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A Web Based Tool for Storing and Visualising Data Generated within a Smart Home

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***Abstract*—There is a growing need to re-assess the current approaches available to researchers for storing and managing heterogeneous data generated within a smart home environment. In our current work we have developed the homeML Application; a web based tool to support researchers engaged in the area of smart home research as they perform experiments. Within this paper the homeML Application is presented which includes the fundamental components of the homeML Repository and the homeML Toolkit. Results from a usability study conducted by 10 computer science researchers are presented; the initial results of which have been positive.**

I. Introduction

THE global population is experiencing a demographic transition. There is now a much higher percentage of older people [1]. The percentage of people over the age of 60 is expected to increase from 10.0% in 2000 to 21.8% in 2050 and is expected to continue to increase to 32.2% by the year 2100 [2]. Average life expectancy has also continued to increase from 75.7 years in 1990 to 79.7 years in 2008, with a continued rise expected [3]. Concurrently, rates of fertility are declining. Studies have predicted that the ratio of 15 year olds to 65 year olds will decrease from the current 9:1 ratio to 4:1 by the year 2050 [4].

The older population are the most common sufferers of chronic diseases, disabilities and co-morbidity [1]. Therefore, as people age they are more likely to experience difficulties with their general health and well-being. As a result it can become increasingly difficult for older people to remain at home. Nevertheless, it is not unreasonable for the elderly to have the preference to remain at home and preserve their independence.

As a result of these demographic changes there is a growing need to re-consider current approaches to health and social care provision. One potential solution being considered is the intersection of health, technology and the home [1].

The remainder of this paper is organised as follows: Section 2 discusses related work, including the concepts of homeML. Section 3 introduces the homeML Application, including the homeML Repository. Section 4 discusses the methods used during the evaluation of the homeML Application. Section 5 summarises and discusses the results of the usability study performed and finally, Section 6 concludes the paper.

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II. Related Work

As people age they are likely to experience difficulties performing day-to-day activities. It is now becoming increasingly common for smart software applications to be employed to monitor, encourage and manage an individual's health behaviour on a continuous basis both inside and outside the home environment [5].

A smart home environment is a residence equipped with technologies that enable the monitoring of its inhabitants whilst promoting independence and the maintenance of health and well being [4]. A considerable amount of effort has been directed towards research in the area of smart home environments, in order to facilitate the combination of health care provision and home based support. There has therefore been a large number of solutions developed to support and assist older people who may experience challenges living independently; in addition to people suffering from physical and cognitive impairments.

A. Open Home

The previously proposed Open Home concept comprised a series of solutions to assist researchers and practitioners in the construction of openly available, scalable and shared home behaviour datasets [6]. Open Home consists of a range of approaches to support the management of data generated within smart environments along with how it can be further processed. These included homeML [7], HomeCI [8], HomeTL [9], HomeADL [10] and HomeRuleML [11].

B. homeML

An abundance of data is being generated within the smart home research domain. This data is considered heterogeneous given that it is gathered from numerous sources and is therefore stored in a variety of formats. As a direct result data exchange, re-use and the ability to compare data is being limited.

A number of projects have attempted to develop standards to assist researchers within this domain. The AALIANCE project aims to develop a common strategic vision for short

to long term research in the area of Ambient Assisted Living (AAL) [12]. The Project considered the availability of standards within the area of AAL to be inadequate. Steps have been suggested that should be taken to resolve this issue, including increasing the awareness of existing standards within the AAL research domain [13]. SensorML [14] is an Open Geospatial Consortium (OGC) approved technical specification; providing standard models and XML encoding to describe sensors and measurement processes [14]. Although both of these approaches have been successful within their own application domains, the need for an open format to support the exchange and storage of data generated within intelligent environments has yet to be addressed [7].

To date, our work has focused on the development of homeML; a proposed solution which aims to overcome the issues caused by the heterogeneous nature of data generated within smart environments. homeML is an XML-based format that has been developed to support the exchange and storage of data generated within smart environments [7]. homeML has been extensively tested and evaluated. A number of datasets generated by various institutes including Massachusetts Institute of Technology (MIT) [15], University of Amsterdam (UA) [16], University of Texas at Arlington (UTA) [17] and Washington State University (WSU) [17] were collected. The structure of each dataset was compared to the homeML format to ensure the structure was compatible with a range of data sources and structures.

III. Methods

The aim of this work has been to extend the concepts of homeML and to create the necessary technical components to facilitate its usage and evaluation within the Research Community. Users of this concept will require access to a repository where data is stored along with requiring access to a set of tools which will allow the creation of the underlying data schemas according to the homeML format and functions for retrieving and visualising the information from the repository.

Users will therefore be able to design experiments to be conducted within smart environments in addition to having the facility to upload and store the data generated through such experiments. A further core component of the system will provide a means to retrieve and view the data in order to recognise any patterns or changes in a patient's behaviour.

Figure 1 depicts the hierarchical site map of a web based interface which aims to provide users with access to the aforementioned features.

The web interface and repository was developed using the following technologies: HTML, PHP, XML and MySQL.

A. homeML Repository

A centralised repository in its simplest form is a data warehouse capable of storing large amounts of data from multiple sources [18]. As previously mentioned the data generated within this domain is heterogeneous, making it essential to store and manage data within one central location, whilst adhering to one specified format, homeML version 2.0 [19].

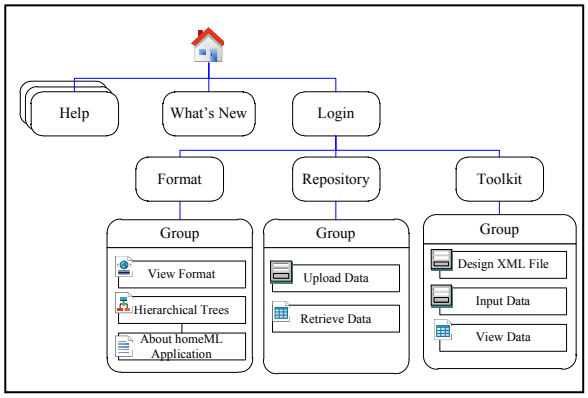

Fig. 1. Site Map of the homeML Application.

Figure 2 represents a sequence diagram of how users upload data to the Repository. As depicted by the diagram a method has been developed to allow all registered users to upload and store data within the Repository. All data uploaded will be validated prior to being stored within the repository to ensure that it adheres to the homeML version 2.0 format [19]. Any datasets not adhering to the format will be rejected. Once uploaded and validated, the user will be able to retrieve and view data through the visualising features accessible via the browser.

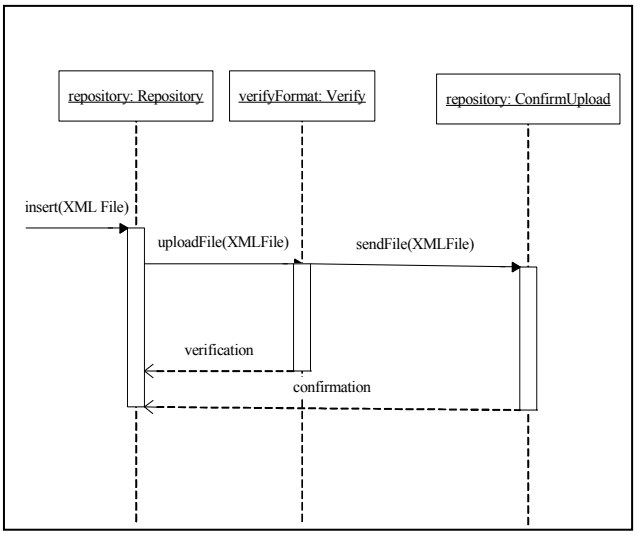

Fig. 2. Sequence Diagram depicting the various processes involved when uploading data into the Repository.

B. Software Features

A suite of tools to support data management in relation to storage and retrieval to/from the repository along with data visualisation have been developed.

Users are able to design a data format suitable for the storage of the data specific to the requirements of the smart environment within which they will conduct their experiments. Whilst being specific to the experiment they will be performing, the format will adhere to the homeML version 2.0 schema [19]. Once the format is designed it can be downloaded in an XML file.

Users who have not designed a suitable format prior to performing their experiments will also have access to a tool

that will allow them to populate the homeML version 2.0 format with the raw data they have generated. *Figure 3* is a screenshot showing the form available via the Browser that enables users to upload to the Repository. Finally, users are offered the facility to view data extracted from previously uploaded data sets.

Fig.3. Screenshot of the 'Upload Dataset' form, used to upload data to the Repository

IV. Evaluation

To verify the concepts of the homeML Application, 10 volunteers were recruited to evaluate the software from within the Faculty of Computing and Engineering, University of Ulster (Ulster) [20]. All participants were members of the Smart Environments Research Group and were engaged in research of a similar nature.

Each participant completed 4 pre-defined tasks within a 30 minute period, before completing a questionnaire reviewing their experience of using the application. The questionnaire consisted of both quantitative and qualitative questions regarding usability, usefulness, design and rate of error; enabling the identification of both the strengths and weaknesses of the homeML Application. While participants were interacting with the software observational notes were recorded by a member of the project team.

The 4 pre-defined tasks enabled the user to interact with both the homeML Repository and corresponding software tools. The first task tested the homeML Repository whereby each participant was asked to upload and view an XML file within the homeML Repository.

Each of the subsequent tasks tested the software tools available via the Browser. The second task involved the participant designing and downloading an XML file suitable for the storage of data generated through an experiment within a smart home environment. Data was also supplied to enable the participant to populate the homeML format and download the file created to complete task 3. Finally, task 4 involved the participant viewing the data extracted from within the previously uploaded dataset.

Each task assessed the usability of the homeML Repository and corresponding software tools in addition to the ease of which the task could be completed by the participant. Participants were also given the opportunity to provide suggestions for further development of the homeML Application.

V. Results and Discussion

The usability study and evaluation process discussed within the previous section did not identify any technical issues with the homeML Application. A number of design issues were, however, identified. The questionnaire completed provided an opportunity for each participant to document these issues. Each of the identified design issues have since been addressed and rectified. An overview of the issues identified from the usability study and the alterations made to the homeML Application to rectify these issues are presented within *Table 1*.

The homeML Application has undergone a second evaluation process, whereby participants involved in the first usability study have been asked to re-evaluate the application. The second evaluation process was similar to the first, whereby each participant completed 4 pre-defined tasks within a 30 minute period involving both the homeML Repository and corresponding software tools. Upon completion of the 4 tasks the participant completed a questionnaire consisting of a series of both quantitative and qualitative questions.

Issue	Alteration
Input forms should be more intuitive.	Radio buttons have been used to reduce the chance of errors occurring when data is being entered by the user.
The logout button did not appear on every page.	Navigation is improved within the homeML Application by employing a consistent layout throughout.

Table.1. Sample of issues identified from the usability study and the alterations made to the homeML Application.

During the initial evaluation process 80% of participants agreed that the homeML Repository and software tools available enabled them to sufficiently complete the 4 tasks. The second evaluation process was successful, with all participants agreeing that the online resource was useful and well designed.

VI. Conclusion

As the global population continues to grow there is a growing need to reassess the current approaches to health and social care provision. As a result there has been an abundance of research in the area of home based support, particularly in the area of smart home environments.

It was the aim of this study to develop a central repository and complementary suite of tools to assist researchers as they perform experiments within the area of smart home environments.

This paper has presented the homeML Application; including the homeML Repository and corresponding suite of tools. Usage of the homeML Application will provide researchers with an efficient method for designing experiments and managing data generated within smart environments; whilst adhering to a standard format. Through the development of the homeML Application data storage, exchange and analysis has the potential to be significantly improved.

Initial testing of the homeML Application has been documented within this paper. Work will now continue to perform additional validation tests on the suite of tools

developed. To support this activity, a number of researchers within the area of smart home environments will be approached and asked to use and evaluate the homeML Application. In addition to being asked to evaluate the homeML Repository and suite of tools; they will also be asked to provide feedback regarding future developments of the application. The feedback from this validation process will shape future developments of the homeML Application.

Work is also plannedto develop a means of enabling data sharing amongst researchers within this domain, via the homeML Application.

Finally, this work has the potential to be developed further to incorporate other elements of Open Home [6], HomeRuleML [11] and HomeCI [8]. HomeRuleML was proposed as a means of encouraging the exchange of decision support rules generated within intelligent smart environment. Similarly to homeML this work will involve the development of a standard approach for the storage and exchange of decision support rules. HomeCI was originally created as a standalone application for assisting healthcare professionals create rules for patients' smart homes in order to promote independent living. An updated version of this service could be provided online and could be used to generate HomeRuleML rules. It is hoped that this work may also eventually be incorporated within the homeML Application.

Access to the homeML Application can be obtained using the following link: www.home-ml.org/Browser

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