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Development of a wireless system for the remote monitoring of muscular activity

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INTRODUCTION

With the improvements in healthcare, people of industrialized countries are living longer. On the other hand, the burden of severe chronic disabilities is increasing with high social costs. Wearable sensors for biomechanical and electrophysiological signal sensing are gaining high attention for moving some rehabilitative treatments at home [1], The monitoring of the human movements requires the acquisition of kinematic, dynamics and electrophysiological variables. Among them, the electromyographic signal (EMG) plays a fundamental role to monitor the muscular activity.

In this work, we developed a new sEMG acquisition system, consisting of a set of wireless modules (two sEMG channels each) interfacing directly to a portable device and streaming the acquired data to a web-server. The developed system can be used in several application scenarios, ranging from sport activity monitoring to occupational medicine and tele-rehabilitation (Figure 1).

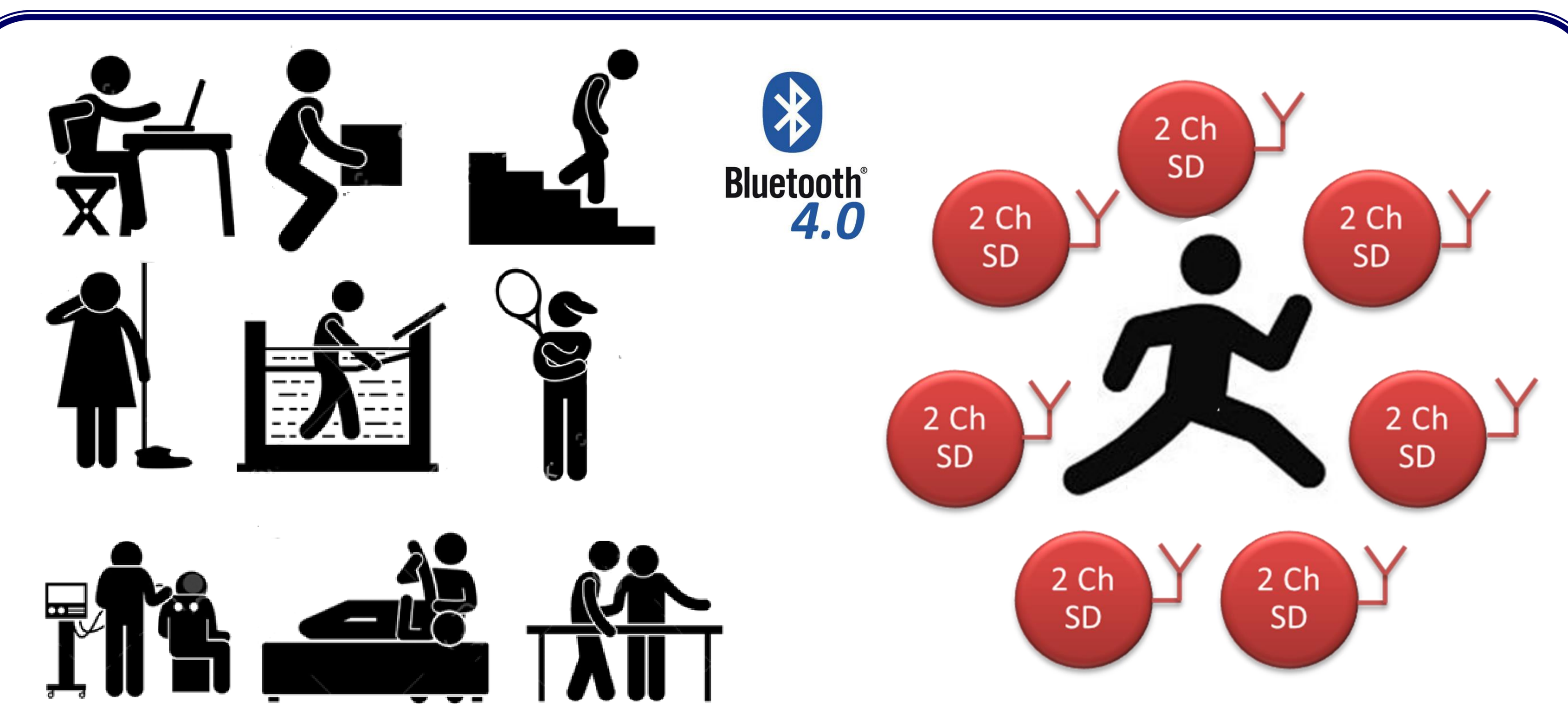


Figure 1 - The system is composed by seven modules (Sensor Unit) each one managing two EMG bipolar channels sampled at 2 kHz with 16-bit resolution. The sampled signals are sent via a Bluetooth 4.0 link to a mobile device streaming the acquired data to a web-server.

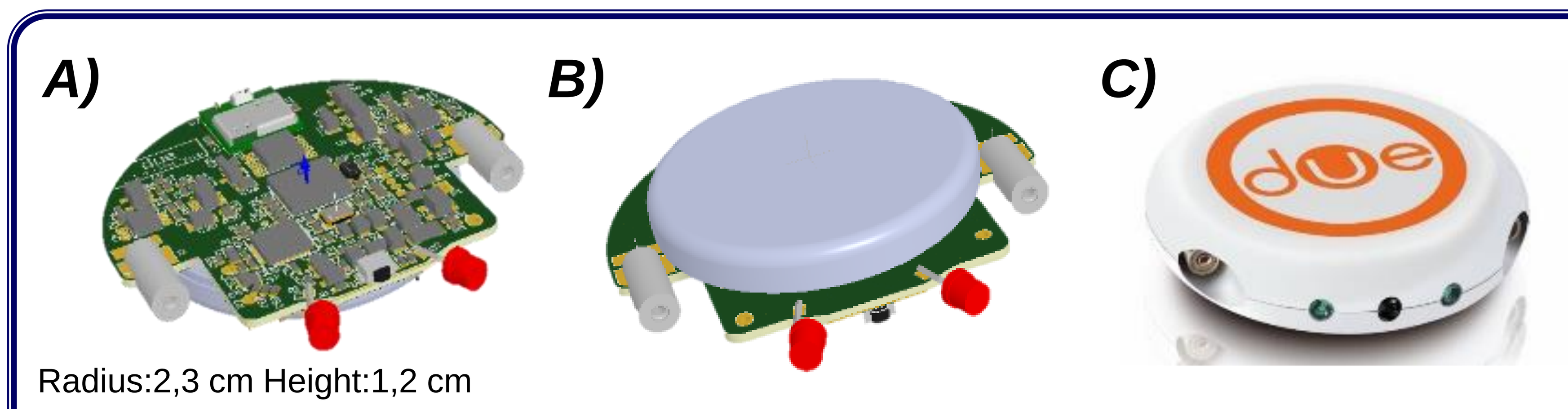
METHODS

The system architecture (Figure 2) consists of one or more modules, each one detecting two bipolar EMG signals sampled at 2048Hz with 16 bit resolution. The sampled signals are sent to a mobile device acting as a receiver through a Bluetooth 4.0 link. A web client mobile application, written using the C++ programming language, acquires the data, calculates the EMG envelope and send it to a remote web server using a TCP-IP socket. The web server has been written using the Python programming language and is hosted by the Heroku PaaS (Platform as a Service) service. The signals received on the web server, can be displayed in real-time on a website (http://lisinsite.herokuapp.com/) designed using the HTML language and the Highcharts javascript library.

Figure 2 - System architecture. a) The system consists of up to seven sEMG wireless sensors (each one conditioning two sEMG channels), sampling and transmitting the signals to a smartphone acting as a web client. The signals are processed in order to extract the sEMG envelope that is sent to a web server through Internet. b) The real-time monitoring of the muscular activity is possible by connecting to a web site resident on the server.

RESULTS

The Sensor Unit PCB (Printed Circuit Board) was designed using a two layers, 1mm thick PCB (Figure 3.A and Figure 3.B). The system is embedded into a 3D printed case (Figure 3.C) having a Velcro pad attached on the bottom side in order to make easy to fix each module through elastic bands. A prototype with seven Sensor Units has been realized and tested. Figure 4 shows the application of the system for the remote real-time monitoring of gastrocnemius muscle activity during running. The Sensor Unit module is connected to the receiver (Smartphone) that acquires two sEMG raw signals, calculate the sEMG envelope and streams the corresponding data to a web-server. It is possible to see the data in real-time from a web page.



Radius:2,3 cm Height:1,2 cm

Figure 3 - First prototype of the Sensor Unit module. A) Front and B) rear side of the PCB. C) Packaged version of the Sensor Unit module. The electrodes are connected through two concentric connectors.

CONCLUSIONS

The main innovation introduced by the described system is the ability of the Sensor Units to directly interface to a portable device such as a tablet or a smartphone acting as receiver and streaming the sEMG envelope data on Internet.

The system is compact, easy to use and requires only a smartphone and a web browser for signal visualization. The real-time streaming of the acquired signals makes the system suitable for the monitoring of the muscle activity without constraints on transmission distance or acquisition time. Such a system may be used as a tool for movement analysis and biofeedback either in sport, clinical, or telemedicine contexts.

The system has been successfully tested on two subjects during a marathon organized for the "Just the Woman I Am" event held in Turin on March 2017.

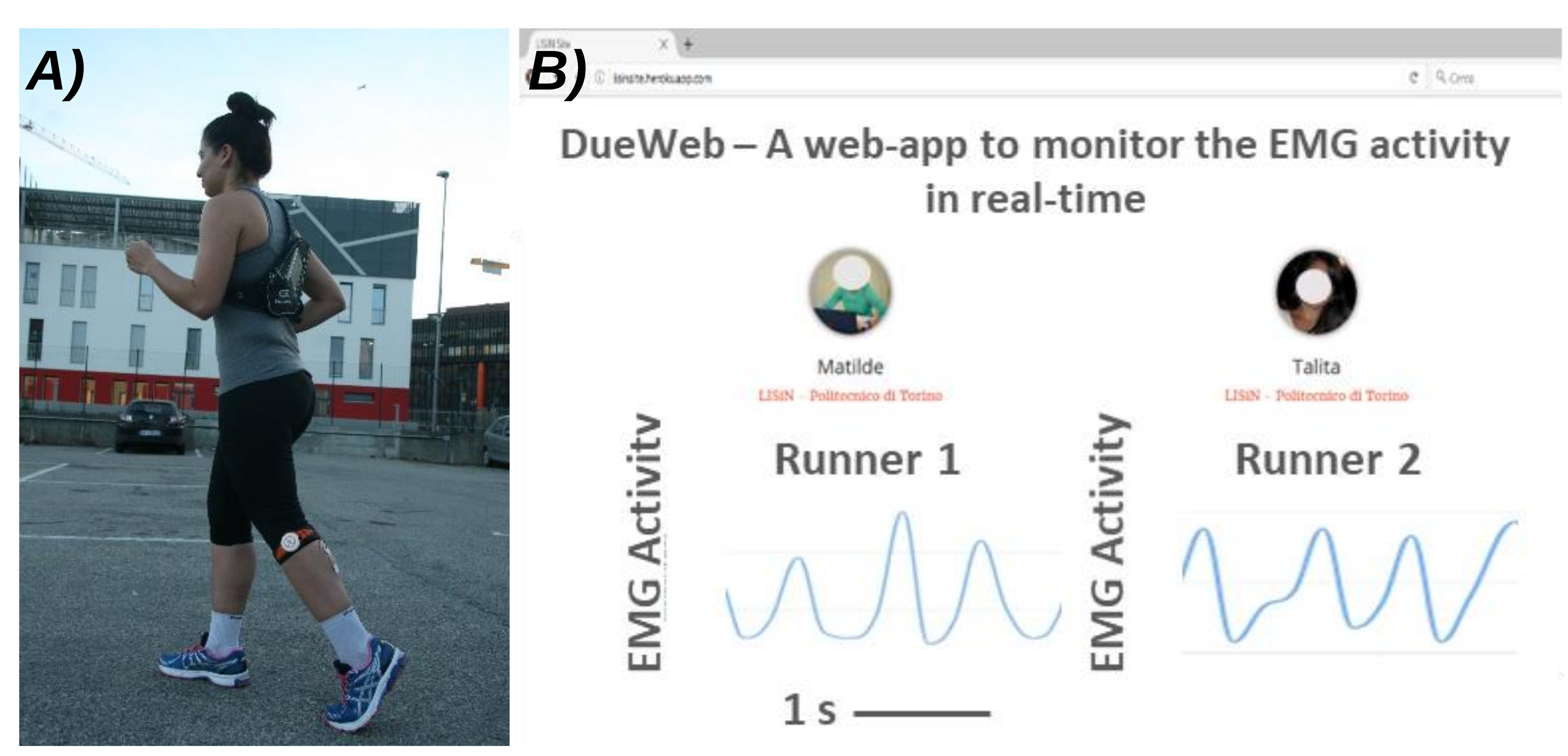


Figure 4 - Example of remote monitoring of muscle activity. A) Bipolar electrodes are positioned on the gastrocnemious muscle. The Sensor Unit module conditions the sEMG signals and send the raw signals to a smartphone that acts as receiver, calculates the sEMG envelope and streams the sEMG envelope to a web-server. The system can work with two Sensor Units (four sEMG channels) and can monitor different subject in parallel. B) It is possible to show the muscular activity in real-time in a web page hosted on the server without constraints on the transmission distance.

REFERENCES

[1] S. Majumder W, T. Mondal , M.J. Deen, "Wearable Sensors for Remote Health Monitoring", Sensors, vol.17,130, 2017

ACKNOWLEDGEMENTS

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