

An Intelligent System for Prolonging Independent Living of Elderly

Bogdan Pogorelc

Department of Intelligent Systems, Jožef Stefan Institute & Špica International d.o.o., Jamova c. 39, 1000 Ljubljana, Slovenia
+386 1 477 3230, bogdan.pogorelc@ijs.si, http://dis.ijs.si/bogdan/

The number of elderly people is constantly increasing in the developed countries (Toyne, 2003). Elderly tend to lead an isolated life away from their offspring; however, they may fear being unable to obtain help if they are injured or ill. During the last decades, this fear has generated research attempts to find assistive technologies for making living of elderly people at homes easier and independent, as is the aim of this research work.

Research study proposes a generalized approach to an intelligent and ubiquitous care system to recognize a few of the most common and important health problems of the elderly, which can be detected by analyzing their movement. In the event that the system was to recognize a health problem, it would automatically notify a physician with an included explanation of the automatic diagnosis. It is two-step approach; in the first step it classifies person's activities into five activities: fall, unconscious fall, walking, standing/sitting, lying down/lying. In the second step, it classifies walking patterns into five different health states; one healthy and four unhealthy: hemiplegia (usually the result of stroke), Parkinson's disease, leg pain and back pain. Moreover, since elderly having these health problems are less stable and more prone to falls, recognizing them leads not only to detection but indirectly also to prevention of falls of elderly people.

In the initial approach movement of the user is captured with the motion capture system, which consists of the tags attached to the body, whose coordinates are acquired by the sensors situated in the apartment. In the current approach wearable inertial sensors are used, allowing monitoring inside or outside of the buildings. Output time-series of coordinates are modeled with the proposed data mining approach to recognize the specific health problem.

Related work. In the related work, motion capturing is done with inertial sensors (Bourke et al, 2006), computer

vision (Thonnat, 2008) and also with specific equipment, such as sensor for measurement of angle of joint deflection (Ribarič and Rozman, 2007) or with electromyography.

We do not address only the recognition of activities of daily living such as walking, sitting, lying, etc. and detection of falling, which has already been addressed (Confidence, 2009; Luštrek and Kaluža, 2009), but also recognition of health problems based on motion data.

Using infrared motion capture system as in our approach, the automatic distinguishing between health problems such as hemiplegia and diplegia is presented (Lakany, 2008). However, much more common approach to recognition of health problems is capturing of movement which is later examined by medical experts by hand (Ribarič and Rozman, 2007; Craik and Oatis, 1995; Moore et al, 2006). Such approach has major drawback in comparison to ours, because it needs constant observation from the medical professionals.

Miskelly (2001) presented a review of assistive technologies for elderly care. The first technology consists of a set of alarm systems installed at person's homes. A system includes a device in the form of mobile phone and pendant with alarm button. They are used to alert and communicate with the warden. When the warden is not available, the alert is sent to the control centre. However, such devices are efficient only if the person recognizes an emergency and is in the physical and mental condition allowing him/her to press the button. The second technology presented is video-monitoring. The audio-video communication is done in real-time over the telephone line. The video can be viewed on monitor or television. The problems of the presented solution are ethical issues, since the elderly users do not want to be monitored by video (Confidence, 2009). Moreover, such approach requires constant attention of the emergency center.

Another presented technology in (Miskelly, 2001) is the group of fall detectors. They measure the accelerations of the person with the sensors worn around the waist or the upper chest. If the accelerations exceed a threshold during

a time period, an alarm is raised and sent to the community alarm service. Bourke et al (2007) present the acceleration data produced during the activities of daily living and during the person falls. The data were acquired by monitoring young subjects performing simulated falls. In addition, elderly people have performed activities of daily living. By defining the appropriate threshold they can distinguish between the accelerations during the falls and the accelerations produced during normal activities of daily living. However, threshold based algorithms produce mistakes, for instance fast standing up from/sitting down on the chair could result in crossing the threshold which is erroneously recognized as a fall.

Work performed and future work. The aim of presented study is to realize an automatic classifier able to support autonomous living of elderly by detecting falls and health problems recognizable through the movement. Earlier works, e.g. (Kaluža et al, 2010), describe machine learning techniques employed to analyze activities based on the static positions and recognized postures of the users. Although that kind of approaches can leverage a wealth of machine-learning techniques, they fail to keep into account the dynamics of the movement.

Our previous work differentiates between the above mentioned five health states. It uses 13 attributes, which we defined with help of a medical doctor and are specific to those 5 health states. Later, we performed investigation of decreasing of number of tags of the infrared motion capture system, attached to the body from 12 to 1 and for each number of tags we calculated the classification accuracy. Moreover, *F* test was used to check the statistical significance of change of classification accuracy in comparison to the complete set of tags. The aim of decreasing the number was to evaluate the less intrusive variants. At the same time we varied the noise added to positions from the motion capture system to evaluate the robustness of the approach.

In an improved approach, we propose multidimensional dynamic time warping (DTW) method as a similarity measure for k-nearest neighbor classifier for classifying time series of elderly movements. It is useful for calculating similarity measure between several time series (e.g. from multi sensors) simultaneously. Several time series are created using general attributes of all measurable angles between body parts, allowing the system to use the same attributes and the same classification methods for recognition between five activities and between five health states. It takes into account all of the sensors' readings in parallel, considering shape of their time series.

At first, the approach was evaluated with infrared motion-capture system, which requires that cameras are positioned in the apartment, which does not allow to detect health problems of elderly outside the apartment. Since our newly proposed approach using multidimensional DTW

doesn't require specific attributes, it turned out to be suitable also for wearable inertial motion sensor system, which allows detecting of activities/falls and health problems also outdoor. For the evaluation we used 256 recordings of healthy subjects and subjects with particular health problems of which each subject was recorded 4-5 times with different speeds and ways of performing. Similarly to the approach using medically defined attributes and IR motion capture, approach using inertial sensors and dtw achieved classification accuracies over 96% for both activity/fall and health problems recognition.

In the following months we will evaluate the performance for the smaller number of inertial sensors, from 10 to 1, since one inertial sensor is part of the most new mobile phones which makes the usage easier and cheaper. Since the author is also employed in the Research Institute's spin-off company Špica, he is collaborating with the development team to develop the final product on the basis of his research. Company is interested for the solution to sell it as a service to the elderly people who prefer staying at home instead of moving to nursing homes.

Generality of the approach makes it suitable also for classifying time series from more than one type of sensor at the time. It was successfully tried for combination of accelerometers and gyroscopes. In the forthcoming project we will use the DTW approach for monitoring activities of the cardiac patients with combination of inertial and physiological sensors.

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