CareBed: A Low Cost Approach for Improved Safety and Functionality of Existing Home Care Beds

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Abstract

Intelligent beds support continuous weight monitoring and automated safety-actions, e.g. turning on the lights when leaving bed and alerting staff if its occupant does not return within a set time. Also, an intelligent bed may provide decision support for the detection of the early onset of illness to healthcare staff and relatives and provide a more holistic understanding of its occupant's health status. Such services have the potential for providing better care with fewer resources than today. However, existing intelligent bed products on the market are expensive, thus hampering **the proliferation of this type of product for large scale implementation. The aim of this study was to investigate the feasibility of creating a low cost add-on sensor product for existing care beds, and to learn whether it is feasible to use for automatic and continuous measurements of the weight of the bed-occupant, and as a bed-occupied-or-not context-aware service. A feasibility prototype was constructed to evaluate the feasibility of the approach. It was tested as a weight unit using four test users, and as a context sensor unit using ten test users. Results indicate that it is feasible to employ such a low cost add-on device, providing the same benefits as existing intelligent beds. Minor changes to the physical layout are required for optimal usage. When CareBed is used as a component in a system of ambient assisted living devices, it may be used both as a continuous weight measurement component, as well as a high precision context sensor to support the prevention of falls and night wandering.**

Introduction

The Western world, Japan and China are struggling with increasing economic burdens stemming from their aging populations, also known as the "double demographic challenge" (1-4) . The research field ambient assisted living is investigating how to counter such age-related challenges by inventing and evaluating novel innovative technology devices and services and investigating their perceived usefulness and effectiveness for care and healthcare improvements (5).

The concept of intelligent and sensing furniture is gaining momentum, especially the concept of intelligent beds allowing for the monitoring and automated safety-actions, e.g. turning on the lights when leaving bed, as well as for providing decision support for the detection of the early onset of illness to healthcare staff and relatives, including hear-failure, cancer, dementia and other conditions and diseases (6).

In the home care sector, a major focus lies on the support of a range of modalities or activities of a resident in a single home apartment, including assisted living care facilities (nursing home), rehabilitation facilities, private homes, or in other types of assisted living facilities. Of these, the prevention of falls, especially during the nighttime, is the most important modality and event. Furthermore, there are a range of other effects to be gained from intelligent beds, including detection of night wandering of residents suffering from dementia, the early identification of the onset of illness, as well as residents leaving their homes at night. Finally, high precision monitoring devices have been reported to stimulate citizens suffering from "fear of falling" to increase their mobility and independence level, which may increase their perceived quality of life and feeling of safety, motivating them to be more autonomous (7,8).

According to the World Health Organization (9) approximately 28-35% of people aged 65 and over fall each year, increasing to 32-42% for those over 70 years of age. The frequency of falls increases with age and frailty level. We see that falls exponentially increase with age, which is leading to a high incidence of falls and fall related injuries in the ageing societies. Thus, if preventive measures are not taken, the number of injuries caused by falls is projected to double by 2030. In this context, assistive monitoring devices that could help to alleviate this challenge appear to be highly relevant (10).

In the US it is estimated that "falls are the largest single cause of restricted activity days among older adults, accounting for 18% of restricted days. Moreover, fall-related injuries accounts for 6% of all medical expenditures in the US for persons over the age of 65 (11).

Falls are in Denmark the most frequent type of accident among citizens in the age group over 65, and it is the fifth most frequent cause of death. It is estimated that each year around 13.000 elderly are hospitalized due to fall accidents, and of these 1.350 die. Around 1% of all fall accidents in Denmark results in a hip fracture, and around 95 % of all hip fractures are caused by falls. It is estimated that the total cost of falls in Denmark annually lies around EUR 270 million, of which around EUR 105 million are municipal costs. For each hip fracture, this amounts to around EUR 27,000, of which EUR 11.000 is municipal expenditures (12). In a European perspective, this amounts to an estimated number of more than EUR 27 billion annually. US numbers have been estimated to be USD 30 billion in direct medical costs and around USD 20,000 for each fall accident involving elderly over the age of 72.

Another service of intelligent beds is weight tracking. Weight tracking is relevant for several illnesses and conditions as well as during rehabilitation after illness or surgery. A sudden rise in weight obtained over a few days may indicate one or more critical conditions. One of these is heart failure, a condition where the heart fails to pump sufficient amount of blood around in the body (13). This often results in a rapid build-up of fluid in the body, a condition known as edemas, followed by symptoms such as increased tiredness, and shortness of breath. Fluid corresponding to 2-4 kilos of additional body weight retained in the body is often an indicator of a serious deterioration of the disease and/or insufficient medication-levels (14). In Denmark alone, heart failure results in 11,000 patients being admitted annually, corresponding to around 5% of all admissions, and the related costs amounts to around 2% the entire healthcare budget in Denmark (15). In the industrialized part of the world, around 2% of the adult population experiences one or more heart attacks, rising up to 10% in the age group above 65 (16). The number of heart failures have doubled over the last 15 year, and are expected to follow the demographic development, and continue its rise over the next decades. In Denmark, the price per heart failure admission is around EUR 4,000, and in total the national Danish healthcare system spends around EUR 44 million annually on heart failures. It is estimated the total cost of heart failure is EUR 4.5 billion in the European Union.

Fall prevention and early detection of a falls, combined with early identification of the onset of illness (e.g. heart failure) are thus important objectives, with a high related savings potential. In a recent study on health professionals' user experience of a commercially available intelligent bed, it was suggested that intelligent beds could also result in more individualized care, workflow redesign, and time savings for the health professionals in caring for elderly patients, but also that the technology intruded on patients' perceived privacy (6).

However, existing commercially available intelligent bed products are expensive, and require that existing care beds be replaced. As an existing high quality care bed represents an investment of EUR 1.500 to 3.000, depending on the vendor, most nursing homes and care facilities, both private and public, may not find it feasible to replace their existing care beds with intelligent beds, as these comes at an added price of EUR 5.000 to 8.000 depending on the vendor. Thus, the lack of low cost alternatives to the emerging intelligent beds is considered a barrier for the proliferation of this technology. As a consequence, creating a low-cost, but effective, technology alternative for the intelligent bed is considered to be of major importance.

The aim of this study was to investigate the feasibility of creating a low cost add-on device for existing care beds, turning them into intelligent care beds by using sensors and communication technology, without changing the physical layout of the existing care beds, and thus maintaining their full operational status at the same time. We also wanted to learn whether it is feasible to automatically and continuously measure the weight of the bed-occupant, as well as use the bed sensors as a context-aware service, for learning whether the bed is occupied or not.

Methods

Using the systems engineering method of prototyping, an add-on prototype for use with the most widespread type of care bed in Denmark, Guldmann was created as a prototype system called CareBed. The CareBed prototype utilized four load cells placed on a metal frame, allowing for a normal care bed to be rolled up on it, and rolled off again, which is required by law in Denmark. CareBed features wireless (WiFi) based web service integration, allowing external care systems access to its data in real time. Services include automatic weighing of bed residents, automatic detection of poor sleep quality, context sensing of bed residents getting out of bed at night, as well monitoring of sleep-patterns. CareBed was included in the OpenCare assisted living system, and was used in combination with a night-vision camera and remote controlled light switches, allowing to turn on the light when the bed resident would leave his bed.

Figure 1. An image of the steel frame onto which the care bed (here a GB4 from Guldmann A/S) can be rolled on and off. Four load cell sensors are mounted underneath the steel frame.

The CareBed prototype was evaluated in a controlled laboratory setting for effectiveness of its main functionality, as well as longitudinally tested for one year at the ambient assisted living lab facilities of Aarhus University, Department of Engineering, to learn the long time implications of the technology. Weight measurements of four test persons were compared to a clinically certified weight scale, while context measurements (in or out of bed) were verified through manual observations. Finally, system responsiveness was tested after one year.

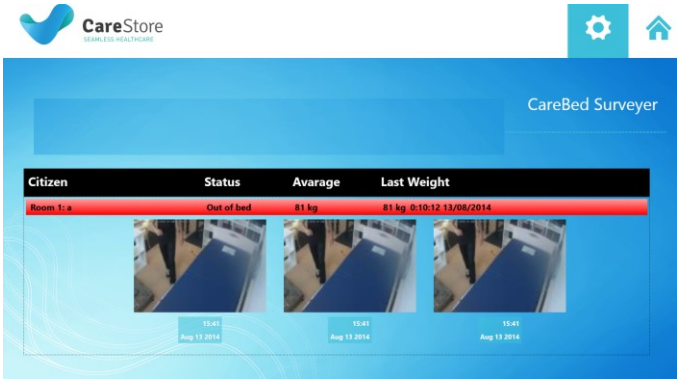

Figure 2. One of several use cases of CareBed is surveillance of patients leaving their bed at night, in case they do not return, here integrated with a surveillance camera with night vision. Prototype runs in the OpenCare infrastructure, and as part of the EU FP7 funded CareStore project.

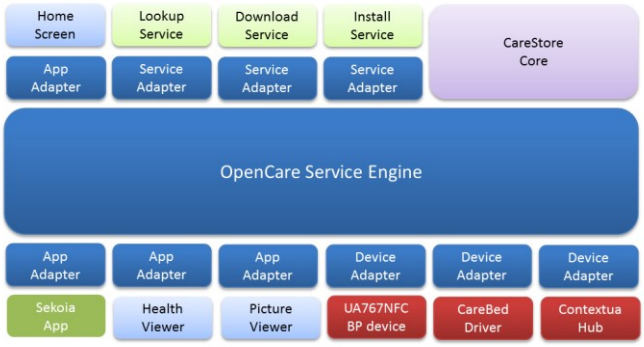

Figure 3. The OpenCare Service Engine, a software infrastructure for secure and reliable AAL servicesm integrates with the CareBed prototype as a driver, allowing weight and context data and events to be shared with all clients running OpenCare software, including products from the companies Sekoia and Medica with a focus on ambient assisted living for nursing homes.

Results

We found that the CareBed system could accurately weigh bed residents and provide the data to third party application. Four test subjects participated in the weight range of 60.4-81.5 Kg. Error rates were less than 1% when compared with a validated weight scale device, specifically the UC-321PBT from vendor A&D. A follow-up sensitivity study of one person over spanning three days also found error rates below 1% Also, we found that CareBed could accurately track bed residents being in bed, entering the bed, and leaving the bed, based on a population of ten test-users, with a resulting error-rate of 0%.

Discussion

CareBed is a low cost alternative to replacing existing care beds and replacing them with expensive intelligent beds. CareBed is estimated to cost around EUR 300 to produce based on the technologies used. CareBed was able to provide information on weight development over time, night-wandering, as well as sleep quality. Weight development over time is useful for dieticians and physiotherapist, while a sudden raise in weight over a short amount of time has been shown in other studies to be an early predictor of heart failure. Automatically turning on lights at night when leaving bed has been shown to prevent falls, as well as unintended events at the toilet. Context-aware systems, such as CareBed has the potential to reduce the number of "safety visits" by staff or relatives during the night time. The open data integration based on web services allows for third party care systems to be able to easily integrate with CareBed. The system could easily be extended with a moisture sensor, thus providing early detection of bed-wetting as well. It was observed that rolling on, and off, of the bed on the CareBed frame was difficult. This is likely due to the frame being too shallow, and it the frame should be extended accordingly in a commercial setting.

Conclusion

In conclusion, we found it feasible to employ a low cost add-on device, such as the CareBed prototype, providing the same benefits as existing intelligent beds. Minor changes to the physical layout are required for optimal usage. When CareBed is used as a component in a system of ambient assisted living devices, it may be used both as a continuous weight measurement component, as well as high precision context sensor to support prevention of falls and night wandering.

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