Android Application for Remote Monitoring of Patients with Movement Disorders

Lazar Berbakov, *Member, IEEE*, Bogdan Pavković, *Member, IEEE,* Vladana Marković and Marina Svetel

***Abstract*—In recent years, there exists a trend of adding sensing and communication capabilities to different objects in our environment. The area where this makes most sense is healthcare, where remote monitoring of patients can improve their quality of life and potentially allow doctors to detect symptoms that otherwise may not be perceived in ambulatory environment. In this paper, we propose an architecture of remote patient monitoring system whose main part is Android application TremorSense that is used to collect data from wireless inertial sensors and convey them to the remote server for centralized storage and analysis. The application has been tested in clinical trials in Neurology clinic with patients that suffer different movement disorders. The trials have shown that such application can be of great help to doctors that can use it in everyday procedures for quantification of patient symptoms and evaluating the disease evolution over time.**

***Index Terms*—Telemedicine; Inertial sensors; Tremor monitoring;**

I. Introduction

We are all witnessing the speed that the technology is changing the world around us. With recent advances in microelectronics and wireless communications, a myriad of new types of consumer devices have emerged out of nowhere. One of the devices that has achieved the widest spread is the smartphone, device so deeply integrated in life of the people that are relying on them many of their daily tasks, such as communication, learning, reading, etc. Smartphones that are available on the market today have the computational power comparable to that of desktop computers 5 years ago, making them suitable for new application areas that can make use of the available resources.

On the other hand, there exists a trend of adding intelligence and communication capabilities to different home appliances and objects, making smart home a reality today. This trend is expected to further grow, with predictions that more than 24 billion different devices will be connected as a part of the so called Internet of Things (IoT) by 2020, in different application areas such as industry, agriculture, transportation, living, etc.

One of the areas where IoT revolution offers great promises is healthcare, where it has already been applied to some extent, although wide spread has not been reached yet. Using IoT in healthcare promises to cut the costs, and at the same providing more quality healthcare access to people, even for those who live in distant areas. The entrance of wearable devices [1] [2] to consumer market has shown that there exists a huge potential in such kind of devices that currently target the group of people that regularly practice sports. It can be expected that after empowering such devices with more sensors that are suitable for health monitoring and further decreasing their market price, they will find their places in new niches that are more health oriented.

This trend has already been recognized in scientific community that has been investigating the application of smart devices in monitoring of different diseases such as of patient's movement and heart parameters [3] and patient's heart rate, oxygen saturation, and heart rate variability [4]. For kind of diseases where patients experience movement problems, e.g. Parkinson's disease, the application of inertial sensors for symptom monitoring has been investigated with specific emphasis on patient's motor status [5] and different parameters of motor behaviors [6] and [7].

In this paper paper, we propose a system that is used to remotely monitor tremor in patients with movement disorders. First, we describe the system architecture along with each building block it comprises. The specific emphasis is given to the Android application TremorSense that is used to collect the data from wireless inertial sensor platform that is attached to different patient's body locations. Finally, we present some results obtained by using the proposed system with patients that experience movement disorders.

II. System Architecture

In order to provide an overview of the system and its main blocks, in Figure 1 we present the system architecture. As can be seen, the system consists of the following blocks:

1. **Bio-medical sensing** block is using different types of sensors whose aim is to monitor the health status of the patient. Nowadays, there exist sensors that can measure patient movement (accelerometer, gyroscope, magnetometer), its heart-rate and blood oxygen saturation, breathing rate, temperature, blood pressure etc.

Lazar Berbakov is with the Mihailo Pupin Institute, University of Belgrade, Volgina 15, 11050 Belgrade, Serbia, (email: lazar.berbakov@pupin.rs).

Bogdan Pavković is with RT-RK Computer Based Systems, Narodnog Fronta 23b, Novi Sad, Serbia and Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovica 6, Novi Sad, Serbia, (email: bogdan.pavkovic@pupin.rs).

Vladana Marković is with the Neurology Clinic, Clinical Center of Serbia Belgrade, Serbia

Marina Svetel is with the Neurology Clinic, Clinical Center of Serbia and School of Medicine, University of Belgrade, Belgrade, Serbia

Since the sensors are usually battery operated, they are equipped with a low range energy efficient communication technology (Bluetooth LE or ZigBee) that is used to send data to the *data aggregation* block.

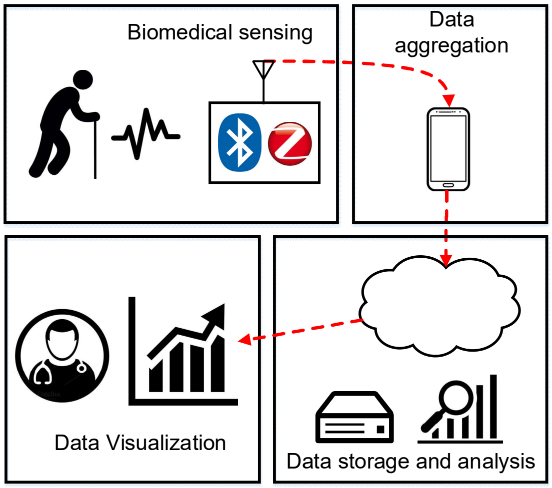

Figure 1. System architecture

2. **Data aggregation** block serves as a gateway between low power sensors and the cloud based central data storage. Its main function is to aggregate the data provided by sensors and perform some analysis since it has more computational resources than the sensors themselves. Once the data are processed, the data aggregation block relays them over the Internet to the central data storage facility.
3. **Cloud based central data storage** block provides long-term data storage and backup of the data obtained by the sensors. In such a way these data can be remotely accessed by doctors in order to provide them with a better overview of patient's condition in real-time. In addition, by using pattern analysis and machine learning, potentially dangerous health conditions can be detected on time and alert can be send to both patient and doctor.
4. **Data Visualization** block can be implemented as a web based, desktop or mobile application whose aim is to extract meaningful information from the patient's data and present them in a way that is suitable for doctors.

In this paper, we will focus on the first two blocks in a scenario where the aim is to monitor patients with movement disorders.

III. System Implementation

A. *Wireless inertial sensors platform - NODE*

In this paper, we consider a system aimed for monitoring tremor in patients with movement disorders (Spasmodic torticollis, Parkinson's diseases, etc.). As a sensor, we have selected a multipurpose inertial sensors platform that communicates via Bluetooth – NODE.

Figure 2. Node – Bluetooth enabled inertial sensors platform

The NODE sensor, which is shown in Figure 2, is equipped with different sensors that can be used to sense the motion: gyroscope, accelerometer, and magnetometer, as well as two expansion ports on either side that can be used to attach additional sensing devices, if necessary. The NODE device is attached to the plastic support so that it can easily be strapped to the patient's head or other body locations where the tremor is to be monitored. Since the platform is wireless, it allows a patient to move freely, without interfering with its normal posture, thus providing a more objective measurements. The range for accelerometer can be selected up to +/- 16g, whereas the gyroscope has the range up to 2000 degrees per second. These ranges are shown to be sufficient for monitoring the human movement with high accuracy, On the other hand the sampling frequency can be selected up to 1000 Hz. Nevertheless, we choose the lower sampling frequency of 33 Hz (sufficient for tremor signals up to 16 Hz) in order to preserve the energy and bandwidth and allow a near real-time data transmission to data aggregation block.

B. *TremorSense Android application*

Data aggregation block has been implemented as Android application – TremorSense (See Figure 3). The Android smartphone has been selected since it is most widely adopted by users and provides support for all the functions required by data aggregation block (open source libraries, Bluetooth and mobile network connectivity). Once the user starts the application she is required to enable the Bluetooth connectivity. Next, she is presented with the list of Bluetooth devices nearby so that she can select the one that is attached to the patient's body. Once the Bluetooth connection to the NODE sensor is successfully established, the user can start the signal acquisition and data transfer to the smartphone (Figure 3c). The data are stored in the smartphone as a series of raw files for each signal (acceleration, angular speed and magnetic field) in the following format:

```
timestamp in ns; value-x; value-y; value-z;
```

Background process constantly monitors the new files that are created, and synchronizes them to the cloud based data storage. In the current implementation state, the files are downloaded from cloud data storage, and analyzed by Matlab program. For the future work, we plan to implement a web based interface for data access and analysis.

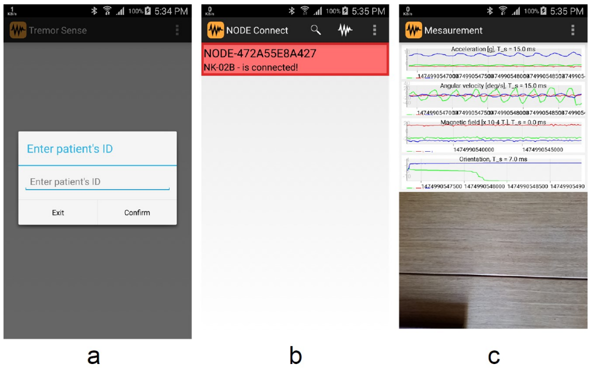

Figure 3. Android application TremorSense

IV. RESULTS

We have run a number of trials in laboratory environment in Neurology Clinic, Clinical Center of Serbia with patients that suffer different kinds of movement disorders. In this section, we show some results obtained from the measurement campaign.

In Figure 4, we show the modulus of angular velocity for patient that suffer the spasmodic torticollis before (top figure) and after (bottom figure) receiving botulinum toxin therapy. Botulinum toxin is used as a standard therapy in such patients, since it paralyzes the muscle that is responsible for tremor. Until now, the patients were able to provide opinion on the improvement of their symptoms, which is highly subjective and prone to errors. With our system, we were able to objectively quantify the improvement by observing the angular velocity speed signal. As can be seen, the botulinum toxin therapy has significantly decreased the head dystonic tremor magnitude.

In Figure 5, we show the head tremor for patient suffering torticollis with different components shown. Up to now, doctors were not able to objectively quantify the most prominent axis of tremor. Our system allow them to identify the strongest component, that could allow them to better identify the source of tremor.

V. CONCLUSIONS

In this paper, we have presented an architecture of remote patient monitoring system based on Android application TremorSense. We have performed initial testing trials in a laboratory environment in order to validate our idea. The results have shown that the angular velocity can be used as objective measure of head dystonic tremor and that we were able to quantify improvements in symptoms from Botulinum toxin injections. For future work, we will put more focus on the implementation of the automatic analytics in TremorSense app and the development of web based application with the aim to analyze and track patient's condition remotely.

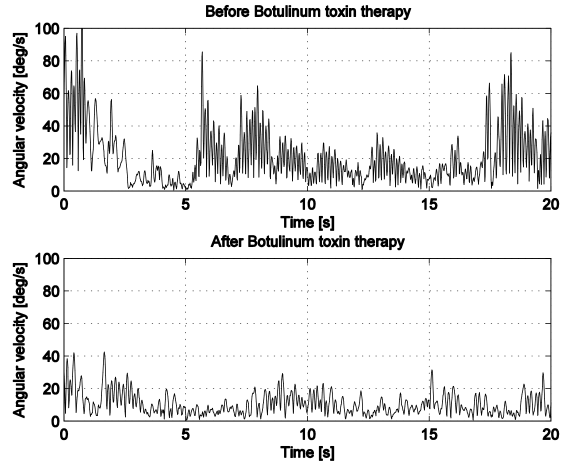

Figure 4 Angular velocity before and after receiving Botulinum toxin

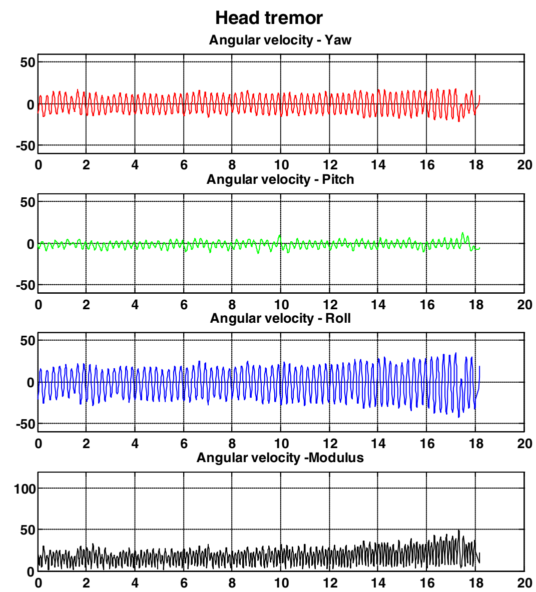

Figure 5 Three components of head tremor

ACKNOWLEDGMENT

This work was financed by the Ministry Science and Technological Development of Republic of Serbia (Pr. No: TR-32043).

REFERENCES

[1] Motorola. [Online]. Available: https://www.motorola.com/us/products/moto-360-sport
[2] Crossbow technologies. [Online]. Available: https://www.fitbit.com/
[3] A. Milenkovic, C. Otto, , and E. Jovanov, "Wireless sensor networks for personal health monitoring: Issues and an implementation," vol. 29, no. 13-14, Aug 2006, p. 25212533..
[4] H. H. Asada, P. Shaltis, A. Reisner, S. Rhee, and R. C. Hutchinson, "Mobile monitoring with wearable photoplethysmographic biosensors," IEEE Engineering in Medicine and Biology Magazine, vol. 22, no. 3, pp. 28–40, May 2003.

[5] F. Rahimi, C. Duval, M. Jog, C. Bee, A. South, M. Jog, R. Edwards, and P. Boissy, "Capturing whole-body mobility of patients with parkinson disease using inertial motion sensors: Expected challenges and rewards," in 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Aug 2011, pp. 5833–5838.

[6] Dai H, Zhang P, Lueth TC. "Quantitative Assessment of Parkinsonian Tremor Based on an Inertial Measurement Unit" Passaro VMN, ed. Sensors (Basel, Switzerland). pp. 25055-25071.

[7] P. Bonato, D. M. Sherrill, D. G. Standaert, S. S. Salles, and M. Akay, "Data mining techniques to detect motor fluctuations in parkinson's disease," in The 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, vol. 2, Sept 2004, pp. 4766–4769.