REHABILITATION USING ACCELEROMETERS: TINNETI BALANCE ASSESSMENT TOOL AND MEASUREMENTS OF PACIENT AFTER HIP REPLACEMENT

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Abstract

In this article, the use of accelerometers for Tinneti balance assessment tool and rehabilitation of patient after hip replacement is described. The appropriate rehabilitation process is a key approach to monitoring different rehabilitations. The main problem of rehabilitation processes is a subsequent evaluation of their quality and observing improvements of patients. This study describes using accelerometers for objective evaluation of quality and monitoring the results. Measurements with accelerometers were used for measurements progress of patient rehabilitation after trauma or for example hip replacement. For these measurements, the 3D MEMS accelerometer implemented in the STM32-Primer2 development kit was used. This study is preparation for development of feedback software for home rehabilitation of patients using accelerometers.

Keywords

accelerometer, rehabilitation, hip joint, Tinneti balance assessment tool, STM32Primer2

Introduction

This article is a continuation of previously published article Rehabilitation of Patients using accelerometers: First experiment [1]. The previous article describes the importance of an objective evaluation of any musculoskeletal rehabilitation. Measurements were focused on Tinneti balance assessment tool. Published measurements were obtained on healthy person who rose from the chair and then sat back down. Then the same person simulates possible difficulties with balance.

This article will be continuing of the study rehabilitation patients using accelerometers. The previous tests were measured on the healthy persons only. The Tinneti balance assessment tool was tested here on seniors. In addition, we focused on the rehabilitation of patients after hip replacement.

Measurement system

The measurement system is the same that was described article [1]. For measuring device was used development kit STM32 Primer 2, which has a built-in 3D MEMS accelerometer [2]. The system communicates with the PC by the USB HID component in C# [3]. Sampling frequency was set to 50 Hz.

Signal processing

Signal processing was designed and implemented in Matlab environment.

In the acceleration signal is necessary to filter out dynamic acceleration using nonlinear filter. Nonlinear filter means perform decimation of the 10 Hz signal, then on the decimated signal applied the 10^{th} order median filter and eventually perform interpolation of filtered signal at 50 Hz sampling rate. Using nonlinear filter, we obtain the static acceleration. We are able to get information about, how was turn accelerometer by static acceleration of all three axes. The angle α is calculated according to equation (1) and the angle β by equation (2).

These relationships were derived according to Fig. 1.

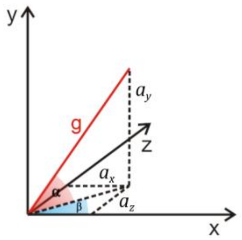


Fig. 1: Representation of x', y' and z' axis after rotation by α and β angles

The Tinneti balance assessment tool

Balance measurements were carried out according the Tinneti assessment tool on three senior people. A case history of seniors is listed in Table 1. Seniors performed only act to stand from a chair and then sit down according to the Tinneti assessment tool [4].

Tab. 1: Case history of seniors

S.	Sex	Age	Case history
1	F	74	healthy musculoskeletal system due to age
2	M	77	1. hip after replacement 16 years ago, 2. hip before replacement
3	F	76	knee replacement half year ago

Seniors have mounted Primer 2 on the side of the thigh. Then they had to get up from a chair, stand still a moment and sit back. Results from rotated accelerometer I entered in charts and visually evaluated.

The first senior (Fig.2) didn't have problem with standing up and sitting down. It was continuous movement without hesitation (α angle). But in standing up swing β angle who represent moving on sides. It could mean unsecure balance in stand.

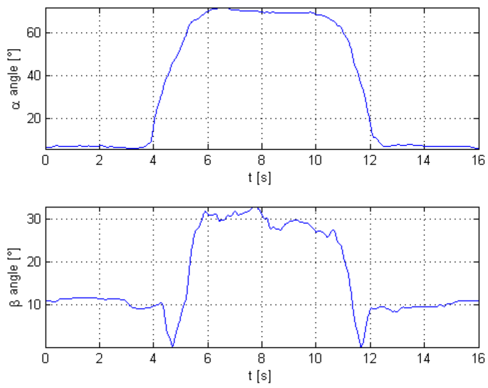


Fig.2: The computed tilt angles of the first senior

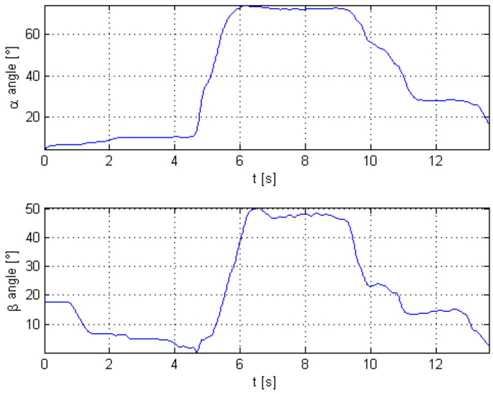


Fig.3: The computed tilt angles of the second senior

The second senior (Fig.3) had good standing up movement, but sitting down was careful. Stand position was certain.

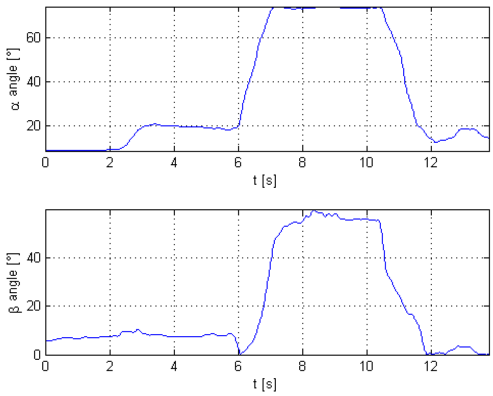


Fig.4: The computed tilt angles of the third senior

The third senior (Fig.4) had on other side little problem with standing up, where standing up was sequent movement. Sitting down was without problems. Stand position was confident.

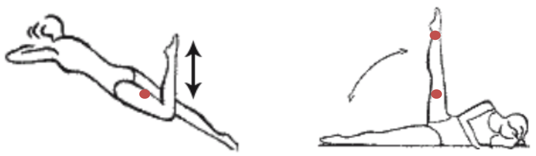
Rehabilitation of patient after hip replacement

Two rehabilitation exercises were measured on patient after hip replacement. His basic case history is listed in Table 2.

Tab. 2: Case history of patient

Sex	Age	Case history
M	77	1. hip after replacement 16 years ago 2. hip after replacement 2 weeks ago

This part is focused on the progress of the patient during rehabilitation, the patient was rehabilitated for three weeks. The first exercise is shown in the Figure 5(a) and the second exercise in the Figure 5(b).



(a) (b)

Fig.5: Two measured exercises for strengthening the gluteal muscle. Red dots indicate the location of the Primer 2 accelerometer.

Exercise in the Figure 5(a) was performed only with the help of rehabilitation specialist. The exercise was measured on sick and on healthy leg too. Measurement of this exercise was carried out twice. Second measurement was performed after seven days rehabilitation. Results are displayed in the Figures 6to 8..

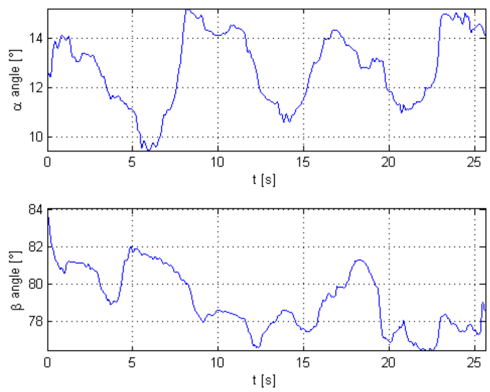


Fig.6: The computed tilt angles of the first exercise on Fig. 5(a) with sick leg

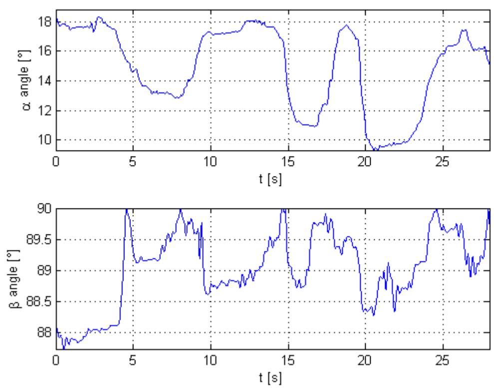


Fig.7: The computed tilt angles of the first exercise on Fig. 5(a) with healthy leg

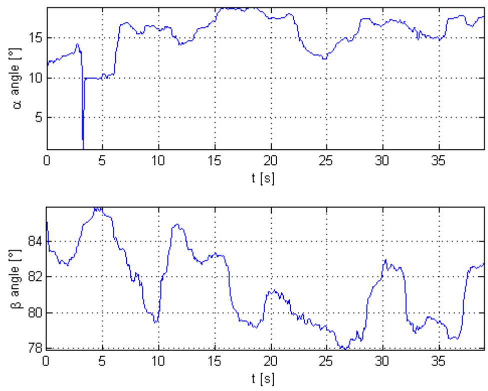


Fig.8: The computed tilt angles of the second exercise on Fig. 5(a) with sick leg after 7 days rehabilitation

Values of measured ranges from the Figures 6 to 8 are shown in the Table 3. The exercise in the Fig. 5(a) was repeated in each measurement three times.

Tab. 3: Range results α angle for exercise on Fig. 5(a)

M.	Leg	1.range[°]	2.range[°]	3.range[°]
1.	sick	5,7	3,57	3,9
1.	healthy	5,18	6,68	8,06
2.	sick	6,87	4,44	4,63

In the Table 3 is result of patient's progress after seven days. The amelioration after seven days rehabilitation is evident. Patient improved range of the movement about 1°.

Exercise in the Figure 5(b) was practiced with a specialist and alone too. The measurement is carried out twice, when second measurement was performed after 11 days rehabilitation. Exercise was measured on sick and healthy leg for comparison. Results are displayed in the Figures 9 to 11.

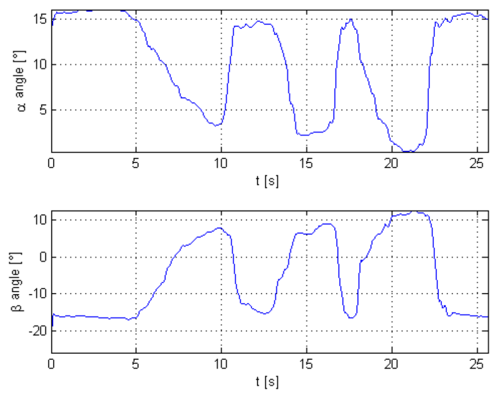


Fig.9: The computed tilt angles of the first exercise on Fig. 5(b) with sick leg

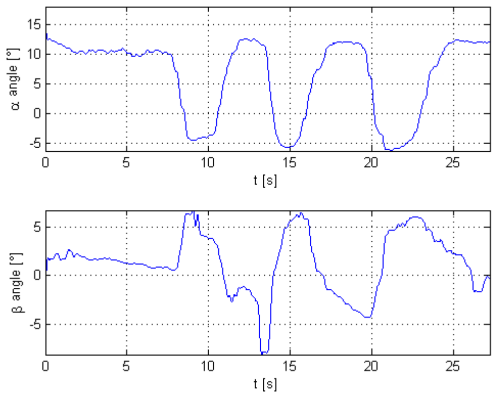


Fig.10: The computed tilt angles of the first exercise on Fig. 5(b) with healthy leg

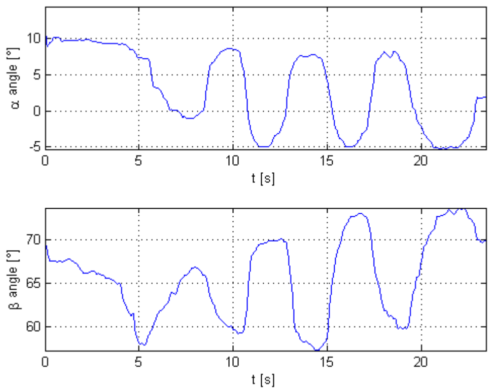


Fig.11: The computed tilt angles of the second exercise on Fig. 5(b) with sick leg after 11 days rehabilitation

Values of measured ranges are shown in the Table 4. Exercise was also repeated in each measuring 3 times, except the second measurement, which was performed 4 times. Graphs are shown for accelerometer placed on the thigh, because in the 2nd measurement on the sick leg slipped Primer 2 from ankle and some data were missing.

Tab. 4: Range results α angle for exercise on Fig. 5(b)

M.	Leg	1.r [°]	2.r [°]	3.r [°]	4.r [°]
1.	sick	12,17	13,37	13,47	--
1.	healthy	14,93	18,19	18,38	--
2.	sick	10,99	13,6	12,79	13,5

In this case amelioration after 11 days may not be evident. But difference between the Figure 9 and 11 is significant. Movements are more continuous and leg persists on top longer without swing. Lifting leg is not so steep, but it is slower.

Summary

Based on these measurements can be argued that the monitoring of rehabilitation process during various types of exercises is important. Patients are motivated to rehabilitate because he can see results of his efforts objectively. For medical personnel could be these results significant for planning of rehabilitation and reproductions of exercises.

The aim of this study is based on measurements featured in this article to create software that will serve patients like feedback when practicing at home. Medical personnel could gain objective information on rehabilitation patients at home. This software will be based on measuring data with rehabilitation specialist exercise. Patient will be exercise home according to figures which was measured with rehabilitation specialist. This software however will need to use wireless accelerometers instead of Primer 2. Accelerometer should be attached by wristband to don't hold down movements.

In the future the more patients will be involved in the study with the physiotherapist cooperation. Then the rigorous statistical analysis of rehabilitation progress will be made as well.

Acknowledgement

This work has been also supported by the research program No. MSM 6840770012 of the Czech Technical University in Prague (sponsored by the Ministry of Education, Youth and Sports of the Czech Republic). SGS

This work has been also supported by the grant No. SGS12/143/OHK3/2T/13 of the Czech Technical University in Prague

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