A Pervasive Way: Elderly People Falling Detection and Ambient Intelligence

Abstract
A stairway falling detection prototype is designed to warn when elderly people fall on the stairs and also accumulatively and unobtrusively study elderly people’s walking patterns. With this prototype, we try to demo a new design strategy, a pervasive way, to facilitate developing proper algorithms and living patterns for elderly people at home. Evaluation of the implicit interactions and potential cooperations with other research domains are then discussed.

Keywords
Pervasive computing, Ambient intelligence, Falling, Algorithm, Evaluation.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Design, Miscellaneous.

Introduction
Using pervasive technology to help and enhance elderly people living alone at home has become an emerging research area in HCI and pervasive computing. Researchers have started applying new sensors and technologies monitoring elderly people’s body and daily...
activities at home, analyzed and evaluated for signs of trouble. They believe "Remote Health Care Monitoring may seem like the best answer to managing the care of the next generation of older people." A large scale of intelligence is also expected to give proper information based on the monitored data [6]. However, there is a bottle neck in this direction: difficulties in properly defining people's daily living pattern without intrusiveness and privacy invasion. Providing a truly smart system that can understand or accurately model people's behaviors, moods and intentions is difficult [5]. Just like a "Strong" AI fails to achieve its goal, a "Strong" pervasive intelligence might also fail to model people's daily activities. Another case study, a retrospective analysis of sensor data gathered in elderly apartment, also claims extra work to provide early "warning" system that a condition needs additional attention for monitoring. Meanwhile, elderly people already struggled with the new aware technology and tensions appeared, between assistance and autonomy, and between privacy of independence [3]. "While most problems surrounding the monitoring of people, they are not easy to solve and have ended up overwhelming UbiComp research. [5]" The dilemma, system has to smart enough and also calm enough seems very difficult to achieve.

In this project, our goal is trying to focus on one specific issue, elderly people falling at home, and trying to find an accumulative, unobtrusive way to learn people's behaviors. With the consideration that fallings cause a lot of serious injuries to elderly people [1], this research aims on implicit interaction on the stairs to know older people's walking patterns without intrusive monitoring or raising privacy and security concerns.

Prototype Implementation
In this part, we introduce the physical layout and algorithm structure of this system. We also describe how they work together by elaborating the way of code running and the method of falling detection.

Physical layout
Figure 2 shows the real environment of our prototype. Ardunio [2] board (Ardunio Mega) is the central physical device to collect/send information from/to deployed sensors in a stairs environment. Meanwhile, Pressure Mats are used as the major signal inputs for recognizing the stair on which someone is standing. We put a pressure mat on every stair and then covered the whole stairway with carpet to make the mats invisible to users. For the current prototype, a door bell is used to raise alarms; in the future, we can send warning messages out by enclosing it as part of the ETHOS [7] central system. Two buttons are fixed on the wall at the two ends of the stairs, which are for cancelling the false alarms. Cables connect these input and output components in parallel to a single breadboard that is connected to the Ardunio Mega board.

Algorithm structure
Our algorithm for the whole system is based on the periodical running mode of Arduino looping [2]. On the running of a loop, Arduino board checks the electronic signal of each pin port and performs the functionalities we implement due to the values it reads. What we do in each loop is to check the input signals from the pressure mats, and then maintain parameters like the current step being pressed, the time when that step was touched etc. These input signals along with the
parameters we keep can be used to identify the situation on the stairs. An alarm can be raised when the system detects a fall. The user can interact with the system by cancelling false alarms or raising an immediate alarm before the system realizes it should be done. We also implemented methods for handling some exceptional scenarios. The workflow is shown in Figure 3.

Idling, Upstairs and Downstairs Mode

We defined three working modes for the system: idle mode, upstairs mode and downstairs mode. When there are no people on the stairs, the system will detect that none of the pressure mats is triggered, and the system is in idle mode. If someone is walking from the lower floor to the upper one, he or she would step on the lowest pressure mat, and the system will switch to the upstairs mode when it recognizes this. The downstairs mode starts up in a similar way, when the highest mat is touched. Considering our target users are elderly people and they usually walk slowly and do not skip steps, we believe it is reasonable of using the contact to an end mat as the beginning of a walking processes.

Time Interval and Falling Identification

When the system is working under non-idle modes, we record the current step being touched. Since usually people have their feet on two steps any moment when they are walking on stairs, we use the lower one as current step for upstairs mode and the upper one for downstairs mode. This is for the convenience of determining the finish of a walking process and handling some of the exceptions. We also record the starting time of the pressure on current mat.

If the system finds a new step is touched, which ordinarily means the user steps on the next stair, it will check if some steps are skipped or if the time interval between the starting times of current step and this new step is too short. Both of these two situations may indicate a falling because when people fall they would roll down, causing short time intervals or skipping steps. If the system finds the user has been staying on a same step for too long a time, it also assumes he or she has fallen, because elderly people may lose their consciousness if they fall and stay where they fall. There is also a chance that more than two steps are found to be touched at the same time, which could mean that a person has fallen and is lying on the stairs. When one of these situations happens, the system will raise an alarm.

Interactions with the User

Sometimes the system cannot react immediately when people fall. For example, people may fall and lie on the floor but contacting less than three pressure mats, thus the system will not assume a falling has happened until it finds the person has been lying at the same place for too long. But if the person is still conscious, he or she would want to ask for help immediately, and then he or she can pull the rope along one side of the stairs to send a signal to the system. We check in the beginning of every loop for this signal, and if there is one, an alarm is raised. What also may happen is that people sometimes unintentionally touch one of the end mats, for example when they stand there talking to others, and if they stay there too long, a false alarm can be
raised. Now they can press one of the two cancelling buttons to cancel that alarm.

Exception Handling

Exceptional scenarios include unfinished walking processes and mode switching in the middle of walking processes. People may step on one of the end mats and then leave, or turn around and go in the opposite direction when walking half way on the stairs. We implemented methods for detecting these situations to make sure the system works correctly when they happen. At the same time, we take into account the scenarios like falling when turning around and handle these situations, too.

Evaluation of the Current Prototype

After implementing the first prototype, an evaluation is then needed to help us know the performance of the current system and improve it in all possible aspects. The goal of the evaluation is to fine tune the algorithm and to find how robust the system is in terms of interacting with the intended users and handling exceptional scenarios. In detail, the evaluation is intended to study the walking patterns of elderly adults on the stairs, decide on proper time intervals for upstairs and downstairs modes respectively between two steps, investigate elderly adults’ opinions and suggestions toward using this system, and find whether the elderly people change their walking patterns because of using this system. To serve this purpose, in-situ study [8] can meet our need and can provide significant statistic results, if used for the evaluation. On the other hand, lab-based study is also a good resource for finding and solving some early-stage problems. We plan to apply both methodologies to our evaluation.

First we will investigate elderly adults’ original behaviors on the stairs to learn their walking patterns through a questionnaire and a 30 minutes interview for each testing subject. The feedbacks will be collected and the major issues related to daily life and walking at home will be analyzed. After investing the walking patterns, we will invite elderly people to the ETHOS house to find if there is any irregular behavior when they walk on the stairs. We will then try to solve these problems according to our observation of the scenarios and their suggestions regarding to them. For the next
step, we will install our system in elderly houses. We plan to turn off the alarm functionality in some of them and keep this functionality on in the others. We will then record the number of successful walking processes and also the number of those that trigger the alarm, and then we will compare the results to see if there is any significant difference in people's walking patterns because of the alarm. The next stage is to study people's behaviors from system log, evaluate the walking patterns which trigger the alarms more than the others, determine the average time intervals of upstairs and downstairs modes respectively for the original algorithm. Based on what we learn in this stage, we will refine the algorithm and customize the system for each participant. Finally, we will evaluate the system accuracy, reliability, agility and ability. We will also study the user behavior changes in terms of warning signals and how they react to the warnings given by the system.

Discussion

The traditional way of designing user behavior related applications is to find out the suitable algorithms before implementing a prototype. However, people's daily behaviors are unpredictable and thus it is very difficult to find general algorithms for all specific cases. Therefore, in lack of existing methodologies, we preceded our design procedure in a reverse way by implementing a prototype first and then evaluating it with the target users. We expect to get samples from our testees in the evaluation and analyze the walking patterns based on them. This prototype also has a potential to be customized for each elderly individual and his/her home.

We got lots of feedback after demonstrating the first prototype, a very important one of which is that our system can only be used by independent older adults. Although this is due to our designing purpose in the beginning, our system can only serve a small-scale of people because of that. To improve the system from this aspect, we will probably need to include various modes in order to support the multi-user environment. The setting of time interval between two steps is also an important issue which may affect usability of the system. One of our solutions is to use machine learning mechanism on the initial samples from our evaluation and to decide on a proper value for each individual user. Furthermore, our prototype has the potential to be improved for a broader range of users and different environments other than the living home. For example, we can collaborate with Applied Sport Science students to analyze the walking patterns of teenagers, children and adults, or apply it to a medical center where it may help study the recovery progresses of patients. Besides the engineering concerns, our system may also bring some psychology problems. Does our system change the users' walking patterns? Do users find this system secure? When a false alarm is raised, will they walk faster to clear away the annoying noise? And will this situation cause serious safety issues? These questions are very valuable and worth further investigations.

Finally, the contribution of our research is a reverse design process: quick implementation in the first beginning and evaluation to normalize elderly people's walking patterns. Our system will be improved in the near future after we carry out the evaluation. The future researches may also be extended to other areas as new applications are created for different ranges of users and usage environments.
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References