

Comparison of Two Ambient Intelligence Approaches to Elderly Care

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ABSTRACT

There is more and more elderly in the developed countries and not enough younger people to take care of them. We are presenting a semantic ambient media system for health-care monitoring to allow quality and safe living of elderly at their homes instead of needing them to go to nursing homes, which are overcrowded. Moreover, their offspring would not be overwhelmed with care for the elderly. The study illustrates two ambient intelligence approaches to the elderly care, both in the sense of four concepts of the semantic ambient media.

Keywords

Semantic ambient media DTW, AAL, elderly, health problems, motion capture.

INTRODUCTION

In the paper we are presenting the system as an example of the semantic ambient media for ambient assisted living (AAL). The reasons for such classification are:

- it is embedded in the natural environment of elderly,
- it uses AI approach to interpret the health status,
- it provides natural explanation of the hypothesis.

The motivation for this research study is increasing rate of the elderly population in the developed countries [16]. 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 easier and independent. The aim of this study is to provide ambient assistive living services to allow quality and safe living of elderly at home instead of needing them to go to nursing homes, which are overcrowded. Moreover, their offspring or other relatives would not be overwhelmed with care for the elderly.

In this study, two approaches 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, are proposed. In the first approach we use medically defined attributes and support vector machine classification into five health states: healthy, with hemiplegia (usually the result of stroke), with Parkinson's disease, with pain in the leg and with pain in the back [12].

In the second approach we classify into same five health states using more general data mining approach. The movement of the user is captured with the motion capture system, which consists of the body-worn tags, whose coordinates are acquired by the sensors situated in the apartment. Output time series of coordinates are modeled with the proposed data mining approaches in order to recognize the specific health problem. In the case that health problem is recognized, the medical center is notified.

RELATED WORK

Review of the literature revealed, that motion capturing is usually done with inertial sensors [15, 2], computer vision and also with specific sensor for measurement of angle of joint deflection [13] or with electromyography [17]. For our study, the (infra-red) IR camera system with tags attached to the body [7] was used.

We do not address the recognition of activities of daily living such as walking, sitting, lying, etc. and detection of falling, which has already been addressed [3, 6, 9] but more challenging 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 [8]. However, much more common approach to recognition of health problems is capturing of movement which is later examined by medical experts by hand [13, 4, 11]. Such approach has major drawback in comparison to ours,

because it needs constant observation from the medical professionals.

The paper [10] 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 [10] 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 don't want to be monitored by video [3]. Moreover, such approach requires constant attention of the emergency center.

The third technology in [10] 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.

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. [1] 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. [18] 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 differ significantly between the two groups of people during the test.

The aim of our paper is to present an application of semantic ambient media for ambient assisted living. The presented application is an automatic classifier able to support autonomous living of elderly by detecting health problems recognizable through the movement.

SEMANTIC AMBIENT MEDIA APPROACHES TO AMBIENT ASSISTED LIVING

The concepts of the semantic ambient media

For the semantic ambient media, four concepts are very important:

- Business
- Content & Media
- Interactive Design & Experience
- Concepts & Models

We will present our proposed system through these concepts.

Business

- Elderly care at the institutions is very expensive and this study provides cheaper solution. Insurance companies could be interested in this solution.
- Work is part of the research project with plan to finish with the prototype.
- Collaborating company *Špica International* is interested in developing and selling the final product from research results.

Content & Media

- What is 'content' and how can it be presented in the age of 'ubiquitous' and 'pervasive'? How to present, select, compose and generate ambient content?
 - It is information of the health state of the elderly, composed through the automatic interpretation of their motion patterns

and presented in the form of the system's explanation.

- How to manage and re-use ambient content in specific application scenarios?
 - The models for the interpretation of the health status (content), trained on the initial group of elderly with specific health problems is used on the new elderly users, who are healthy when starting using the system, for the interpretation of their potential health problems.

Interactive Design & Experience

- How can collaborative or audience participatory content be supported?
 - Audience participatory content is supported through the possibility of the physician to see/hear the alarm and explanation of the reasons for the alarm (including live kinematic visualization of user's movement).

Concepts & models

- How can sensor data be interpreted and intelligently mined?
 - Sensor data from the motion capture system are modeled with data mining methods.
- How can existing media such as TV, be extended by ambient media?
 - Existing media can be used for visualization of the interpreted health states.

Targeted activities and health problems for detection

The research is comparing the specific and the more general approach to recognition of health problems. It classifies walking patterns into five different health states; one healthy and four unhealthy. All the health problems we are recognizing were suggested by the collaborating medical expert on the basis of occurrence in the elderly aged over 65, the medical significance and the feasibility of their recognition from movements.

The following four health problems were chosen as the most appropriate [4]:

- Parkinson's disease,
- Hemiplegia,
- Pain in the leg and
- Pain in the back.

Classification was done using:

- 1) Medically defined attributes and SVM classifier and
- 2) the k-nearest neighbor machine learning algorithm and dynamic time warping for the similarity measure.

Features for data mining

The recordings consisted of the position coordinates for the 12 tags worn on the shoulders, the elbows, the wrists, the hips, the knees and the ankles, sampled with 10 Hz. The tag coordinates were acquired with a Smart IR motion-capture system with a 0.5-mm standard deviation of noise. From the motion capture system we get position of each tag in x-y-z coordinates.

In the first (specific) approach using medically defined attributes attributes, such as average angle of the right elbow, the quotient between the maximum angle of the left knee and the maximum angle of the right knee and difference between the maximum and minimum height of the left shoulder, were defined with help of a medical expert.

We compared the specific approach with the general approach where movements were represented with more general attributes. The advantage of latter approach is that we can add some new health state(s) to be recognized using the same algorithm and attributes.

Considering the abovementioned, in the general approach we designed attributes as the angles between adjacent body parts:

- left and right shoulder angles with respect to the upper torso at the time t
- left and right hip angles with respect to the lower torso
- the angle between the lower and upper torso
- left and right elbow angles, left and right knee angles.

Dynamic Time Warping

We will present dynamic time warping (DTW) as a robust technique to measure the "distance" between two time series [7]. Dynamic Time Warping aligns two time series in the way some distance measure is minimized (usually Euclidean distance is used). Optimal alignment (minimum distance warp path) is obtained by allowing assignment of multiple successive values of one time series to a single value of the other time series and therefore DTW can also be calculated on time series of different lengths.

The DTW algorithm commonly described in the literature is suitable to align one-dimensional time series. This work employed a modification of the DTW which makes it suitable for multidimensional classification.

First, each time point of the captured time series consisting of the positions of the 12 tags coming out of motion

capture system is transformed into angle attribute space, as defined in this paper. The classification will then be performed in the transformed space.

To align an input recording with a template recording (on which the classifier was trained), we first have to compute the matrix of local distances, $d(i, j)$, in which each element (i, j) represents the local distance between the i -th time point of the template and the input at the time j . Let C_{js} be a generic feature vector element relative to a template recording, and Q_{is} be the feature vector element relative to a new input recording to recognize, where $1 \leq s \leq N$ is the considered feature.

For the definition of the local distance the Euclidean distance was used, defined as follows:

$$d_{Euc} = \sum_{s=1}^N (C_{js} - Q_{is})$$

Given the matrix of local distances a matrix of global distances D is built. The value of the minimum global distance for the complete alignment of DTW procedure, i.e. the final algorithm output, is found in the last column and row, $D(T_r, T_r)$. The optimal alignment can also be efficiently found by back tracing through the matrix: the alignment path starts from $D(T_r, T_r)$, then it proceeds, at each step, by selecting the cell which contains the minimum cumulative distance, between those cells consented by the alignment path constraints, until $D(1, 1)$ is reached.

Usability

Considering the usability perspective, it is very important to obtain an explanation for the interpreted health state. Thus we developed a control-panel prototype, which is intended to be used by physicians (shown in Figure 1).

When a health problem is recognized, the red alarm button appears in the upper-left-hand corner of the screen with a description of the recognized case for the relatives and for the medical center with the control panel.

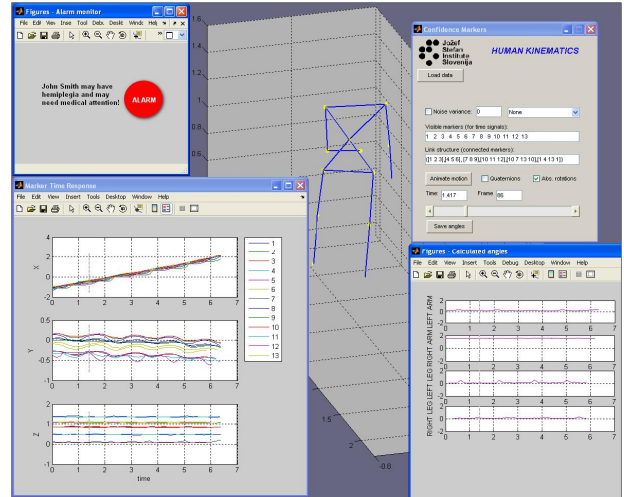


Figure 1: Explanation of automatic interpretation for the physician

RESULTS

In the first (specific) approach, for each recording attributes were calculated and SVM classifier was used to classify them into five health states.

In the second (general) approach, the DTW algorithm was used to stretch and compress an input time series in order to minimize a suitably-chosen distance measure from a given template. We used a nearest neighbor classifier based on this distance measure to design the algorithm as a health state classifier.

The classification process is considering one input time series, comparing it with the whole set of templates, computing the minimum global distance for each alignment and assuming that the input recording is in the same class of the template with which the alignment gives the smallest minimum global distance (analogous to instance-based learning).

The 10-fold cross-validation for 5-nearest neighbor classifier resulted in classification accuracy of 97.9% and 97.6% for the specific and the general approach, respectively. Thus, the performance of both approaches is similar.

More detailed results are off the scope of this paper; however we will just mention them in few sentences. They show that in both proposed approaches false positives/negatives are very rare, i.e., they would not cause much unnecessary ambulance costs. Since the method accurately classified most true health problems, it represents high confidence and safety for the potential use in elderly care.

CONCLUSION

We presented an application of semantic ambient media system for health-care monitoring. It allows prolonging of

the independent living of elderly in their own homes. The study illustrates two ambient intelligence approaches to the elderly care, both in the sense of four-topic concept of the semantic ambient media. Both approaches classify movement of elderly person into five health states; one healthy and four unhealthy. Even though the second approach is more general and can be used also to classify other types of activities or health problems, it still achieves high classification accuracies, similar to the more specific approach.

The system is example of the semantic ambient media for AAL because it is embedded in the natural environment of elderly, it uses artificial-intelligence algorithms to interpret the health status and provides natural explanation of the hypothesis.

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