

# **An Industrial Perspective on Future ICT in Hospitals**

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**Abstract.** The use of ICT in hospitals is becoming more important as the demands upon hospital-based healthcare change. Identifying directions for development of future ICT for healthcare depends on understanding the context in which solutions are to be deployed. This paper reports on several activities carried out as part of a case study, focused on one hospital and drawing upon existing technology capability as well as interaction with healthcare professionals. Existing in-house technologies from different application domains were investigated for their relevance to the healthcare sector; scenarios were developed for future ICT use in healthcare based on existing literature on ICT application deployment in healthcare; and interviews and workshops were carried out with healthcare professionals to obtain their insights into ICT application in hospitals. These methods gave insights into how to carry out future development of ICT solutions for healthcare.

## **1 Introduction**

The use of ICT (Information and Communications Technology) for information gathering and retrieval is already important in the healthcare sector, and likely to become more important in the future. In the UK the National Health Service (NHS) has acknowledged this through the National Programme for IT (NPfIT; National Programme 2004). This large-scale ICT activity reflects changing demands on the healthcare sector with demographic and social change, with increasing life expectancy and changing patterns of disease, as well as with changing

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technological capabilities. In addition to the current plans for NPfIT, other ICT technology is likely to be useful in the healthcare sector in the future.

However future ICT solutions need to be developed with some understanding of the environment into which they are to be deployed. In order to gain greater knowledge of the general issues of what is needed to provide future ICT capabilities in hospitals, this paper presents an exploratory study focused around one location, a large regional hospital, possibly representative of many such locations in the UK. Reflecting on existing technology capabilities, as well as insights from the hospital environment considered, a case study is carried out as a basis for further investigation and technological development.

The paper reports on activities carried out to identify directions for future ICT software application development, for deployment in hospitals. The focus is on applications in the hospital context while being aware that the healthcare sector encompasses other activities. The activities considered come under the general heading of requirements capture or requirements engineering (Nuseibeh & Easterbrook 2000) whilst not being part of a specific programme in that field. Below the different techniques needed to identify directions for development of future ICT applications in hospitals are considered, examples are given of what has been achieved so far, and what insights can be learned about future hospital ICT are discussed.

## **2 Methods**

This study involved several activities to identify information about future ICT development in healthcare. All these could be considered as part of requirements capture or requirements engineering (Nuseibeh & Easterbrook 2000) for future healthcare ICT systems development. However these initial studies did not use formalised requirements engineering methods. Instead they started from a background of research within telecommunications and IT research, hence with an interest in ICT applications in a variety of domains.

The first activity involved investigating existing technologies available in-house, developed for different application domains but maybe having properties that might lend themselves to development or modification into the health space. There is a large body of software

applications inspired by complex systems (Marrow 2000, Shackleton et al. 2004). Although the complex systems that previously provided inspiration (e.g. Bonabeau et al. 1999, Camazine et al. 2001) were unrelated to healthcare, it was thought that they might give insights into the healthcare domain because of the complexity of the healthcare activity.

A second activity involved reference to existing literature, and existing examples of application development for ICT in hospitals, looking for information about scenarios for ICT use. This activity was carried out in order to elicit information about the tasks that users might want to perform with ICT in healthcare, by providing scenarios as particular paths through use cases. This activity was carried out as a literature review, with an intention to focus on scenarios that were most widely supported by existing examples.

The final activity involved interaction with local healthcare professionals, comprising partly meetings with healthcare practitioners at work, to learn about their use of ICT, and their opinions and requests about future ICT deployment. This also involved roundtable meetings with groups of healthcare professionals, to brainstorm future ICT problems and identify the application areas that they viewed most important. This was a very important activity in order to ensure that future technology development took into account stakeholder issues.

Interviews were held with a number of professionals located in different departments of a large regional hospital. The departments and individuals involved were chosen partly by the hospital trust's business manager, and partly in response to an invitation circulated within the hospital. Interviews were not conducted with clinical staff directly involved in the process of patient care - partly to avoid ethical problems that might arise and partly to avoid disconcerting patients. The interviews were conducted informally in order to give the participants the maximum opportunity to express their own opinions about the directions that future ICT in hospitals should take. Detailed notes were recorded based on summaries taken during the interviews - general summaries were recorded from these notes and it is these that are discussed here. The results of the interviews discussed here are based on the author's interpretation of the reactions of the members of staff interviewed, and consequently are not intended to focus on the views of particular individuals or of the hospital trust.

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The workshops started as a two-way discussion between industrial researchers and hospital staff. Presentations were given about relevant topic areas in order to stimulate discussion - but there were also workshops held internally within the hospital, in order to discuss the results of previous interaction and identify separately their preferred directions for further research. Feedback from the workshops was passed in the form of documents and email messages to participants on both sides. In this way participants on both sides could be informed of the progress of the interaction.

### **3 Results**

#### **3.1 Existing research programmes**

The first activity in this work focused on what existing technology resulting from previous research programmes can tell us. Preceding work programmes have developed software applications inspired by complex systems (Nicholis & Prigogine 1989, Shackleton et al. 2004), particularly biological (Marrow 2000), economic or social systems. The healthcare environment, within hospitals or elsewhere is a very complex system. The activity carried out here focused on drawing upon the insights that had already been gained from studies of complex systems in other domains.

Complex systems have attracted considerable interest in computer science, particular in the area of software development, because they appear to show ways in which to devise persistent structures from simple rules. Previous work addressed especially biologically-inspired systems, because of the efficiency of evolutionary algorithms at solving optimisation problems (Goldberg 1989) and because of the potential of the field of Artificial Life (Langton 1987) to provide entirely new ways of doing computing. However in thinking about means of addressing present and future problems in healthcare we need to find more proximate reasons for applying ideas.

Complex systems research has contributed useful insights about network properties, and other regular structures (Nichols & Prigogine 1989). Network properties are useful when thinking

about efficient ways to share information - important in the healthcare domain as well as in other sectors. Collaboration between individuals is important for the effective functioning of organisations, hospitals and other healthcare organisations as well as non-healthcare entities. In order to effectively transmit information across an organisation it helps if individuals can easily find the people they need to communicate with. In large enterprises, or in a large healthcare trust, this can be a problem simply because of the difficulty of finding the right person. In order to address problems like this in computational directory systems, work was carried out drawing upon ideas for modelling networks of social interaction. The complex system that is a social network of collaboration between individuals can be described using the mathematical notion of Small World Networks (Watts 1999). If the social network of interactions within an organisation is modeled in this way, matches from searches within large groups of people can be prioritised. If an individual is searching for someone that they have not had any contact with previously, then the organisational structure can be used to initiate social prioritisation. If they are searching for someone that they have had previous contact with, then the contact will move that person up the priority list. Continual searches will change the pattern of interactions and thus affect future outcomes of searches, and thus assist the progress of collaboration within large organisations. Given the size of organisational units within the NHS, and the NHS itself, tools of this sort may be useful in such a context. A technology based on this is in use internally and has attracted interest when demonstrated to NHS and other audiences.

Another area of existing research in the complex systems space that suggested relevance for healthcare applications was in the context of decentralised systems. The term *decentralised system* refers to the nature of control of software applications. Software applications may be constructed with multiple connected nodes, and thus be described as distributed systems. If one constructs software applications as distributed systems, how they are controlled is relevant. The easiest and historically most common approach has been that of a centralised application, where one node takes the role of a server, and controls all the other nodes, or clients. This client-server architecture has been widely and successfully used, but has limitations in situations where the server may be prone to failure. Accordingly an alternative decentralised solution shares control among nodes, for example in a peer-to-peer network (Oram 2001). Previous research has

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investigated decentralised systems implemented in the form of agent-based middleware. The DIET Agents platform (Hoile et al. 2002, Marrow et al. 2003) was originally developed as a tool for general purpose information management applications, but has also demonstrated its capabilities for deploying software agents as middleware (Wang 2002; Marrow et al. 2003; Wang 2003). Software agents are autonomous processes that enable flexible application development (Wooldridge 2002). Middleware is software that acts as coordination tools for other software applications - between individuals or processes. The DIET platform supports especially simple or lightweight agents, enabling processes or applications to be interconnected with only limited use of valuable computational resources. Having demonstrated itself as useful in applications that are unrelated to the healthcare sector (Wang 2002; Marrow et al. 2003; Wang 2003), it could be useful in that sector as well as others.

### **3.2 Scenarios from existing literature**

The second area of activity involved identification of novel application scenarios based on a synthesis of existing material. A number of researchers have sought to analyse and anticipate trends in healthcare (Foresight 2000, Headstar 2001, Wilson 1999). Demographic and economic changes can be to some extent forecast (Office of National Statistics 2004, Wanless 2002, 2004) showing aspects of the future context in which ICT has to be deployed in healthcare. Other researchers have considered the potential of new technology in healthcare (Wilson 1999). This might include, for example, robotics, nanotechnology and sensors quite separately from ICT.

Identifying application scenarios for ICT requires taking into account a series of problems that are relevant to ICT as they are to some other areas of application - scalability, timeliness, user-friendliness, security, accuracy, robustness and privacy seem particularly important. Bearing this in mind several scenarios were identified that focused on particular aspects of ICT application in healthcare. Examples are given here from a process that generated a large number. Through discussion with technical experts the number of scenarios were reduced down to a few that could feed into the technical development process. Several scenarios are outlined here.

- Integration of decision support tools across hospitals

Clinical and administrative staff in hospitals have to deal with information about their patients from a variety of sources, and in a variety of forms. Different departments in hospitals have to communicate with each other and with primary care that typically provides the link between patients and the hospital. The UK NPfIT seeks to deal with these problems by providing an electronic patient record system, a network for medical information communication, and an electronic booking service to link primary care with hospitals. But these must be deployed in a continually changing information environment, and it is important to enable the maximum flexibility for decision-making across and within hospitals. Technologies for distributed and adaptive systems (e.g. Goldberg 1989, Marrow 2000) may be useful in supporting integration together with flexibility.

- Provision of self-care information to public

The changing nature of the population has led to policies seeking to reduce the dependence of healthcare activities on hospital-based care. There have been a number of initiatives seeking to increase the importance of self-care (Department of Health 2001; Wanless 2002, 2004). The development of the Internet and changing communication media allow for potentially greater access to information about, and control over, their own care, by individuals. New web services and interactive interfaces can assist the process of self-care and possibly self-diagnosis in certain circumstances, giving an indication of what path to follow next, and whether to involve clinical professionals.

- Provision of on-line training tools for healthcare professionals

Clinical staff need to learn how to use the ICT devices that are becoming an increasingly ubiquitous part of their working environment. Part of this training will come from the lectures and courses that they will need to carry out as part of their continuous professional development. Some of the novel ICT solutions, perhaps on mobile devices, can provide opportunities to carry out training at convenient points in their working schedule. It allows them to interact with other clinical professionals engaged in similar training, and thus to acquire understanding of the novel ICT deployed in healthcare

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without losing the collaborative interaction that is important in learning or being distracted from their main role in healthcare.

- **Asset tracking in hospitals**

Mobile technology is widely used in hospitals today, and the deployment of further ICT suggests that more mobile devices will be used in the near future. The security of valuable assets is already a concern, in an environment where access by clinical staff, patients and visitors is essential. This issue is likely to worsen as advances in technology support further miniaturisation. Solutions to this could arise through the use of RFID (Radio Frequency IDentification) tags or similar small devices attached to valuable assets, which might not just be items of equipment but possibly also laboratory specimens, transplant or transfusion material. This may even extend to patients however a number of obvious privacy and ethical concerns must first be debated and resolved.

These scenarios have shown a part of the space of possible activities that could develop from current understanding of ICT into future healthcare ICT applications. In these scenarios, as others, several common themes are clear: information integration and sharing; training and/or learning; tracking and/or resource management. They provided some background for the interaction with healthcare professionals in the third part of the research.

### **3.3 Shadowing healthcare professionals**

Shadowing was used in order to carry out informal interviews with staff in a number of different departments of one regional hospital. The details of the interviews are not given here, but it became apparent that several common themes ran through the issues raised of the hospital staff interviewed.

#### **3.3.1 Resource management**

Several of the staff interviewed were responsible for resource management in one form or another. This varied from bed management and patient tracking, to elective admissions

management and temporary nurse shift management. Each member of staff was responsible for updating and checking data in a resource management system - which might involve interaction with many different departments. The actual activities involved varied from interaction with a simple database stored on a spreadsheet to travelling around the hospital interacting with many wards and departments in order to update records continuously. Several different systems were in use to manage resources, varying from card or paper records to electronic systems, only some of which were integrated and networked. Hospital staff members were keen to obtain more efficient electronic systems to manage resources with, but were concerned about the lack of control that might result from giving up existing systems with which they were familiar. There were also concerns about the reliability and security of proposed ICT solutions. However there was a widely positive view of the potential of new systems to better manage complex distributions of resources.

### **3.3.2 Medical Imaging**

High-quality diagnostic images are of key importance in current healthcare, and several members of staff referred to imaging activities or processes related to this. Hospital diagnostic imaging at present is of course dependent on substantial computing resources, but there are questions as to whether effective results can be produced more efficiently. A lot of imaging activity is still dependent upon film records, which need to be stored and take up very large amounts of space. As well as being inconvenient to access in order to refer back to, these are using up space that might better be used for other activities. Consequently there was a lot of interest in seeing the benefits of PACS (Picture Archiving and Communications Systems) due to be progressively rolled out as part of the NPfIT, but not yet uniformly accessible across the UK. The involvement of images in Multi-Disciplinary Team (MDT) videoconferencing raised issues about how to make this more mobile or accessible, as currently high quality images are only available to MDT meetings in relatively few locations.

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Clinical care in hospitals depends significantly on the analyses that are carried out in hospital pathology departments. Staff in hospital pathology departments have considerable experience with electronic and automated systems for analysis of specimens, but many systems as currently deployed do not always integrate seamlessly with the rest of the hospital. Pathology staff members expressed concerns about the tracking of specimens in and out of the pathology department, and the issue of consistency with other methods of tracking used around the hospital. This can be thought of as part of the general issue of resource management that was emphasised in several areas of the hospital - but arguably in pathology it is more significant since errors can have catastrophic results. Tracking of blood supply and blood allocations already uses barcodes and temperature sensors, but this is not the case for all non-blood specimens. Non-blood samples are labelled by hand while on the wards, with the attendant potential for error. There was also concern about the different formats of data input for requests, and how the results from tests would all be integrated into the forthcoming electronic patient records under NPfIT. The pathology department also works under strict requirements to maintain legacy data, in some cases for up to thirty years - which will place substantial demands on new and forthcoming systems.

#### **3.3.4 Legacy systems**

One feature that was common in discussions with a number of specialists from different hospital departments was the need to maintain activities or systems that had been going for a long time together with new systems being introduced - the general problem of legacy systems. Legacy systems have been identified as a problem of system development in large organisations in general, not just in healthcare. In the case of healthcare the problem may be more severe as health services must be tailored to the life of individuals in the population that they are serving, and this may involve intervals much longer than the plausible life cycle of a computer system.

#### **3.4 Workshops**

Workshops with senior members of hospital staff were used to stimulate discussion within the hospital as to the most productive areas for collaboration. From a wide range of initial suggestions, many concepts fell into two fields described broadly as Patient Care/Safety and Communication/Tracking. In the area of Patient Care/Safety there was a lot of interest in improving technologies to enable the surveillance, monitoring and administering of blood transfusion and of other complex treatments. There was also interest in developing non-invasive patient monitoring outside of the hospital and back to home - in order to allow earlier discharge and reassurance for the patient. Associated with the administering of complex treatments was an interest in improving the ordering, monitoring and distribution of drugs from stores, and in overseeing the remote administering of drugs that require a very carefully controlled regime.

The workshop groups were interested in communication and/or tracking particularly in the context of patient tracking. This was seen as a concern throughout the hospital, but Accident & Emergency was seen as a department where there were potentially distinct issues in patient tracking that might require a separate focus. In either event, everyone was in agreement that the ethical and privacy issues brought on by 'tagging' patients require careful attention. Apart from patient tracking there was also a considerable interest in use of communication tools to facilitate remote and/or mobile access to diagnostics images, either through a hospital LAN or over an external network. These communications tools were thought to be particularly relevant in the context of multi-site MDT meetings.

#### **4 Discussion**

The first approach identified several existing projects with relevant properties outside the healthcare context that showed potential for development in healthcare. Much more needs to be done in terms of discussion of these existing projects with healthcare professionals, and development of the technology away from its original domain. But this initial examination indicated the usefulness of connecting technology design in different domains.

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The reference to existing literature stimulated a scenario development process that focused on particular uses of ICT in healthcare. A number of scenarios showed common features that gave indications of important areas to consider when developing ideas with healthcare professionals.

It was arguably collaboration with professionals in healthcare that was most important in this study in developing a perspective on future ICT development in hospitals. Informal discussion revealed the range of opinions of healthcare professionals about the direction of future ICT developments, and about the priorities that should be followed. But at the same time there were common themes that were consistent with those identified in earlier activities. These suggested that future ICT health application development, although drawing upon previous technology research, could benefit from links with potential users at an early stage.

This study was a preliminary investigation and as such did not form part of a formal requirements engineering (Nuseibeh & Easterbrook 2000) process. Reflecting the difficulty in evaluating the effectiveness of information technology in healthcare (Heathfield et al. 1998), it included only informal analysis of healthcare professionals' interaction with ICT. Other studies have adopted methodologies from the social sciences (e.g. Adams et al. 2005a, b) to study the social interaction of people with technology in a healthcare context. Such methods could form the basis of further investigations.

Many additional questions exist which are needed to identify truly effective applications for the sector and the user base. How will future ICT solutions be deployed? Upon what devices will they be used? What forms of user interface will be most effective? How will future ICT systems link to existing systems and existing healthcare practices? These are some of the questions that need to be addressed further in order to ensure a productive collaboration between industry and the healthcare sector in developing future ICT solutions in hospitals.

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