An Ubiquitous and Intelligent System for Prolonging Independent Living of Elderly Users

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***Abstract*—The doctoral research presented in this paper is proposing a health monitoring system for the elderly for the purpose of providing them an independent living. The movement of the elderly user is captured with the motion capture system, and output is modeled with the proposed time-series data mining approach. The goal is to automatically recognize falls and health problems in the elderly and in case of recognition to notify the emergency. Results show that the approach achieves classification accuracies over 95%.**

Keywords-health; gait; dtw

I. INTRODUCTION

The number of elderly people aged 80 years or more is expected to increase in the developed countries at least by sixfold by 2050 [1]. 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.

The presented 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 observing and analyzing the characteristics of 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 a two-step approach; in the first step it classifies person's activities into five activities including different types of falls. In the second step, it classifies walking patterns from the first step into five different health states; one healthy and four unhealthy. The activities are: fall, unconscious fall, walking, standing/sitting, lying down/lying. Types of unhealthy walking are: hemiplegia (usually the result of stroke), Parkinson’s disease, pain in the leg and pain in the back. Moreover, since elderly having these health problems are less stable and more prone to falls, recognizing them leads not only to detection but also to prevention of falls of elderly people.

In the presented approach, the 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.

II. RELATED WORK

In the related work, motion capturing is usually done with inertial sensors [2],[3], computer vision and also with specific sensor for measurement of angle of joint deflection [4] or with electromyography [5]. For our study, the (infra-red) IR camera system with tags attached to the body [6] was used.

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 [7],[8], but also recognition of health problems based on motion data.

Using similar motion capture system as in our approach the automatic distinguishing between health problems such as hemiplegia and diplegia is presented [9]. However, much more common approach to recognition of health problems is capturing of movement which is later examined by medical experts by hand [4],[10],[11]. Such approach has major drawback in comparison to ours, because it needs constant observation from the medical professionals.

The paper [12] 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, pendant or chainlet that has an 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 has the physical and mental capacity to press the alarm button.

The second technology presented in [12] is video-monitoring. The audio-video communication is done in real-time over the ordinary telephone line. The video can be viewed on monitor or domestic television. The problems of the presented solution are ethical issues, since the elderly users do not want to be monitored by video [7]. Moreover, such approach requires constant attention of the emergency center.

The third technology in [12] is based on health monitors. The health monitor is worn on the wrist and continuously monitors pulse, skin temperature and movement. At the beginning of the system usage, the pattern for the user is learned. Afterwards, the deviations are detected and alarms are sent to the emergency centre. Such system detects collapses, faints, blackouts etc.

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Another presented technology is the group of fall detectors. They measure the accelerations of the person with the tags 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. [13] present the acceleration data produced during the activities of daily living and during the person falls. The data was 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. Therefore, the accelerometers with the threshold can be used for monitoring elderly people and recognizing falls. 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.

In [14], architecture of a system that enables the control of the users at their homes is described. It consists of three levels. The first level represents the ill persons at their homes equipped with communication and measurement devices. The second level represents information and communication technology that enables the communication with the main server. The last level represents the telemedicine center including duty operator, doctors and technical support; the centre for the implementation of direct assistance at home; and team of experts for implementing telemedicine services. Such system does not provide any automatic detection of an unusual behavior but instead requires constant observation by the medical center.

Williams et al. [15] have showed that the ability to perform daily activities is decreased for the people that have fallen several times and that the decrease can be detected using accelerometers. They have tested elderly people that have not fallen yet and those that have fallen several times. All of them were asked to perform a predefined scenario including sentence writing, objects picking etc. The accelerations differed significantly between the two groups of people during the test.

The aim of this paper 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. [16]) 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.

The present work has instead the aim to recognize movements by observing the time series of the movement of the users. Better activity recognition performance can be achieved by using pattern-matching techniques which take into account all of the sensors' readings, in parallel, considering their time course.

III. OUTLINE OF PROGRESS AND PLAN

The initial study of the research 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 make the equipment less intrusive. At the same time we varied the noise added to positions from the motion capture system to evaluate the robustness of the approach (results published in two SCI papers).

In an improved approach, we used 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.

The approach was evaluated with infrared motion-capture system. Results show that the approach achieves classification accuracies over 95%.

Since our proposed approach using multidimensional dynamic time warping does not require specific attributes, it is suitable also for wearable inertial motion sensor system, which allows detecting of activities/falls and health problems also outdoor.

In the following months we will minimize the diagnostic system from ten to the minimum number of inertial sensors (accelerometers and/or gyroscopes, which are integrated in several mobile phones), preferably one. The modified dynamic time warping approach is anticipated to be the most suitable for the task, since it does not need any specific attributes. We are collaborating with the development team of the company Špica to develop the final product on the basis of the presented research. The telecommunications 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.

In the future also other health problems and unusual activities can be detected. Since the approach is general, it is capable also for classifying time series from more than one type of sensor at the time. This was successfully tried for combination of accelerometers and gyroscopes. However, in future more additional sensors, such as sound, pressure or physiological sensors are anticipated to be added. This will be performed in the forthcoming project for monitoring activity of the cardiac patients, where the combination of inertial and physiological sensors will be used.

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