smart garments had all the electrical elements attached externally to the garment, usually with a power pack strapped on the side. The second generation has fibres that can conduct electricity and can themselves be combined with the normal fibres in a garment to create localised conductive areas and pathways.

Research in the second generation electronic textiles has produced heat-generating knitted structures, knitted transducers and sensors and light-emitting fabrics.

The advantage of using knitted structures, as opposed to woven ones, is that knitted structures can be fitted close to the skin. With knitting, conductive fibres can be incorporated into the structure by using intarsia techniques (knitting techniques used to create patterns with multiple colours) to create localised conductive areas, called electro-conductive areas (ECAs).

The advantage is that ECAs are fully integrated with the basic knitted structure. Electro-conductive fibres include metal yarns (mono-filament and multi-filament), metal deposition yarns (coated), carbon fibres and yarns and conducting polymeric yarns.

Two examples are nylon fibres with a thin coating of metal film around them, and silicon yarn that has been loaded with carbon fibres.

As part of the research, the smallest area (unit cell) that could be replaced by a resistor was identified. Mathematical models were developed to characterise the functionality of ECAs. The accuracy of the models was evaluated with experimental results. The models were used to develop a heated glove as the first product. Carbon-loaded silicone yarns were used to create knitted heater elements and metal-coated fibres were used to form knitted connecting leads (conductive pathways) of the heater elements. Then an electric current was passed through the conductive pathways to activate the heater elements of the glove. The glove can remain heated for up to four hours using a 3.6 V battery. Three-dimensional knitted technology is used for creating heating elements and an electrical circuit with conductive pathways. Heating products are being used commercially in heated gloves for skiing and back-warming belts.

Other garments that have been made are a seamless knitted vest with integrated electrodes with conductive pathways to be used for ECGs and respiratory monitoring, and knitted resistive stretch sensors in a sensor-sock used for monitoring 3D orientation in the foot of people who are recovering from a minor stroke.

Another application of electronically active textiles is in knitted switch technology using skin resistance to operate switches in fabrics by touch (KSwitch). This seems to work more consistently when a female touches it and is not so successful when touched by a male or an older person. This difference in the level of conductivity has been found to be dependent on age, the amount of moisture in the skin and gender.

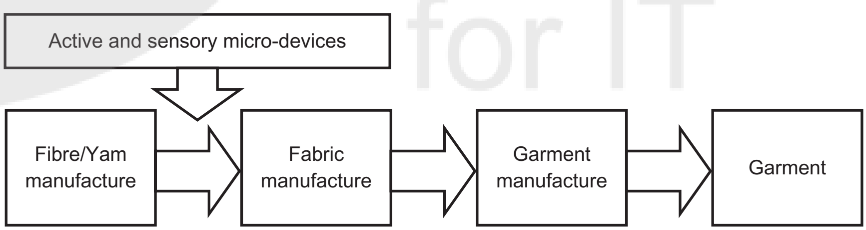
This application has been used for prototype switches in the fabric on the inside of car doors (e.g. to operate electric windows). The advantages of this technology are easy and reliable manufacture, higher degree of design capability, cost-effective manufacture, higher durability and straightforward integration of KSwitches for different applications. The limitations are that switch characteristics are dependent on skin resistance and are ineffective with other materials, so they do not work when the operator is wearing gloves.

THE NEXT STEPS

The next stage is to develop fibres and yarns that have sensors and transducers, actuators and data processors in them, but that look just like normal fabrics.

The key steps in the integration of electronic devices with apparel during the manufacturing process interface can be seen in Figure 2. If the sensors and microprocessors are integrated into the yarn itself, they will not interfere with the normal manufacturing process of the garment. The technology is based on the encapsulated area not exceeding 110 per cent of the threaded thickness.

Figure 2 Key steps in the integration of electronic devices with apparel



The vision is the development of novel technology for fabricating electronically active and sensor fibres that will be the basic building blocks of the next generation of smart fibrous materials. In the future your shirt could monitor your ECG, be your iPod and talk to you!

It is possible to incorporate electronic chips, optical and thermal devices into yarn. However, this has not been done by anyone before so it is necessary to start from scratch. Yarns were created with LEDs in them so that the functionality could be easily demonstrated. Hitachi is the first company to produce a chip small enough to be embedded with textile fibres, called the Mu-chip. It is 0.4 mm × 0.4 mm × 0.15 mm.

Work is now being carried out on light-emitting yarns, ones that will measure stresses and strains on fabrics and that will sense fluids and liquids.

Professor Dias went on to show two videos that demonstrated knitted switches in a waistcoat and in gloves that could be used for stroke rehabilitation, in people with a disability or for game playing. The fastest area of growth for the use of electronically active smart textiles is in the sports industry. There is no need for clinical evaluation before they can be used and there is a significant market.

However, the NHS will need convincing of the benefit and may not be willing to fund the clinical evaluation. Use of smart textiles in the NHS will need to be patient-driven as suggested in the Government's information revolution document.

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www.bcs.org/content/conWebDoc/40770

10 SPEECH RECOGNITION AND DIGITAL DICTATION

'More for less' is a current motif of the health care headlines. The use of digital dictation and speech/voice recognition in hospitals around the UK is already demonstrating a rare combination: an increase in activity (productivity) and cash savings. The BCS Health Informatics (Northern) Specialist Group tapped into local North West expertise to find out what is happening. Phil Paterson reports.

The speakers at the group's meeting were Margaret Cosens, then at NHS Connecting for Health and previously programme manager at The Countess of Chester Hospital, and Keith Richardson, PACS, DD and VR Lead, Chief Information and Knowledge Office, NHS North West.

Margaret Cosens led a project at the Countess of Chester Hospital to implement speech recognition in radiology. The results far outstripped expectations and led to other hospital clinicians asking to be included in the implementation. She contended that NHS Trusts now have a tool available to:

- reduce turnaround times;
- help deliver the 18-week and other waiting times;
- reduce administrative costs by a great deal;
- free up skilled staff;
- enhance the delivery of high-quality patient care.

Keith Richardson is leading a project across the North West to promote the digital management of correspondence (clinical letters, workflow, digital dictation, voice recognition and electronic discharge management) in all 63 acute, mental health and community Trusts. Keith spoke about the current usage in the North West and the scale of the benefit that could be realised within the context of QIPP (quality, innovation, productivity and prevention).

Margaret Cosens demonstrated speech recognition by speaking to the audience and giving control commands to the computer alongside her, such as 'open' and 'close'. The software included Microsoft® Word and Outlook®. Her words appeared on the screen in a Word document immediately after she had spoken them. This demonstration was performed using Talking Point software. One of the control commands is 'change language', which allows the user to switch from plain English to special terminologies such as clinical terminology for radiology reports.

Margaret started on digital dictation and speech recognition at the Countess of Chester Hospital, where speech recognition was deployed as part of the PACS (Picture Archiving and Communications System) project. The speech recognition system linked the PACS with a radiology information system (RIS) and became a treasured tool, providing the rare combination of clinical benefit and business benefit.

The Countess of Chester Hospital was the first in the North West and West Midlands cluster to implement the NHS National Programme for IT PACS in July 2006. The speech recognition programme started in 2006/7 and even before implementation had been fully rolled out there was a queue of radiologists wanting to use it. Radiology reporting was automated and linked directly with the RIS. Radiologists could produce their reports, then sign them off straight away.

The hospital measured the number of days taken to get reports signed off. Over the one year 2006–2007, the use of digital dictation reduced average turnaround times from about seven days to three and a half days, and the addition of speech recognition reduced this further to between one and one and a half days. By September 2008, 91 per cent of all the radiologists were reporting by speech recognition.

CLINICAL AND BUSINESS BENEFITS

Clinical benefits accrued because, after digital dictation and speech recognition were introduced on top of PACS, the radiologists suffered far fewer non-clinical interruptions. Reporting was quicker and questions were fewer so they could be clinically more productive.

Business benefits were achieved through a big reduction in staff costs. The annual cost of radiology department staff to type reports and so on was reduced from about £120,000 p.a. to £45,000 p.a.

Secretaries left naturally, but were not replaced. The workload for the remaining staff went up in terms of numbers of reports each, but with digital dictation and speech recognition making the job so much easier there were no objections.

TAKE-UP

Digital dictation users have got a mix of two products, Winscribe and Talking Point. Take-up was fast and there was a 30 per cent saving in costs. The speech recognition take-up was slower. The key to the success of speech recognition was PACS. Speech recognition suddenly became beneficial as radiologists could write their own reports alongside the scanned patient images in their own office.

The hospital moved on to hospital-wide digital correspondence, the principal drivers being:

- to reduce the time for key clinical information to get to GPs or other requestors to within 24 hours;

- to release senior secretarial staff to manage patient care activities and the overall business;
- to reduce staff costs by providing support for typists.

The hospital uses MedisecNET, which captures clinical letters from PAS (e.g. outpatient clinic letters) and sends them to over 100 GP surgeries in Cheshire. The implementation rollout needs handholding, personal support and encouragement to clinicians.

Speech recognition results in reports being ready the same day, at the end of a clinic, produced and signed off by the clinician. Digital dictation results in letters being signed off a few days later, but it too speeds up the typing process.

There are challenges:

- **Funding for the products and the people** – this needs a commitment to support the implementation before the benefit is delivered and to the ongoing, recurring costs, as well as finding the capital.
- **Vision** – letting others catch it, the heart of change management.
- **Time** – resisting the pressures to pull away from it.

The big positive is that the technology works and, with a robust approach, every Trust could reduce their turnaround times, help deliver waiting time targets, reduce administration costs by a great deal, free up skilled staff and enhance patient care.

TRANSFORMATIONAL PROJECTS

Keith Richardson explained that he was now working at the NHS North West Strategic Health Authority, but that he had also worked at the Countess of Chester Hospital and was a supporter and enthusiast for digital dictation and voice recognition. This area has been identified by NHS North West as one of the 'Top 10 Transformational Projects' under the QIPP Programme.

The NHS in the North West produces about 15 million letters per annum, about half of which are dictated by a clinician. Some 63 NHS Trusts communicate with 1,315 GP practices, which receive an average of 5,750 clinical letters a year each, or 110 per week.

The consequences at the GP practice are that staff currently spend about five hours a day processing and scanning paper clinical letters received from hospitals into their GP computer systems. In the North West that equates to 812 staff, costing about £16.25 million a year, simply processing hospital-generated paper.

The consequences for hospitals are that staff members are employed stuffing envelopes at a cost of about £60,000 a year per hospital. About 75 per cent of letters are sent with hospital transport such as the pathology tests pickup van, but the rest are posted: costing about £1 million a year per Trust for postage.

One option is to try to move the Trusts and GP practices to improve on the traditional, paper-based process. Digital dictation offers more methods for dictation, at the office or home or on the move, with reports going onto a computer network, with an interface to PAS for demographics and reference data, which gives more options for typing, again at the office, home or remote.

After initial transcription, what is required is an editor, more than a typist, who can email a document to the author for online review and sign-off. The process becomes one of electronic letters, electronically processed.

A more advanced option is to replace the secretary with a background computer and the person who dictates the report edits it via online access: but the consultants want to keep their secretaries.

A further option, in radiology, has the consultants dictating directly onto the screen using voice recognition technology; they can verify their reports, sign them off and send them to the GP practice the same day. Both these options present cultural challenges. Responses vary with exposure to change, IT awareness and so on.

Digitised reports and letters enable the concept of an integrated clinical communications hub between hospitals and GP practices, routing electronic letters to the right place. Cheshire Trusts are using this approach to send electronic discharge letters.

CONSISTENCY IS EVERYTHING

Typing errors can arise due to the author of a letter typing and sending it off without a proofreader. You do see what you hear yourself say. Some radiologists will dictate, leave it for a while, and come back to their reports as a batch at the end of a session.

Systems are voice profile-based and very quickly pick up the profile for new users. Consistency is a factor. The systems are very accurate. Microsoft® Windows® 7 includes free voice recognition software. Basic professional voice recognition software is commercially available for about £300 to £650.

WHAT IS THE DIFFERENCE BETWEEN DIGITAL DICTATION AND SPEECH/VOICE RECOGNITION?

The more established approach is to dictate to a tape and give it to a typist. Tapes are then stored until the typist has time to get round to them. If the consultant wants a particular report to be found and typed urgently, it can take the typist hours to search all the tapes to find the right one. Work scheduling is disrupted. This technology uses analogue recording to tape. Most of the NHS is still on this old technology.

Going digital

Digital dictation, which really came in with PACS, produces a 'digital tape' instead of an analogue tape. Digital recordings can be stored on a computer network and made available wherever is most appropriate for typing.

The consultant talks, a digital recording is produced and the secretary types it. The secretary gets an indexed list of dictated letters with priority reports highlighted in red at the top of the list. Management can provide performance statistics on turnaround times and so on.

Speech-to-text

Speech-to-text technology allows a secretary to open up some hard-to-understand reports to find keywords that are converted to text (the words are typed out for the secretary) allowing the secretary to edit this into a proper report.

Speech/voice recognition takes it further and provides a full process. The words come straight back on screen for the clinician to read and edit on the spot.

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11 SHORTER WAITING LISTS AND RAISED PRODUCTIVITY

The implementation of an electronic patient record (EPR) system at NHS Rotherham was intended to make patient information available more easily to clinicians and carers, but created major challenges for some of the Primary Care Trust's (PCT) community services organisation. Paul Chapman, Clinical Lead for Information Technology, The Rotherham NHS Foundation Trust, explains how the Trust got around some of the problems by introducing digital pens.

The new system required all patient information to be entered via a keyboard, which was a fundamental change for services such as physiotherapy, where practitioners traditionally record a lot of information in drawings and diagrams. What Rotherham's physiotherapists used to represent visually, for example in body charts, and with profession-specific notation symbols now had to be described verbally.

As a result, they had to spend 40 minutes extra in administration time for each new patient they assessed. This was equivalent to two new patient appointments per day, resulting in fewer appointments, overrunning clinics and a rapidly growing waiting list.

The need for transcription and loss of profession-specific information also led to delays in data entry and a drop in the quality of information recorded, creating a source of clinical risk and potential litigation.

FINDING A SOLUTION THAT WORKS

In order to address these issues, the Trust searched for a tool that would allow practitioners to capture the required information directly in electronic format and ultimately help improve the process of entering physiotherapy data into the PCT's shared database.

Having considered tablets, NHS Rotherham opted for a digital pen and paper solution from Ubisys, a specialist IT provider to the NHS. The technology, patented by Sweden's Anoto Group, allowed them to write and draw as they had done previously without the need to then go and type up the information later.

The digital pens look and work like normal ballpoint pens. An infrared camera at the tip of the pen tracks its movements relative to a barely visible dot pattern on the patient form, recording and storing what is being written or drawn. After consultations, the pen data can be downloaded either via USB or, for field staff, via a mobile device.

It is then sent to the Ubisys software, which immediately produces electronic versions of the documents in PDF, Microsoft® Word, XML and other formats. These can be added easily and quickly to the patient's electronic record or used by other health care applications as required. The dot pattern can be printed on normal paper using a laser printer, along with the patient form itself.

This means physiotherapists can continue using the same forms and follow the same processes as before, with the benefit of an electronic version of their graphical notes being created at the same time as the paper version.

IMPROVED OUTCOMES FOR ALL

The digital pen and paper solution was quick to deliver benefits, enabling the physiotherapy service to meet its objectives for a more complete care record while increasing productivity and efficiency.

The physiotherapy service was able to recoup the 40 minutes per session lost through new patient administration after the introduction of the ERP system. More importantly, using the digital pens also helped increase consultation time with existing patients by 15 per cent.

Each clinician now had the capacity to see an additional three new patients and an extra five returning patients per week. Instead of having to wait six weeks for an appointment, patients could now be seen within three weeks.

Reduction in clinical administration allows practitioners to focus on the patient and quality of care, allowing more time for detailed subjective and objective examination. More time spent with patients means a reduction in the number of visits that need to be scheduled, as more can be achieved in a single session.

Overall, productivity gains of 35 per cent were achieved as a direct result of using the digital pen and paper system, with a return of investment in terms of increased clinic time within three weeks of its implementation.

In addition, the above outcomes have supported the physiotherapy service in meeting the requirements of the NHS QIPP (quality, innovation, productivity and prevention) agenda and the Commissioning for Quality and Innovation (CQUIN) framework.

REDUCING RISK AND STRESS

The clinical information captured and stored provides an accurate and up-to-date record of history and treatment. The ability to add the information to the patient record immediately allows other clinicians to view clinically relevant information in real time, ensuring patients are provided with the most appropriate care in a timely manner.

Thanks to improved record keeping the exposure of the service to clinical risk, and potential litigation, could be reduced significantly.

Beyond clinical and practical improvements, the introduction of the digital pens also had an impact on the clinicians' working environment. While the physiotherapy team could see the benefits of EPRs, the complications associated with having to type up profession-specific information raised clinicians' stress levels.

As a result of working with the digital pens, staff felt more in control of clinical time and less stressed. It also highlighted the ability to return to a more personable approach in their work with patients.

WHAT NEXT?

Following an initial pilot phase, the digital pen system was rolled out to the entire organisation, including clinic-based and domiciliary physiotherapists, at a cost of £14,000 for 25 pens and associated software.

In addition to 25 digital pen users in physiotherapy, another 150 pens were introduced to speech and language therapy, community elderly medicine, the Stop Smoking team, health visiting and school nursing. The organisations manage the system themselves in terms of designing dot pattern forms and providing ongoing technical support.

The digital pen and paper project showed that this type of technology can contribute significantly to enhancing staff productivity, financial savings and, ultimately, patient outcomes in the NHS.

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12 GROWING UP

The NHS Infrastructure Maturity Model (NIMM) is a comprehensive approach to improving IT infrastructure by benchmarking and managing performance. Andy Savvides, Principal Consultant at Atos Consulting, provides some background to this useful maturity model and contextualised insight into how the top-down approach taken by the NIMM can improve the quality of IT infrastructure.

The NIMM was developed by the NHS Technology Office in collaboration with a number of different NHS IT organisations. Atos Healthcare worked closely with the NHS, helping to define and develop the NIMM as well as support initiatives to raise awareness across the NHS IT leadership community and NHS infrastructure partners. A number of different models and approaches were considered (Gartner, Microsoft®, ITIL® and others), but the NIMM was developed specifically for the NHS.

INFORMATICS PLANNING 2010/11

The Department of Health issued the following guidance in its Informatics Planning 2010/11 Annex 1, National Expectations, Developing Maturity of Technical Infrastructure:

'NHS organisations should publish their current position on the NIMM and determine the priority elements of infrastructure for analysis using the NIMM, aiming to achieve at least Level 3 and ideally Level 4 of the NIMM across the priority elements of its technical infrastructure within the next 12 months.'

Effective use of the NIMM requires NHS organisations to understand and prioritise how they invest in improving their IT infrastructure capabilities. This prioritisation should be done by first reviewing business objectives and strategies and then by identifying the infrastructure maturity levels and services needed to deliver these goals.

THE NIMM APPROACH

Maturity modelling of IT infrastructure is a popular and general-purpose approach often used when there is a need to benchmark and manage performance. Maturity models exist for many different capabilities, including software development, process optimisation, operations, IT governance and so on.

The NIMM uses two sub-models as the basis for describing a standard definition of infrastructure classes (service groups) and capabilities. The classes defined in each of these taxonomies will have a number of component capabilities, for example, 'server patch management' is a capability in the 'operating systems' class in the technology sub-model of the NIMM.

CLASSES AND SUB-MODELS

There are six classes in the business sub-model of the NIMM, which cover management priorities:

- governance;
- procurement;
- financial management;
- business alignment;
- people and skills;
- principles, standards, procedures and guidelines.

There are seven classes in the technology sub-model of the NIMM, which cover the key technology component groups that make up a typical IT infrastructure:

- patterns and practices;
- end-user devices;
- common applications and services;
- operating systems;
- infrastructure hardware platforms;
- network devices and services;
- IT security and information governance.

NIMM MATURITY LEVELS

The NIMM has five capability maturity levels, which are used to score all capabilities in all classes. Since the NIMM covers a broad range of classes and capabilities, generic statements are the most useful way of describing what life is like for an organisation at each of the five levels.

- **Level 1 (basic): avoiding downtime –** Organisations at Level 1 are characterised by ad-hoc manual infrastructure management and support processes. At this level, an organisation has no effective control of its infrastructure. There are no infrastructure principles, standards, procedures and guidelines in place for the most basic capabilities, such as IT security, desktop management, network services and common infrastructure services.

- **Level 2 (controlled): infrastructure visibility, service monitoring and achieving control –** The motivation for moving to this level is usually a need to have a better and more consistent view of existing infrastructure, and taking control. Organisations at Level 2 have the ability to exercise adequate levels of control over key infrastructure components such as IT security, desktop management, network services and other common infrastructure services. Although the infrastructure is still unnecessarily complex, the potential impact of changing it can at least be recognised. However, it is difficult to understand adequately and mitigate risks.
- **Level 3 (standardised): standardising the infrastructure and adopting proven best practice –** The motivation for moving to this level of maturity is usually a need to reduce errors and improve consistency by adopting standardised and repeatable ways of delivering infrastructure services. Organisations that achieve Level 3 have a highly standardised infrastructure. This uses the control capabilities achieved in Level 2 to implement principles, standards, procedures and guidelines for managing key infrastructure capabilities such as IT security, desktop management, network services and common infrastructure services. IT staff will be using a common set of tools to help with learning and sharing knowledge and best practice.
- **Level 4 (optimised): infrastructure optimisation –** The motivation for moving to this level is usually a need to drive operational efficiency by eliminating non-value adding services and introducing a number of optimisation and lean initiatives. At this level, organisations will have optimised their infrastructure to the point where the costs involved in delivering and managing core infrastructure are low when compared with similar industry norms. Processes and policies will also be optimised to support technology, enable agility and help the organisation achieve its strategic goals.
- **Level 5 (innovative): IT infrastructure that enables innovation –** The motivation for moving to this level is to exploit the investment made in infrastructure maturity. The objective is to support the transformation of services and business change based on innovation. Organisations that achieve Level 5 will have a robust and agile infrastructure that is the acknowledged catalyst for technical and business innovation.

THE NIMM SELF-ASSESSMENT BALANCED SCORECARD

In order to help an organisation determine its current NIMM maturity level, the model includes an infrastructure balanced scorecard. It is designed to help achieve balanced IT infrastructure maturity and avoid the tendency of seeing infrastructure services as being purely about technology. It therefore promotes IT objectives as part of achieving business objectives.

The balanced scorecard provides a holistic approach to self-assessment, which is achieved by evaluating and scoring infrastructure service maturity from a number of different perspectives:

- strategy alignment and business value;
- IT security and information governance;

- process;
- technology;
- people and organisation.

MAKING THE NIMM WORK FOR YOU

In order to get the most value from the NIMM and really achieve lasting benefits for your organisation, you may well find the following suggestions promote lively discussion:

- **Make the NIMM a long-term plan for managing performance –** The NIMM should not be viewed as a one-off exercise. Use it to create strategy and use the outputs to report progress to your board.
- **Get the right people involved –** Make sure that you choose the best mix of people: those who are responsible for delivering the service as well as those who consume the service.
- **Aim to get the majority of your infrastructure capabilities to NIMM Level 3 before you focus on achieving Levels 4 or 5 –** Innovation initiatives tend to fail unless infrastructure is mature enough to support them.
- **Engaging the NHS IT leadership team, specifically the chief information officer (CIO), is critical –** Aim to have director-level ownership of the NIMM. By doing so, you will position the NIMM as a strategic management initiative and not a technical programme. Only by taking a top-down approach will you succeed in getting the right kind of senior management focus on the importance of achieving mature IT infrastructure.
- **Strategy alignment and business value often hold the key –** The root causes of lack of capability are no clear vision, no sense of scope and no alignment of the NIMM with business objectives. Getting these right can lead to quick wins that improve the overall score for organisational maturity.
- **Be honest –** View the assessment as an opportunity to highlight those areas that need investment and those areas that are already mature enough for the current needs. There is no right or wrong NIMM score, the working out is as important as the answer. The NIMM can be extremely useful in helping NHS organisations arrive at a consensus of what the real NIMM score and actual state of play are. The CIO should play an active role in creating and promoting a no-blame culture and encouraging a realistic assessment.
- **Using the balanced scorecard helps you see the bigger picture –** A number of NHS CIOs have commented that the balanced scorecard has helped them examine different management and technical perspectives and discover aspects of their organisation's performance that were previously hidden. Moreover, the collective endeavour of a team approach will see the bigger organisational picture. A single individual, working on their own, however hard, is unlikely to do so.

13 A REAL ROLLERCOASTER RIDE

Dr Julie Greensmith is part of the Intelligent Modelling and Analysis Group in the School of Computer Science at the University of Nottingham. Here she talks to Justin Richards about her work and why computer science is such an exciting subject to research at the moment.

Can you provide some background on yourself (college years to present)?
I started out as a pharmacology student at the University of Leeds. I was really interested in how drugs interacted with the body and the creative aspect of it: developing new cures. But I found the lab work was quite repetitive and I wasn't really very good at it. I was quite good at coming up with my own processes, but when I had to follow other people's procedures I was less adept at it.

During that time we had to use a lot of analysis software, which I found really frustrating and it didn't work. My ex-boyfriend, who was doing a computer science degree, got fed up with me winging about the software and chucked his textbook at me and said 'right, make one yourself, if it's that bad!' I did; I wrote my own analysis software for my own experiments in the lab. I could do all the maths so it was just a case of learning how to program, which I did. It was a hell of a lot easier than I thought, but because I'd never done it before I didn't know that I could do it.

So I decided to take modules in computer science in the second and third year, which I did much better in than the pharmacology modules. I was in the top ten of the year for those modules that I took, which was really cool. I decided at the end of it that it was obvious that I should be doing computer science and not do pharmacology; hence I did a Masters in Multidisciplinary Informatics, which is a pain to write on every application form I have to do!

It roughly translates as funky applied computing. It's the application of computing to lots of different types of stuff. You view computing and computer science as a tool and then get your teeth into what the domain actually requires and match the two up. So it's not being a bit of a mongrel, where a biologist is a bit of a computer scientist or vice versa. It's learning to marry up the two disciplines.

Then for my PhD I studied biologically inspired computing. That involved the development of artificial immune systems. I worked with practical immunologists at the University of the West of England, in Bristol, and would build some models of how a particular cell in the immune system works and go down and get them to verify, experimentally, if the model was valid or not.

If there were any questions, they would ask me. We'd discuss it until we got a good enough model, then I'd make an algorithm from that model and apply it to computer security; so using an artificial immune system to detect artificial pathogens, effectively. And that's where the bulk of my research has been.

So you're modelling the potential problems and also the potential solutions?
Yes, that's right. At the same time, because that's what you need to do to develop anything that complex.

How would you describe an artificial immune system?
There's not just one artificial immune system – it's not like a genetic algorithm – with an artificial neural network. There's an archetypal one and then you have variations within that. Artificial immune systems aim to use metaphors of components of the actual immune system to perform computation, to solve problems in the engineering domain (it's like a 'double hot process'). However, the immune system is not just made up of a single immune cell.

An immune system is a complex collection of what they call heterogeneous cell types. It's got loads of different cells with lots of different properties solving lots of different problems in parallel, which gives you protection against pathogens. So there's not an artificial immune system because there's not an immune cell. So, therefore, what artificial immune systems are is a collection of algorithms, each one picking out the different properties of computation inherent in the different types of cell, which collectively form the immune system.

So could systems like this help to cure certain diseases?
They are applied back to biology, but that's just one of the applications that they are used for. They're mostly used for applications that are 'noisy, real-world apps that require error tolerance, require decision making and require adaptivity' in their function.

So, basically, any kind of complex, real-world, 21st century problem is where they're coming in. Data is getting bigger, it's getting messy, it requires correlation, it requires fault tolerance in our systems, because the systems are getting too big to monitor, so that's where these kinds of algorithms come in, not for solving little toy problems in optimisation anymore.

Is that where your dendritic cell algorithm comes in?
It's one of them. It's what we call the second generation.

Is that 'dendritic' in the old sense of the word – with different strands branching off?
Yes, it's an immune cell, which has an up-regulated surface area when it sees damage. It up-regulates its surface area for lots of reasons. Dendritic cells, to put it nicely, are the policemen of the body; they run around the tissue collecting evidence regarding the health of that particular tissue. And they also hoover up, through a process called phagocytises, loads of protein molecules.

So they're checking if everything is kosher and then 'eating' all this other stuff and, if they see enough damage, they mature and go to a lymph-node where all the other immune cells hang out. They communicate with them, telling them where the damage is and what proteins they found nearby the damaged area, as one of those proteins has to belong to something that actually caused the damage.

So how do you actually model for that – without getting too technical?
Well, you stay awake for many, many nights! You spend a lot of time on a train visiting immunologists, you look in the lab, you poke these cells, you see what happens, you hypothesise various 'what if?' scenarios. It's a really iterative process; it's not a case of you finding out some information and then making a model from it.

You start off with pen and paper, or as I did with bits of string, Sellotape, Bluetac and bits of coloured paper on a big sheet of A0 paper and then you put the different characters down and you make different components of your paper for different analysis and that's how you generate the conceptual model, or that's how I do it because I'm from the Blue Peter age.

Because you've got someone from the computer security domain trying to understand the usefulness of this model and you've got an immunologist sat next to you, how are you going to make these people talk together? You can't really do it by showing the biologist an algorithm and you can't really do it by showing some experimental results to a computer security guy so you've got to resort to basics. Everyone's kind of done the old Blue Peter thing. So that was basically my role, to get feedback from these very different sets of people at the same time. Because of my history I spoke both languages.

It must be useful for you coming from a biological background, but also understanding the IT side of things.
Oh yes. Communication is the key part of any interdisciplinary stuff; if you don't have someone who speaks both languages it must be really, really difficult.

Tell us a bit about your work on emotion discrimination for the entertainment industry?
It's basically the incorporation of bio-sensing technology into computer interfaces; that's where the proper, serious facing research is.

And how is it progressing?
It's really coming to the fore. What we do is to put people into different scenarios and see if we can physiologically measure their emotional state. Whether we can actually determine emotion or not, I'm not entirely convinced, but we can certainly discriminate between fear and enjoyment.

I suppose in the case of fear you can measure aspects of physiological change by monitoring how much sweat they produce and so on...?
It's not quite that simple. I wish it was. If you look at the characteristics of the GSR (Galavanic Skin Response), you can tell what a person is thinking from that, or at least how stressed out a person is. It's never that simple. You need more data. This is where the artificial immune systems come in because they can process multiple streams of complex data that occur asynchronously.

So you've got someone's heart rate, you can stick a hat on them, (a bio-sensing kit, to measure their EEG and their brainwaves), which is pretty weird to look at, you can measure their breathing rate, you can measure how often they're blinking, how often certain muscles are being activated… the smiley ones or the frowny ones, so you can tell the difference between that. Just looking at any one of those data streams in isolation you can't tell what the person is doing. Just one of those standard time series statistical techniques is insufficient.

However, you can also measure the productivity of people; you can measure workplace stress of people. Products like this are already on the market and can be given to people. For example, to help those with bipolar disorder, to give them the ability to monitor whether or not they're about to have an upper or a downer, then they can interface with the computer, which can then give them a program to calm them down, to cheer them up or just to bring them back to a more appealing state.

I like to use it in entertainment because, well, it's fun and it gets me out of the office! Seriously though, rollercoasters were used, initially, to collect data since people thought that it was a constrained extreme response, because you need extreme responses, not just to test out an idea.

So, for example, you can do sensory deprivation where someone just sits there in a room with ambient lighting, controlled temperatures, no windows, no sound, the room is soundproofed, and you can give them no stimulation and then you need something at the other end. But you need it to be reproducible, so just giving someone a shock isn't really very good.

We didn't like the idea of electroshock therapy in this case because that would affect the equipment. It's all transmitted via Bluetooth® and stuff, so it's not cool. By sticking them on rollercoasters we thought it might generate a large enough effect for us to be able to see what's happening. Plus it's reproducible because rollercoasters are inherently temnistic, with the exception of one in the UK, Spinball Whizzer at Alton Towers, which is now called Sonic Spinball. They're recently repainted it. It's a Maurer Sohne construction one, like the rollercoasters at Blackpool pleasure beach in the late 1960s, with the sharp turns, but the rollercoaster carriages are on a rotating base so you've got four people in the carriage and, depending on the weight distribution, that will determine how many times carriages spin at the different corners, and it also depends on who you've got in with you and how wet the track is and how hot the ambient temperature: you can get a different ride every time. By carefully monitoring people on these rides, watching if they're about to be sick and so on, you could lock down the degrees of freedom, as long as it's suitably easy to replicate.

What aspects of the job do you enjoy the most and what parts are more difficult?
That's a difficult question, but I really enjoy finding new ways of doing stuff. For example, developing complex analysis tools and thinking about how complexity can actually be applied. I think that's pretty awesome because it's hard.

If you read some of the old complexity sites, which are full of abstract maths and physics, and then you look at something elegant like a bunch of starlings swarming off Aberystwyth pier and you think how amazing that is, we should really be able to fathom this activity using computational systems. I really enjoy thinking about that sort of stuff and then actually doing it.

On your website you mention danger theory. Can you explain danger theory?
Danger theory is the core theory of immunology from which we build our models, dating from a couple of years back. The classical theory of immunology is a bit like a lock and key scenario in that the immune system is trained to respond to proteins which are defined as non-self; so you have this classical view of immunology, which is the 'self–non-self' theory, which is very discriminatory.

This theory stipulates that the human immune system is tuned and developed to mount responses against any particles that are not belonging to self. The theory was that while you're in embryonic development you sample enough proteins from your own body to build up a representative picture of self so the immune system is tuned by the deletion of anything that matched self to produce the detectors that would then go out into the body to detect anything that was non-self. And this theory stood for about 70 years as the central dogma of immunology.

But there are loads of problems with that theory because what is known as self changes over time and friendly bacteria in your gut are not part of self and yet co-exist there. Also, why do we get auto-immune diseases, which a lot of people have got, for example, rheumatoid arthritis, where the immune system attacks itself? So if it's trained not to do that, why is it doing it? There are a lot of things the classical 'self–non-self' theory can't explain.

So in 1994 this rather wayward immunologist Polly Matzinger came along and said the immune system doesn't respond to self and non-self, it responds to whether it's in danger or not and the 'self–non-self' thing is just another filter. So what it says is that you have an initial 'self–non-self' path and then you have additional signals, which come potentially from things like bacterial sugars. So if you encounter these you pretty much can be sure it's a bacterium, which is signal-based.

Then you've got the danger-based model, which says if this protein is around when there's danger, then you should really respond to it because where there's danger there's often damage. So danger signals are generated when cells undergo necrosis as opposed to signals of tolerance that occur when cells undergo apoptosis, which is controlled cell death.

If you've got a greater level of necrosis as opposed to apoptosis, then the immune system should either take a closer look or sort it out and send the boys in really! It's the dendritic cells that relay the information 'danger' back to the central processors of the immune system in the lymph nodes.

The immune system gets it wrong from time to time though... and detects danger where there isn't danger?
Yes, or it's marginal... or the threshold on the direct current (DC) was too small or you get the 'bystander effect', which is how they think MS happens, which is where a person gets an infection, too much cell protein is taken in, the damage is seen at the same time as an invader, so the cells are presenting the two proteins. Both sets of protein are then responded against by the immune system. However, one was from a minor infection and one is yourself, therefore the 'danger' persists and the immune system keeps attacking it.

So the danger theory is not saying immune systems are brilliant, it says immune systems are flawed, but they're much more sophisticated than the classical 'you're either in or you're out' sort of 'bouncer with a blacklist' approach to immunology.

It's still very controversial. The receptor for the detection of danger signals was only found about 18 months ago, so that's about 14 years after the theory was first proposed. That's why we like to try and model it because there's a lot of work now being done in that area. Initially it was to try and disprove this lady's theory, but now it's a case of 'oh, she's kind of right, we were all kind of right, so now we need the evidence to back it up'. It's a really interesting time to be working on IAS because immunology is changing really rapidly.

[…]

What would you say have been the most exciting, most groundbreaking, changes in the IT industry over the last five or six years?
Mobile computing. It's completely changed society. It's introduced people to computing in a way in which they're not even aware that it's computing. I think that's awesome, because that's a revolutionary thing to do. To get people involved in something they're not even aware of and then it just becomes part of the language.

I mean my mum looks at my Twitter to see what I'm up to; if she can't reach me on the phone, she looks for me on the internet. It's so different from how it used to be. So I would say mobile computing and social networking via mobile computing have changed everything. I wasn't expecting it to be that big. I mean when you first got a camera on your mobile you thought it was such a white elephant, but now it's a staple ingredient. When the first Nokias came out with WAP on them, or something like that, and the internet took forever to open, we thought internet on phones would never work.

When I get into a school, as part of my talk about 'computing is everywhere', I get the kids to put their hands up if they've got a mobile and pretty much everyone puts their hand up. Then I say 'keep your hand up if you've got a smartphone,' and about a third keep their hands up, and these are 14-year-olds! They're not like my lot, who you'd expect to have one – I don't personally. So I think that is impacting the entire spectrum, that's massive, and the development of apps for that has changed the business model for IT.

What are the biggest challenges in your own sphere of study that you see will need to be cracked over, say, the next decade?
Maintaining the security of these networks and devices is going to be a problem. Nobody has really gone to town so far on mobile or cloud security and this is where I see these complex analysis tools coming in.

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