UTILIZING OF MEMS SENSORS IN REHABILITATION PROCESS

Ján Karchňák, Dušan Šimšík, Daniel Siman, Marcel More

Department of Automation, control and human-machine interaction, Faculty of Mechanical Engineering, Technical University of Košice

Abstract

The potential for utilizing of MEMS sensors, especially of accelerometers and gyroscopes is significant. They are used not only in consumer's electronics, but also in so called wearable sensors that can be worn on body or in part of garment without interrupting comfort of person who is wearing these sensors. In the same time, we are able to collect data about person carrying the device. This paper focuses on analysis of current state of utilizing of MEMS sensors in rehabilitation process or in motion analysis.

Keywords

MEMS, wearable sensors, motion analysis

INTRODUCTION

The abbreviation MEMS is intended for micro-electro-mechanical systems. Devices that belong into this group of sensors (e.g. accelerometers, gyroscopes, etc.) can be found in various applications, such as airbag sensors in cars, miniature gyroscopes for flying applications, wireless devices, etc. [1]. Dimensions of MEMS devices vary in general from one micrometer to few millimetres [2]. Into the so called "family" of MEMS devices belongs besides of the most known "members" - the accelerometers, gyroscopes and magnetometers, also the microphones, clocks, temperature sensors, pressure sensors and many others. Accelerometers and gyroscopes are commonly used in smartphones, 3D controls, pedometers, wearable sensors, inertial navigation, even in targetable ammunition [1], [4-6]. Typical structure of capacitive MEMS accelerometer is shown on Fig.1.

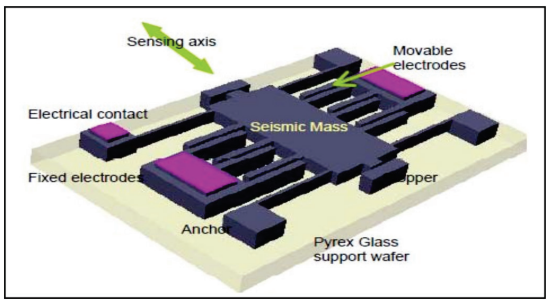

Fig. 1: Typical structure of capacitive MEMS accelerometer [7].

It is trend to integrate as much as possible devices on one chip, so usually most of the MEMS sensors has its own A/D converter and it is no rarity if user can set internal high pass or low pass filters for better reliability and accuracy of measurements. Such sensors (accelerometers, gyros, etc.), as mentioned above, can be found in customers' electronics or in more scientific applications such as motion analysis using wearable sensors [8-9].

CURRENT STATE

European Union assumes that in year 2015 will be mortality rate higher than natality and this trend will continue in the future while the population ageing will appear [10]. Similar course is expected also in USA [11]. According to current possibilities and knowledge about MEMS sensors and of course according to the expected demographical course, many research tasks are aimed on development of intelligent households environments and their elements [12-16] intended for specific groups of population (e.g. elderly or physically disabled persons) for which is necessary to monitor various parameters (e.g. blood pressure, motion, blood sugar). Such monitoring should be conducted in order to improve healthcare. It should be executed remotely without compromising the comfort of the monitored person. Another aspect of such environments is executing preventive actions that will prevent unwanted events, e.g. falls and in case of appearance of such events intelligent

environment will contact the caregivers [11]. Essential elements of such environments are obviously wearable sensors. These sensors can be used for monitoring upper or lower limb parameters and for the further

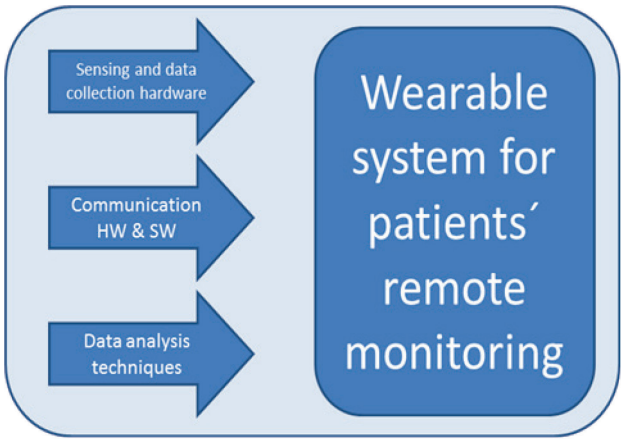

Fig. 2: General structure of wearable sensors [11]

rehabilitation or telemedicine activities, respectively [9,17].

Fig. 2 shows general structure of wearable sensors according to review of wearable sensors and systems with application in rehabilitation [11]. Sensing and data collection hardware provides raw data, e.g. data about motion activities and events (gait, fall). The essential elements of this section are sensors (e.g. accelerometers) and other necessary hardware such as microcontroller; Communication hardware and software conducts data transfer into evaluation unit. According to the effort of remote monitoring such data are mainly transmitted by wireless technologies. Data analysis techniques are summary denotation for techniques of filtration, processing and evaluation of incoming data.

As mentioned above, development in MEMS area is fairly significant. From the view of improving technical parameters the integration of several sensors into one chip is widely used, along with using advanced data processing algorithms and filtration of measured data [9]. Market contains various commercial solutions for motion

Fig. 4: MTw Development Kit [20]

analysis using wearable MEMS sensors, e.g. PAMSys™ from BioSensics (Fig. 3). It is intended for long-term evaluation of physical activity during every day's life, while it is possible to obtain information about position and posture, gait, falls, etc.[19]. Another commercial solution and available tools for similar motion analysis is from Xsens with their MTw Development Kit [20].

There are also many academic projects in this area, e.g. Mercury platform that is intended for long-term data collection [21] or research work from Bruneti et. al [13] that uses wireless communication based on standard IEEE 802.15.4. Very interesting results are from To & Mahfouz [22] who made a comparison of experimental results from motion analysis of the lower limb performed by optical method and MEMS sensors in the same time.

Our previous work has been aimed on development and implementation of wearable devices based on MEMS sensors intended for rehabilitation process. The idea of development was that these devices could be used in case of dangerous states monitoring (e.g. measuring tilt of the shoulder or its acceleration) and in the same time it would be suitable for evaluation of motion parameters of the patient during rehabilitation

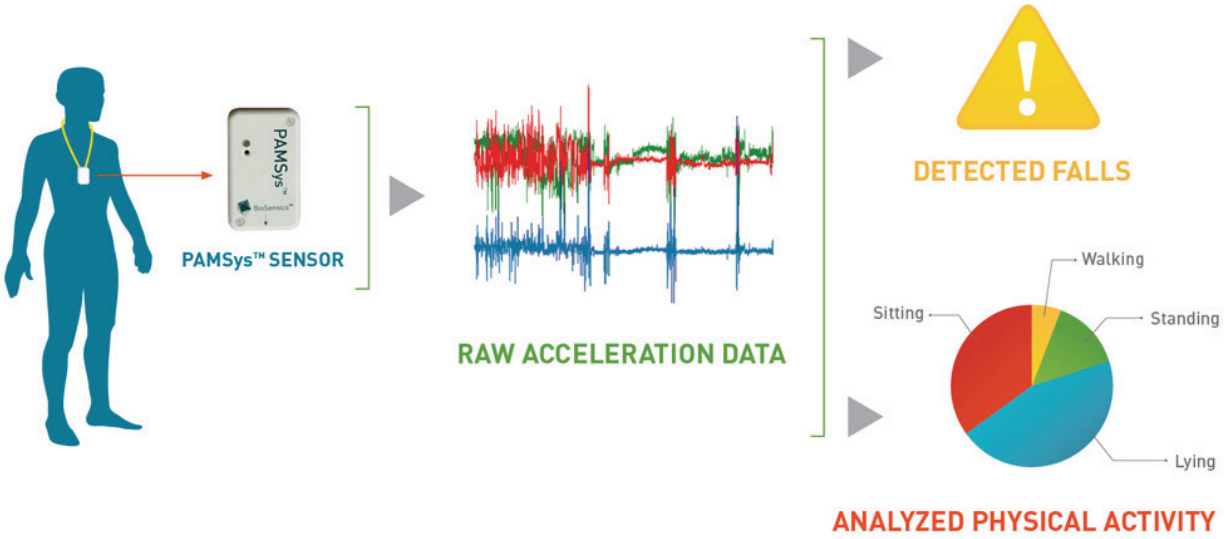

Fig. 3: Structure of PAMSys™ platform [19]

process. Used rehabilitation device is based on pneumatic artificial muscles. For mentioned purposes, a prototype of wearable device has been developed.

DESIGN OF DEVICE

In the designing of the device, we had several requirements for it, such as control system of the

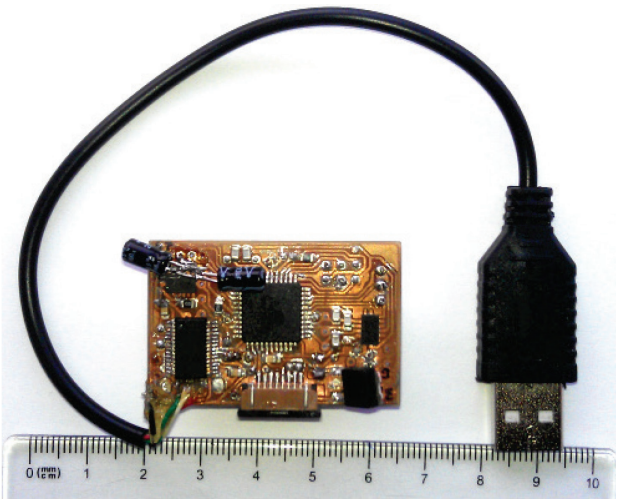

Fig. 5: Prototype of wearable sensor

rehabilitation device must be able to act very quickly and in the way of no harming of the patient if dangerous states are sensed. Of course, rehabilitation device will be mounted with incremental encoders, but it seems to be appropriate to complement its data with data from accelerometer. The reason for this is that accelerometers can provide information about vibrations in the construction of the rehabilitation device. So for the task of quick proper behaving of the device are accelerometers suitable solution. Another requirement to the wearable sensor is the possibility of connecting the sensor into PC and data transfer via USB. In the same time, USB works as a power supply to the sensor board. We decided to use 3 axis accelerometer MMA7431 from FreeScale and gyroscope ITG3200 from Invensense. As a control unit, ATMEGA32L was employed. There is also possibility to send data via UART. The prototype of wearable sensor is shown on Fig. 5. More about this prototype can be found in [25].

CONCLUSION

Wearable sensors are subject to the research and development of many interdisciplinary teams. Those teams are working on creating of suitable elements for intelligent environments that will improve quality of life of the specific group of the population (e.g elderly persons or disabled persons) and thus decrease their dependence from caregivers. The proposed paper is aimed on evaluation of current state-of-the art in the area of wearable sensors and shortly introduces work of authors in the given area.

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Prof. Ing. Dušan Šimšík, Ph.D.
E-mail: dusan.simsik@tuke.sk

Ing. Daniel Siman, Ph.D.
E-mail: daniel.siman@tuke.sk

Ing. Marcel More
E-mail: marcel.more@tuke.sk

Ján Karchňák
E-mail: jan.karchnak@tuke.sk

Department of Automation, control and human-machine interaction
Faculty of Mechanical Engineering
Technical University of Košice
Letná 9, 040 00 Košice
Slovak Republic