Design of a Holistic Dashboard for Technologies Enhancing Aging in Place

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***Abstract* — The goal of aging in place is to allow seniors to remain in the environment of their choice with supportive services as needed, helping them attain independent living at old age. In TigerPlace, a retirement community helps residents in 'aging in place'. The senior residents' medical records and telemedicine data are stored in separate systems. Date-time stamped sensor data collected from their daily activities is also stored but not linked with their health records. Employing a human-centered evaluation framework to facilitate the decision making process, we conducted task and functional analyses, which provide descriptions of user characteristics, required functionality and basic tasks for an effective relational data representation. In this paper, we report the preliminary results from the above analyses, and a few prototypes resulting from the human-centered integrated display of health data. This project aims to offer a holistic and comprehensive view of all available scattered health information of the residents through a single interface that could add efficiency to the clinical decision making process.**

***Keywords* — Human Factors, Health Data Display, Congestive Heart Failure, Aging in Place, Human-Centered Design.**

I. INTRODUCTION TO TIGERPLACE

Various forms of assistive technologies are employed to address common aging problems that are related to the functional decline of the elderly [1]. The chronic illnesses of the patients are addressed from multiple perspectives as technology and informatics provide creative options over the mainstream healthcare facilities. It is believed that the appropriate program that uses supportive, restorative and assistive services can help improve adult's health and wellbeing without the need for the traditional nursing home care. With this vision the "aging in place" project had begun having two major parts: senior care and TigerPlace [2].

The senior care designed for the residents at TigerPlace, is a state-of-the-art senior independent living facility. For promotion of health of older adults, the aging in place model has environmental and health supportive services in place, providing more options for advanced senior healthcare research [2]. The wellness center operated by senior care has ongoing assessments for the resident health-promotion and improvement activities, i.e. exercise, yoga, etc. to keep them active. Senior care also provides other home care services, i.e. medication management, assistance with daily living activities, care-coordination of health conditions with the residents' physicians and provide home health and hospice services to qualified residents [3].

Researchers at TigerPlace have found that the most common encounters in care for the seniors are: falling or fear of falling, incontinency in urination, assistive or complete hearing loss, partial or absolute blindness, reduced mobility and muscle strength, social isolation, cognitive impairment and problems in medication management.

II. TECHNOLOGY EMPLOYED AT TIGERPLACE TO ASSIST "AGING IN PLACE"

The TigerPlace requires sophisticated technology to monitor the daily activities of the residents, their medication management and electronically save the health records of the patients for easy retrieval and diagnosis. Technology helps the care providers track progress reports of the senior residents' daily activities, general health, and chronic diseases especially who show signs of functional decline [4].

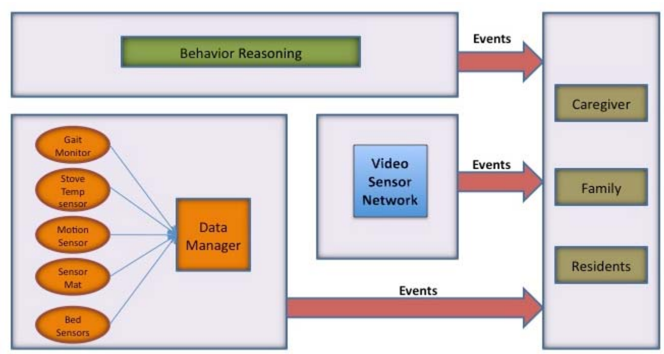

Figure 1. Data sources supporting a human-centered integrated health data display at TigerPlace

There is an electronic medical record (EMR) system that provides overall information related to the health problems of the residents helping deduce the symptoms of diseases. Various kind of sensors [5] i.e. electrodes with electrical amplifiers, vision sensors, video sensors, light pressure, and sound temperature etc. are installed in TigerPlace and are connected wirelessly to small personal computers in the residents' living rooms that jointly produce a sensor network [2]. These sensors derive various physiological measurements and play an important role in tracking progress of patients and

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monitoring their activities of daily living (ADLs) and instrumental activities of daily living (IADLs) [5]. The sensor provides measurement of the outcomes of the risk factors which can be used to minimize problems[6] by assessing the risk factors associated to individual residents, as shown in Figure1.

There is a telemedicine system where the vitals, i.e. body weight, blood pressure, pulse, heart rate, temperature etc., of the residents and their general health assessment are recorded on a daily basis. Information related to their general well being, i.e. discomfort, fall, appetite, shortness of breath, chest pain, headache, edema, etc. are also recorded. This data is interpreted in a weekly or monthly basis to track the progress of the resident. TigerPlace approaches an advanced concept "smart homes", which is an emerging trend in health informatics. It employs technology to help elders live a more independent life and improve their functional ability [3]. These three systems are disparate in nature and currently do not have a holistic view of the information [4].

III. Theoretic Background and Design Framework

Relational data is the most important component of the sensor data and patient records in TigerPlace. A relational information display (RID) represents relations among different type of information; i.e., "Name" of a resident related to his sensor data has multiple relations. This relationship can be represented in a table format and can be transformed into different formats, i.e. bar chart, pie chart, scatter plot matrices etc., which carry the same information but may have different effect on the users due to the distributive patterns of the conveyed internal and external information. For example: the observed values of the bradycardiac firings of a senior resident for 12 months are the external information. The normal range (pulse rate of 1 to 39 beats per minute) is the internal information. Both can be presented in a table format and/or graph and can use different data scales. To improve the quality of information representation in the sensor data management system, researchers need to have a thorough understanding of the pattern of interaction between internal and external. To achieve this, one has to come up with an algorithm that transforms the data display into the best format for different users.

Guided by distributed cognition, we have developed a theoretical framework for representing relational data, which also depends on the nature of each associated search tasks. Distributed cognition emphasizes that elements of human knowledge and cognition are not confined to individuals, but distributed across time, space, people and artifacts [7-9]. For the sensor data of bradycardiac, external artifacts are created specifically for memorizing and are used to enhance internal memory. The data scale format of information represented in scales i.e. nominal, ordinal, interval, ratio [10], affects the user searching information performance [11] in addition to the distributing pattern that explains the internal and external requirements.

Studies have identified that different users i.e. clinicians and medical researchers use the same set of data in different ways [12-15]. They usually have common questions to be answered for solving a problem or decision-making (treatment and diagnosis). While examining the medical records or residents' sensor data, they may use different approaches to conduct the task. Clinicians typically are interested in different aspects of a particular patient at an individual level that are with-in the key tasks of the patient searches, whereas clinical researchers may view the patient records as collective level data revealing the trends of diseases.

We are in the process of developing search tasks for each type of scale for the sensor data associated with the EMR and telemedicine system, using a human-centered approach, UFuRT [16, 17]. UFuRT examines users, functions, representations, and tasks for effective design and evaluation of human-centered distributed information systems and also provides systematic principles, guidelines, and procedures for designing information systems. Theoretically, an information search interface design guided by UFuRT ensures that the design matches the information search task with users' characteristic for a better task performance.

IV. Methods

Literature Review: We systematically reviewed all the published research papers about Tigerplace and the technologies employed there [1, 2, 4, 6]. Variety of sensors have been installed at the residence for monitoring the health and daily activities of the seniors, backed up by an electronic medical record system to store health information [5] and a telemedicine system for the purpose of efficient medicine administration and collecting daily vitals of the residents [2].

Interviewing data managers for understanding the different kind of information and the workflow in the clinical setting helped us understand the relationship between the data and its importance at TigerPlace. It helped to understand how historical data is stored and viewed by the clinicians. Managing the data retrieval and representing the required information in an appropriate format [1] are the most important aspects for clinical decision-making.

Field trip as an interaction with nurses proved to be beneficial to understand the clinical setup, the problems with patients and the shortcomings of the system. It provided pointers for future investigations that can make the system user-friendly.

By analyzing congestive heart failure (CHF) guidelines, one prototype was developed. CHF is a chronic disease which affects a number of elderly patients due to bad lifestyle management and family history [18]. We developed a scenario that is most relevant to CHF elderly patients and discussed how effective clinical decision support system could alert the care providers using the dashboard we plan to develop. It is expected to promote preventive care that has the potential to decrease the risk of myocardial infraction.

In order to derive the needed clinical information, the data repository that contains the vitals and the sensors need to be cleaned and clinically meaningful data have to be filtered and mapped to each other. Finer data scale mapping was conducted, for example: there were sensor firings when the bed restlessness of a patient was higher than the threshold. It was important to filter the firings that were more significant towards showing abnormalities [4]. Here ordinal data mapping was predominant. When we consider decline in functional ability of the patient, binary nominal data was filtered to find if the dynamic activity decreased from the current trend observed in an interval of time [4]. Clinical decision support for physicians, nurses, physical therapists and patient family members has a high impact on the treatment of patients when technology enables such functionality to filter the information depending on user needs. The data collected from the telemedicine system to the sensors needed to be mapped with significant relevance to categorization of the data and just not their count or continuous values [4].

V. Design and Results

A. Objective

The objective of this research is to design and develop a dashboard that facilitates decision making with the help of the information integrated from the telemedicine and sensor data at TigerPlace by providing a more holistic view of the data. We used the human-centered framework, UFuRT to design a web-based dashboard. The dashboard eventually can have associated clinical decision support features embedded to support decision making, thereby decreasing the probability of medical errors [4]. A human-centered framework for integrated display of health data has been tailored to all interested parties such as caregivers, family members and residents in TigerPlace. Our design does not demonstrate the complexity of the interface itself; rather it approaches to demonstrate the process of integrating distributed data resources in the healthcare systems.

B. Concept

We have illustrated a chronic illness that the aging population face for our research. We have taken into consideration 'Congestive Heart Failure' (CHF) associated with Cardio-vascular diseases and mortality of chronically ill aged patients. Human being's body mass index (BMI), temperature, oxygen saturation, muscular force, and arterial pressures follow biological rhythms. The daily activities of human beings vary according to work schedule like meals, leisure, sleep time etc., due to individual social rhythms. Biological as well as social rhythms both are interdependent and play a vital role in monitoring a disease [5]. A subtle change in these behaviors of the elderly population having a chronic disease can provide enough evidence for the progression of the disease. It is believed useful in medical profession that for aged patients detected with emerging medical conditions before they become critical, through carefully monitoring the activities of daily living ADLs, IADLs and EADL's [5]. This includes activities like having food, getting in and out of bed, getting in and out of their room, going to toilet, cooking, preparing meals, housekeeping, doing laundry and managing medication [5].

C. Key Scenario as Congestive Heart Failure (CHF)

Diagnosis of CHF starts with findings from pertinent medical history of a patient, i.e. significant coronary artery diseases, prior heart attacks or strokes, hypertension with high blood pressure, very high alcohol use, etc. Detection can also be done with careful physical examination showing presence of extra fluid in the body, heavy breathing detected by breathing sounds, swelling of leg, edema (swelling of veins) [18]. It can also be detected by other conditions of heart, i.e. pulse rate, pulse pressure, heart rate, heart sound, sleep disorders, murmurs in sleep, shortness of breath, orthopnea, etc. [18, 19]. We consider a case of CHF and demonstrated how the above information from the conjugation of telemedicine and sensor system can be used for meaningful decision-making employing UFuRT framework. This may help in a more effective decision support for clinicians and address potential reversible factors for CHF patients.

Case: *Low systolic blood pressure (SBP) or low diastolic blood pressure (DBP), irregular heart rate or pulse rate along with oxygen saturation level, sudden decrease in glucose level, increase in body weight caused by gain in fluids, edema, chest pain, head ache. These conditions may lead to fall, decline in mobility, limping, decreased daily activity revealed in the sensor data [4].*

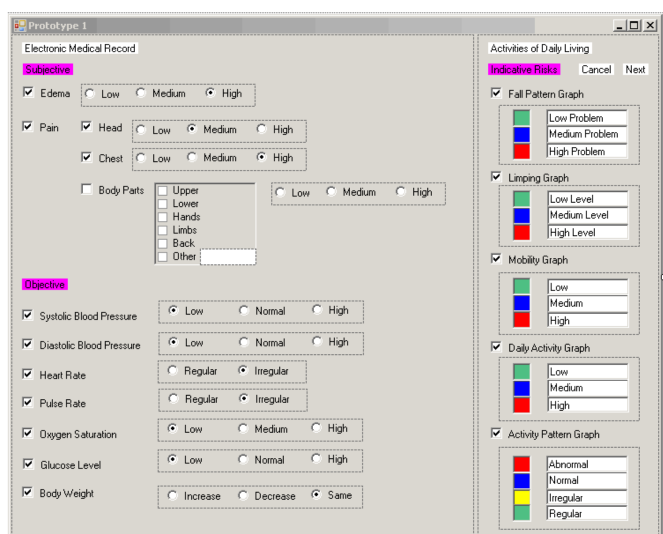

Figure 2. An interface for congestive heart failure patients with mobility constraints

Description: When observing the telemedicine system if we find that the CHF patient has increased weight, it indicates he has increased body fluids. There could be a direct correlation between his blood pressure level going down and irregular heart rate [20] or pulse rate. When we look up the sensor information, we may find that patient had a fall as a result of which he is limping or has decline in mobility. This is typically caused by pain in parts of the body, especially in the leg region, back pain or edema (swelling in the legs due to irregular blood circulation in the body) [18]. We can also see the gait pattern to observe the abnormality or find out which part of his body that has been hurt as a result of fall [4]. Most importantly, if the resident is a CHF patient, an alert can be generated to inform the clinicians about the risk. The type of alert generated depends on the resident's health information related to his existing problems, past medical history of heart failure or current health condition. This data has a one-sided relationship. This scenario occurs to a resident having a chronic illness but shows signs of it when he falls sick quite often. The prototype is shown in Figure 2.

VI. DISCUSSION AND FUTURE PLAN

The long-term goal of this project is to lay the foundation of developing a human-centered design guideline or framework for effective health data display in the area of aging in place. This prototype design would advance the usability and functionality of monitoring systems employed currently at TigerPlace. For an efficient clinical decision-making, it is essential that all available patient information is viewable to the care providers in a single and holistic presentation to ensure the quality of care. Technologies may help them live a longer life with more independence and decreased risks of accidents [6], which otherwise, can cause additional disabilities or can even be fatal.

At present, our effort is to demonstrate the process and present a preliminary integrated display for the vital signs and the sensor data, assisting critical clinical decision-making. We are not aiming at showing the complexity of the entire process, but our effort is to visualize the effect that would help us design the human-centered framework. We have kept the design simple, natural and externalized the internal information requirements to make the display more usable. We are careful about the presence of staggered data, which could turn out to be more harmful for patient care and patient safety. For the efficiency and optimal performance, the tool has been designed with greater transparency.

In the next level, it is required to make the design more comprehensive which should aim to present information case by case. This goal can be achieved if the design is made dynamic which supports different forms of graphs embedded in the workflow. This design can be better enumerated if we create a view in which care providers can see multiple views of the same information in different formats and also compare results in a graphical format for easy interpretation of health status and monitor changes.

VII. LIMITATION

Usability evaluation is still required though UFuRT framework theoretically makes sure that the design is human-centered. In our design phase, we have not used real resident data. In the next stage, there are plans to evaluate effectiveness and efficiency of the prototypes with empirical experiments, which will measure time, correctness for each type of questions, and analyze the interaction and the covariates of health profession users using real available information.

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