User Interface Design for Ambient Assisted Living Systems

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Abstract. Ambient Assisted Living (AAL) systems and the interface design principles applied to them is vitally important in facilitating the elderly in achieving their daily goals of health monitoring, social interaction, physical exercise or daily reminders. Design principles for AAL systems have accommodated for a user's physical and cognitive abilities and Activities of Daily Living (ADL's) but does not give enough recognition to interfaces that require various key user interactions as age profiles increase. This paper seeks to explore if User Interface (UI) design for the elderly needs to address this issue.

Keywords: Ambient assisted living · User interfaces · Design principles

1 Introduction

World Demographics have changed within the elderly [1], longevity of life in conjunction with medical science has resulted in humans living long, active lives, with their representation within the population increasing. In order to facilitate the independent lives of these individuals [2] and to reduce the economic burden of such long-term care, Ambient Assisted Living (AAL) systems have become a priority [3]. The aging process requires increasingly sophisticated medical supervision and AAL systems have provided this unobtrusive reassurance [4] for the healthy elderly [5] and for those with cognitive decline [6] through dedicated User Interfaces (UI). UI design is paramount within the area of AAL as its success influences future system usability [7]. Good User Interface (UI) design practice commonly cite Neilsen's 10 usability heuristics [8] along with Shneiderman's [9, 10] 8 golden rules, whilst specific elder design principles [11] are less well-known. Several research studies have been conducted within the area of elder usage of UI's [12] and the promotion of a universal interface design [13], in particular for the elderly user [14] using touch-based [15] and multimodal user interfaces [16]. Research has argued that the elderly cannot be considered as a combined age group but should be considered in terms of a third (65–80 yrs) and fourth age (80+ yrs) [17, 18]

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yet there is no evidence to suggest that this theory is applied when system interfaces are being designed. Many studies in design principle application acknowledge the differences in UI usability between younger and elderly adults [19, 20] but not between these two elder age groups [21, 22]. This paper examines whether UI design principles are reflected in various ambient systems and the consequent usability of these systems for the inherent stakeholders.

2 Human Computer Interaction

In 1995 Buxton proposed a basic framework around which the various aspects of computing could be categorised [23] see Fig. 1, incorporating a foreground and background, representing conscious and un-conscious activities. AAL system success is dependent upon technological expertise and user input to include implicit and explicit foreground interactions [24, 25] fading into the background when no longer required. Ambient interface interaction should be seamless offering unobtrusive background data while the user operates uninterrupted in the foreground [26].

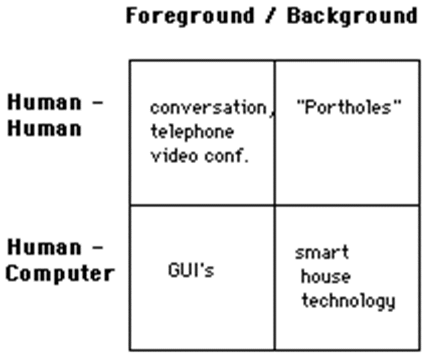

Fig. 1. The Basic Model

They should be efficient, effective and easy to learn for all stakeholders, including health professionals, family members, carers and elderly users. User-friendly interfaces improve system interaction [27] however disparate interfaces across several devices discourage user uptake and hamper elder assimilation of the technologies [28]. Heterogeneity in elder UI design is paramount particularly within one system in order to establish best practice guidelines for future ambient interface success.

2.1 User Interface Design Principles

Central to good UI design is the notion of usability [29] and its virtues have been given extensive commentary over several decades [30] along with its inherent difficulties integrating technology with how humans live their lives. Sophisticated software systems can only implement their intended search and query tasks if the UI enables the user [31] to adequately interact with it. Effective UI design incorporates several facets including how we behave when information is presented to us and how we subsequently assimilate this information whilst accommodating for any limiting factors [32]. As technology evolved the term Ambient Intelligence (AmI) [33] became synonymous with various computer science fields such as engineering, in conjunction with the areas of health and education. Human-centered Computing (HCC) [34] principles facilitate the design of more effective intelligent interfaces. AAL systems require a unique level of context focus [35] as the user often enters and receives information which needs to be easily understood without prior medical or computational expertise. Commercially available systems deemed effective [36] include ActivPal [37], ADLife [38] and Quietcare [39] as they facilitate users with UI's which offer iconic visual representations of daily tasks.

2.2 Review of Europe's AAL Systems UI Design Approach

The AALIANCE AAL Roadmap [2] outlined its future aspirations for system development and highlighted that standardisation was required, in particular within UI design to facilitate the user's continuing requirements via adaptive interfaces. Several AAL systems reviews [40], [41], [42] have repeatedly stated that issues of data accountability, economics and security have manifested themselves in poor UI design thus propagating a lack of continued user engagement. Interfaces that can adapt to continuing user needs [43] should be supported with relevant UI design frameworks in order that the goal of independent living is achieved. Many systems and their methodologies have been assessed for effectiveness [44], with many successful systems developed. UniversAAL [45] is the most prominent AAL platform in Europe, with several input projects, Soprano [46], Persona [47], Amigo [48], Oasis [49], Genesys [45], MPower [50] all feeding their research into the advancement of an open source platform for researchers [51] to use as a baseline. This paper reviews Europe's most popular AAL systems so as to establish what weighting has been placed upon each UI design and its importance within the overall system architecture.

PERSONA: is a self-organising AmI system, with a relevant UI framework, platform modules and the goal of combining technologies to provide independent living possibilities for the elderly [52] within their own homes. An in-depth end user analysis was conducted and a scalable open standard platform was developed upon which a range of user services would be facilitated. Interface design is discussed in terms of OSGi layers and conclusions drawn were that future investments should be made in usability not further component manufacture.

SOPRANO: is a self-learning ambient system based on manually entered commands via various technologies such as sensors and actuators, interfaces are designed for medication reminders [53], encouraging exercise programs, enhancing social interaction and living safely. This required user led technologies to support an elder at home were included [54] and social separation, safety, daily routines, healthy physical and psychological attitude were on the highest tier of needs. Subsequent tiers included community awareness [55], shopping independence & supporting mobility levels for indoor/outdoor independence. The technical core named Soprano Ambient

Middleware (SAM) [56] receives user commands and through modularisation their approach to sensing, processing and reacting to users data has facilitated the use of scaled abstraction levels and user involvement remains crucial to the success of this system.

REMOTE: strives to improve health care delivery to infirmed elderly living independently [57], particularly those in rural areas with chronic conditions, such as hypertension, arthritis, asthma, stroke, Alzheimer's and Parkinson's disease. Efforts are being made to improve health care systems and tele-healthcare [58] in combination with Ambient Intelligence (AmI) enhances daily ambient surroundings with audio-visual, sensor and motoric data collection. Vital daily physiological readings are recorded along with the proactive monitoring of movements and at-risk situations [58], information is shared across heterogeneous devices where all services and technologies are required to interact seamlessly. UI's that facilitate the evolving physical and health care needs of its intended users will be available on various devices matching the technological literacy of each user [59]. This project was scalable, less rigid, more amenable to integration with previously installed software or hardware and interfaces [60] were adaptable to a user's needs and Information Technology (IT) ability. The project concluded that sensor monitoring [61] of frail elderly was successful in terms of decreasing cardiac mortality rates, increasing self-confidence and providing unobtrusive health monitoring for health care professionals. Interfaces will be optimised with user input to enhance software interaction.

MonAMI: is an open source platform [62] that seeks to assist the elderly with daily tasks, increasing their safety and quality of life [63]. Designed for the Slovakian environment [64] to deliver services using wireless and wired networks, it incorporates user friendly interaction technology with wearable devices and components for health monitoring. The OSGi4AMI uses TV controlled multimedia software with an ASUS touch screen interface and has facilitated the development of new interfaces for various platforms such as Android and iOS. This projects intention was to develop new services from pre-existing technologies such as wireless *(ZigBee)*, SON networks, wired networks *(1-wire technology)*, user-friendly interaction technologies, wearable and health monitoring technologies. The system interconnects via specified open source interfaces within OSGi4AMI on three levels, sensors, computing and interfaces [65]. Assorted smart devices could support the MonAMI UI, which is HTML based and comprises of three distinct UI's intended for the elderly, carers and system developers. The UI's are user friendly and accessible via a devices internet browser facilitating access to family members, playing/reading online, thus increasing feelings of safety, self-confidence and autonomy. Devices are separated into those with sensors *(ambient temperature, lighting)* and those with actuators *(ability to change status, on/off)*, subsequently added devices need to be included within the system structure and are visible at UI level.

I2HOME: main goal was to implement a standards-based open platform named the Universal Control Hub (UCH) in order to facilitate the user with a series of interfaces controlling the smart home. This project's achievements include the development of personalised UI's implemented via a user-centred design approach customised for users with special needs or those with cognitive difficulties. Devices should be touch-screen along with speech input/output, TV's with a simple remote control and mobile phone UI's (Windows & Android). The digital home is available to all citizens via pluggable interfaces through its flexible application framework, the UCH, which controls all aspects of heating, lighting, ADL reminders and facilitates integration of various target devices.

EMERGE: this monolithic [66] system supports elderly users with emergency monitoring and prevention through ambient, unobtrusive sensors and reasoning regarding emergency situations. Information is analysed in conjunction with recurring patterns and ADLs in order to create a database of daily and long-term living habits, to facilitate prompt detection and reaction to emergency situations. Relying on the constant evaluation of ADLs [67] initially defined in the Katz index, EMERGE is proactive in terms of fall detection and emergency response alerts. A Sensor Abstraction Layer (SAL) offers a simple interface for accessing and maintaining sensor data and assimilates semantic sensor information. The Human Capability Model (HCM) [68] represents the clinical knowledge of the elder created with the assistance of their medical experts. Avoidance of possible sensor data complications is achieved via a Multi-Agent-Based, Event-driven Activity Recognition System (EARS). This was developed to meet various detection and monitoring demands, all in-coming data is regarded as capacity boundless low-level sensor data, in contrast to hi-level specific outgoing data [69].

I-Living Project: approach was to develop an assisted living environment where several embedded devices (sensors, actuators, displays, & Bluetooth-enabled medical devices) could either operate independently or cooperate within an Assisted Living Hub (ALH) [70]. The ALH could be a dedicated PC, Personal Digital Assistant (PDA), or a black box enabled with one or several wireless interface cards communicating via the Assisted Living Service Provider (ALSP). This server simultaneously provides carers and health care professionals with HCIs in order to monitor all raw sensor data, examine it in closer detail if required and invoke alerts if necessary. Events can be organised by medical professionals or carers through interfaces via the ASLP server. Within the users home the reminder daemon regularly polls the server, chooses an appropriate device and forwards the reminder message to that device. The user reads their daily vital signs with Bluetooth-enabled medical meters, these results are encrypted and forwarded to the ALSP server where health professionals can access daily biometric data at any time.

SAAPHO: the Secure Active Aging: Participation and Health for the Old (SAAPHO) Project [71], encourages elderly participation as it elevates future product acceptance and usage. Elderly users were queried about their SAAPHO technology interactions, opinions on the system based on experience and possible system enhancement suggestions. The system itself assists elders in maintaining their daily living independence along three interconnecting trajectories of active aging, healthcare, participation and security services via intelligent interfaces on fixed and mobile devices. The architecture employs various interface tools in order to maximise user interaction whilst avoiding user information overload.

HOME SWEET HOME: this project [72] began in 2011 and one of the test pilot sites was located in County Louth, Ireland. It evaluated how the telemonitoring of an elder's physical and mental health, environment factors and ADL reminders would impact upon their lives. A simple user-friendly interface monitors each elder's health and well-being via data collected from environment sensors, video conferencing and various other support services. Sensors were fitted in all homes such as environment and temperature, smoke, water and presence detectors. InTouch devices consisting of broadband routers and medical devices were installed, glucometers and asthma monitors based on the health profile of user. Health monitoring is carried out daily and abnormal measurements produce alerts which request the user to retake the measurement, if the alert continues then their General Practicioner (GP) is contacted. Emergency alerts from a smoke or Mambo device will contact the emergency services, passive alerts contact carers and relatives. The medical monitoring devices installed included a Blood Pressure (BP) monitor and a weighing scales, a Mambo phone was deployed to all participants homes which is carried on their person outside the home and a key fob within the home. Video conferencing enabled elders to contact friends and relatives via broadband and personal well-being is also monitored through the use of game playing. The project is still in its pilot stage with many of the initiatives still to be implemented.

3 AAL UI Best Practice Guidelines

Having undertaken this review of AAL systems it emerges that while representative subjects from the third age have had *some* involvement in the UI design, representatives from the forth age have had a very marginal input if any. Buxton's basic matrix was expanded in 2008 based upon an axis of criteria, see Fig. 2. [73] facilitating subtle, more implicit interactions between humans and machines, or a system. Conventional computing can be implicit or explicit and interactions are divided between attentional demands, that is, interaction required of its user and understanding a user's interaction with a given demand. Reactive interactions are user initiated and proactive if system initiated. AAL systems require implicit and explicit communications and users want unobtrusive systems, therefore information exchange must not manifest itself within the attentional foreground of the user. AAL systems need to be chameleon in nature, in the foreground if required by the user otherwise fading into the background.

The premise behind Buxton's [23] original Framework and the extended versions [73, 74] is that all human-computer interactions can be evaluated along various spectrums of activity balanced against the level of invasiveness for the user. This is the keystone to UI evaluation of AAL systems, the balance between assisting when requested or when health and safety requires intervention. This evaluation framework facilitates independence not isolation, inclusivity not exclusion and a bi-directional channel for communications. Ambient systems that adhere to UI design guidelines have the power to be an effective technological assistant providing they achieve a balance between user initiated interactions and unsolicited system intrusions.

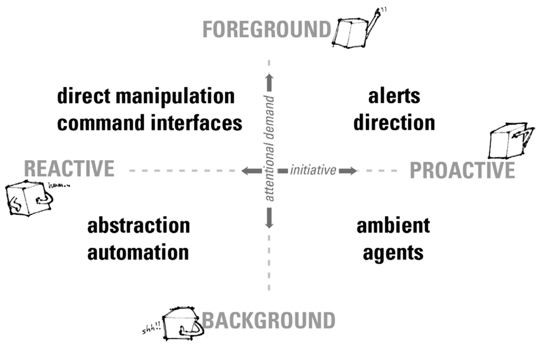

Fig. 2. Implicit interaction framework with a range of interactive system behaviours

4 Recommendations

This paper recommends that UI best guidelines for the elderly [11] as stated previously should be adhered to when designing and implementing AAL systems in parallel with Nielsens [8] and Shneiderman's [9, 10] general usability guidelines. The four main areas of focus in designing for the elder user include vision, hearing, mobility & cognition, with individual suggestions for each target area of concern. Given the elderly are considered in terms of a third (65–80 yrs) and fourth age (80+ yrs) [17, 18] then this premise should be applied to AAL UI design facilitating dynamic interfaces capable of being tailored for an age and medical health appropriate user. Representatives from both elder groups is necessary when testing systems in order that both cohorts increasingly complicated daily living needs are accommodated. AAL designers acknowledge the UI usability differences between these two elder groups [19, 20] yet persists with homogeneity when designing and testing [21, 22] systems. A reasonably healthy 65 yr old with IT skills has radically different AAL systems requirements to an 85 yr old with limited mobility, attention span and IT skills.

5 Conclusion

Ambient systems provide users with daily living assistance, some are less unobtrusive than others and users are still required to interact with a systems interface to a lesser or greater aspect. UI's affect uptake which impacts upon usability and those achieving commercial success have employed easily recognisable icons to represent daily activity tasks. Given ambient systems require subtle user interactions from an audience which will become progressively more infirm then perhaps the only solution is that of multimodal UI's which are dynamic and fulfill the users needs at any given point in their health continuum. Adaptivity of the system interface tracking the longitudinal progression of age, circumstance and condition is paramount for system adoption and persistence. This benefits users as the interfaces remain familiar and do not represent a stress factor when they are least capable of absorbing new system information.

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