Mobile activity scanning for medical prevention and care

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Abstract

Preventive measurements are reducing costs of healthcare. The number of applications for Telemetric Personal Health Monitoring systems and body area networks are increasing rapidly. Today these systems are measuring physiological parameters like blood pressure, hard frequency, oxygen saturation and other values.

This paper presents results of a mobile activity scanner to quantize movement for medical applications. The hardware analyses 200 acceleration data per second and an algorithm is scanning the minimums and maximums for step counting. The system is able to differ between walking modes like walking slowly, walking normal, walking fast, waking stairs, running, running stairs and jogging.

Introduction

Preventive measurements are reducing costs of healthcare [1] without lowering the quality of care. Various exercises can help to protect people from many cardiovascular diseases. This paper evaluates technical systems for suitability concerning the acquisition of motion data to compare expected values of prevention programs with reality.

Methods and Materials

Different motion types can be classified by different criteria. One approach is to find out the energy consumption and to allocate it with specific types of kinetic sequences of moving. Another method is to measure acceleration of different body areas and to compare this information with known patterns [2].

A system for classification and measurement of kinetic sequences of moving like walking uphill or downhill and running uphill or downhill was developed by the Heinz Nixdorf - Lehrstuhl für Medizinische Elektronik. Therefore a mobile accelerometer (two dimensions) was developed and combined with an altimeter and heart rate sensor.

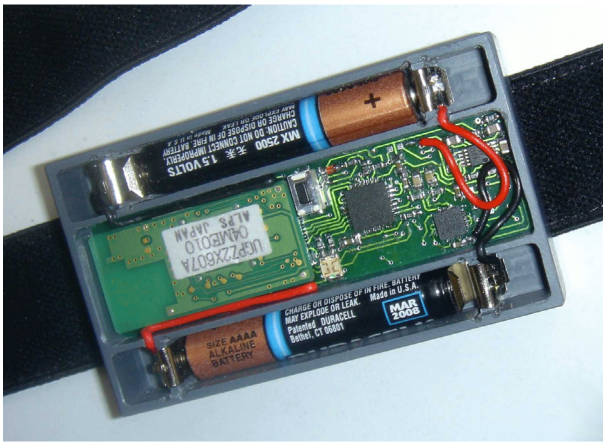

Figure 1: Chest-belt-sensor measuring accelerations, air-pressure and the heart frequency by ECG. Sampling Rate 200, resolution 16 bit, rage -10g to 10g

This paper is discussing acceleration values while walking. Other parameters measured, are unaccounted for the results.
For covering a wide range of different types of walking, a suitable test run has been designed.
Therefore the candidates had to go up and down stairs at different speeds, to pass positive and negative slopes and to move on a flat extent. In order to eliminate personal influence, the candidates had been selected with different size, weight, age , body mass index (BMI) and sex.

Table 1 shows a survey of the test candidates.

	Age	Sex	Weight	Size	BMI
Candidate 1	23	m	70kg	1.90m	19,4
Candidate 2	25	m	72kg	1.81m	22,0
Candidate 3	28	f	65kg	1.68m	22,3
Candidate 4	27	m	115kg	1.88m	32,5

Figure 2 shows candidates walking on slope two times uphill and two times downhill. Subsequent the results

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will be evaluated. First the differences respectively the properties shared of the test personnel will be considered.

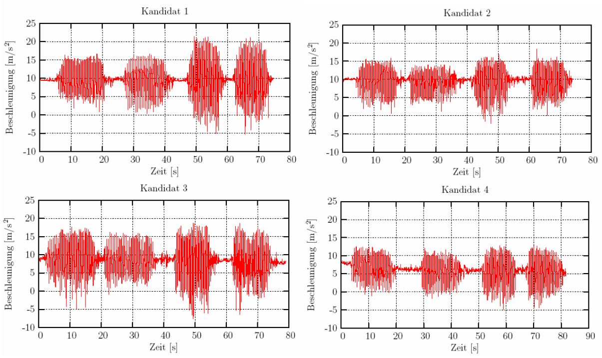

Figure 2: Vertical acceleration for candidates 1, 2, 3 and 4 while walking on slope

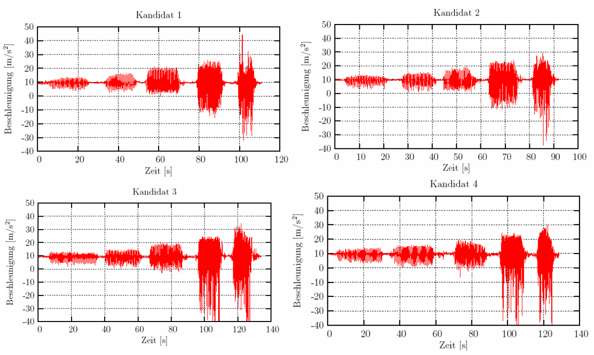

Figure 3: Vertical acceleration for candidates 1, 2, 3 and 4 while walking

Figure 3 shows the acceleration when walking on a horizontal range. The velocity has been augmented from slow, via normal to swift walking followed immediately by jogging and finally by sprinting of the candidate. A short break of some seconds between the different speeds had been applied, to recognize the transition between the 5 modes more evidently. It points out clearly, that augmenting speed brings up the amplitude of the vertical acceleration. It varies only slightly with the persons, nevertheless at higher velocities the deviations will increase. We deduct from this, that the amplitude of acceleration within certain limits might be a measurement for the speed of walking, i.e. the length of step. Empirical investigation resulted in the (quadruple) root of the amplitude of the vertical acceleration, measured at the hip, to be almost proportional to the succeeded distance [3].

The basic structure of the pedometer is a minimum - maximum recognition. Therefore an algorithm has been developed which selects from the maxima via several criteria those caused by walking and not just by disturbance. In order to achieve best possible accuracy of hits, the cycle of acceleration will be used. Subsequently the algorithm will be described: First the average value will be drawn from three relevant measured values. Then, based on the last three measured data a check on the maximums and minimums will be performed.

This kind of recognition for minima and maxima results in the fact that for each maximum exactly one minimum will be detected. When the difference between a minimum and a neighboring maximum or a maximum towards a neighboring minimum be less than a certain threshold value, the minimum and the maximum, that differ only slightly will be filtered off. This is necessary to eliminate disturbances and noise. The threshold value allows adjusting the sensitivity of interference suppression. The last ten minimum - maximum twin values that have been detected via these criteria will be kept available in the store of the microcontroller, for further detection. The proper detection is using different and variable threshold values, to make the decision whether a detected maximum is valid and therefore matches a pace or not. The first threshold value will be calculated from the figure of the last 10 minimums and maximums as follows:

$$thre_{\text{dyn,i}} = 10 + 0{,}125\max \cdot \left. \sum_{k=i-9}^{k=i} \frac{\max_k - \min_k}{2} \right| \qquad (3)$$

When the respective maximum is surpassing the threshold value resulting from the last ten minimum and maximum, the value will be examined whether it is this bigger than the preceding threshold value and the subsequent minimum. This threshold value will be dynamically created from the history of the minimum and maximum and consequently is adapting to changes in the amplitude of the vertical acceleration. Figure 4 illustrates the above introduced criteria graphically.

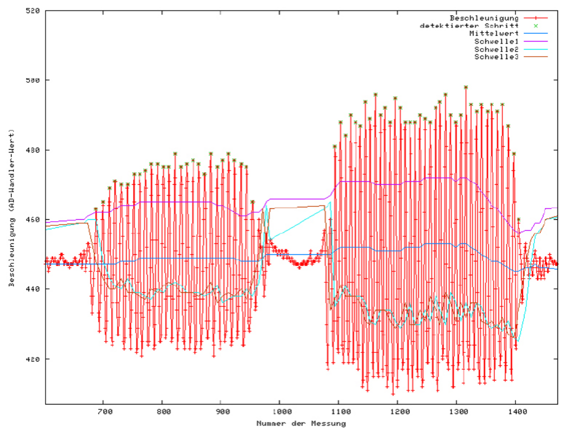

Figure 4: Vertical acceleration for while walking and Thresholds for the minimum – maximum detection

You will recognize the average of the last ten minimum and maximum and the three dynamical threshold values. A pointer in the maximum means that this has been evaluated as a valid maximum, which has been caused by a step.

Besides this absolute threshold value the maximum will also be examined for temporal criteria. In order to count the steps only at steady walking, a valid max has

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to lie within a certain time window after the last step. A permissible deviation of ± 25% from the time of a step has proven to be suitable. Besides this sophisticated criterion there are others of trivial nature. For instance the time between two steps may not fall below 250 ms and not exceed 800 ms. This covers the range from slow walking to speedy jogging. The calculation of the amplitude of acceleration points out to be easy to implement on a microcontroller. The values of the maximum will only be reduced from that of the minimum and an average determination performed to suppress disturbances.

Results

Movement patterns in different gaits (walking conditions) were measured and evaluated with a mobile chest belt. 150 data sequences were acquired.

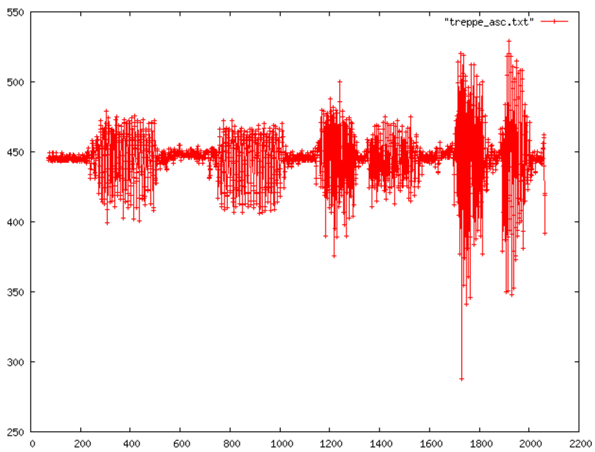

Figure 5: Vertical acceleration for different walking conditions. (Walking slowly upstairs; walking slowly upstairs; walking slowly downstairs; walking slowly downstairs; running downstairs; running downstairs)

The sensors are measuring altitude with a resolution of 0.3 meter and acceleration in two dimensions. It was possible to find a match of patterns for different combinations of sensors. Three sensor configurations were tested. Table 2 shows the results of the pattern recognition.

Table 2: Results of the pattern recognition.

Item	Accele-ration	Accele-ration/ pressure	Acceleration/ Pressure/Puls
Steps up	No	Yes	Yes
Steps down	No	Yes	Yes
walking	Yes	Yes	Yes
Running	Yes	Yes	Yes
Uphill	Yes	Yes	Yes
Downhill	Yes	Yes	Yes

An accelerometer (two dimensions / 100Hz) was able to detect the difference between walking a hill down- or upwards but was not able to make a difference between walking steps down- or uphill.

The sensors were implemented into the telemetric personal health monitoring System [4] to obtain an easy handling and to get values compared with heard frequency and blood pressure. The combination of a kinematical movement sensor and a heart rate sensor fits in a small box wearable at the chest and held by a rubber belt.

Discussion and Conclusion:

The detection of steps and activity by curve stretching is very fast and enables a full data interpretation with a 5 MIPS microcontroller. In contrast to pattern recognition of the two dimensional acceleration histogram [5] the curve stretching method needs only the vertical acceleration vector. The system is able to evaluate patient activity for prevention programs objectively and in a measurable way. Furthermore, it can be used for medical care applications to monitor long term changes in health status.

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