REHABILITATION OF PATIENTS USING ACCELEROMETERS: FIRST EXPERIMENTS

Jakub Parak[1], Lucie Talacková[1], Jan Havlik[1], Lenka Lhotska[2]

[1]Deparment of Circuit Theory, Faculty of Electrical Engineering, CTU in Prague

[2]Deparment of Cybernetics, Faculty of Electrical Engineering, CTU in Prague

Abstract

In this article, the use of accelerometers for rehabilitation of patients is described. The appropriate rehabilitation process is a key approach to treat a broad range of different diagnoses. The main problem of rehabilitation processes is a subsequent evaluation of their quality to achieve best results. This initial study describes a possibility of using accelerometers for objective evaluation of quality and monitoring the results. The first measurements with accelerometers were conducted on several exercises which are part of the Tinetti balance assessment tool. For these measurements, the 3D MEMS accelerometer implemented in the STM32-Primer2 development kit was used. After the assessment of results obtained on healthy persons, the clinical tests on senior patients will follow.

Keywords

accelerometer, rehabilitation, Tinetti balance assessment tool, STM32Primer2

Introduction

The rehabilitation of patients is commonly used therapy after traumas or commas. Moreover the rehabilitation is used for the patients who have various problems with a musculoskeletal system.

The main problem of rehabilitations is an objective evaluation of the quality and progress. It means that today the physiotherapist or doctor evaluates the results of rehabilitation only watching the patient. Every physiotherapist or doctor evaluates the progress and results on his way and there is no objective aspect. It means that two conclusions from two doctors can be totally different.

The other problem is that the patients do not have any feedback from therapy process. It means that the patients cannot monitor the progress independently without physiotherapist or doctor.

The use of accelerometers in the rehabilitation process can improve the evaluation of results and make the rehabilitation process more efficient. Based on measured signals, the quality and progress of rehabilitation therapy can be established. A detailed analysis of using the accelerometers in rehabilitation of patients is described in [1].

The diagnostic method which is used mainly in rehabilitation is called the postugraphy. This method is used for used to quantify the postural control in upright stance in either static or dynamic conditions. The objective evaluation of results of postugraphy method is based on accelerometer data during postugraphy tests [2].

The rehabilitation training of a patient with elbow ligament injury was improved by the supplementary monitoring system. This system is based on the wireless accelerometer network and integrates remote monitoring and intelligent crossplatform terminal [3].

The accelerometers are used for monitoring the rehabilitation training of the hemiplegic patients as well [4].

Another usage of the accelerometer is upper extremity rehabilitation of the children with the cerebral palsy. In this rehabilitation is used feedback from trunk wearable accelerometer during playing the game on the multitouch display [5].

In addition the signal from accelerometers is used for physical activity detection. The personal mobility monitoring is very important for patients with physical disabilities or chronic cardiac diseases. This type of monitoring is a part of rehabilitation process for these patients [6, 7].

Several possible solutions and related works which implements accelerometers in rehabilitation process are presented below.

In this article the application of the accelerometers in diagnostic rehabilitation process is described. This initial study is focused on exercises from Tinetti balance assessment tool enhanced with measurements on the accelerometers. The acquired signals show the possibility of using accelerometers for objective quality and results evaluation in this diagnostic method.

Measurement system

The measurement system consists of two main parts: the development kit with integrated accelerometer and the PC application for data acquisition.

Development kit

The development kit STM32-Primer2 was selected for this project. The kit is product of France Company Raisonance. The kit contains 32-bit microprocessor ARM CORTEX STM32F103BVET with maximal clock frequency 72 MHz. The device uses especially these kit components: LCD display, accelerometer, joystick button and external USB connector.

In the development kit there is integrated three-axial MEMS accelerometer LIS3LV02DL. This inertial sensor has a user selectable full scale of ± 2g, ± 6g and it is capable of measuring acceleration over a bandwidth of 640 Hz for all axes. The device bandwidth may be selected accordingly to the application requirements [8].

The precision and accuracy of the accelerometer in the development kit was analyzed on the several measurements with pendulum and gramophone.

In the firmware application for development kit there was implemented USB HID device driver for accelerometer data transmission. An acceleration sampling frequency was set to 50 Hz.

The development kit is shown in the Figure 1.

PC application

The PC application for data acquisition from development kit is based on USB HID Component for C# [10]. The application allows saving raw data from the development kit into a file in real-time. The Realtime Chart and Graph component is integrated in the application for visualization of receiving data [11].

The application screenshot is shown in the Figure 2.

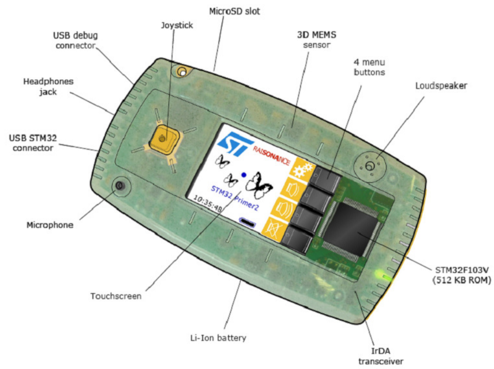

Fig. 1: The STM32-Primer development kit [9].

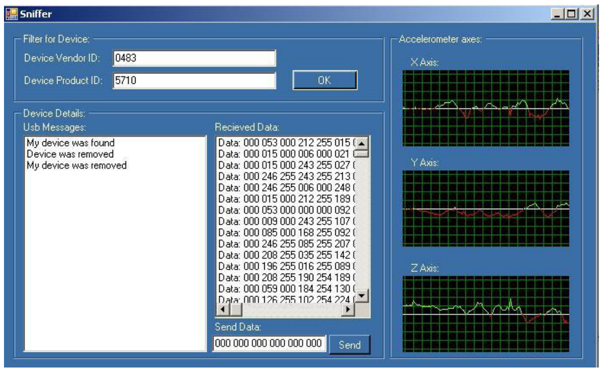

Fig. 2: The screenshot of PC application for data acquisition, logging and visualization.

Signal processing

Signal processing was designed and implemented in Matlab environment.

At the beginning the dynamic acceleration is non linear filtered from raw signal. The signal is decimated to 10 Hz sample frequency firstly. Then the median 10^{th} order filter is applied on the signal. Finally, the signal is interpolated back to 50 Hz sample frequency.

After this filtration the signal contains only the static acceleration. This acceleration is dependent on direction of gravitational acceleration. Further the static acceleration is used for computing tilt of sensor.

The sensor tilt angle in particular axis can be computed by using formula (1). In this formula φ_x is the tilt angle in the axis X, a_x is the actual measured acceleration in X axis depended on tilt angle and g_x is is measured acceleration of gravity in axis X. The analogously same formula can be applied for other two axes. Although the formula is very simple it is not used for determination of the tilt angle.

$$\varphi_x = \arccos \frac{a_x}{g_x} \tag{1}$$

The other way how to calculate sensor tilt angle is to measure the acceleration of gravity in two specific plane of Cartesian system. This method is explained in the Figure 3. For computing the angle in XY plane was used the formula (2). In this formula α is tilt angle in plane XY, a_x is acceleration in X axis and a_y is acceleration in Y axis.

$$\alpha = \arctan \frac{a_y}{a_x} \tag{2}$$

The formula (3) was used for computing the angle in XZ plane (1). In this formula β is tilt angle in plane XZ, a_x is acceleration in X axis and a_y is acceleration in Z axis.

$$\beta = \arctan \frac{a_z}{a_x} \tag{3}$$

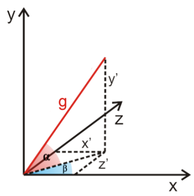

Fig. 3: Representation of x', y' and z' axis after rotation by α and β angles

Experimental measurements

The experimental measurements have been composed of three exercises which are a part of Tinneti balance assessment tool. These exercises are listed in Table 1.

Tab. 1: Selected exercises from Tinneti balance assessment tool [12].

Exercise	Execution of exercise
Rises from chair	Able, uses arms to help Able without use of arms
Standing balance	Unsteady Narrow stance without support
Sitting down	Unsafe (misjudged distance, falls into chair) Uses arms or not a smooth motion

In this first study the exercises are practiced by healthy persons. The measured person tries to simulate health problem during the exercise according to the description in Tinnet's test. The description and the results of the performed measurements are in the next subsections.

Measurement of person who rises from a chair and sits down back

During this experiment the device was set on the side of the tight. The computed tilt angles of the healthy person who rises from a chair and sits down back are displayed in the Figure 4.

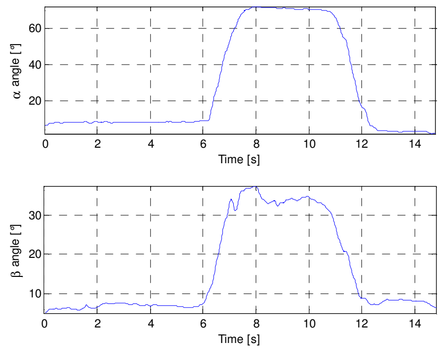

Fig. 4: The computed tilt angles of the healthy person who rises from a chair and sits down.

In the Figure 5 there are displayed the computed tilt angles of measured healthy person who simulates problem with rising from a chair and sitting down. A person stands up with the aid of hands.

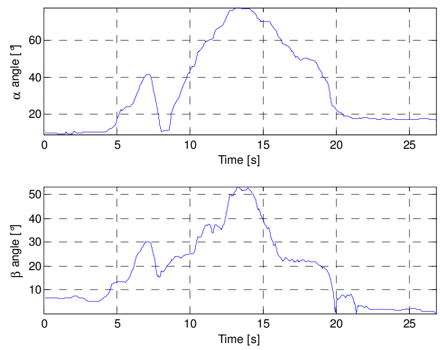

Fig. 5: Tilt angles of simulation problem with rising from chair helping with arms.

The computed tilt angles of the healthy person who simulates trying to stand up without success is shown in the Figure 6.

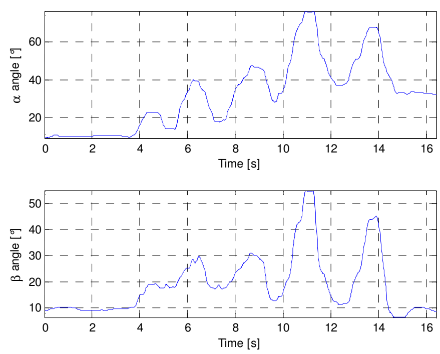

Fig. 6: Tilt angles of simulation problem with rising from chair without final stand up.

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Measurement of person balance with opened and closed eyes.

The sensor was attached on the side of the belt during this measurement. In the Figure 7 there are displayed tilt angles computed during simulation of the balance problems with opened eyes. The simulation of the same problem with closed eyes has similar results.

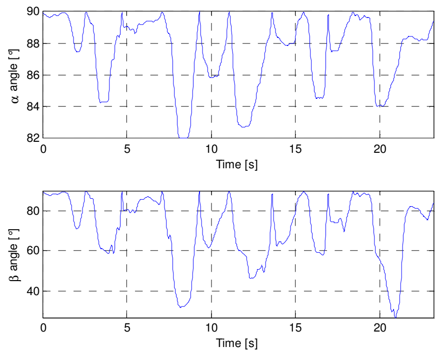

Fig. 7: Tilt angles of simulation balance problems with opened eyes.

Conclusion

The simple measurement system with accelerometer was developed for evaluation of the quality and progress of the rehabilitation. The system can be very easily extended and adapted for other measurements during rehabilitation using the development kit.

Based on experimental measurements applied on exercises from Tinetti balance assessment tool it may be argued that accelerometer can provide suitable information about rehabilitation process.

The proposed method of computing the sensor tilt provides better results than using information only about acceleration in the one specific axis.

The study will be extended with clinical tests on the geriatric department. The exercises from Tinetti assessment tool simulated by healthy people will be measured on real geriatric patients. The data will be acquired periodically during the whole rehabilitation process in order to watch the rehabilitation progress and its quality.

Another parallel research will apply this knowledge in rehabilitation of patients with artificial hip joint

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Ing. Jakub Parak
Department of Circuit Theory
Faculty of Electrical Engineering
Czech Technical University in Prague
Technicka 2, 166 27, Prague, Czech Republic

E-mail: parakjak@fel.cvut.cz
Phone: +420 224 355 86