Wearable sensors network for activity recognition using inertial sensors

I. Orha

Electric, Electronic and Computer Engineering Department,
Technical University of Cluj-Napoca,
North University Center Baia Mare, Baia Mare, Romania
ioan.orha@cunbm.utcluj.ro

S. Oniga

Electric, Electronic and Computer Engineering Department,
Technical University of Cluj-Napoca,
North University Center Baia Mare, Baia Mare, Romania
onigas@cunbm.utcluj.ro

Abstract—**The aim of this paper is to present the implementation of an activity recognition system based on a data acquisition system with inertial sensors. One of the requirement of data acquisition systems used in human activity recognition is their level of acceptability or their level of obstruction [2, 4]. Starting from this important requirement, we designed a few wearable data acquisition systems using inertial sensors. The idea from which we started, takes into account the need to obtain more complete information about the studied human subject, in complex activities recognition systems. In our experiment we used inertial sensor built into so called "9DOF inertial module". Our systems contain, on the wearable side, a maximum of three inertial sensors, a microcontroller module, and a communication module which can be one of the three solutions. For data reception, on the fixed part of the system, we have a communication module corresponding to the one on wearable parts and a microcontroller module connected to a PC through a serial port. For activity recognition, data files are transferred to a PC, and data is processed in Matlab using artificial neural networks as classifier. The networks have been configured according to the number of sensors that acquired data and the number of activities that we want to recognize.**

Keywords: inertial sensors, data acquisition, neural network, activity recognition.

I.INTRODUCTION

In our research, taking into account the references studied, the requirements of such system and hardware resources that we had, we designed and implemented several data acquisition systems. In designing these systems, we considered the following issues:

- The number of sensors used
- Possibilities of placing sensors on the body
- The minimum required level of usability
- Wearable system power consumption
- Further processing possibilities of the data
- Interfacing with the user

A data acquisition system should include the following components:

- Sensors comprising transducers which convert physical phenomena into an electrical signal that can be measured;
- Adapting circuits for signal isolation, conversion and / or amplification of the signal from the transducer;
- Data acquisition subsystem (which may include multiplexers and analogue – digital converters);
- Computing system;
- Software for data acquisition.

In modern systems, sensors include adaptive and signal conditioning circuits and analog-digital conversion, providing the output information in digital form. In data acquisition systems, two categories of sensors are being used for activity recognition: environmental sensors and wearable sensors. In real-world scenarios using a single sensor type normally cannot provide enough information for detecting activities, especially for some complex ones, thus multiple sensors are needed to provide more accurate information related to activity monitoring.

As environmental sensors, simple binary sensors, including state-change sensors, motion sensors, contact switches and pressure sensors, may be deployed on a range of objects in smart home environments for monitoring users' movements and locations [1]. A variety of other sensors such as temperature sensors, light sensors, humidity sensors or power sensors have been also used in smart home environments to help in the detection of activities. Radio-Frequency Identification (RFID) works as a combination of environmental sensor and wearable sensor technologies. It consists of a reader worn by the user and an electronic tag attached to an object.

Wearable sensors can be divided into inertial sensors and vital sign sensors (or biosensors), and refer to sensors that are attached to human body either directly or indirectly, and which usually provide a continuous flow of information. Their small size allows to be embedded into belts, clothes, glasses, wristwatches, shoes and mobile devices to make them easier to wear. Accelerometers are the most frequently used sensors for ambulatory activity monitoring [2-11]. Data collected from accelerometers has four attributes: time, acceleration from x-axis, acceleration from y-axis and acceleration from z-axis. Gyroscopes use a small vibrating mass inserted into the sensor to measure angular velocity and maintain orientation. The change in angle compared to the initial known value can be detected over a period of time. In the field of ambulatory activities monitoring, most researches are focusing on the use of accelerometer sensors or the combination of accelerometer and gyroscope sensors. In terms of activity monitoring, the system benefits from some features of inertial sensors including their compact size, low power requirements, low cost, non-intrusiveness and the capacity to provide data directly related to the motion of the user.

Monitoring activities through vital signs provided by biosensors or wearable sensors is recently gaining research interest. In health monitoring vital signs such as Electrocardiogram (ECG), heart rate, blood pressure, blood glucose, oxygen saturation and respiratory rate are related to healthcare services [1].

In terms of information processing, specialized platforms have been developed which, in addition to processing facilities, ensure the delivery mode to the user.

II. Data Acquisition Systems

Our main goal was to design and implement an activity recognition systems capable of acquiring different types of data from inertial sensors, to process the results and to be able to extract a set of behavioral patterns.

A. Hardware description

To design reliable data acquisition systems we tested various configurations using one, two or three inertial sensors. As we presented in a previous research [12], an important aspect is sensors placement on the human body, the number of sensors should be as small as possible. Thus we create a possible optimal configuration in this case, using two inertial sensor placed on right thigh and left wrist, as we present in figure 1. Our system has two main parts: a wearable system and a receiving system. The wearable system contains two inertial sensors, a microcontroller for data processing, a micro SD card for data storage, and an XBee module for wireless connectivity. Receiving part, which is the fixed part of our data acquisition system, contains an XBee module for connectivity and a microcontroller connected through a serial connection to a PC. Data collected through I2C interface from two inertial sensors is transmitted wirelessly, after a minimal processing, to the receiving system where it can be stored in text files, or can be processed in real time, depending on the type of recognition system used.

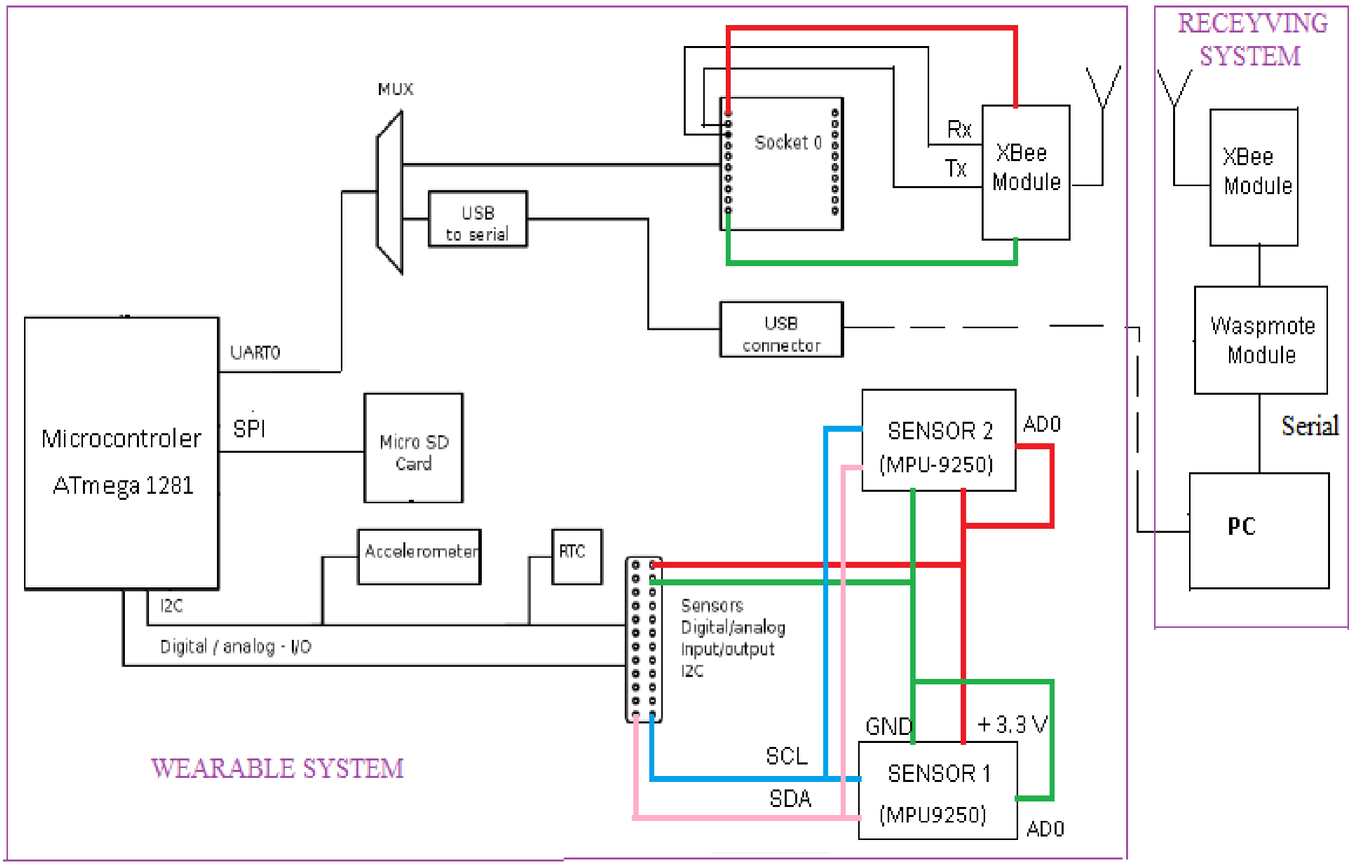

Fig.1. Data acquisition system using two inertial sensors

In our experiment, after studying a large part of the published works addressing this issue [2-11], we placed the two sensors on the right thigh and on the left wrist. Data acquired from the two sensors is transmitted to a PC or portable intelligent devices for processing. This system is a part of our complex assistive assembly consisting of a smart and assistive environment, an assistive and telepresence robot, together with the related components and cloud services [1, 2, 3, 4, 10, 11]. One of our experimental platforms of data acquisition system is presented in figure 2.

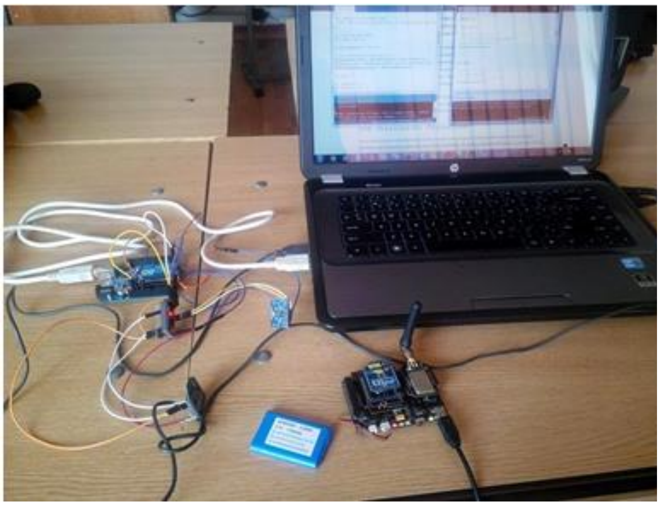

Fig. 2. Experimental platform of data acquisition system using inertial sensors

B. *Software description*

The software component of this work consists of two main parts: the data acquisition and processing software, and the data analysis software. The first part handles data acquisition from the wearable system and its transmission to a PC through a serial port or to an SD card for storing. Data acquisition is achieved through a MPIDE software platform. In figure 3 we present a piece of software cod for data acquisition from two inertial sensors.

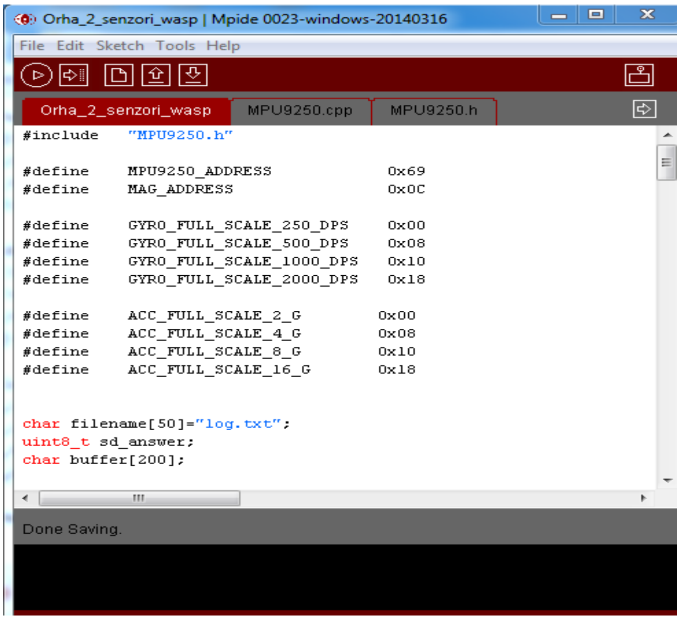

Fig.3. MPIDE software interface for data acquisition

The structure of the data acquired from our wearable system can include, a number of maximum 18 data vectors in case of two inertial sensors. Due to the size of this matrix, we present the structure of a matrix only for one sensor, it having the shape

$$
\text{data} = \begin{bmatrix} a_{1x1} & a_{1y1} & a_{1z1} & \theta_{1x1} & \theta_{1y1} & \theta_{1z1} & m_{1x1} & m_{1y1} & m_{1z1} \\ a_{1x2} & a_{1y2} & a_{1z2} & \theta_{1x2} & \theta_{1y2} & \theta_{1z2} & m_{1x2} & m_{1y2} & m_{1z2} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{1xn} & a_{1yn} & a_{1zn} & \theta_{1xn} & \theta_{1yn} & \theta_{1zn} & m_{1xn} & m_{1yn} & m_{1zn} \end{bmatrix} \quad (1)
$$

where a is the acceleration, θ is the angle of rotation, m is the magnetization, and n is the number of samples acquired. An example of data acquired in our experiments is presented in figure 4.

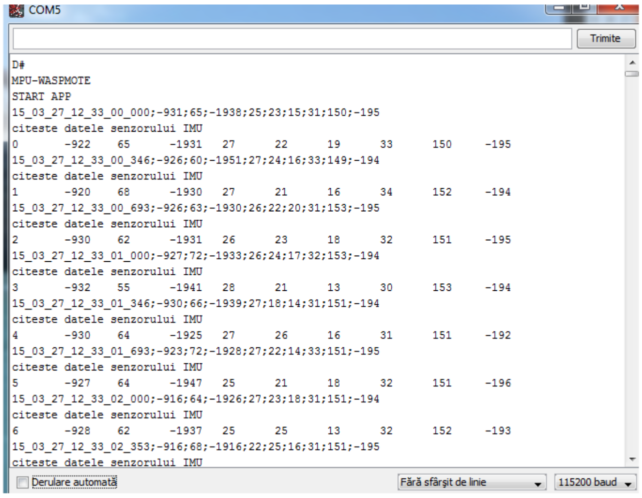

Fig.4. Data acquired with our experimental platform

In the second part, data was imported into Matlab software environment and after processing and analysis, we can draw conclusions on how the data from two inertial sensors can be used in the activity recognition. The recognition system is implemented on a PC, on which the Matlab software is running.

IV. Activity Recognition System

The same as in our system presented in [12], in our study we have proposed to recognize seventeen activities or postures as follows: standing, sitting, supine, prone, left lateral recumbent, right lateral recumbent, walking, running, left bending, right bending, squats, settlements and lifting the chair, falls, turns left and right, upstairs, down stairs. In figure 5, the recognition system structure using System Generator is presented.

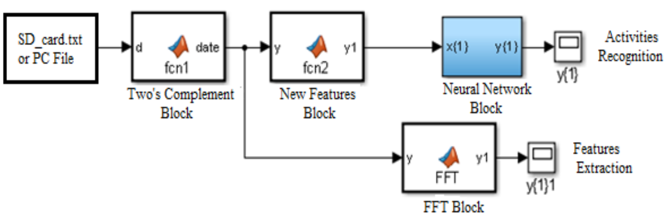

Fig. 5. Recognition system structure using System Generator [13]

The recognition system includes the following functional blocks: Two's complement, described by Matlab script twos_compl; new features, described by Matlab script new_features; the neural network described by Matlab scripts training_data_set and ffbpnn; FFT described by Matlab script transFourier. The most important block of our system is the neural network block, and its configuration is one of the challenges for a better recognition with low hardware costs. One of the possible structures of the neural network, if we use all data vectors from two inertial sensors (a total of 18 vectors), is presented in figure 6.

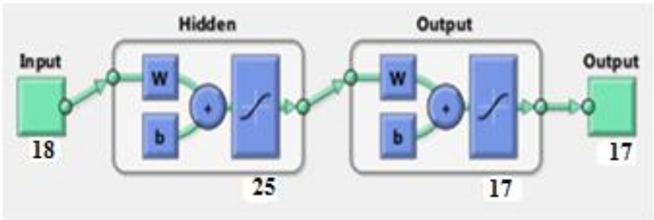

Fig.6. A possible structure of neural network

For performance evaluation of the neural network several performance functions can be used, the most used being MSE function. It is also possible to calculate the total number of errors of recognition for each activity, which is a relevant parameter on the performance of neural network recognition. In figure 7, recognition errors for the seventeen activities in a studied case are presented.

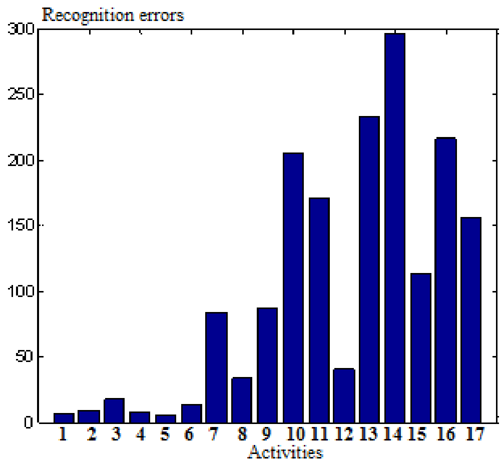

Fig. 7. Recognition errors for the seventeen activities

V. CONCLUSIONS

In this paper we present a data acquisition system using inertial sensors, for acquiring data related to body position and some simple movements.

The presented system allows recording sensors data from a wearable system containing two inertial sensors, in files for storage and further processing or real-time tracking of the parameters provided by sensors.

This type of system allowed us to create a local area network for activity recognition.

REFERENCES

[1] Qin Ni, Ana Belén García Hernando, I. Pau de la Cruz, The Elderly's Independent Living in Smart Homes: A Characterization of Activities and Sensing Infrastructure, Survey to Facilitate Services Development, Sensors 2015, 15, pp.11312-11362, ISSN 1424-8220

[2] Chun Zhu, W. Sheng, Motion-and location-based online human daily activity recognition, Pervasive Mob. Comput. 2011, 7, 256–269.

[3] Y. Zheng, W. K. Wong, X. Guan, S. Trost, Physical activity recognition from accelerometer data using a multi-scale ensemble method. In Proceedings of the 25th Conference on Innovative Applications of Artificial Intelligence, Bellevue, Washington, DC, USA, 14–18 July 2013.

[4] L. Gao, A. K. Bourke, J. Nelson, Evaluation of accelerometer based multi-sensor versus single-sensor activity recognition systems. Med. Eng. Phys. 2014, 36, 779–785.

[5] H. Gjoreski, M. Gams, Accelerometer data preparation for activity recognition. In Proceedings of the International Multiconference Information Society, Ljubljana, Slovenia, 10–14 October 2011; pp. 10–14.

[6] M. Jiang, H. Shang, Z. Wang, H. Li, Y. Wang, A method to deal with installation errors of wearable accelerometers for human activity recognition, Physiol. Meas. 2011, 32, 347–358.

[7] J. R. Kwapisz, G. M. Weiss, S. A. Moore, Activity recognition using cell phone accelerometers, ACM SIGKDD Explor. 2011, 12, 74–82.

[8] P. Siirtola, J. Röning, User-independent human activity recognition using a mobile phone: Offline recognition vs. Real-time on device recognition. In Distributed Computing and Artificial Intelligence; Springer: Berlin/Heidelberg, Germany, 2012; Volume 151, pp. 617–627.

[9] C. S. Hemalatha, V. Vaidehi, Frequent bit pattern mining over tri-axial accelerometer data streams for recognizing human activities and detecting fall. Proc. Comput. Sci. 2013, 19, 56–63.

[10] A. Mannini, S. S. Intille, M. Rosenberger, A. M. Sabatini, W. Haskell, Activity recognition using a single accelerometer placed at the wrist or ankle. Med. Sci. Sports Exerc. 2013, 45, 2193–2203.

[11] Chun Zhu, "Hand gesture and activity recognition in assisted living through wearable sensing and computing", Ph.D. Dissertation, Oklahoma State University, Stillwater, OK, USA. Advisor(s) Weihua Sheng.", December, 2011.

[12] I. Orha,S. Oniga, Study regarding the optimal sensors placement on the body for human activity recognition, 2014 IEEE 20th International Symposium for Design and Technology in Electronic Packaging (SIITME), 23-26 Oct. 2014, pp. 203-206.

[13] S. Oniga, J. Sütő, "Human activity recognition using neural networks", 15th International Carpathian Control Conference - ICCC 2014, Velke Karlovice, Czech Republic, May 2014, pp. 403-406.