Algorithm of physical activity detection according to the accelerometer data of implantable pacemaker with rate-adaptive pacing.

A.V. Krechetova, L.S.Komleva, A.N.Tikhomirov
Bauman Moscow State Technical Unirversity, Moscow, Russian Federation

Contact: Krechetovaanna1995@mail.ru

Abstract

The number of implantable pacemakers increases every year. Rate-adaptive pacing improves the quality of life of patients with implantable pacemakers. The accuracy of current algorithms is not sufficient for a productive life of patients. The object of this article is to demonstrate new algorithm of physical activity detection according to the accelerometer data.

Keywords

Rate adaptation, pacemaker, accelerometer.

1. Introduction

There is a trend towards improvement in quality of life in today's world. Rate adaptation allows patients with implantable pacemakers to bring their life as close to normal as possible. Rate responsive pacemakers allow to increase the heart rate, depending on the patient's physical load. Figure 1 illustrates how pacemaker works without rate adaptation. The frequency of the stimulating pulses remains constant during the day with changes of the physical activity intensity. Figure 2 shows the operation of a pacemaker with frequency adaptation, in this case the frequency of the stimulating impulses is adjusted to the change in physical activity.

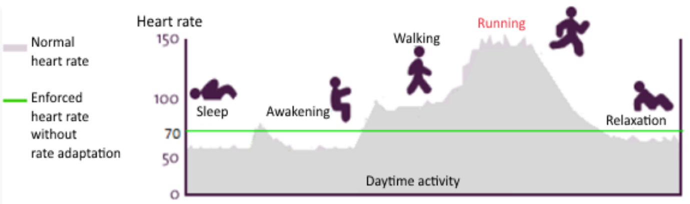

Figure 1 – Enforced heart rate without rate adaptation

Figure 2 – Enforced heart rate with rate adaptation

This article describes the development of algorithm of physical activity detection according to the accelerometer data of implantable pacemaker. Rate adaptation is achieved by using sensors that determine the parameters related to the load and associate them with the frequency of stimulation. Methods of stimulating impulses frequency adaptation depending on various parameters were examined in the article [1]. Incorrect interpretation of passive movements continues to be a disadvantage of the developed algorithms.[2]

2. Methods and materials

2.1 Experiment description

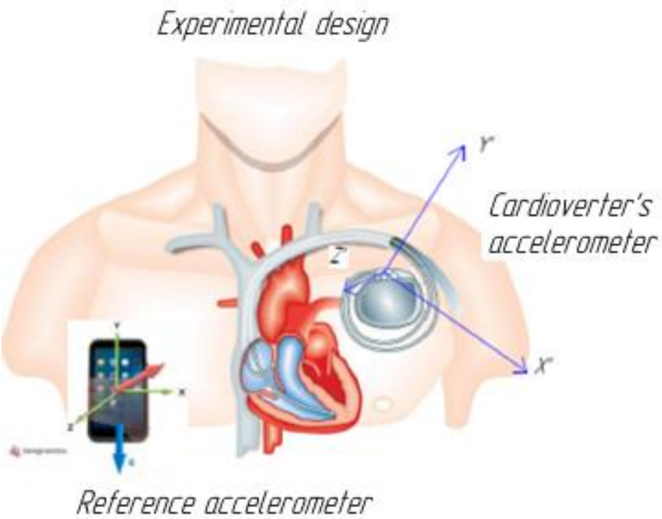

Figure 3 – Experiment setup

The accelerometer sensor was chosen for the experimentation because it directly measures physical activity, unlike other sensors, which measure only the parameters affected by physical activity. The experiment was conducted with the aim of obtaining physical activity data that was used to develop an algorithm.

Two accelerometers were used in the experiment. The first sensor required for accelerometer axes reorientation was fixed on the subject's abdomen so that its axes were directed according to the human body axes. The second sensor, which simulated the accelerometer of implantable pacemaker, was also fixed on the abdomen, but was located at an arbitrary angle in the range of 0 to 90 degrees, the axes of the second accelerometer didn’t coincide with the human body axes. (Figure 3)

Accelerometers of the LIS302DL type built into a mobile phone were used for carrying out the experiment. Basic technical specifications of LIS302DL accelerometer are presented in Table 1.

Table 1

Technical characteristic	Value
Sampling frequency	50 Hz
Supply voltage	2.16 V to 3.6 V
Amplitude range of g	± 2g/± 8g

2.2 Database

A database was created according to the results of the experiment for three motion types: running, walking and stair climbing. The experiment was conducted on eight volunteers. Each database file contains data obtained from the accelerometer (time and acceleration in three axes) and the necessary parameters for the information analysis: the motion type, sex, age, weight and height of the test subject.

2.3 Accelerometer axes reorientation procedure

Axes of the implanted pacemaker accelerometer should coincide with the human body axes in order to implement the algorithm of physical activity detection. Calibration is performed by means of external accelerometer during the implantation. The direction of the vector of gravity has to coincide with the vertical axis of the implantable pacemaker accelerometer. For this purpose three experiments were carried out using the external accelerometer, whose data was taken as a reference.

The following matrix equation is used to convert the data obtained from the accelerometer:

$$A = \begin{bmatrix} X1 & X2 & X3 \\ Y1 & Y2 & Y3 \\ Z1 & Z2 & Z3 \end{bmatrix} \begin{bmatrix} X'1 & X'2 & X'3 \\ Y'1 & Y'2 & Y'3 \\ Z'1 & Z'2 & Z'3 \end{bmatrix}^{-1} \quad [3]$$

Where A - coordinate transformation matrix
X,Y,Z – reference accelerometer data
X’,Y',Z' – pacemaker accelerometer data.

Computing matrix A is calculated once and loaded into the pacemaker.

Each signal from the collected database contains information from both accelerometers. All signals pass primary processing of accelerometer axes reorientation, which is necessary for further application of the algorithm of physical activity detection.

2.4 Algorithm of physical activity detection.

Threshold algorithms are used to detect the physical activity using an accelerometer sensor.

The data processing begins with dividing the signal received from the accelerometer during the experiment into 3-second intervals in order to reduce the delay time. 3-second delay is optimal, because the change in heart rate after exercise is normal within 3 seconds. [4] The threshold value determined by the experimental data for the sensor signals is 0.25g. The quantity of peaks above the threshold value is calculated. Figures 4 and 5 show peak detection signal processing at the 3-second interval.

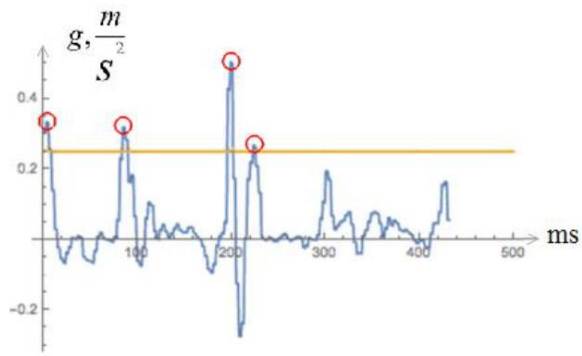

Figure 4 – Quantity of peaks for slow walking motion

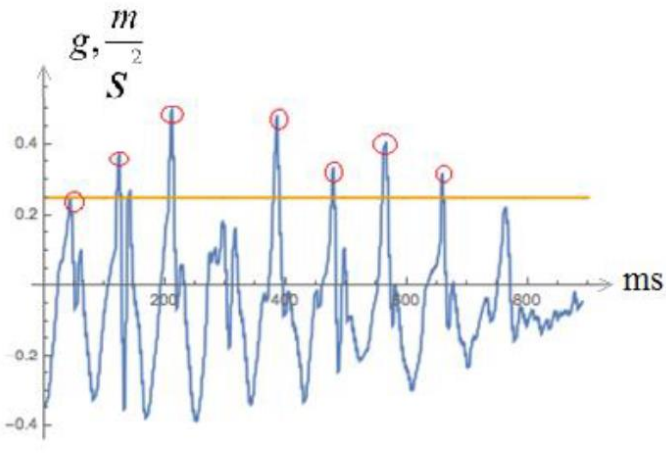

Figure 5 – Quantity of peaks for running motion

The percentage of signal counts over the threshold value to the total number of samples is calculated. This percentage describes the intervals duration above the threshold value and the acceleration increase.

Based on the results of the experiment, a space of attributes was formed for each type of physical activity.

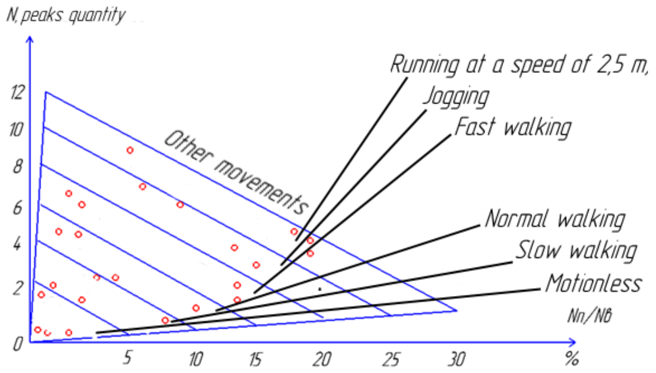

Figure 6 - Diagram of the physical activity detection

The stimulating heart rate is selected in accordance with Table 2.

Table 2 — Dependence of heart rate on physical activity [5]

Motion type	Heart rate, BPM
Slow walking	86
Normal walking	104
Fast walking	122
Jogging	135
Running at a speed of 2,5 m/s	155

3. Results

The space of attributes was formed for each type of physical activity. Another outcome of this work is the generated database. The algorithm of accelerometer axes reorientation was created, that was necessary for application of the physical activity detection algorithm. Algorithm of the physical activity detection was developed.

Table 3. Results of applying the physical activity detection algorithm

Motion type	Total intervals	Intervals recognized	Correctly recognized intervals
Relaxation	4	4	4
Slow walking	4	4	3
Normal walking	4	3	3
Fast walking	4	2	1
Jogging	4	6	4
Running at a speed of 2,5 m/s	4	5	4

The developed algorithm was tested on the collected database.

4. Discussion

As a result of the algorithm application for physical activity detection, 5 out of 24 intervals were determined incorrectly. This may be associated with small difference in the number of peaks above the threshold value for walking fast and jogging motion types. Furthermore, algorithm application errors may be related to the presence of passive movements. At the present time, the possibility is being considered of analyzing the third criterion included into the algorithm with the aim of creating a three-dimensional space of attributes model. It is also planned to add the possibility of recognizing passive movements to the algorithm.

Conclusion

This article describes the development of the physical activity detection algorithm applied with help of accelerometer sensor when using the implantable pacemaker rate adaptation. Preprocessing the data using the algorithm of accelerometer axes reorientation is explained. The features of the experiment for data collection and database formation are described. In the future, it is planned to increase the amount of movements in the database and the number of physical activity detection algorithms.

Reference list

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Any acknowledgements may appear here.