

# Adaptive User Interface for Healthcare Application for People with Dementia

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**Abstract**— Adaptive user interfaces can be more effective in increasing accessibility of the interaction between people and systems, especially for elderly or people with different impairments such as cognitive impairments in people with dementia. There are two possible types of adaptation for interfaces: navigation and content-based adaptation. Both types of adaptation must be made based on the context (devices that are used) and on the user profile. This paper presents a method for interface adaptation using user classification. Users are classified based on their interactions with the interface.

**Keywords**— adaptive interface, dementia people, user classification, decision tree

## I. INTRODUCTION

Dementia is a syndrome due to a disease of the brain, usually of a chronic or progressive nature [1]. Dementia often causes a disturbance of multiple higher cortical functions, including memory, thinking, orientation, comprehension, calculation, learning capacity, language and judgement. Consciousness is not affected. Impairments of the cognitive functions are commonly accompanying, and occasionally even preceding the disease, by deterioration in emotional control, social behavior or motivation. Dementia occurs in Alzheimer's disease, in cerebrovascular diseases, and in other conditions primarily or secondarily affecting the brain. Although symptoms of dementia may vary, each of the following main mental functions must be significantly affected to be considered dementia [2]:

1. Decline in memory and thinking to an extent that impairs daily activities, or makes independent living either difficult or impossible;
2. Initially preserved awareness of the environment, including orientation in space and time;
3. Decline in emotional control or motivation, or a change in social behavior evidenced by: emotional lability, irritability, apathy or worsening of daily activities (eating, dressing and interacting with others).

Because the world's population is progressively ageing, more people are falling into the age groups where dementia prevalence is highest (above 60 years old). The number of people living with dementia worldwide is currently estimated at 35.6 million [3]. This number is expected to double by 2030 and more than triple by 2050. The ageing of the

population is the main reason for such large estimated numbers of dementia cases, excluding any change in the age-specific incidence rates.

Sadly, there is a lack of awareness and understanding of dementia in most countries, resulting in stigmatization, barriers to diagnosis and care, and impacting caregivers, families and societies physically, psychologically and economically. Governments are naturally concerned by these population trends, particularly with the associated rise in the cost of healthcare, which if not successfully managed, will become the most expensive problem for healthcare systems.

In this context, strategies for developing solutions that help elderly people to live independently for longer time are being supported through national and multinational programs. The Active and Assisted Living (AAL) program is funding the emergence of innovative ICT-based products, services and systems for ageing well at home, in the community, and at work. Its goal is to increase the quality of life, autonomy, participation in social life, skills and employability of elderly people, but also to reduce the costs of health and social care.

The IONIS platform, developed under the AAL "Indoor and outdoor NITICSplus solution for dementia challenges" project (AAL IONIS 2017-2020), brings together technologies and services to build a user-centered modular ICT-based platform. The aim is to offer a wide range of specific solutions that support people living with dementia and their caregivers in coping with daily activities. By providing continuous support at home (indoor) or outside (outdoor), the platform improves independence, enhances self-confidence, security and safety as well as wellbeing. The designed interface will address some difficulties observed in people with dementia when accessing interfaces: scrolling difficulties, hidden information, becoming lost on a page, clicking on the wrong link, clicking on text which is not a link and becoming worried or upset, etc. Not all of these difficulties can be observed at once during the interaction between users and interfaces. This paper proposes a method for classifying these difficulties in order to adapt the features of the interfaces. Thus, a set of rules are associated with each user based on the interaction with the interface. These rules are obtained by constructing decision trees.

In addition, also caregivers will be able to benefit from the IONIS platform capabilities and exploit the gathered information (e.g. health monitoring and alerting, mobility pattern indicative of disease progression and other age-related problems, sleep quality supervision) in order to intervene adequately and timely. A tuned version of the interface was developed for the caregivers which is an extended version of the caretaker interface. This version allows the caregiver to monitor the health parameters of the caretaker, to check the status of the issued notifications, to add activities to the caretaker's calendar, to adjust the profile of the caretaker and the configuration of the caretaker system (e.g. acceptable range values of the blood pressure, add or remove a module, etc.) but also to receive alerts and notifications regarding the status of the caretaker.

The rest of the paper is organized as follows: Section II describes related work. Section III gives the description of the proposed interface. The adaptation of the interface is given in Section IV. Conclusions and future work are given in Section V.

## II. RELATED WORK

Contemporary technology can support people with dementia to handle their daily activities, improving the quality of life for patients and their caregivers. Designing of computer interfaces to interact with these technologies should consider two approaches [4]:

1. A universal design that makes conventional technology approachable and manageable to those with disabilities.

2. An assistive technology which is developed through user-centric methodologies.

Moreover, according to Ancient and Good [5] when designing interfaces three main factors should be considered: accessibility, usability and user experience. However, when designing for people living with dementia, two main ideas need to be considered holistically: personalization and user acceptance [6].

The notion of personalization refers to the changing of the user interface in order to meet the needs of the user. Personalization would be a solution to respond to a wide variety of needs for people living with dementia, making the technique appropriate at all stages of the disease. A diagnosis of dementia does not imply that the person is unable to utilize technology to its full potential. Any interaction difficulties should be assessed on a case by case basis rather than making generalized assumptions about the state of a person's cognitive ability [7]. Personalization of the interface is a delicate process, being important to ensure the right amount of support in a timely manner. Moreover, the interface and caregivers should provide an appropriate amount of assistance in order to avoid the possibility of deskilling of people living with dementia. A dynamic interface is needed to respond to the progress of the disease with a gradual increase in the amount of support which is required from the system. The process of personalization should tailor the interface to provide the necessary support to compensate for a person with dementia's declining abilities whilst maintaining the abilities which currently remain intact [8].

User acceptance can be split into two sections which are linked to each other: user experience and technology

implementation. An important consideration for user acceptance is the user's previous experience with ICT and computers. The decline in memory means that the user is less able to cope with complex navigation structures or long lists of instructions. Care must be taken to reduce the load on the memory by using short messages [9]. There is a disagreement regarding the acceptance level of ICT in earlier stages of the dementia progression. Thus, Aloulou et al. [10] considers that acceptance of ICT is lower for people in earlier stages of dementia progression, when the perceived need is lower, and higher in people whose abilities have significantly declined. Whilst people with higher cognitive ability would find learning new interfaces easier, they may believe not to require the system and therefore, may find the system stigmatizing [11].

Research has shown that older people are not against adopting new technologies if designers can ensure that their interfaces are accessible to people with dementia. Gowans et al. [12] defines a set of criteria which an interface should address in order to be suitable for people with dementia. These criteria are: (1) support easy start-up; (2) support intuitive navigation; (3) elicit memories to prompt and support reminiscence, communication and social contact; (4) promote 'non-immersive' engagement (i.e. the system should work as a communication prompt, not a purely sedentary pastime); (5) support an enjoyable shared experience; (6) support the cognitively impaired person in having a more proactive and equitable role in conversations; (7) relieve caregivers of the pressure of constantly needing to 'prop up' conversations; (8) promote 'failure-free' activity (in this context 'failure' refers to both technical and emotional 'failures' such as frustration due to poor technical performance and emotional distress caused by, for example, inappropriate/distressing data content); (9) support customization of content, for example to accommodate individual personalization and/or different geographical requirements; (10) promote and support good practice in reminiscence intervention.

Other important criteria relate to short term memory loss as well as motor and visual impairment [5]. By taking into account these specific issues, Ancient and Good [5] recommend for interfaces to minimize the amount of information which the person with dementia is required to remember. The need to remember the relative position within the system can leave persons with dementia feeling disorientated if they fail to recall their location. When an interface expects a response within a specific length of time - such as 'time-outs' when completing an online form - interface designers should take into account slow movements which might hinder people with dementia in their timely response.

In their study Loureiro and Rodrigues [13] showed that traditional input devices, such as mouse and keyboard can be a major barrier for elderly. Also, inadequate interfaces (small font, button and icon sizes, too much complexity or "user-unfriendliness") can disappoint and prevent them from further use. They propose multi-touch as an interaction modality of natural user interfaces offering new opportunities for the elderly to interact with the computer.

The goal of ongoing research efforts is to devise a set of guidelines to aid interface designers with the development of dementia friendly interfaces. The challenge lies in the diversity of dementia symptoms and the large variability of

individual needs. Thus, a new field of possible palliative treatments aimed at mitigating the symptoms is being developed. Gowans et al. is using the term “reminiscence therapy” [12]. It involves the use of photograph albums, artifacts, memorabilia, music, tactile activities like biographical painting or knitting, even reminiscence theatre and retro-environments and so on are used to stimulate long-term memory to promote positive interaction, activity and communication.

### III. IONIS INTERFACE

The IONIS platform is a flexible and modular system that will provide a viable solution for AAL by contributing to the development of a next generation of AAL intelligent frameworks. IONIS will provide environment aware services with natural and comfortable interfaces for performing: indoor & outdoor localization; health & home monitoring (including sleep monitoring); easy communication through one-button calls; user interaction through dynamically adapted interfaces for different devices, easy and intuitive to be used by both people with dementia and their caregivers; smart data aggregation, fall detection, home automation, etc.

The platform is developed starting from a user-centered design prioritizing features that are specific for people suffering from dementia in incipient phases, *i.e.* having mild memory and cognitive problems. However, the IONIS interface is also suitable for elderly people in general. From interface point of view, we proposed the following features: (1) easy start-up; (2) intuitive symbols and navigation (large, color-coordinated buttons and also voice commands); (3) support adaptation of content, for example to accommodate individual personalization; (4) support easy contact to caregiver; (5) various help menus (written, verbal and even small videos); (6) include multimedia features such as personal photos, music, etc. for therapeutic effect.

Reading can represent a major barrier for persons with dementia to access relevant information. Users report that some elements, visual and technical, can reduce this barrier: (1) large enough screen; (2) high contrast color scheme; (3) minimum 16px text and not condensed; (4) always use visible sitemap and "Where am I?" control with audio explanation; (5) sometimes it helps to use the possibility of "listening the contents" - a pre-recorded voice or software reads the contents of the interface; (6) use familiar pictures (contacts) or pictograms when appropriate to facilitate recognition of tasks; (7) avoid generalizations and make the text easy to understand.

Thus, IONIS interface is developed by respecting specific requirements such as font size, elements position, colors, buttons size etc. The interface also allows a smooth access to the different functionalities of the system as well as personalization.

The home-page displays for the current day the last health measurement results, the daily number of steps and the sleep duration. It also displays the daily appointments of the user, the number of reminders, some smart notifications regarding the user’s health status and activity, and two buttons that allow the user to call directly a relative and the emergency service. The interface gets the data directly from the IONIS cloud. The home-page is illustrated in Figure 1.

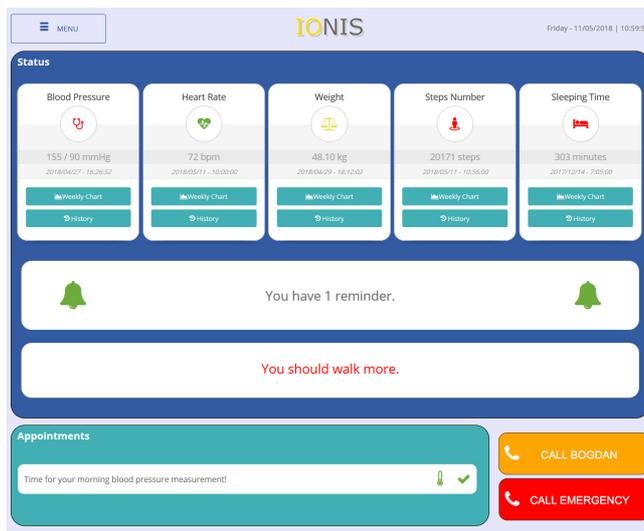


Fig. 1. IONIS Home Page

For each measurement, the interface displays beside its value, the time when the measurement was taken, a specific icon and two smart notifications. The icon color varies depending on the measurement result. If the result is within an acceptable range, the icon color is displayed in green. If the value is outside the acceptable range, the icon is yellow if some care is required and red if special care and attention are needed. These colors are the default ones. However, the users can change the colors to match his/her preferences using the settings page. The smart notifications will illustrate for the user, the variation of each measurement result (stable, increased or decreased) and if the measurement result is good or bad and what should the user do to optimize his health status.

Next to each appointment, the interface displays an icon that illustrates the importance of the appointment. The color of the icon depends on the importance of the appointment: green indicates low importance, yellow indicates medium importance, and red indicates high importance. The appointment colors can be easily modified by the user from the setting page.

The interface allows users to quickly visualize charts that illustrate the variation of their measurements during the last seven days (see Figure 2). However, the user can request to visualize the measurements for any given time interval with the possibility to visualize the results in a form of a chart or a list. Moreover, the user can visualize the different measurement types together or each type of measurement separately.

The design of the interface is optimized for touch screen devices. It is developed using HTML, CSS and Javascript. It works across platforms and is device independent. The interface is multilingual, it supports five languages: English, French, Romanian, Polish and Italian with the possibility of easily adding additional languages.

Multimodal interactions provide the user with more options to interact with the IONIS platform and, at the same time, make the interaction easier. Therefore, the interface integrates a vocal module that allows speech interactions between the platform and the user: the user can give speech commands while the system can generate artificial speech synthesis outputs.



Fig. 2. Weekly Steps Number Chart

The vocal module supports English and French languages with the possibility of adding new languages. It is composed of 5 main parts as illustrated in Figure 3: The Audio Preprocessing ensures the best results for the Automatic Speech Recognition (ASR) by setting-up the bit depth, the proper frequency and the number of channels. The ASR converts the spoken words to written text, then the Natural Language Understanding (NLU) converts the written text to a machine-reading representation. The Dialog Management (DM) is responsible for the state and flow of the conversation, it generates a list of instructions for the dialog system in a semantic representation. The Natural Language Generation generates a natural language text from the machine representation system. Finally, the Text to Speech (TTS) synthesis converts the generated output text into spoken sounds. The implementation of the vocal module is detailed in [14].

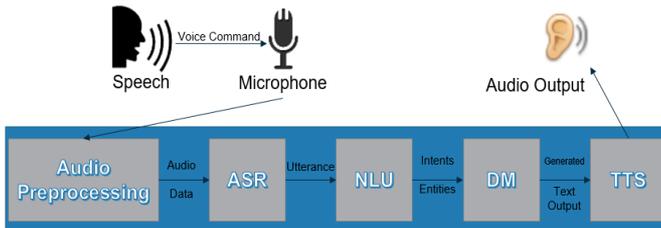


Fig. 3. Schematic Representation of the Vocal Module

#### IV. INTERFACE ADAPTATION

IONIS interface adapts itself to the device screen size and orientation (using Bootstrap) but also to the system features: the interface checks which features are integrated and hides all options and information that are related to the features that the system does not integrate (e.g. if a user does not use the weight measurement service, all the options and information related to this service will be hidden). Moreover, IONIS interface adapts itself based on the emotional status of the user.

To recognize the user's emotions, as illustrated in [15], we used a Kinect sensor to acquire images of the user's face. The acquired images are converted into greyscale images then a histogram equalization is applied. From the user's face, we map 53 reference points generated by the Microsoft.Kinect.Face API, to action units that are associated to basic emotions. We use 20 reference points for the mouth, 11 for the nose, 6 for each eye and 5 for each eye brow. We associate each resulted action unit with an action unit from FACS (Facial Action Coding System) based on which the emotions are recognized. 19 action units and 19 support vector regression networks (SVR) are used to compute

intensities of the action units. Another SVR is used for computing the user's emotion based on the intensities previously obtained. We consider 4 basic emotions and the obtained accuracy is: happiness - 99%, sadness - 91%, fear - 87% and disgust - 92.5%.

In order to make navigation and content-based adaptation of the interface, users are classified based on their preferred options, type of navigation (gestures or voice commands), emotional state. We create a set of different user classes with different types of preferred interface configuration: health status, preferred gestures, system configuration, language preferences, type of speech commands, emotional state. Each class has an associated set of rules that describes the interface properties. Users classification is done using decision trees, computed with the C4.5 algorithm [16], an extension of the ID3 algorithm. We use C4.5 in order to work with continuous values of some used attributes (parameters that describe the health status of a user: e.g. heart rate etc.). In the case of a new user, the default version of the interface will be displayed in order to extract his preferences based on his interactions with the system (preferred gestures and type of speech commands). After this step, the user will be classified based on the already built decision tree and the interface will be generated based on the rules associated with the user's class, e.g. in case of a bad health measurement result, the interface will display the value of the measurement if the user is happy, but the interface will display a message that accompany the value of the measurement if the user is unhappy.

The adaptation was evaluated in the laboratory by 25 elderly people with cognitive and memory problems (indicative of dementia onset). Each user interacted with the system during 8 sessions to perform 4 scenarios. Each scenario was performed twice, once with the adaptation feature of the interface turned off and once turned on. During each session we monitored the number of interactions and the time needed to perform the scenario as well as the emotional status of the user.

To reinforce the collected data, after each session, each user was asked to fill a multiple-choice questioner regarding the users' experience during the session to evaluate the interface ease of use. The questions were inquiring about how hard the scenario was to be accomplished, what the user preferred during the session, were all type of output clear enough for the user, was there anything that the user disliked or made him feel uncomfortable, was the duration of the session acceptable and what was the degree of satisfaction of the obtained result. The questioner answers validated the collected data and all the users reported improved navigation and easier evaluation of the scenario by 30% with the adaptation feature turned on.

#### V. CONCLUSIONS AND FUTURE WORK

This paper describes an interface designed for elderly people and particularly for those suffering from dementia. The interface is adapted based on the user's profile: health status, preferred gestures, emotional status, system configuration, language preferences and type of speech commands. User are classified using decision trees. The interface adaptation is positively evaluated in the laboratory by young people. As future work, we will test the interface adaptation on our target users.

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