Optimization of Motion Analysis System for Using in Daily Living

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Abstract

Understanding the biomechanics of the human body is important for applications in healthcare, sport, and also in daily life. To optimize a rehabilitation or medical surgeries, improve sport results, or improve daily life of regular people, we need to effectively collect data of their movements during their activities and daily living. Effectively means sufficient amount and suitable types of data. For that purpose, we developed various types of wearable sensors. Started with bulky system placed in a case on a belt of a patient. The system used accelerometer attached to a limb and it was connected by wires to the system. Ended with small, lightweight, and affordable system attached directly to the body, what eliminates any distractions. The system consist of 9DOF sensor and can be extended by surface EMG. The battery has enough capacity for long-term monitoring.

Key words: motion analysis, wearable electronics, daily living, long-term monitoring

1. Introduction

In the orthopaedics there is a strong need from the physician´s point of view to monitor progress of patient´s recovery and daily life improvement after surgical or conservative treatment of major trauma, congenital affections, degenerative or neurogenic diseases, with respect to joint mobility control in particular. There are various methods, how to determine a motion activity of a patient, but all of them have their limitations. There are expensive motion labs on one hand, which can only monitor ranges of motion and tell nothing about daily living and wearable sensors, as smart watches or bracelets, on the other hand, that give only basic information about activity or expansive inertial sensors, that are mainly focused on locomotion. For that reason we are developing custom-made device that can be use in any environment and it is usable for monitoring motion activity of upper or lower limb during daily living without any distractions.

2. Construction

2.1. First version

The first version of the device was built in 2015. Brain of the device was microcontroller board 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. This board was equipped with an external shield with SD card slot, which was used as data storage during the measuring. For measuring the motion activity was chosen accelerometer ADXL335 (Analog Devices Inc., USA), it is small 18mm x 18mm triple axis MEMS sensor. The device was powered by from commercially available power bank. This device was bulky and wires leading from the device to the sensor could distract the patient. Price of the whole system was around €100 and it was fitted in camera case (150mm x 68mm x 85mm) on subject’s belt. The battery life was more than 7 days.

2.2. Second version

In 2016 Arduino Leonardo was substituted by Arduino Micro. Micro is smaller and even cheaper than Leonardo. The new board made the device lighter and it fitted better into the case. We also added surface EMG sensor for measuring muscle activity. Price of the second device was little bit higher than price of the first one, that was caused by the SEMG sensor. The price was around €130. Everything else stayed the same.

Figure 1, Second version of the device on a patient.

2.3. Final version

The third and so far final version is more complex and sophisticated than the other versions. The device is based on programmable board with SD card slot for storing data.

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For measuring the motion activity, the board is equipped with 9 DOF inertial sensor consisting of triple axis accelerometer, triple axis gyroscope and triple axis magnetometer. This system can be extended by SEMG sensor. The device is powered by 1000mAh Li-Po battery, which provides sufficient energy for whole day measuring without recharging. The system is in custom printed plastic case with dimensions 44x45x22 mm. The price of the complete system is around €100. There are no wires outside the box and the system is attached directly to a patient's limb.

This version has various usage thanks to its multiple sensors. Magnetometer can be used for direct measuring velocity for example. Using magnets placed defined distance from each other, we can estimate the velocity as time elapsed between each peak on the magnetometer as shown in Figure 2. Since the distances between the magnets are known and they are 1m and time elapsed between the first and the second one is 1,33 s, so the average velocity in the first section is 0,75 m/s.

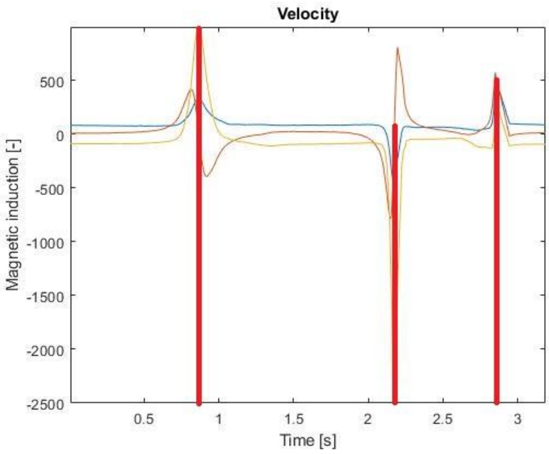

Figure 2, Measuring velocity by a magnetometer.

3. Discussion

The device was upgraded thru the years. Comparing to the first version, it has more sensors and wider usage. It is smaller, lighter and even cheaper. Comparsion of all versions is in Table 1.

Even the final version can be upgraded. It is not possible to measure velocity or estimate location of the patients from measured accelerations. This is caused by positional drift of the sensors. The drift can be eliminated by adding another sensor, which is not effected by the drift, for example GPS sensor. The final version has sufficient capacity for any extension of the device with more sensors.

Table 1. *Comparsion of different versions of the device. Acc – Accelerometer, Gyro – Gyroscope, Mag – Magnetometer, SEMG – Surface EMG*

Version	**Sensors**	**Dimensions [mm]**	**Price [€]**
First	Acc	150x68x85 + wires & sensor	100
Second	Acc, SEMG	150x68x85 + wires & sensor	130
Final	Acc, Gyro, Mag, SEMG	44x45x22	100

4. Conclusion

A device for motion analysis was developed. It was optimize for its purpose and upgraded thru the time. It uses various sensors for better recognition of daily living activities and motions. Thanks to all the sensors, the system has wider usage than its primary purpose. There can be done more upgrades on the final version, especially in the software of the system.

Acknowledgement

The research has been supported by AZV grant No. 15-31269A.

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