Monitoring of shoulder joint motion activity

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Abstract

A device for determination of shoulder joint motion activity was designed and built. The device can be used during daily living activities. Programmable desk Arduino was chosen as a basis of the device. The activity of the shoulder joint is captured by an accelerometer and a surface EMG sensor. Data are saved on SD card with 20Hz sampling frequency. The device was experimentally verified. Individual activities are identified by decision tree algorithm.

Keywords: motion capture, Arduino, accelerometer, surface EMG, shoulder joint

1. Introduction

Functional examination of joint mobility is one of the basic examination carried out in orthopedics. The function is measured in a number of different ways, such as through the use of impairment measures, self-report measures, and physical performance measures [1]. All of these methods have unique contributions and dedicated limitations.

Clinical special tests are used to determine the tissue source of pain and are impairment-based assessments. A typical clinical examination is measuring the range of motion (ROM) of joint using goniometers [2]. It is known, that limited ROM, alone or in combination with other factors, can contribute to limited function and ultimately may have consequences for physical functioning. For example, restricted ROM at the hip may lead to a limp during gait.

However, some clinical tests do not demonstrate high levels of sensitivity and/or specificity, thus questioning the validity of use [3],[4]. A clinical examination finding of an impairment does not always correspond to a functional loss. Poor ROM and other commonly used indicators of a limp may be subthreshold for patients whose activity levels are low, thus do not compromise the individual to the point where their expectations are altered [1]. The similar problem could be observed after surgery. Some measurable surgical end-points, even when they suggest success, do not always result in satisfied patients [5].

More accurate estimation of joint movement is based on motion analysis using modern electronic motion capture (MoCap) techniques and motion parameters reflecting the complexity of movement activity. Motion analysis systems, either passive or active, require specific setup, calibration and markers placement on patient. These analyses are time consuming and are carried out mostly in biomechanics laboratories [6]. Clinical application of motion analysis is restricted to certain diagnoses like cerebral palsy in children and is not used in everyday clinical practice.

Wearable motion trackers have been introduced recently. Their accuracy is relatively low and serve to rather estimate the level of activity than to provide quantitative information on ROM and daily range of motions [7].

In addition to objective measurement of joint excurse, the joint function could be evaluated by self-reports. The self-reports with ROM may be combined in clinical score, e.g. Harris Hip Score or Mayo Hip Score [5],[8]. Self-report measures are highly subjective, should be utilized cautiously, and serve only as one component of the assessment of function.

In the orthopaedic day to day clinical life there is a strong need from the physician´s point of view to monitor progress of patient´s recovery after surgical or conservative treatment of major trauma, congenital affections, degenerative or neurogenic diseases, with respect to joint mobility control in particular. The most typical anatomical localities requiring gradual dosing of ROM are elbow, knee, shoulder and hip. The motion pattern recommended to patient in the recovery phase differs from both the type of the injury and the anatomical locality (type of natural joint motion). Therefore, there is a strong clinical need to introduce a tool helping the orthopaedic surgeon to actively control and monitor the resting, rehabilitation and progressive phases of the patient´s recovery.

2. Construction

Our choice of the microcontroller board is Arduino Leonardo, which is one of the cheapest boards and it has a Micro USB port for easy communication with PC, also the board can be powered by this port. There is a possibility of connection an external shield with SD card slot, which is used as data storage during the measuring.

For measuring the motion activity were chosen two sensors – accelerometer ADXL335 (Analog Devices Inc., USA), it is small 18mm x 18mm triple axis MEMS sensor and surface electromyography (SEMG) sensor Muscle sensor v3 (Advancer Technologies, LLC, USA).

The device is powered by from commercially available power bank and the SEMG sensor is powered by two 9V batteries connected in parallel.

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The price of the whole system is around €130 and it is fitted in camera case (150mm x 68mm x 85mm) on subject's belt. The battery life more than 7 days and the data storage can handle over 23 years of measuring.

3. Programming

The device is programmed to measure with sampling frequency of 20Hz. The sampling frequency is chosen with respect to data volumes and Nyquist-Shannon sampling theorem, which says that the sampling frequency has to be at least twice greater than maximal measured frequency to minimize the loss of information. We are interested about movements with harmonic frequencies around 1Hz or 2Hz, thus sampling frequency of 20Hz is sufficient. It also sufficient for SEMG measuring, since muscle activity level is measured.

The system saves data into a .csv file on the SD card and every hour creates a new file to prevent loss of data from whole measuring in the case of error.

4. Verification

Both sensors were verified by commercially available systems, which has stated accuracy of measuring. Inertial MoCap system Xsens (Xsens Technologies B.V., The Netherlands) was used to verify the ADXL335 accelerometer and SEMG system MA300 (Motion Lab Systems, Inc, USA) was used as reference for Muscle v3 sensor.

Exact value verification of EMG can be disputable but our aim was to verify that our cheap SEMG sensor gives us signal associated with a defined muscle activity and not just random signal or noise.

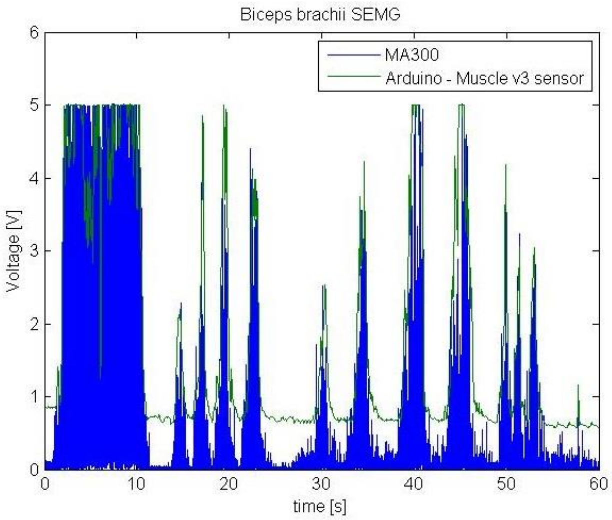

Figure 1. *Data from SEMG verification measuring.*

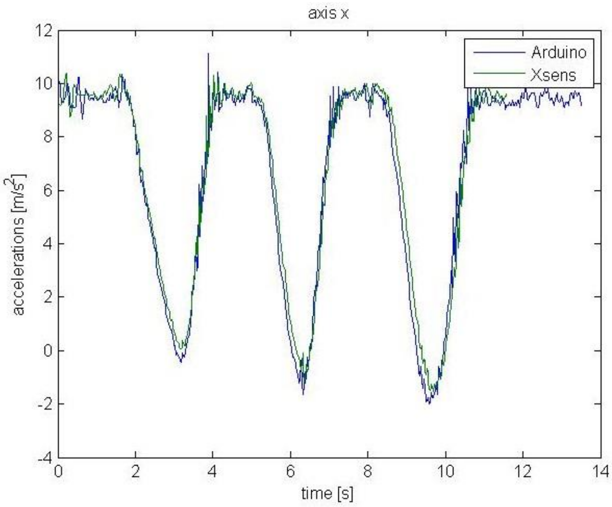

Figure 2. *Data from accelerometer verification measuring – axis x.*

5. Data evaluation

A decision tree algorithm for data evaluating was written in MatLab (The MathWorks, Inc., USA). The data are evaluated by characteristic parameter of each minute of the signal. The parameters are – mean of the acceleration vector magnitude, standard deviation of the acceleration vector magnitude, mean of the SEMG signal, mean of the angle of the acceleration vector magnitude in sagittal plane. To get more parameters, a frequency analysis of the signal by Fast Fourier transform (FFT) has to be done. Then characteristic frequency (frequency with maximal amplitude) and amplitude of this characteristic frequency can be determined.

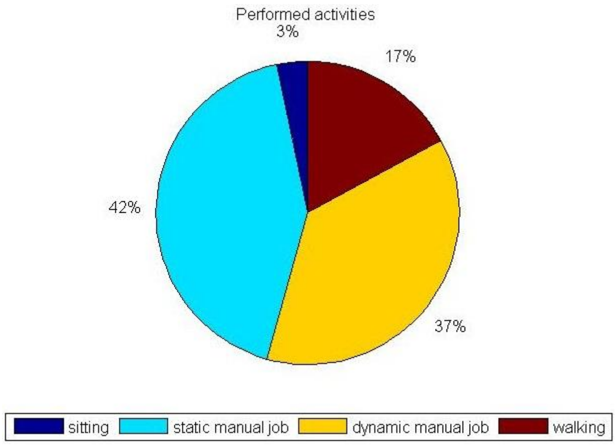

Figure 3. *Performed activities during 4 hours measurement.*

Using these parameters help us to divide the activities groups, such as static or dynamic activities and then rest or manual job or locomotion. The SEMG sensor provide us possibility to tell, if the subject walks or runs with or without load, which is fundamental in relation to joint stress.

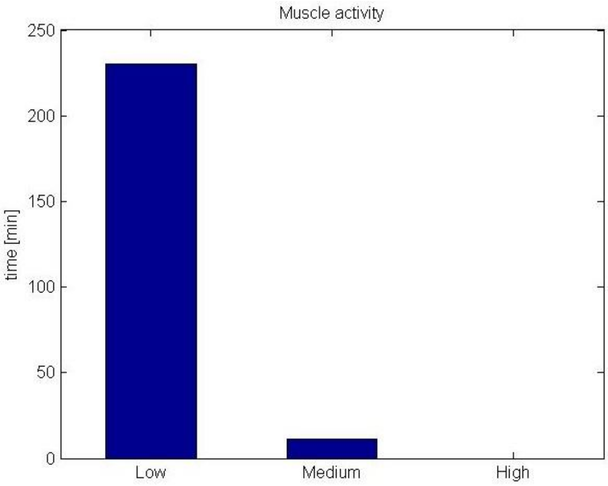

Figure 4. *Muscle activity of deltoid muscle during 4 hours measurement.*

6. Conclusion

A functional device for determination of the shoulder joint motion activity was built. The device is financially viable (around €130) due to its commercially available components. It uses an accelerometer and a surface electromyography sensor for measuring. It does not need any calibration. It can provide more data about the shoulder joint activity compared to wearable sensors for the same price.

The main advantage of the proposed setup is in utilization of the SEMG sensor. This sensor allows to quantitatively estimate the muscle activity and thus to provide more accurate information regarding the function of the musculoskeletal system.

It can be used during a clinical examination as well as for daily use without any distraction.

Acknowledgement

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