E-Health System Development based on End User Centered Design

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***Abstract*—Legal and ethical aspects need to be taken into consideration during the development of an e-Health system, especially if this system monitors and assists elderly people. Furthermore, privacy and psychological aspects as well as the end user requirements are essential, since developing Ambient Assisted Living technology without integrating the end user results in products or functions which are not desired by the end user. Not considering the end user requirements (e.g., privacy concerns, desired functions) leads to the issue of less acceptance for new technology, since no benefit for the end user can be provided. In order to respect the end user's needs from the very beginning of a project, the integration of the end user throughout the whole project is seen as a key factor. This includes the analysis of the user requirements and regular feedback loops during the project. An example of the user centered design during the development of an e-Health system within the AAL-JP project *fearless* is presented in this paper.**

***Keywords*-end user integration; ambient assisted living; fall detection;**

I. Introduction

Fear of falling is a common problem for elderly and lead to reduced activities, even if the elderly did not fall [1]. Furthermore, falls are considered to be a great risk for elderly since the mortality of fallers is higher compared to other elderly and elderly may lie on the floor for hours [2].

This motivates the introduction of an event detection system which is able to detect falls automatically. The aim of the AAL project *fearless*[1] ("Fear Elimination As Resolution of Elderly's Substantial Sorrows") is the reduction of elderly's fears by providing alarms if unusual events (e.g., falls or fire) are detected. An all-in-one e-Health system is developed, focusing on fall detection at the beginning but offering a high degree of adaptability and standardized interfaces to be able to integrate other systems (e.g., alarm systems) at a later stage.

A main problem when developing AAL technologies is the proper integration of end user during the development process and the evaluation of the system. Despite this fact, developed approaches are tested under laboratory settings only (e.g., [3]–[7]), thus yielding in promising results. But to verify these results, field tests with elderly have to be conducted and their feedback need to be integrated into the development process. The contribution of this paper is to present a user centered development of an e-Health system and the end user integration strategy evolved in the *fearless* project.

The rest of this document is structured as follows: Section 2 gives an overview of the technical system methodology, whereas Section 3 discusses the user centered design process. Finally, a conclusion is drawn in Section 4.

II. Methodology

The structure of the *fearless* system is depicted in Figure 1, showing all relevant interfaces and involved end user. The proposed e-Health system consists of sensor units (Xtion Pro + small PC for data processing) installed at the elderly's house or flat. The system is adaptable, hence standardized interfaces to third parties are provided (e.g., alarm system, gas detector). Unusual events (e.g., falls) are detected automatically and alarms are sent to the telematics platform. This platform enables elderly, relatives and care taker to access the alarm events. Furthermore, the telematics platform offers interfaces to different standardized electronic health record systems (e.g., ELGA in Austria) to include health professionals.

Autonomous sensors detecting falls automatically are needed, since it is important to reduce the cognitive load on the user, especially when dealing with dementia [8]. The use of computer vision is feasible, since it can overcome the limitations of other sensor types [9] and no devices need to be worn. Zweng et al. [7] show that the accuracy of their fall detection approach is higher compared to 2D cameras when using a calibrated camera setup and a 3D reconstruction of a person. Hence, we propose to use a Kinect / Xtion pro, since 3D information is available for distances up to ten meters without the need for a calibrated camera setup. However, the SDK is optimized for a range from 0.8 to 3.5 meters and thus not all features provided by the SDK can be used for higher distances (e.g., NITE). Moreover, the scene can be analyzed in more detail (e.g., estimation of the ground plane) in comparison to standard cameras.

However, the use of computer vision raise privacy issues. Due to this facts, the Kinect respectively the Xtion Pro

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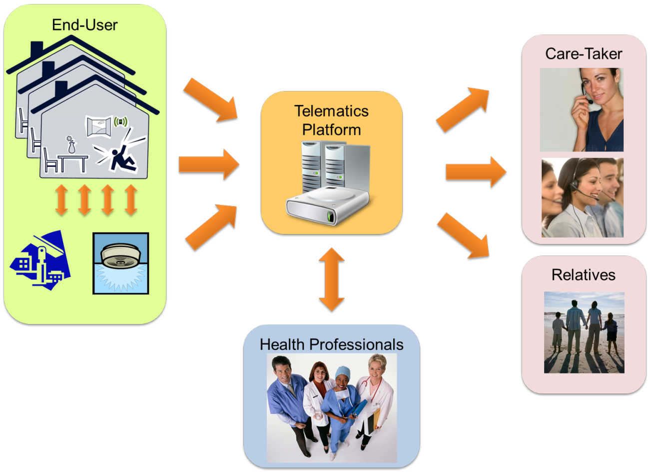

Figure 1. *fearless* e-Health system

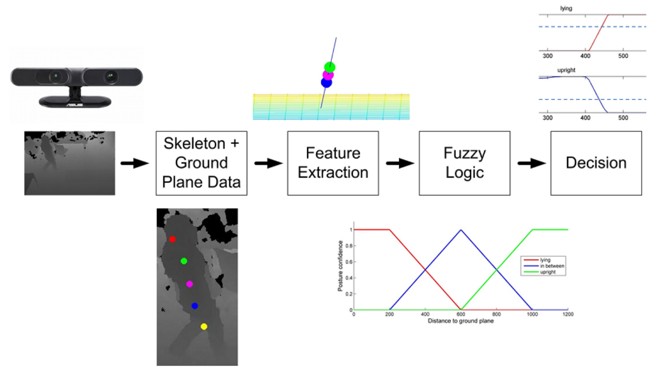

Figure 3. Technical Workflow

sensor is used, since depth data can be used to detect falls (e.g., [4], [5]). Using depth data respects the privacy of elderly, since neither the person nor the surrounding can be identified from depth images. A depth image only visualizes the position and the distance to the sensor. Figure 2 (left) shows an example of a depth image illustrating a person, tables and a mat lying on the floor. This visualization illustrates the distances of subjects and objects to the sensor. The brighter the color in the depth image, the more far away the person or object is. On the other hand, the darker the object is, the closer to the sensor it is. Furthermore, black indicates that there is no data available (e.g., due to sunlight or reflections). In contrast, the corresponding RGB image is shown in Figure 2 (right), representing the same scene.

The workflow of our approach is depicted in Figure 3: starting with a depth image, the skeleton and ground plane data is extracted by the use of OpenNI [10]. The skeleton joints of the shoulder, spine and the center of the hip are extracted and analyzed using fuzzy logic. Based on the results of the fuzzy logic, a decision is made if the person is in an upright position or lying on the floor. Since only the skeleton joints are used, the privacy of the elderly is respected due to the use of an anonymous and abstract visualization only using lines and dots. An example of this visualization is shown in Figure 4: the dots are representing the upper part of the body, whereas the line represents the major body orientation and the ground floor. In case of an alarm, the alarm including this abstract visualization is sent to the telematics platform, depicted in Figure 1. Moreover, the alarm is stored and forwarded to the appropriate care taker organization or relative by using this platform.

Figure 2. Depth image (left) and corresponding RGB image (right)

To be able to meet the required end user demands, the following criteria need to be fulfilled:

- **False Alarm Rate:** false alarms (false positives, FP) are events, where the system reports a fall, although the person does not fall. Since each fall event is monitored by a care giver organization or a relative, FP result in time and cost consuming actions. On the other hand, false negatives (FN) are events, where the person falls down but the system does not detect the event. The drawback of FN is that the system misses the fall and thus no help can be provided. In summary, the number of FP and FN need to stay below a threshold (e.g., the number of FP and FN when using a panic button), otherwise the system will not be successful. To reduce the number of FP and FN, the verification of an alarm by a call center agent or relative, before taking countermeasures, is proposed by sending additional verification illustrations. These illustrations, depicted in Figure 4, show abstract visualizations of a person representing the upper body of the person by three dots (shoulder, spine, hip) and a line as well as the position of this person with respect to the ground floor. Due to this representation, the illustration is even more anonymized than when using depth images, although the relevant information (person is in an upright position vs. person is lying on the floor) is still obtained.
- **Security and Privacy:** Ensuring high security and privacy standards are essential for a successful e-Health system. Hence, only abstract and anonymized illustrations are accessible, shown in Figure 4. Furthermore, all connections of the *fearless* system are encrypted

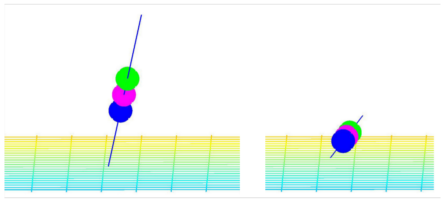

Figure 4. Verification image of a person (a) being in an upright position (left) and (b) lying on the floor (right). The upper body of a person is represented by only three dotes and one line.

using the AES-256 encryption standard. To ensure privacy by design, it is not possible to view a camera picture, since no (RGB) camera is used. Moreover, the system does not look like a standard camera and thus no stigmatization takes place since the sensor can be integrated into the flat or house.

- **Affordability:** Technology for elderly need to be affordable, hence the system is built of low-cost standard components to ensure to meet the end user requirements. Similar to the panic button, elderly will be able to rent the system and thus covering the hardware as well as personal costs.
- **Adaptability:** To be able to provide an all-in-one solution, interfaces to other systems (e.g., alarm systems, smoke detectors) are provided. Hence, the system can be personalized according to the end user's needs and a single safety and security system can be provided.
- **Control belief:** This end user requirement is fulfilled by providing access to all information gathered by the system via the use of the telematics platform. This platform acts as central point of information and all alarms are sent to this platform. Elderly, their relatives and care taker organizations have access to this platform. This solution fulfills the requirement of empowering elderly to have control over their data, although conflicts arise since elderly perceive the use of the Internet as costly and difficult [11].

III. End User Centered Design

The *fearless* consortium brings together ten interdisciplinary partners from Austria, Germany, Spain and Italy. To be able to integrate end user, two caregiver organizations are responsible for the recruitment of the test persons. Technical partners are responsible for developing fall and fire detection algorithms, but also for providing the telematics platform. Since the aim of the *fearless* project is the reduction of the fears for elderly living in their own homes, the impact of this assistive technology and its relation to fears is analyzed by psychologists. Business experts are responsible that the research within this project results in a technology which is affordable for elderly, whereas medical experts monitor the health status of the elderly throughout the project.

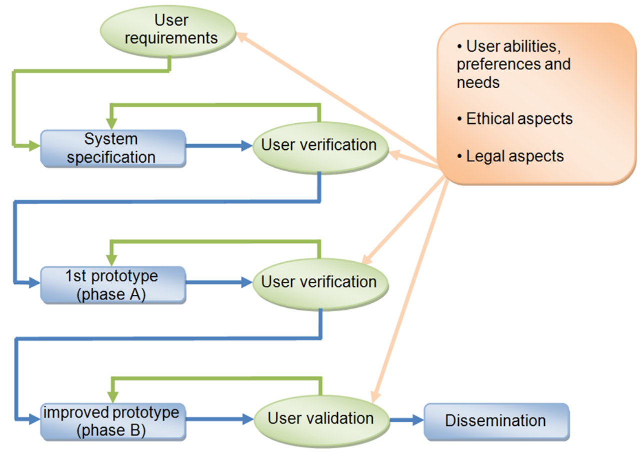

Figure 5. End user are integrated throughout the whole project duration

Figure 5 illustrates the integration of the end user within the *fearless* project: at the beginning of the project, a user need analysis is conducted to assess the needs and fears of end users are by theoretical derivations from existing psychological models and theories and semi-structured interviews. According to the user requirements, an initially defined system specification is continuously evaluated by end users and redefined through regular feedback loops. Field pilots in combination with semi-structured interviews are conducted to ensure that the system is developed according to the end user needs. Since end user provide regular feedback, the technical specification of the *fearless* system is adapted throughout the project.

During the field pilots the *fearless* system is installed in elderly's flats in Austria, Germany, Italy and Spain. The field pilots consist of two different phases: during phase one, the first prototype of the fall detection system is installed in four flats (one flat in each country) to obtain first results of the system. Due to these results the prototype is enhanced before phase two with 30-40 installations will be conducted. The aim of the field pilots is not only to test the fall detection system itself, but also to assess technological and psychological aspects (e.g., enhanced mobility) as well as integrating care taker organizations and relatives throughout the project. The mobility aspect is evaluated during the field pilots by the use of step counter: if elderly have less fears, they do not avoid activities and are thus more mobile. Furthermore, also the ethical comissions are involved during the field pilots to verify the feasability of the *fearless* system from a legal and ethical point of view.

The project benefits from the different interdisciplinary perspectives, from which the results of the field pilots are analyzed. From a technical point of view, the fall detection algorithm [5] is tested under real settings and is adapted to the end user's needs while overcoming the lack of realism when performing falls in the laboratory. Furthermore, the overall system including its interfaces as well as the feasibility of the system setup is evaluated. From an organizational point of view, end user organizations are able to integrate the system into their workflow and provide feedback to adapt the system to their needs. Elderly are involved to provide essential feedback to the technical partners. Additionally, we assume to reduce their fears by providing safety while using our system. Since the field pilots are conducted with medical and psychological support, changes and benefits for elderly can be determined and these assumptions can be verified.

In summary, the following end user are involved during the project:

- **Elderly and relatives** are involved during the end user requirement analysis and during the field pilots. Elderly install the system in their flats during the field pilots, whereas their relatives can receive the alarms if unusual events are detected.
- **Care taker** are involved during the end user requirement analysis and are fully integrated during the field pilots. Hence, the care taker's call center is integrated and alarms are forwarded to the appropriate call center. Thus allows to verify the feasibility of the overall workflow in case of an alarm.
- **Health professionals** provide medical guidance and assistance throughout the project.
- **Electricians** are involved during dissemination activities since elderly contact their already well-known electricians around their corner and thus electricians need to be aware of new technologies such as e-Health systems.

IV. Conclusion and Future Work

This paper presented an overview of the user centered development of an e-Health system and the end user integration within the *fearless* project. Since AAL technologies are tested under laboratory settings, tests with elderly are missing. Hence we focus on field pilots and regular end user feedback loops. To enhance the acceptance of such technologies, end user need to be integrated even during early project phases. The integration should not only focus on primary end user (elderly), but also on secondary end user (e.g., caregiver organizations, relatives) since these people are also confronted with the use of AAL technologies. In order to achieve this, all relevant stakeholders are included and the end user feedback is received from all stakeholders, establishing an interdisciplinary view. Due to the feedback, adaptions and improvements of the system are developed (e.g., integration of a power switch to ensure the end user's control belief).

Future work deals with the improvement of the system according to the end users feedback gathered during the field pilots. The improvement of the system includes further technical devlopement and the development of additional features, but also design issues might be adressed by the end users. Furthermore, the workflow for the end user integration (i.e., relatives and call center) will be analyzed and optimized as well as the feasibility of the verification images to distinguish between true and false positives.

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