Home deployments for independent living

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Abstract. This paper reports on the research and data/infrastructure challenges faced in moving pervasive computing technology to large numbers of home deployments from both a controlled clinical and laboratory setting. The purpose of these home deployments is twofold; to provide a number of services to a cohort of elders and to collect a rich array of physiological, environmental and computational context data for clinical study. By adopting a scenario based design framework we can incorporate the results from ethnographic study, ongoing application development to help realise a suite of hardware, software, services and sensors from our technology platform suitable for in-situ study.

Key words: Home Deployments, BioMOBIUS^{TM}, context management, data management, TRIL

1 Introduction

The TRIL Centre is a coordinated collection of research projects addressing the physical, cognitive and social consequences of ageing, all informed by ethnographic research and supported by our BioMOBIUS^{TM}, Research Platform: an open, shareable software and hardware system. A component of the research platform is a hardware element called SHIMMER (Sensing Health with Intelligence, Modularity, Mobility, and Experimental Reusability). This is a small wireless sensor platform designed to support wearable sensing applications such as wirelessly monitoring patients with neurological disorders [3].

For our research, the motivating question from the call for this workshop is, *"why do we want to put technologies in people's homes and what does it really take for that to be successful?"* In our home deployments we aim to collect rich context data to help elders *prevent falls*, improve their *cognitive function* and to improve their *social connection*. To be successful in the short-term, our in home deployments must collect high quality context data suitable for clinical research and for useful feedback to the elder. In the long-term, to be successful our technologies must ultimately help elders "age in place", ideally in their own homes.

For our research, we adopt a form of scenario-based design and development.

Figure 1 shows a single pass through our process from concept through to in-home evaluation. In practice, different phases of this process are occurring in parallel at differing levels of maturity akin to a spiral model. For initial analysis, lab/clinic analysis and in-home study, stakeholders and details of current practice are collected through both clinical and ethnographic research. The ongoing ethnographic research consists of both direct investigation and observation including, in-clinic and in-home interviews, field studies, and questionnaires. This provides a real-world understanding of what old people need, what they find acceptable and how their quality of life can be improved. This is a ongoing process, which is reflected on at every phase as new technologies or more refined clinical questions are proposed.

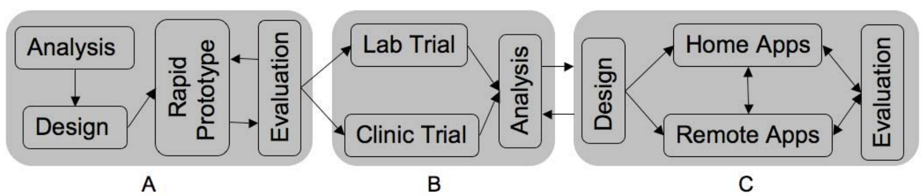

Fig. 1. Our technology transfer from concept, through clinical/lab trial to home deployment

The initial analysis phase also includes clinical modelling that seeks to identify which behavioural markers which can be reliably correlated with specific conditions. For example, a limited time spent outside the home could be associated with an increasing risk of social isolation. Specific activity scenarios allow a clinical researchers to establish the exact context data to be collected to identify these behavioural markers. The initial design of a particular solution is an iterative process including storyboards, interaction design, sketches and group discussion.

We have developed the BioMOBIUS™, research platform given the nature of the problems to be studied. This acts as a common technology platform of hardware, software, services and sensors. This platform supports the development of both health care monitoring applications using wearable technologies but also more traditional pervasive computing applications which rely on a rich source of context data. The platform supports rapid application prototyping including body worn and environmental sensors, local and remote systems, data processing, biosignal processing and customised interfaces. The creation of these initial prototypes as shown in Figure 1 (A), typically act as a "sketch" for engineers, designers and clinicians to discuss and work with in the next phase.

In practice the prototypes developed allow the clinicians to understand the full range of data which can be collected. Such prototypes are refined through a range of inputs including results from preliminary data analysis, new or refined

technologies, ethnographic results, and experimental design conditions. After an initial evaluation, a refined application can be used in a controlled lab experiment (trial) by researchers or in an actual clinical experiment (trial) by clinicians, Figure 1 (B). Both summative and formative evaluation processes are undertaken in the ongoing use of the application.
At this point, these applications are designed to collect rich experimental data sets from controlled clinical and laboratory experiments. These experiments range from highly instrumented elders (Electroencephalography skull caps) and environments (sudoku games) with dozens of participants through to large scale clinical data collection (video/accelerometor data) with hundreds of participants over the course of a year. In either case (lab or clinic) the environment can be closely monitored to ensure the data collected is useful for behavioural marker study as noted in Figure 1 (B).

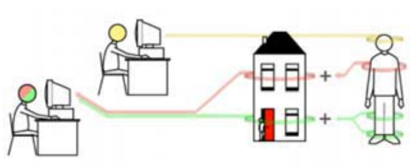

Fig. 2. Remote Interaction Storyboard

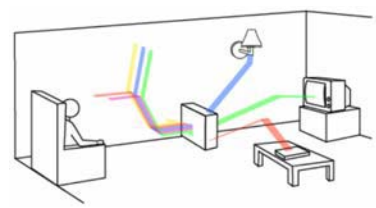

Fig. 3. Home Instrumentation Storyboard

The end to end scenario-based design and development process described so far is straight forward. The analysis, design, protoype and evaluation steps are in a well controlled environment as described in Figure 1 stages A and B. Storyboards such as those shown in Figures 3 and 2 are used in the design phase as noted in C of Figure 1. These storyboards provide a view of the extent of the in-home computing environment in terms of the deployed services and sensors. In addition, these storyboards help convey the required and appropriate level of detail in the data collection and sharing between home and researcher, or between end users. Section 2.2 describes these data issues in more detail.
Translating the applications or prototypes developed from a lab or clinic setting into a home requires us to develop refined scenario descriptions before a home system can be built and its impacts felt. Figure 1 suggests the design of home and remote pervasive computing applications occurs once the previous phase is complete. However, our spiral model of scenario-based design and development allows us to leverage the ongoing ethnographic, prototype, application development and lab/clicnic trials, in parallel. A further strength of this approach is that we can identify cross-overs between projects and stakeholders who can participate in multiple studies for the individual projects in the physical, cognitive and social consequences of ageing.

2 Home Deployment

The BioMOBIUS^{TM}Research Platform is a system for rapid application prototyping and the development of both clinical and in-home systems for health care monitoring and social connectedness. These three phases can loosely be described by the three boxes as shown in Figure 1. In the home, once deployed, the infrastructure forms the basis for further pervasive computing at home opportunities. As a common sensor, computing and communications platform for in-home research it can be used to support the application needs of a range of stakeholders, from end users through to system administrators.
One example application consists of a series of in-home sensors (pressure sensor, galvanic skin response and video cameras) along with hand-held devices and processing elements. This application collects the behavioural markers and provides feedback to the older person, to carers and clinicians. The collected data is securely stored both locally and hence remotely to a central infrastructure.

2.1 In-Home Application Users

In the first home deployments we must collect high quality context data suitable for both clinical research and for context-aware feedback (audible, haptic or visual) to the elder. In our typical home based deployments there a number of stakeholders to consider, who can be defined by the following conceptual groups, Subjects (elders), Family, who may sharing data for social applications and certain alerts, Extended Social Network, Primary Clinical support such as a nursing specialist or physiotherapist, Secondary Clinical Support such as clinicians and researchers, and System Administrators. In a clinical or lab setting we have other stakeholders such as interaction designers, biomedical engineers, hardware engineers, software engineers who are involved with analysis, design, prototyping, development and evaluation. Once deployed to a home setting for long term study, many of these stakeholders cannot be involved to ensure the user to user or user to Primary/Secondary Clinical support remains undisturbed and can be hence evaluated.

2.2 Data Collection

Our system consists of two components. The Home Deployment Platform which collects, processes, shares and persists data in the home, and a central component known as CITADEL (Central Infrastructure for TRIL Acquired Data from Experimental Locations) which processes the data collected from the remote sites at a central location. The CITADEL is used for to support both clinical data and a myriad of end-user to end-user services.

At the lowest level as shown in Figure 4, all of the context data collected through an end-users interaction with an application can be captured, processed, analysed and retained at its highest level of quality. The platform supports this level of data collection from wireless and fixed sensors, cameras, audio recorders

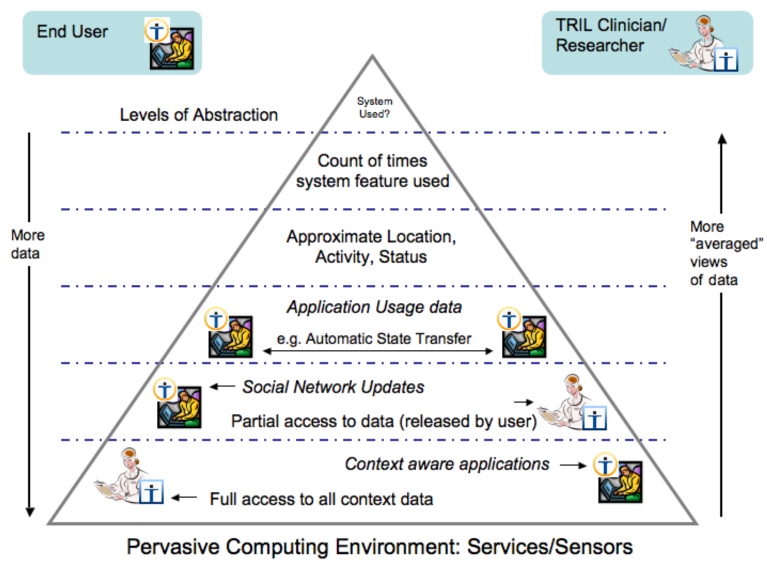

Fig. 4. View of data collection in terms of volume of data versus levels of abstraction

and other computational elements. The software aspects consist of a range of software blocks for arithmetic and mathematical operations, digital signal processing, video processing, display, data acquisition (from various interfaces such as serial, Bluetooth) and file/database access. However data collection at this level results in a vast amount of data which may include both raw audio and video feeds. Clearly, to collect, process and retain such voluminous datasets from many locations would require massive amounts of storage in the CITADEL. Instead, we aim to support context aware applications which process these voluminous datasets locally through inference. Some of this inference comes from clinical models established in the lab/clinic trials. Other aspects of this inference comes from standard pattern detection which extracts signatures from the raw data sources (eg. stick figures, aggregate noise levels per hour, average duration of sitting in a particular seat). Other classes of application at this level are direct such as medication reminder or social interaction applications such as digital scrapbooks [7].

At the next level in Figure 4 will be a class of end user application which will log data from a range of sensors tied to specific end user applications (falls dectors, cognitive state measurement games, audio bridge applications). Some experiments will require specific end user consent to release the data back to the researchers. Facilities also need to be introduced to allow users to blackout or obfuscate experimental results to help preserve their privacy. Generally, the volume of data collected at this level will be less than the raw data streams and it will often be acquired in an asynchronous manner.

At the next level in Figure 4, many forms of context-awareness in terms of local processing, aggregation and filtering will be built into the end user applications. As a result minimal amounts of data may need to be persisted locally and hence remotely to the CITADEL. In addition, some of the user context may be converted into inter-application state data for multi-party applications. Examples of such include "user is online" state transfer to other users in family awareness applications or aggregate location data for "family whereabout clock" applications. Clinical examples may include remote monitoring of Sudoku game play by therapists and clinicans in the Cognitive strand projects.
The highest levels of abstraction may provide data in a highly anonymised form or data for each user in a highly obfuscated manner. Examples which can be realised at this level include location based applications [5] which push user location at a country level to a social networking site or applications which share public photos locally with others [1]. Moving further up the levels of abstraction we see less and less raw data collected and increasingly more abstract views of a users interaction or data stored or shared. Data collection at these levels while more abstract is also much smaller (in terms of both storage and network bandwidth use).

3 Discussion

The nature and scale of our home deployments to hundreds of elders, informed by lab and clinical trials, makes these applications and the supporting infrastructure ideal for the study of "pervasive computing at home" research questions. Our evaluation methodology to date has been as expected for lab and clinic based trial. The lessons learnt from these trials along with the ongoing ethnographic studies has focussed our design process on the need to blend our technologies into the devices and objects currently in use. This is particularly important for those with cognitive issues or a propensity to fall. The layout of their homes provides a "framework" for supporting their mobility as well as helping maintain their regular patterns of life. For our home deployments a particular challenge stems from the need to both collect high quality context data suitable for en-masse clinical analysis at the same time as providing relevant and useful pervasive applications and services to our elder cohort. This is in contrast to a standard view of pervasive applications where only user generated content and sufficient information for developed inference models needs to be retained.

4 Acknowledgements

This research is supported by a grant from Intel and by the Irish Development Authority. Thanks also to all the TRIL Technology Platform team and in particular Ben Dromey our a TRIL designer in UCD for the story boards in Figures 2 and 3.

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5 Biography

Aaron Quigley is an academic staff member of the School of Computer Science & Informatics UCD. He currently directs a team of 22 (postdocs, postgrads and research engineers) with support from colleagues. His research interests are in Pervasive Computing and Visualisation. He is one of the Principal Investigators for the TRIL Centre on the Technology Platform. He is the program co-chair for LoCA 2009, the Late Breaking Results co-chair for Pervasive 2008, the co-chair for PPD'08 and was the conference chair for Pervasive 2006 [2]. He has published over 60 peer reviewed publications including book chapters and research papers in leading journals, conferences and workshops along with several edited proceedings with 30 on Pervasive Computing. His publications in this area have included projects incorporating technology probes [6], in-lab experiments [5], demonstrations [4], elder user trials [1] and comparative age group trials [7].