A Mobile Proposal for Frailty Monitoring by Rehabilitation and Physical Daily Activity

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Abstract—Frailty refers to a condition in which elderly people have medical and social problems, determining the index of vulnerability. This process begins by presenting a reduction in the ability to care for oneself. It is caused by characteristics like shrinking, weakness, poor endurance, slowness or low activity levels. In this work we present a proposal for frailty monitoring through the control of rehabilitation and daily activities. After the frailty index diagnosis, elderly people are continuously monitoring by using a mobile phone-accelerometer enabled. Only, carrying this device all day, it is possible to control daily activities, recommending rehabilitation exercises and checking whether there could be a risk according to the frailty index.

Keywords—Frailty, Accelerometer, Rehabilitation, Physical Activity Recognition.

I. INTRODUCTION

Frailty is the result of decreased physiological reserves in the elderly. It produces an erosion of these physiological systems, causing an increased health risks measured in terms of mortality, morbidity and institutionalization. Regarding mobility, we consider risks of falls and, due the lower bone mineral density, bone fractures. Frailty is a difficult term to conceptualize, and in most cases it is related to ageing, disability and co-morbidity [1]. Different symptoms and signs make up the phenotype of frailty proposed in [2] to determine the clinical syndrome of frailty. The phenotype has multiple factors related to physical activity, such as abnormal gait, balance, speed reduction, inactivity and weakness among others. The measurement and assessment of the state of fragility of an adult person is at the discretion of the physician itself, through previous observations and existing questionnaires. The implementation or not the ADL/IADL (activities of daily living and instrumental activities of daily living) is a turning point and one of the main indicators that mark the beginning of a possible person deterioration, becoming frail.

In this work we present a proposal for diagnosis and monitoring frailty by using accelerometers embedded into the mobile phone. Thus, it is possible to analyze the movement of the person and establish the state of physical frailty combined with existing medical tests. An example of this is gait analysis. The gait of an elderly person changes over time. Our mobile system can detect this trend and obtain an assessment and valid recommendations for the geriatrician. After that, our system is ready to monitoring the calculated frailty index through rehabilitation by means of supervised exercises and daily activities at home.

II. RELATED WORKS

There are many approaches of the integration of accelerometer sensors for movement recognition. In this sense, Hong [3] presents a method for activity recognition of daily life through accelerometers, RFID tagging objects and RFID sensors. Lester [4], has developed a system for recognition of 8 different physical activities, evaluated in 12 elderly satisfactorily. This system is based on independent accelerometers, but the development of integrated system in a mobile phone is considered. In [5] is proposed the use of smartphones to monitor physical activity levels and gait of the older people in their homes or at retirement homes. Finally, several works [6,7,8,9,10,11] study the accuracy of the accelerometer-based physical rehabilitation monitoring such as limb’s motion, gait analysis before strokes, and other illness or accidents that cause malfunction in the physical condition of a patient.

III. PROPOSAL FOR DIAGNOSIS AND MONITORING

We intend to model, design and develop the architecture capable of offering a geriatric support. It determines, in an objective way, the physical state of pre-frailty or fragility of an elderly people, from quantifiable values of different physical components used to determine the frailty syndrome [12]: mobility, balance, endurance and physical activity. We provide
analysis, monitoring and individualized treatment based on the results produced by the architecture through mobile devices.

Once we have discovered the frailty index in a set of elderly people we are ready to monitor the elderly at home. Only by carrying the mobile phone is it possible to recognize the daily activity and check whether there could be a risk according to the frailty index. Some advice by voice can be presented to prevent risk activities. Also, some exercises to firm up the mentioned index are allowed. Finally, the mobile phone continuously evaluates the index and modifies it if necessary.

Frailty Diagnosis
In order to know the accelerometer’s behavior we put into practice an experiment in an elderly people’s residence. During the experiment, some walking exercises were studied.

Figure 2 shows several iterations of each exercise performance. Each one allows us to obtain increasingly accurate information about the gait. After several iterations we perceive a gait disturbance, which we can see at a glance in iteration T+i+1. Finally, iteration T+i+j+1 reveals the high degree of gait disturbance that happens from the beginning of the exercise. Oscillations and the gradual loss of the sense of balance with the need for more time to perform the exercise of full motion are detected. In this case, it could give an indication of the presence of symptoms that are related to Parkinson’s disease. The interpretation of each iteration result is shown in the mobile device and detailed in an audio visual way.

Figure 3 shows different data from the accelerometer regarding to sit down and stand up from a chair and few meters slow walk. We have made these exercises for different elderly
patientss. Their gait is completely different because of the physical condition they have. For this, we must take into account aspects such as speed and trajectory, time and distance, balance and coordination, turning behavior, individual leg movements, etc. In addition, some diseases are important in terms of frailty. Osteoarthritis and leg fractures, inflammatory arthritis, Parkinson’s, peripheral neuropathy, congestive heart failure (CHF), coronary artery disease, peripheral vascular disease, chronic obstructive pulmonary disease (COPD), restrictive lung disease, blindness, severe systemic disease, diabetes, etc. are some of them.

From the medical point of view, the elderly frailty state is based on scales of assessment. In our case, we are interested in those containing scores for the physical aspects, the most important are the Barthel index [13] and Tinetti scale [14]. Both are based on scores given by geriatricians on different skills.

For the moment a study of people without frailty symptoms is needed. With these patterns we can study the accelerometer output thoroughly. After that, and taking into account the patient record and the experience of geriatricians, we intend to solve our proposal by determining the frailty index for each case.

A. Frailty Monitoring at Home

With the knowledge of the frailty index we intend to monitor elderly people daily at home. There are three important features in this environment: prevention, rehabilitation and continuous revision of the frailty index. In addition, features such as fall detection can be considered. For prevention, when the physical activity is approaching the allowed index range, the elderly will be informed. For that, we have to determine the hysteresis margin that is crucial for monitoring each physical activity. According to the rehabilitation feature, we propose particularized exercises to strengthen the physical condition of elderly people. Finally, a continuous frailty index checking is proposed. Through this, and under physician supervision, the index level could be guaranteed. Therefore, daily life without domestic accidents can be achieved.

1) Prevention

At this point it is important to consider the study of daily physical activities at home. In this sense a classification can be seen in Table 1. In it, activities of daily living (ADL) and instrumental activities of daily living (IADL) are included. Through these activities, elderly after 65 years old can be check in terms of frailty. The Bartel test, mentioned before, is used to measure dependence level on the performance of ADL and IADL. In the case of Tinetty test, assessment gait and balance is proposed. However, the result of this and other scales is quite subjective, and the score obtained, which determines the elderly physical condition, depends on geriatrician viewpoint. To avoid it, in [15] a combination of gait analysis and clinical factor, in order to support the decision frailty index, is proposed.

After these premises, we consider evaluating the most important physical daily activity: the walking movement. Also, other movements such as standing, sitting, lying or doing homework. In this sense, it will be important some aspects for prevention when the effort of the movement is abnormal.

<table>
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<tr>
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<th>EXAMPLES OF ADL AND IADL</th>
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<tr>
<td><strong>ADL</strong></td>
<td>Hygiene (bathing, grooming, shaving and oral care)</td>
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<tr>
<td></td>
<td>Continence</td>
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<tr>
<td></td>
<td>Dressing</td>
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<tr>
<td></td>
<td>Eating (the ability to feed oneself)</td>
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<tr>
<td></td>
<td>Toileting (the ability to use a restroom)</td>
</tr>
<tr>
<td></td>
<td>Transferring (actions such as going from a seated to standing position and getting in and out of bed)</td>
</tr>
<tr>
<td><strong>IADL</strong></td>
<td>Finding and using resources (looking up phone numbers, using a phone, …)</td>
</tr>
<tr>
<td></td>
<td>Preparing meals (opening containers, using kitchen equipment)</td>
</tr>
<tr>
<td></td>
<td>Shopping (getting to stores and buying like food or clothing)</td>
</tr>
<tr>
<td></td>
<td>Doing housework</td>
</tr>
<tr>
<td></td>
<td>Managing medication oneself</td>
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2) Rehabilitation control

In previous work we determine a set of rehabilitation exercises defining the following characteristics for them [16]:

- Start and end at the same point and always starts at the same point approximately.
- Slow motion because of the rehabilitation.

Additionally, an exercise can be classified in four types:

- Correct exercise: The patient performs the exercise according to the pattern generated in the training process and imposed by the specialist.
- Wrong exercise: The patient performs the exercise according to the time limits but it was not the expected exercise according to the stored pattern.
- Exercise exceeds the maximum time: The patient performs an exercise but out of the maximum time allowed.
- Exercise does not exceed the minimum time: The patient completes an exercise but does not exceed the minimum time imposed by the specialist.

Once we have selected characteristics and type of exercises it is important to tackle other aspects like data filtering, pattern recognition, segmentation and rehabilitation steps.

It is necessary to use a filter because accelerometer data is noise and redundant. Consequently, we have chosen the following smoothing function for each axis (Equation 1):

$$S(A_t) = \begin{cases} \hat{A}_t, & \text{if } t = 0 \\ A_t * \alpha + S(A_{(t-1)}) * (1.0 - \alpha), & \text{if } 0 < t \leq T \end{cases}$$

S(At) is the filtered acceleration vector output and At is the acceleration raw vector output, which is acquired by the interaction device at time t. Besides α is a smoothing factor in
the range from 0 to 1. The $\alpha$ factor is critical for acquiring valid data to be analyzed in the pattern recognition process.

We have put in practice several experiments by selecting the correspondent $\alpha$ factor in different kinds of exercises. Figure 4 shows some examples of signal charts obtained by accelerometer.

![Figure 4](image)

**Figure 4.** Exercises with different smoothing factors.

Regarding to the pattern recognition, we have applied the dynamic time warping (DTW) algorithm. The reason is simple, requires a simple training and its efficiency has been proved in many approaches [17, 18,19]. This algorithm computes the distance between two exercises $A$ and $B$ by finding the minimum path that will be represented with a numerical value. For that, we use the averaged Euclidean distance by defining the cost between two different points $Ai$ and $Bj$ from the rehabilitation exercise.

Finally, rehabilitation steps have to be addressed. In our proposal there are three modules: capture, training and personal rehabilitation. See figure 5.

In the capture phase, the specialist has to fix a set the movement’s minimum time, the accelerometer frequency, the movement’s name and the smoothing factor.

In the training phase, and by means of the storage of the exercise in the mobile database, it is time to training. DTW algorithm recognizes movements by the specialist supervision.

Finally, in the rehabilitation phase, the mobile device captures all movements showing different outputs depending if the exercise is correctly performed.

**IV. CONCLUSIONS AND FUTURE WORKS**

In this work we have presented a proposal for diagnosis and monitoring of frailty. Through the accelerometer embedded into the mobile devices, it is possible to control the frailty index, first, for diagnosis and, second, for monitoring by the control of daily activities and rehabilitation exercises. All above mentioned, without any explicit user interaction because the only requirement is that user have to carry the mobile device all day. This aspect is very important for elderly people due to the unknown of using technologies.

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