Abstract

Context has been applied to a broad range of domains and systems ranging from location-based tourist applications to motion capture. An area relatively under-represented in the literature is health-monitoring systems. This paper considers the application of context in health monitoring and the role of translational research, a concept that relates to the translation of basic research into clinical practice. This paper posits that intelligent Context-aware systems provide an effective basis for translational research with benefits reflected in improved quality of life for patients, reduced load on clinicians, and efficiency improvements. Case studies are presented to illustrate a number of health monitoring issues and how context can be effectively applied. The paper concludes with a discussion, consideration of practical applications, challenges, and open research questions.

1. Introduction

There is a large body of basic and applied research addressing health and related issues however scientific discoveries made in research programs and hypotheses that require testing in ethnographic research all require field testing; this calls for accurate and robust data collection and processing generally in complex and challenging environments. Data collection ‘in-the-field’ is a reasonably well-developed science with a broad and diverse range of widely known and understood sensor systems and ethnographic methodologies [1][2][3]. There are however recognised issues in the persistent storage and processing of collected data and its use in health monitoring systems [4].

The growing barriers between basic and applied research and clinical practice, along with the increasing complexities involved in conducting clinical research, are making it more difficult to translate the research into practical clinical practice and to return results obtained in clinical practice to researchers. The Translational Research (TR) concept [5] has proven to be a powerful process that drives the clinical research engine. However, a stronger research infrastructure incorporating improved data processing and transfer could strengthen this critical part of the clinical research enterprise with potential benefits for clinical practice resulting from research programs.

This paper posits that intelligent context processing [4] provides an effective basis upon which to process data collected in clinical practice. Such data includes information that describes a patient’s current and evolving prevailing physical and physiological ‘state’ along with environmental factors that effect prognoses and clinical interventions. Intelligent context processing offers the potential to reduce the load on clinicians with concomitant efficiency savings and improved effectiveness in clinical practice; the principal benefit however can be a much-improved quality of life for the patient(s). Significant benefit can also accrue to the research community from TR as proposed in [5].

The remainder of this paper is structured as follows: an introduction to context in health monitoring systems is presented along with issues in clinical research including terminological issues and ontology. Related research is considered including health monitoring and a number of health research case studies to illustrate both the issues and challenges faced in health related research and the potential advantages to be realised from the use of intelligent context processing. The paper concludes with a discussion, practical applications and challenges, and open research questions.

2. Context in Health Monitoring Systems

Context has been applied to a broad and diverse range of domains and systems ranging from the relatively basic location-based tourist applications to highly complex systems designed to address, for example, mobile learning (generally) in tertiary education. Its use in the domain of health monitoring
is however relatively under-represented in the literature.

Context defines and describes an individual’s ‘situated role’ [6][7]. In a health-monitoring scenario a ‘situated role’ represents a patient’s current ‘state’ which may include physical, physiological, and environmental factors [4]. Intuitively, context is inherently complex (this is demonstrated in [4] where the potential range of available contextual information is considered), the range and scope of the data that combines to define and describe a patient’s current ‘state’ confirms this intuition.

Intelligent context-aware systems are required to effectively leverage the potential of context [4] and health monitoring systems present significant challenges in analyzing, interpreting, and utilizing the available data however the derived benefits to be realised by patients, clinicians, health providers, and the research community are potentially great.

Ubiquitous mental health care is an innovative and rapidly developing area that presents both challenges and opportunities to medical practitioners, researchers, and the wider society. Intelligent Mobile Computing to Assist in the Treatment of Depression implementing the MCBT_D system is discussed in [8]; the methodology, results, and conclusions identify the intelligent context concept as an effective and potentially profitable research direction applicable across a diverse range of clinical practice and medical research fields.

A number of clinical research issues that effect basic research and its use in clinical practice have been identified. The following section considers significant issues related to the processing of contextual information.

### 2.1. Issues in Clinical Research

Improvements in human health demand that basic and applied research is effectively translated into effective clinical practice. This requires that the results, the lessons learnt, and the observations made by clinicians are used to assess the basic research efficacy which may stimulate further research; this is termed TR in [5].

There are growing barriers between research and its application in clinical practice driven by the increasing complexity inherent in clinical research. The barriers are reflected in increasing challenges in translating basic and applied research into clinical practice and in the use of the results obtained [in clinical practice] to stimulate further research. The processing and interpretation of collected data (contextual information), often in ‘real-time’, represents a significant challenge for context-aware systems in general [4][7][9]. In health monitoring systems this challenge may be more difficult with results being more critical for the patient.

A significant issue in realizing the aims for TR is the cross-cultural, cross-border, and international nature of health related research; this introduces terminological issues. Ontology provides an effective basis for intelligent context-aware systems [6][7] but may also provide the capability to address the identified terminological issues.

### 2.2. Ontology and Terminological Issues

There is a generally agreed corpus of medical terms known and understood internationally across the medical community. Such a corpus [of medical terms] can be effectively formalized using ontologies. Ontology is defined as “an explicit formal specification conceptualising a specific domain of interest with semantic detail and structure to represent concepts, entities, attributes, relationships, constraints, axioms and their properties in human and computer readable form” [7]. The issue is how to effectively utilize ontologies in clinical practice and research. This is considered further in section 5.1 under data description.

As discussed in [4][7], intelligent context using ontologies implemented using Semantic Web technologies in a rule-based system provides an effective basis for data processing. Intelligent context can thus prove to be beneficial to health monitoring systems with concomitant benefits to the research community driven by improved quality and relevance of results-based feedback.

### 3. Related Research

The great advances and technological breakthroughs in health and medicine over the last two decades or so can take a considerable time to reach the patients and individuals who might benefit from such discoveries and interventions. Turning a scientific concept into a treatment intervention can take years from the molecular or cellular level through to clinical reality. There has been a real necessity in this research domain to demonstrate a faster and more effective approach to translating basic scientific principles to the patients’ bedside [5].
3.1. Translational Research and Context

Translational research has proven to be a powerful process that drives the clinical research engine. However, it has been suggested that to speed up the process of getting bench research into the clinical environment requires a better infrastructure; one that could deliver and accelerate such findings, has been identified as a critical element in the process. It is therefore argued that context-aware systems in translational medical research could potentially encapsulate the infrastructure required for knowledge acceleration and thus facilitating a faster bench to clinic process.

Growing barriers between what’s required in clinical settings and health care delivery, and basic research, coupled with the ever increasing complexities involved in conducting clinical research, are making it more difficult to translate new knowledge to the clinic: and just as important, back again to the bench. These challenges are limiting professional interest in the field and hampering the clinical research enterprise at a time when it should be expanding.

3.2. Health Monitoring

Coupled with the issue of translational research the future of health care systems, certainly in the western world, will to a large extent be dependent on being able to deliver health care at home, away from expensive tertiary and social care home environments.

The paradigm shift in terms of how health care is delivered will create a range of new challenges, which have hitherto not been an issue in the existing systems. This has a particular importance for most western economies as their populations become increasingly elderly [10][11].

The issue of an ageing population has received considerable press but the full implications of home health care delivery and monitoring hasn’t been fully appreciated. However, the upside to this move towards health being delivered at home is paralleled in the technology arena with advances in assistive technologies in a whole range of areas that have applications for the elderly. None more so in health monitoring: as this has the potential to allow the elderly, infirm and disabled to live a happy, fulfilled and functional life at home, in confidence that their health, medical and social needs are being monitored.

However there is still a range of fundamental questions and health related research to be undertaken, and many of the more challenging disabilities have yet still to be considered. There are of course ethical and socio-economic issues to be considered before full acceptance of home health monitoring can be fully integrated into a health care system. But these, plus the technological challenges, make working in this field both exciting and rewarding.

4. Health Research Case Studies

There are many examples in relation to health and health care delivery that highlight the problems around creating the right and appropriate context for maximizing individual health care. There are endless applications where intelligent context-aware technologies could be utilised in medical and health related domains, but the issues emerging from such use are only beginning to be addressed in the literature and the interface between technology and health care delivery remains a huge technological, personal and social challenge [12].

4.1. Selected Case Studies

The concept of a Home Care Hub is a system that facilitates a mechanism for an integration of rich-media observations and data from a wide range of persons and carers at the point of need and use in a home setting [1]. It’s much more focused on the individual, capturing contextual information from various sensors and other technological equipment housed in the home (context-awareness). These are logged in the home/house and accessible to selected persons, either in close proximity, as in the case of a retirement village, or family and friends at a different geographical location (potentially across the world). The concept is not to replace the relatively established concept of telemedicine (medicine is transferred through the phone or intranet) with its supporting academic journals and publications but to complement and offer a more focused homocentric data set.

The real-time monitoring of health parameters in performing artists (musicians [2] and actors) can have a beneficial effect in terms of preparing them for their performance and helping control stress throughout their performance. Work has been carried out on classical solo music performers and ballet dancers [3] and has helped both of these performing disciplines take environmental and personal factors into account in preparation for their performance.

Context awareness in a health care setting is probably best illustrated better in a hypothetical case study. However, interestingly this particular case study was submitted for European funding and is still active in its conceptualization. An individual living at home, with a disability that limits them to using a wheelchair could benefit from a range of technologies that has
built-in intelligent context awareness. For example: sensors on the wheelchair could detect when the wheelchair required a service; smart materials in the cushion could send real-time data back to a clinician in a health centre, indicating levels of pressure in and around the buttock area; rehabilitation e-programmes could be initiated and monitored from the centre to suit the patient. Monitoring devices incorporated into the wheelchair could monitor strength and range of movement for example in a lower leg rehabilitation programme. The individual’s environment could also be linked wirelessly to the health-monitoring centre, relaying important data about the general levels of activity of the individual (moving from room to room, heating status of the house). A log of potential visitors could be checked at the centre and health care status logged in real time back at base. In summary, many of the personal activities and health status needs and requirements, along with concurrent environmental state can be monitored 24 hours per day. These are elements, plus a raft of other relevant data, are continually streamed and recorded, thus allowing the initiation of speedy and appropriately actions.

The use of Computers as an aid to delivering Cognitive Behavioural Therapy (CBT) is not a new concept. This is a method of delivering a tried an accepted from of treatment for a whole range of conditions, particularly individuals who are exhibiting signs and symptoms of depression. Research has shown that this method of delivering the therapy via a computer improves anxious/depressed patients about as much as face-to-face therapy [13]. The main limiting factor with this type of therapy is accessibility, particularly at the point of requirement. PC’s are not always available; people are out and about and may require a therapeutic intervention within a very short time span. This is where context awareness is so important in terms of the individual/patient requirements; a system that could be offered as required, would go a long way to solving the accessibility issue. A solution might be to utilise a system that operates via an existing communication network, the mobile phone. This solution could facilitate CBT instantaneously, 24 hours per day, is not location dependent, and therefore is context specific: encapsulating environmental and personal circumstances. To develop such a system further thought has to be given to the technology as well as the social and ethical issues around mobile phone CBT.

4.2. Translational Research

In the context of translational research the perpetual problem as alluded to above is the translation of basic laboratory research speedily into something that has currency in terms of a treatment for individuals. There is a more fundamental and practical issue relating to translational research in health/medicine, and relates to knowledge transfer itself. Potentially one of the barriers to translational research in health and medicine is the overload of medical research information available through different media sources. Researchers sometime work in isolation and don’t have the interdisciplinary vision or expertise to undertake work that is either relevant or asks the right questions pertaining to the specific clinical problem. A system that perpetuates context awareness in relation to specified areas of medical research would overcome many of the tangible barriers that are evident today. It would facilitate faster gathering of relevant research, information and data (input), allowing the information to be used more speedily, and move the outcome towards clinical utility in a shorter period.

4.3. The Application of Intelligent Context

The case studies support the intuitive conclusion that intelligent context-aware systems implemented in the domain of health monitoring presents opportunities for clinicians to improve treatments and therefore the quality of life for patients.

A significant side effect is the realization of potential efficiencies and results driven TR [5] which may potentially stimulate further research.

A significant challenge is the processing of the data obtained not only in terms of its volume but also in the speed with which it is collected. Intelligent context-aware health monitoring systems as discussed in [4][7][8] have the potential to not only monitor a patients prevailing condition by processing more effectively the ‘real-time’ data that describes a patients current ‘state’ (analogous to h/her ‘situated role’ as discussed in [6][7]) but additionally to combine this ‘real-time’ data with historical patient records data retained in persistent storage.

This data processing function has the potential to provide speedier and possibly more appropriate treatment and interventions (or no intervention at all if the patient monitoring indicates that no intervention is required) with concomitant efficiency savings and improved results feedback for clinical practice and research activity.

This paper posits that intelligent context driven TR offers a potential solution to the challenge of bridging the barrier between basic and applied research and its practical clinical application.
5. Discussion

This paper has introduced context in health monitoring systems and considered terminological issues with ontology. The TR concept as it applies to health monitoring has been considered with related basic and applied research activity and clinical practice issues. Selected case studies have been presented to illustrate the ways in which intelligent context-aware systems can be applied in health monitoring to effectively leverage the available ‘real-time’ and persistently stored patient records data obtained in clinical practice.

This paper posits that the application of intelligent context can produce benefits for clinicians, researchers, and patients with significant efficiencies and cost savings to the health service providers such as the British National Health Service (NHS) in terms of avoiding unnecessary interventions. As identified in the literature there are a number of challenges; space restricts a detailed exposition on the topic however a detailed discussion from a health monitoring perspective with consideration of the technical aspects can be found in [1][2][3][4][5][7][8] however a summary of the practical applications and challenges is et out in the following section.

5.1. Practical Applications and Challenges

As highlighted by a study carried out by the EU Commission [14], the application of technology to assisted living and monitoring is still an unstructured market with lack of transparency, which derives in poor communication channels. As a consequence the end user (health care system and/or individual) of the products is dealing with poor information about the products and their technological capability.

In addition, many of the products (technologies) are developed in a context free environment, without due consideration to individual patient or client needs: basically lacking context and context awareness. Furthermore, many of the developments are oriented towards mobility and miss a whole range of disorders including rehabilitation applications as well as preventative programmes.

The case studies have identified a number of key data processing challenges which are central to the effective implementation of intelligent context-aware health monitoring systems. Research to address these challenges has identified a number of open research questions which can be summarized as:

1. The processing of contextual information captured in the monitoring of a patient in ‘real time’ with the data stored in persistent storage

2. The logistics in actually capturing the data (the contextual information).

In considering (1) a discussion on context processing and the related ontology can be found in [7][4][8]. The algorithmic approach to context processing has been articulated and the results presented to demonstrate proof-of-concept. Development of the context processing process has however identified a number of important implementation issues. Space restricts a detailed discussion on the issues which in summary relate to data description the database schema. For a full exposition on the issues identified with interim and proposed solutions see [4][7][8].

Data description relates to the format in which the context properties are described in the data capture and persistent storage functions. As observed in section 2.2 there is a generally agreed corpus of medical terms and while this corpus can be effectively formalized using ontology the development of a common ontology is an unrealized goal. Much research has been invested in ontology matching as discussed in [15] however success in realizing this goal is limited. The central issue is the matching of subtle variations in terminological usage; approaches investigated have included ‘morphing’ and the use of synonyms and aliases however the effective and accurate merging of ontologies remains an open research question.

The creation of the ontology using Semantic Web technologies has created an additional implementation issue; this is the design of the database schema. Jena2 implements a denormalized database schema with searching and updating functions realized using SDB with SPARQL [16]. While this approach works, it has been recognized in the literature [17][18] that it represents a sub-optimal solution to the creation of persistent storage. The creation of a suitable database schema remains an important open research question.

Addressing (2) introduces a number of significant issue which in summary relates to on the use of centralized versus distributed (decentralized) systems. Space restricts a detailed consideration on topic and the related design issues however a discussion can be found in [7][4]. Currently, the centralized approach is considered to optimal approach [given the amount of processing inherent in intelligent context-aware systems] however the design decisions are domain specific and will reflect developments in mobile systems and technological advances in mobile devices.

6. Conclusion

This paper postulates that the application of intelligent context-aware systems has significant
benefits in the health-monitoring domain; the case studies presented validate this claim. The open research questions identified have a significant impact on the system design and effective implementation of intelligent context-aware health-monitoring systems represents an ongoing research field.

References


