Multi-Agent System Feedback and Support for Ambient Assisted Living

James McNaull, Juan Carlos Augusto, Maurice Mulvenna and Paul McCullagh
School of Computing and Mathematics
University of Ulster at Jordanstown,
Newtownabbey, Belfast, UK

***Abstract*— Technology has been adopted to mitigate adverse effects associated with aging. Ambient Assisted Living solutions provide user assistance and support which is potentially both efficient and effective. This paper describes initial evaluation results for a Multi-Agent system prototype that provides assistance and support during the day and night through an interface that is adapted according to a person's requirements profile, time of day and current activity or event. Appropriate feedback based on user context is important. This includes historical feedback which may indicate trends, which may not be apparent, particularly where the user may be forgetful.**

Keywords-component; Ambient Assisted Living; Multi-Agent System; Interfaces;

I. INTRODUCTION

The proportion of older people in the population is accelerating as a result of increased longevity, due to better medical care and management of previously fatal conditions, and a reduction in the birth rate [1]. This is putting an increased strain on health and social care provisions across global economies. Solutions are being researched to ease this strain and examples include the use of pervasive technologies and assisted living solutions that are implemented in the home. These provide assistance and support with a range of activities including but not limited to activities of daily living (ADL) [2] and reminders to eat regular meals. Research is currently being conducted in the area of Ambient Assisted Living (AAL) [3] as this may offer a possible solution by enabling a person to be provided with the required assistance and support in their own home. Methods for providing assistance and support include implementing intelligent interfaces, as the output of a decision support process. Such interfaces may be adapted based on recorded activity (inputs to the decision support process); Multi-Agent Systems (MAS) [4] utilize software agents which monitor an environment and hence make these decisions. This paper reports the findings of our research on a MAS developed to provide support within the home, including the often neglected nocturnal events. This paper provides an overview of the MAS functionality and adaptable user interface. Results are provided from a usability study that was designed to evaluate the features and functionality of the MAS and the interface.

A. Multi-Agent System (MAS) Functionality and Justification

The MAS was programmed in JADE [5] the Java Agent Development Framework and offers the following functionality:

- Control and dynamically update of an interface based on (i) the event that has occurred in the AAL environment and (ii) the current users requirements as set by a profile agent.
- Intervention messages to the user that provides information on their behavior, and suggest actions or changes of behavior.
- Support that is relevant to both day and night time periods when different types and levels of assistance and support may be required.
- The MAS provides the person with feedback detailing past interventions, activities and how a person has been assisted and supported so that recurring issues may be identified and possibly solved.

A Multi-Agent System (MAS) was chosen over a centralized system as the computational resources may be spread over several processing components. This allows the primary interface that the supported person interacts with to be a bedside Tablet PC. A MAS is flexible and extendable; in the future other agents may be added and multiple interfaces in the same AAL environment may be under control by the same MAS.

B. The Usability Study

Usability studies are considered to be essential in the evaluation of Graphical User Interfaces as discussed in [6] and [7]. The MAS interface and its current functionally has been evaluated by peers to identify usability issues, before further development and a formal evaluation undertaken by various stakeholders. The usability study evaluated: features and functionality, user interfaces, navigation, control, interventions and feedback.

C. The MAS Agents

The MAS consists of several agents including a Sensor data agent that is fed sensor data from a smart home environment; A Sensor Agent that interprets the sensor data and identifies sensor events that have occurred; Context agent that reasons what contextual events have occurred in the environment; Intervention agent that determines the correct intervention to issue to the person based on the event that has occurred, time of day and current activity being carried out; Interface agent, chooses the appropriate interaction methods to put forward an intervention or feedback through a Multi-Modal interface; GUI Agent, determines the GUI content and method of

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displaying messages to the person; Feedback agent, determines the appropriate feedback to give to a person based on the interventions that have occurred, the time an intervention was issued and the context behind an event; Profile agent, chooses the appropriate user profile so that a persons interaction requirements may be set to enable the person to understand the interactions that occur.

D. MAS feedback to a person

The MAS being developed offers a person feedback that is determined based on historical interventions and includes a descriptive picture metaphor, a text based message and when appropriate spoken dialogue. The feedback may be used by the person to identify recurring issues that may be solved and it puts the person back 'in the loop' as they are made aware of actions that the MAS has carried out. The feedback is only provided if set algorithmic conditions are met and these include but are not limited to the number of times an intervention has been issued and the time the intervention.

II. RELATED RESEARCH

A comparison to related research is provided by Table 1. The prototype MAS supports common ADLs including but not limited to: eating meals during the day, reminders to wash hands after using the toilet and go to bed at the appropriate time. The approach enhances communication, delivers reminders, uses user location for context and provides guidance support. The interface may be adapted based on the current detected event, situational changes and the user's requirements. For example, a person may have issues with reading standard size text; if so the interface is adapted so that the text size is increased and where appropriate spoken dialogue is used. Feedback is provided in the form of a summary of past assistance and support that has been provided.

TABLE 1. RELATED RESEARCH

Research	***Feedback***	***Interface adaptation***	***Night/ Day assistance***
Multi-modal pervasive framework for AAL [8]	No	Yes/ Limited	Day
An intelligent home middleware system based on context awareness [9]	No	No	Day
Touch based user interface for elderly users [10]	No	No	Day
A multi-agent service framework for context aware elder care [11]	No	No	Day
Flexible architecture for AAL systems supporting adaptation of multi-model interfaces [12]	No	Yes/ Limited	Day
Research being conducted	**Yes**	**Yes**	**Day/Night**

The AAL research projects evaluated in Table 1 either provide assistance and support with daytime activities (more common) or provide assistance and support during the night (less common). For example, at night the darkness provides the need for lighting support. This potentially reduces tripping hazards, particularly for an older person. The person is more likely to be sleeping in the bedroom, and hence leaving the dwelling during the night would probably be interpreted as an unusual event. The research currently being conducted provides assistance and support through carefully selected interventions that are adapted to daytime or nighttime and provide interventions that are only relevant for the particular period of time. Several of the research projects do not provide tailored assistance and support that is directly relevant to the person.

The AAL system that is being developed in this research is able to offer the person feedback upon request. This provides a summary of the assistance and support interventions that have been previously provided. Such feedback can have a positive impact and help to resolve any underlying issues, e.g. a history of interrupted sleep [13]**.** Other sleep related issues include not going to sleep at a regular time and getting up at night. Forgetfulness during the day [14] and issues with personal security (e.g., a back door is left open for long periods of time) may also be determined .

III. THE MAS ARCHITECTURE

The MAS architecture, Fig. 1. consists of several architectural layers: Layer 1: the AAL environment layer, where the sensing, actuation and interaction occurs; Layer 2: the data layer where the sensor data, profile data and agent action data is processed; Layer 3: the decision and logging layer where the profile is chosen and logging of agent actions occur; Layer 4: The information layer, maintains relationships across time and space; Layer 5: The Context Layer, where contextual changes are detected.

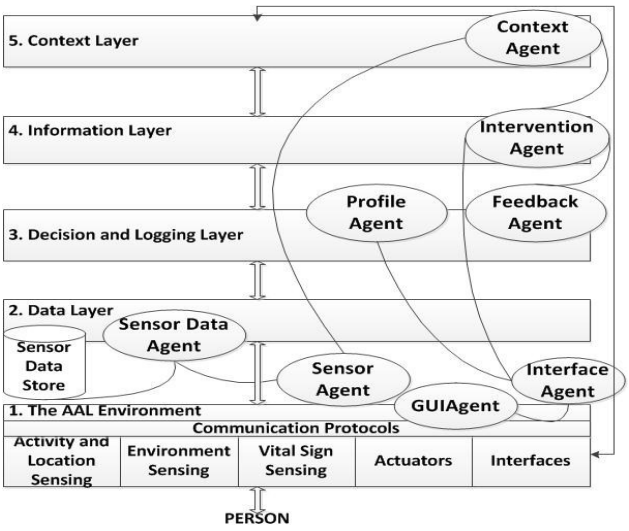

Figure 1. MAS Architecture

IV. THE MAS INTERFACE

The MAS interface may be adapted based on the event that has occurred, time of day and person's requirements. The interface view for giving feedback is shown by Fig. 2.

Figure 2. MAS Interface (restless feedback)

It was decided to initially to offer a simple button based interface that enables a user to carry out the following tasks: (1) View interventions and messages that are (i) designed to highlight potential issues in the environment, e.g. security (leaving back and front doors open) personal safety (mitigation against trip and fall hazards) and health issues (food spoiling due to the fridge door being left open, washing hands after using the toilet). (ii) Issues with the actions that a person is carrying out or (iii) to remind a person to carry out an activity e.g. having breakfast in the morning, going to bed at a regular time, not eating or drinking at night. (2) View feedback messages and accompanying picture metaphors that highlight any issues that may have occurred and that may help the person solve these issues. (3) Listen to music and view pictures that are adapted based on the current period of time. Such feedback may provide some temporal orientation, e.g. soothing music prior to bedtime, or upon wakening, as successfully demonstrated by the NOCTURNAL project [15].

A. Interface functionality

The intervention view enables the person to view messages that detail the currently selected intervention or information regarding an action carried out by the MAS. The feedback view enables the person to see feedback that has been generated based on past key interventions and agent actions. Fig. 2 shows the feedback that is given in relation restless sleep. It provides a picture metaphor for (a person sleeping and a sad face) to illustrate a restless night's sleep. As part of the night time assistance offered by the MAS, calming music is played to help aid sleep. In response to key events, the interface displays pictures and photographs. During the day the pictures will be designed to help with reminiscing [16] where the person may wish to view pictures of past events, places and family and friends. At night the pictures will be designed to help calm the person by allowing the person to view photos of close family and calming landscapes.

B. Multi-modal interface interaction

The interface offers several interaction modalities including: (i) Text based messages: Interventions, information and feedback are provided via text, (ii) Visual picture based interaction: Picture metaphors are used to represent key feedback, (iii) Spoken dialog: Intervention and feedback messages can be spoken., (iv) Music based interaction: In relation to key events, music is played to help to alter the person's mood. The interaction modality chosen is adapted based on the person's requirements profile. For example, if a person is not able to read text based messages, then the messages will be spoken and pictures displayed; if they have specific sight requirements, the size of the text may be adapted.

C. Interface adaption

The MAS system being developed is able to provide assistance and support through the use of tailored interventions (the assistance and support) and interactions (method to deliver the assistance and support) that are relevant to the person, the current detected situation and whether it is day or night. The MAS is able to adapt the method used to interact with the person based on their current profile requirements. Requirements may be set by the person, or collaboratively with his/her care provider or health professional. An Interface Agent requests the correct profile details so that meaningful interactions may be made to the person. For example, with the profile set to 'hearing issues,' the interface is adapted so that text and loud spoken dialogue is used to deliver the interventions. If it is set to 'no specific requirements,' the interface is adapted to make use of a combination of normal sized text and spoken dialogue. If the profile set to 'sight issues,' the person is unable to read small text, then the interface agent will choose to make use of large text and spoken dialogue.

V. EVALUATION OF MAS FUNCTIONALITY AND RESULTS

The MAS system functionally in relation to adapting and controlling the interface was tested in a usability experiment. Eight subjects subsequently completed a usability questionnaire. The questionnaire comprised 27 questions in 5 categories and is based upon Turner's usability testing template [17]. The usability rating for each of the categories is detailed by Table 2.

TABLE 2. RELATED RESEARCH

Person Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Out Of**
Features and functionality	**18**	**18**	**16**	**20**	**20**	**19**	**21**	**16**	**25**
Main person interface	**12**	**14**	**11**	**15**	**14**	**14**	**13**	**12**	**15**
Navigation	**38**	**42**	**26**	**45**	**33**	**37**	**38**	**35**	**45**
Control and feedback	**14**	**15**	**10**	**15**	**15**	**12**	**11**	**11**	**15**
Content and text	**19**	**19**	**15**	**19**	**13**	**13**	**17**	**16**	**20**

A. Usability score explanation and results

The scores in Table 2 are given for each category; the number of questions determines the 'Out Of' score, the number of questions in each category does not have an effect on the overall usability score. A final usability score of 87% was achieved and this falls under the good category (69 – 89) as outlined in the usability questionnaire and gives a firm

foundation for future research and development. The usability score for each question in each category is weighted according to the formula implemented in the questionnaire that determines the importance of a question in relation to overall usability. Interface clarity with respect to the number of messages presented was highlighted. Improvements to navigation include providing more accessibility features including popup descriptions, and 'breadcrumbs' to guide a person round the interface. The button size and size of button labels may be further improved by increasing their size so that they are easier to read.

VI. Conclusion

From conducting research into related Multi-Agent Systems within AAL, it became apparent that a feature that is often overlooked is the provision of a means to present the person meaningful feedback detailing what has occurred in the environment, the interventions that have been provided and how they were assisted and supported. This 'feedback loop' is thought to be important to help the user understand any issues that they may have, and hence to potentially solve them. For example, if they wake up several times during the night but do not remember that this occurred, the feedback provided by the MAS will be very useful. The feedback can also be accessed by a care provider and/or health professional. This may be presented in a more detailed format. When planning assistance and support, it is important to understand current and past events and interactions. The detailed feedback that includes a summary of past interventions may also aid in this planning and with developing new, improved and tailored interventions to further aid the user. The feedback and interventions are provided to the person through an adaptable Multi-Modal interface according to their requirements profile and this helps to ensure that the person viewing the interface is able to understand the interventions and feedback that is being provided. The current MAS Interface has undergone usability testing to determine if core functionally works as expected and if the interface is correctly adapted and updated by the MAS. The results from this testing have been positive and in addition provide evidence for more acceptable feedback.

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