Intelligent Assisted Living Framework for Monitoring Elders

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***Abstract*— Recently, Ambient Intelligence Systems (AmI) in particular Ambient Assisted Living (AAL) are attracting intensive research due to a large variety of application scenarios and an urgent need for elderly in-home assistance. AAL is an emerging multi-disciplinary paradigm aiming at exploiting information and communication technologies in personal healthcare and telehealth systems for countering the effects of growing elderly population. AAL systems are developed to help elderly people living independently by monitoring their health status and providing caregivers with useful information. However, strong contributions are yet to be made on context binding of newly discovered sensors for providing dynamic or/and adaptive UI for caregivers, as the existing solutions (including framework, systems and platforms) are mainly focused on checking user operation history, browser history and applications that are most used by a user for prediction and display of the applications to an individual user. The aim of this paper is to propose a framework for making the adaptive UI from context information (real-time and historical data) that is collected from caregivers (primary user) and elderly people (secondary user). The collected data is processed to produce the contextual information in order to provide assistive services to each individual caregiver. To achieve this, the proposed framework collects the data and it uses a set of techniques (including system learning, decision making) and approaches (including ontology, user profiling) to integrate assistive services at runtime and enable their bindings to specific caregivers, in so doing improving the adaptability parameter of UI for the AAL.**

Keywords—AAL; UI; HCI; contextual information; caregiver; ontology.

I. INTRODUCTION

The first work on AmI systems was implemented in 2001 by the European Commission [1], [2] and since then other works have been implemented that led to the evolution of alternative types of system. This paper outlines the current research being conducted into Assisted Living Systems (ALS) and their components to produce an adaptive system to support elderly people to live independently while improving transparency, adaptability, flexibility and customization of data. Different technologies that will contribute in construction and adaptation of Assisted Living Systems (ALS) in a real environment will be studied and discussed. The proposed framework will be composed of different components which are designed to process different functionalities to improve the performance of ALS by using intelligent user interfaces. Intelligent sensors such as for measuring heartbeat, blood pressure, body temperature, and accelerometers etc. will be investigated. Moreover we will be discussing Wireless Sensor Networks (WSN) such as ZigBee that are used in ALS to produce context information from the elderly and their environment. The framework will contain appropriate algorithm and modeling techniques to enable the system to improve prediction and decision making features. In order to achieve the goal of this project, we will look into different techniques, and approaches that are used for the development of user interfaces. The outcome of this paper will help to define requirements of the proposed framework to improve adaptability of the ALS applications Furthermore the framework will be implemented and each component will be discussed based on our findings.

II. BACKGROUND

A. Elderly

One of the major challenges of the last decades has been continued increase in the elderly population in developed countries. According to the World Health Organization (WHO) in 2010 the elderly population was 650 million and it is predicted to reach 2 billion by 2050 [3] and it has also been estimated that over 11 million people by 2040 will suffer from dementia and Alzheimer related illnesses and this will have an effect on the US economy expected to be near 2 trillion dollars and this will not be limited to just the United States [3]. The Commission of the European Communities indicates that by using advanced technologies such as mobile health monitoring will result in saving about 1.5 billion Euros each year in Germany alone[1]. Consequently advanced technologies could be used in assisted living systems [4] to improve the quality of life and allow elders to live independent lives at home without invading their privacy, and supporting individuals with disabilities, or with cognitive impairments, and help to reduce the cost of health and social care to the country.

B. Applications of AmI Systems

[2] defined AmI as; “a digital environment that proactively, but sensibly supports people in their daily lives.” and IST advisory Group further developed the definition and described five key factors which are reason, sense, act, secure,

and HCI contribution in construction and adaptation of AmI systems in a real environment. Advanced technologies contribute in the development of AmI systems; they offer factors such as Sensitive and Ubiquitous wireless sensors, Responsive and Adaptive UIs, Transparent contextual information, and intelligent interaction with targeted users [5].

There are a number of researchers who have pursued AmI related to different categories and use scenarios, some examples of these applications are used in;

- Smart homes
- Health monitoring and assistance
- Hospitals
- Transportation
- Emergency services
- Education and Workplaces

Further specific examples of healthcare monitoring applications are used for:

- Activities of daily living monitoring
- Fall and movement detection
- Location tracking
- Medication intake monitoring
- Medical status monitoring

The main aim in design of the applications in healthcare is that elderly people should preserve a sense of independence while being monitored [4]. Also according to a technical point of view in the HAPPY AGEING project [5] the main aim is focused on the development of a set of integrated functionalities such as Transparency, Reliability and Affordability, High Flexibility and Customization to support elderly people in independent living. However, at the present time in a majority of cases the use of these applications is not widespread in real life because of difficulties with using them and their weak flexibility to customization to the need of a single person and the high cost of the chosen equipment.

C. Subsystems of AmI Systems

In [3] has indicated that healthcare systems are composed of five distinct subsystems that are interconnected using wireless sensor network as illustrated in Fig. 1 which work together in order to make a broad vision of an intelligent healthcare service possible, the five subsystems are:

- *Body Area Network* (BAN): RFID tags and sensors are the components that are attached to or can be worn by elderly people to collect contextual information such as blood pressure, body temperature, and hearth rate.

- *Personal Area Network* (PAN): is composed of environmental sensors like RFID readers, and video cameras in order to provide contextual information about the user (including user's movement).

- *Gateway to the Wide Area Networks* (WAN): the main role of this subsystem is to connect BAN and PAN subsystems to the WANs.

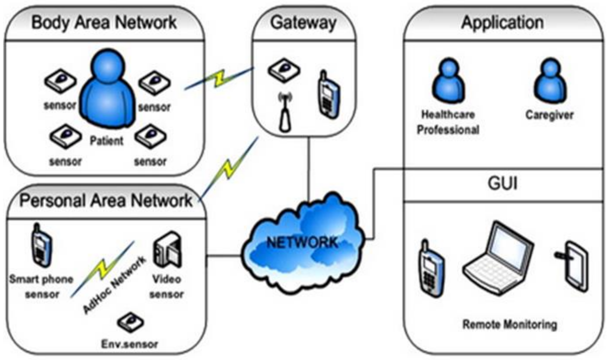

Fig. 1. Overview of a Simple WSN application for healthcare [3].

- *Wide Area Networks*: these enable remote monitoring and tracking in these types of applications.

- *End-User healthcare monitoring application*: is at the center of the system, and it generally includes components such as: machine learning algorithms which can be used for identifying anomaly situations [3], decision software to identify unexpected situations to handle warning messages [5], database management systems to store contextual information, Graphic User Interfaces (GUI) for real time monitoring of the elderly's health status by providing essential information as well as functionalities to professional caregivers.

III. AMBIENT INTELLIGENCE PARADIGM

An Ambient Intelligence (AI) of AmI system includes one or more of attributes such as Sensitive, Responsive, Adaptive, Transparent, Ubiquitous and Intelligent. Definition of the AmI paradigm declares that there is no need for including all of these attributes in one system and it depends on the type of ALS application and a scenario that is generated for design and implementation of the ALS in a real environment. One important issue noticed during our research is that most applications of the ALS solutions are mainly investigated but they are not implemented and tested in a real environment.

Adaptive refers to the presence of a digital environment that is sensitive and responsive to the presence of people who are surrounded with networks of embedded intelligent devices which can sense their state, anticipate, and perhaps adapt to their [1,6]. This clearly gives a good reason for using context information that allows access to sufficient information about the user and the surrounding environment.

Users are interested in adaptive services; they are also a little bit against them, as the user experience can be decreased while adaptive services provide information according to the user's preference. This is because there is a considerable challenge for system developers to ensure they collect comprehensive and relevant information by using a precise technology, method and technique to analyses results in producing an arrangement of multimedia. AmI and in particular ALS application, which is the focus of our project, is required to have context information on different groups of users and also to use data that is collected from the sensors in an appropriate mode.

The challenge is what, when and how information should be used and what type of multimedia should be implemented on the UI for each type of caregiver users. On the other hand hardware capability should be considered as multimedia uses memory and this is a challenge for mobile devices that have especially limited processing power, this fact plays an important role in selecting the right programming technique and technology.

There are a number of challenges that are related to make AmI systems adaptive and responsive to the user's needs especially in ALS to monitor the health status of elderly subjects and then alert caregivers and provide relative information. Information that will be provided to the caregiver can be in the form of a multimedia display on the User Interface (UI) and the multimedia can include menu bars, sound, buttons, scroll bars, and more advanced media. The proposed framework in the background, processes the activities that should be considered and adjusted to ensure the multimedia and the information are appropriate for different types of users and that the system is acting in an adaptive fashion.

A. Context information

There are a number of advantages of context awareness, it is important to support a natural interaction by providing interface support for different types of user and moreover to provide proactive services. During the development of a proposed framework, the following ultimate goals are considered; firstly, "High recall", in detecting every real emergency immediately and secondly, "High precision", to prevent invalid emergency detections and alerts as a consequence of misinterpretations [7].

IV. HCI

Monitoring the interaction between human and information systems shows that a common knowledge base is essential for understanding a different type/group of users, and to providing a precise functionality via UI. It is essential for the system to provide services that make sense to a different group of caregivers, therefore this cannot be achieved unless we take user's actions, thinking and emotions into consideration. In order to clarify this concept, we are using three categories highlighted in work by Don Norman to integrate the meaning of emotion and cognition in the design phase. The following are the three defined categories.

- *Visceral* as product's look and feel: how the product pleases the user visually.
- *Behavioral* category refers to the functionality and practical issues.
- *Reflective* category as how well the product fits to the user's identity and image.

Context and situation are clearly linked, this means that communication and interaction between humans happens in a specific situation, in a certain context, and in a particular environment. These user interactions are identified in a work by [8] and defined in three paradigms described in the table I.

TABLE I. HCI Paradigm.

Paradigm	Definition
Implicit Human–Computer Interaction (iHCI)	HCI is the interaction of a human with the environment and with artefacts which is aimed to accomplish a goal. Within this process the system acquires *implicit input* from the user and may present *implicit output* to the user [8].
Implicit Input	Implicit Input are actions and behaviour of humans, which are done to achieve a goal and are not primarily regarded as interaction with a computer, but captured, recognised and interpreted by a computer system as input [8].
Implicit Output	Output of a computer that is not directly related to an explicit input and which is seamlessly integrated with the environment and the task of the user [8].

A. User modeling and profiling

Two types of users are identified for the proposed framework; including the caregivers (primary user) and elderly (secondary user), they are categorized in Fig 2.

Each user has their-own specific needs from the system and interacts with the system in a different way. In order to improve context information for the system, we have processed a user profile to identify the interaction between users and the User Interface (UI). This information will be used to generate a scenario for our framework development.

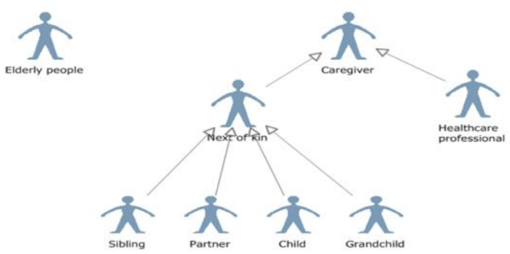

Fig. 2. Stakeholder for the ALS

B. Environment specific information

We are using a Knowledge Management (KM) system for user profiling and modeling information, and environment specific information that is defined in a scenario generation activity, this brings other challenges about the quality of the information as according to [9], acquisition of context is not a straightforward task, due to its dynamic nature and the heterogeneous state of data. Data is gathered from different sources such as the elderly via a wearable sensor device, and from a caregiver's interaction with UI.

Elderly users provide us with important information regarding their health status. Sensor devices are available to collect different types of information about users such as HR, Blood temperature, skin temperature and so on. The main attempt to select a precise sensor device was made, and SHIMMER has been selected based on our comparison among different wearable wireless devices that are available on the market.

Context should include different types of health status from elderly people such as HR, ECG, and EEG, and also it should know how the caregiver needs to know about context. Context and information provided to the user will be different as we have found that adaptive services should provide information according to the user's preferences. As presented in table II, we have created one scenario to define and explain the type of health service application, this scenario is used to develop and implement our proposed framework.

TABLE II. User action and scenario.

User type	Scenarios			Framework behaviour
	Elderly interaction	Caregiver interaction	User Interface	
Professional Caregiver	ECG sensor indicating high heart rhythms.	Response to the elderly's health status. Checking ECG information.	Automate alert to caregiver, indicating level of emergency with supportive information.	Use decision making and triggering a correct action will be important.
Professional Caregiver	Accelerometer indicates that user does not have a movement and HR is at high risk.	Adaptable content information in a medical health format where the user can find them easily.	Displaying accelerometer information with supportive functionality.	Use of system learning technique is important to achieve this.
Professional Caregiver	Elderly having a problem with breathing and he/she has a pain on his heart but it is not at a high risk level.	Automated supportive information (including elderly profile and clinical guidelines) that can help caregiver to act.	Adaptive UI.	Contextual information.
Professional Caregiver	Selecting, editing different formats of information regarding elderly's health status	Personalisation of content information that can be used by an individual caregiver.	Personalised information and UI	System learning technique.

V. THE PROPOSED FRAMEWORK

The personalization of information is important because of different combinations of impairments and capabilities; our solution offers personalized services that use context information (real-time and historical data) about the user and the environment to adapt according to the needs of the user (caregivers). The proposed framework implements an intelligent HCI solution that provides dynamic elements to the user's need to increase adaptability by applying AmI characteristics. The context information and intelligent elements (including; techniques and algorithms) are used to characterize the situation of the user and to provide users with the most appropriate information and service dynamically.

In the previous sections, we have discussed about HCI, context information, attributes of AmI including adaptations, and proactivity. We believe these two factors are playing important roles in the effectiveness and intelligence of the proposed framework for the ALS application, therefore we have applied them in our work to implement a novel framework that consists and interconnects essential components AmI to tune and implement adaptable UI to different groups of users.

A. *Scenario generation*

Throughout the day, an elderly person who lives at his/her home independently has access to a healthcare service. The health status of an elderly person is monitored using the AmI system, the elderly wearing a wireless sensor device (We are using SHIMMER wearable sensor platform) on his/her wrist. The device automatically collects and transfers the health data to a server where it is analyzed and processed. A caregiver receives information related to an elderly person via a User Interface (UI) on his/her portable device (mobile) or desktop, the caregiver is hence required to infer from this information if the elderly person is in good health. The measurement of health in this scenario is depicted by three levels: L° (low risk), L^1 (medium risk) and L^3 (high risk). The caregiver will automatically receive an alert on his device when the system detects a medium risk level to ensure the system is proactive so caregivers can respond to the emergency event in a reasonable time. The SHIMMER sensor uses ECG, EEG, and an accelerometer to monitor heart activities, heart rate and blood pressure to send the caregiver an alert indicating the elderly person has exceeded a predefined threshold. Another factor that the system should take into account is that the level of health should never reach L^3.

B. *Methodology*

In order to improve our scenario and discover how different information and components can be used together to conceive an AmI system, we use a methodology to create and adapt the scenario to the rest of a developing cycle. For this purpose we consider a methodology that is used in [10] to create the SALSA framework and presented in Fig. 3.

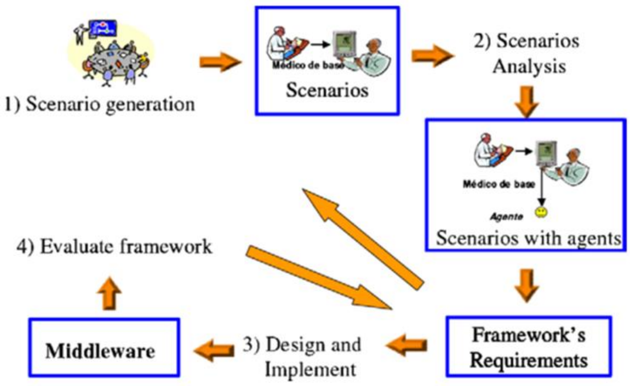

Fig. 3. Methodology followed to create SALSA [10].

C. The conceptual view of proposed framework

A conceptual model of our novel solution is illustrated in Fig. 4. The proposed framework divides the essential technologies and concepts into two segments including front-end and back-end.

The front-end segment includes wireless wearable sensor devices that will be worn by the elderly to measure their health status (e.g. Hearth Rate (HR), blood temperature), and UIs for application that users (including professional health caregivers) should use to interact with the system. There is an additional intention of using UIs, because we are using UIs to collect more information on the user's behavior to improve the context information.

Back-end segment includes techniques and algorithms (e.g. context information and ontology technique and pattern recognition algorithm) that are essential for an adaptive UI. Before we start explaining different components of our novel framework, we will generate a scenario to highlight the ALS application and its functionality requirements which are the focus of this work. The main focus of the proposed framework is on back-end segment including the following:

- *Data acquisition*; this element of the proposed framework, is where context information will be received from a SHIMMER wearable sensor device, data that is collected in this stage will be analyzed and processed in other elements which will be explained.
- *Core rules*; is responsible for semantically modelling the corrected information and creating a set of rules for different cases/events of user interaction (e.g. a rule can be defined for a case where high risk is detected from the sensor and it should be linked to an action).
- *Context actions*; it articulates user actions and behavior based on contextual information (case comprehension), a set of actions will be created for each event.
- *Context events*; provides personalized information and functionality (service) by using context information that are provided in a context information element.
- *Context information*; is using an otology modeling technique to modeling contextual information. Different types of information will be modelled including log ontology, user ontology and domain ontology. We have found using ontology can be more effective in modelling information over agent technique.
- *Algorithm*; a set of algorithm will be used by the framework to support decision making and machine learning processes.
- *Event handler*; is a listener that is responsible for handling new events and users; including the sensor's data are used by individual elderly.
- *Event trigger*; it provides a set of control methods (including trigger action, stop action and pause action). A bidirectional communication is established to pull information from the interface database.

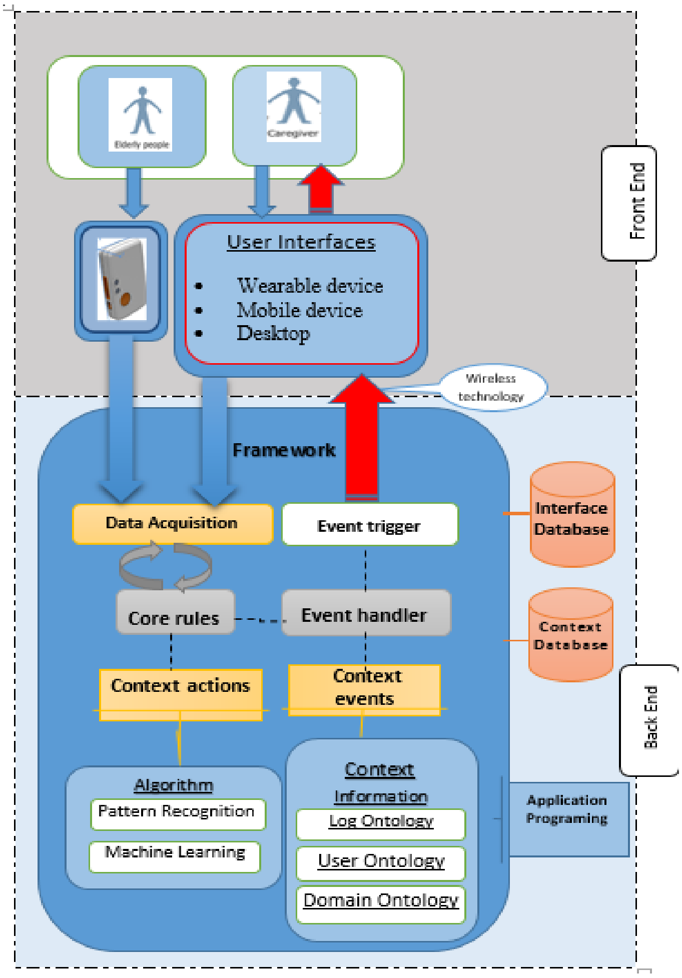

Fig. 4. Conceptual view of proposed novel framework.

VI. FRAMEWORK EVALUATION

The table III shows our proposed testing plan. This includes a block of testing which will be used to evaluate the framework performance and the interface that is using the framework.

- *Evaluating the UI*; Evaluating the UI includes testing the predictability and transparency of the UI, therefore we will use user-model to develop a set of functionality and widgets that are used to allow users to manipulate the information (e.g. Heart Rate (HR), ECG) and to perform interactive tasks (checking HR, blood pressure and general health status of elderly individuals).

TABLE III. Proposed evaluation of the framework.

Interface	*Predictability*	*Transparency*	*Tools and participants*
	•User action should be matched by a response •Operation effect determinable by interaction history •Affordance/logical constraints should be used to indicate available actions.	•Interface should give users awareness of adaptations and the means to inspect, override, discard, revert, store, retrieve, preview.	•User; professional caregiver •Tools; use case and scenarios.
	Adaptation	*Performance*	*Tools and participants*
	•Self-adaptive: evaluating algorithm to measure effectiveness of the framework in providing best possible match to user's need (personalised information). • Accuracy of contextual information is received and saved from the sensor, and caregivers (real time and historical data).	•Context information; including measuring effectiveness of the framework in sensing context and anticipate effects of user's request. • Measure accuracy of monitoring, measuring, modelling when the framework responses to the user's action (this will evaluate performance of event handler, core rules, context action and context events).	•User; professional caregiver •Tools; use case and scenarios.

- *Evaluating the framework*; the use cases and scenarios will be generated based on user-models and user profiling, completed during the early stage of the project. A panel of experts such as GPs and nurses will be invited to participate in evaluation of the framework. We will contact organizations that provide a range of services to elderly people including Age Concern and Age UK to invite a number of expert users to participate in the evaluation of the framework. During a walk through session, we will provide users with use cases to validate different components including their contained and sub-component. Furthermore all components that are used in the architecture and organization of the framework including contextual information, algorithms and the event handler will be tested to emphasize that the framework supporting interface adaptability of ALS application.

VII. Conclusion and Future Works

The drive and focus of the framework have been concentrated on a specific component, paradigm, and the objectives to make the UI of ALS application more adaptive and intelligent in terms of providing the right multimedia and functionalities to the right user by understanding the needs and roles of the user. This required us to study context information including relevant data from the user and the environment with which the system will be used, followed by a feasible scenario. The challenge was to collect and manage information that improves adaptability of the ALS by applying the ambient intelligence paradigm. For future works, the framework can be implemented and interconnect with the UI to test the success rate of the proposed framework. To highlight the strengths and weakness of the proposed framework, context information can be improved by inviting the caregivers in the early stages of the design phase to have a better understanding of the user's need.

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