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ELECTRO OCULOGRAPHY BASED COMMUNICATION FOR NEUROMOTOR DISABLED PATIENTS

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Abstract: In this paper, we present a new complex electronic system for facilitating communication with severely disabled patients and telemonitoring their physiological parameters. The proposed assistive system includes three subsystems (Patient, Server, and Caretaker) connected to each other via the Internet. The two-way communication function is based on keywords technology using a WEB application implemented at the server level, and the application is accessed remotely from the patient’s laptop/tablet PC. The patient’s needs can be detected by using different switch-type sensors that are adapted to the patient’s physical condition or by using eye-tracking interfaces. The telemonitoring function is based on a wearable wireless sensor network, organized around the Internet of Things concept, and the sensors acquire different physiological parameters of the patients according to their needs. The mobile Caretaker device is represented by a Smartphone, which uses an Android application for communicating with patients and performing real-time monitoring of their physiological parameters

Keywords— medical device, electrooculography signal processing, patient communication, neuromotor disabled patient

INTRODUCTION

In recent years, national and international efforts have been made to increase the quality of care for people with various disabilities while maintaining costs that are supportable by society. To achieve these conflicting requirements, researchers have made efforts to introduce various equipment and techniques that involve progressively more sophisticated components of informatics and telecommunications. When it comes to caring for severely disabled people, the requirements for round-the-clock surveillance are universally accepted. As a rule, several trained people, who are responsible for medical compliance and surveillance, attend to the physiological needs of disabled patients. However, the former can do very little for the psychological needs and the quality of life of the latter. Assistive technology ensures greater independence for people with disabilities, allowing them to perform tasks that are otherwise impossible or very difficult to accomplish.

The proposed system provides these possibilities by improving or changing the way that patients interact with the objects and equipment necessary to perform that task [1,2].Progress in the field of electronics in the last few years has generated a real interest in the development of new assistive systems adapted for different types of patients. These systems are very useful for medical investigations and observation and also contribute to an increase in the patient’s quality of life.

Two research directions have been developed for the care of patients with severe disabilities:
(1) Telemonitoring physiological parameters; and (2) ensuring communication with disabled patients. Both directions, alongside remote diagnostics, GPS tracking, and others, are included in what can be called telemedicine. Nowadays, telemonitoring is considered an excellent method for diagnosis and surveillance, as proven by numerous studies and projects that are finalized or still in progress [3–8].

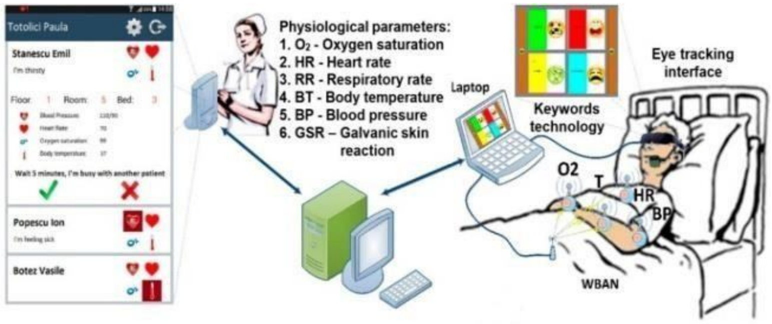
MATERIALS AND METHODS

The system illustrated in this paper, implemented at the prototype level, is the result of an interdisciplinary collaboration of specialists from the fields of electronics, telecommunication, computer science, and medicine. The proposed system helps the healthcare system move toward a drastic decrease in care costs. It functions by using keywords technology for two-way communication with severely disabled patients and uses the Internet of Things (IoT) concept to implement the wireless and wearable sensor network, which is used for telemonitoring the physiological parameters of the patients. Both functions of the system (communication and telemonitoring) share the same hardware platform (except for the sensors used for capturing the physiologic parameters) and most of the software components.

From the communication perspective, the target consists of patients that are able to hear and/or see and understand but are unable to easily communicate (because of a neuromotor handicap, severe dyspnea, depression) using conventional methods, such as speech, writing, or hand gestures. Usually, these patients are able to make only limited movements, such as muscle contractions (raising a forearm, moving a finger or foot) or, as is the case in most situations, eye movements and blinking. Whatever the situation, the problems always remain the same: Patient ↔ Caretaker communication and medical investigation and observation.

The purpose of telemonitoring physiological parameters is to efficiently assess the patient’s current condition, allowing rapid intervention if necessary. The system constantly observes the previously programmed physiological parameters and sends alarms to the caretaker when the values of the monitored parameters are beyond normal limits. All monitored parameters, alarms, and caretaker interventions are recorded in the Server memory for later analysis.

The proposed assistive system is designed for severely disabled patients to enable the simultaneous two-way communication and telemonitoring of the patient’s vital physiologic parameters. The structure of the system is illustrated in Figure 1; it includes the following three subsystems: Patient, Server, and Caretaker. The Server Subsystem is represented by a conventional desktop PC, and the Caretaker Subsystem consists of a Smartphone device (Figure 1).



Caretaker Subsystem implemented on a Smartphone

Server Subsystem implemented on a desktop PC

Patient Subsystem (laptop, USB switch-type sensors, eye tracking interface and a network of wireless and wearable sensors)

Figure 1. Structure of the proposed integrated system for assistance in communicating with and elemonitoring severely disabled patients.

Communication Module

The proposed assistive system uses two types of real-time eye-tracking interfaces to communicate with severely disabled patients:

1. head-mounted device (Figure 3a), which measures the angular position of the eye with the head as the point of reference [45];
2. Remote device (Figure 3b), which measures the position of the eye with the surrounding environment as the point of reference and is implemented with a commercially available interface developed by Tobii [32]; the IR sensors are placed at the base of the screen.

The head-mounted eye-tracking interface illustrated in Figure 3a consists of an infrared video camera mounted on an eyeglasses frame placed close to the eyes and connected to a Patient Subsystem

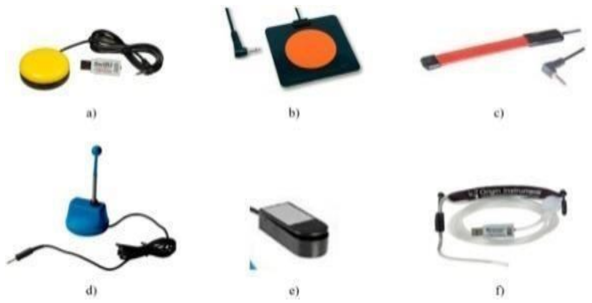


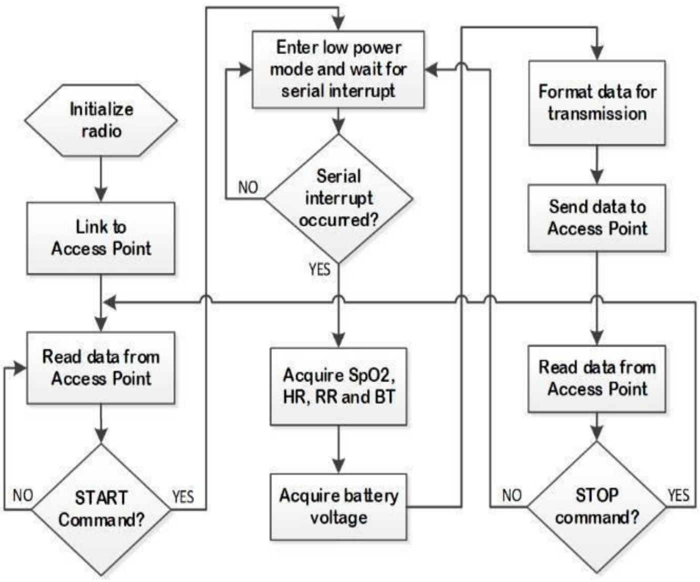
Figure 2.Different types of USB switch- type sensors used for keywords-based detection

Telemonitoring Module

The telemonitoring module is based on a wireless wearable sensor network in which each node is equipped with a sensor for capturing the physiological parameters of patients according to their needs. Thus, each Sensor Node (SN), which represents a medical device in the network, is wirelessly connected to the Central Node (CN), which is USB connected to the patient's computer, which is routed to the Server Subsystem. The structure of this function is based on the IoT concept: by using sensors, the entire physical infrastructure of the system is interconnected to transmit useful measurement information via the distributed sensor network.

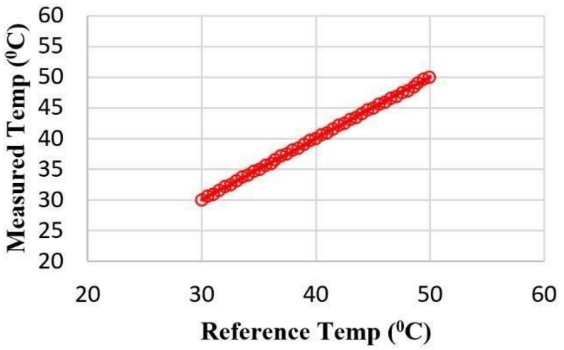
The network management is efficiently controlled by the Server, which transmits the measured data values to the caretaker's mobile device. The operation of the eye-tracking interface is based on the real-time detection of the pupil's center coordinates in the raw eye image provided by the infrared video camera (as shown in Figure 6). In order to do this, the authors developed an eye-tracking algorithm, which runs independently of the PWA on the patient's laptop. The purpose of this algorithm is to move the cursor on the screen according to the user's gaze direction and to perform ideograms/keywords selection by simulating a mouse click. The eye-tracking algorithm includes the following main procedures, which are described in Reference [36] in detail: (1) real-time eye image acquisition; (2) system calibration; (3) real-time pupil center detection; (4) mapping between raw eye image and scene image; (5) ideograms and/or objects selection; and (6) algorithm optimization, which is needed to stabilize the cursor position on the user screen by real-time filtering and high frequency spike canceling from the PDA signals.

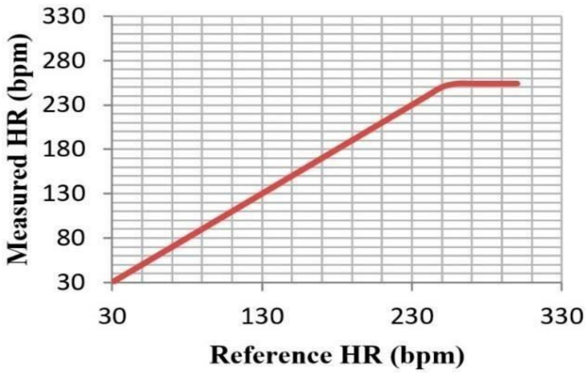
The telemonitoring module illustrated in the diagram from Figure 5 consists of a wireless body area network (WBAN) of medical devices attached to the patient's body for acquiring the following physiological parameters: blood oxygen saturation (SpO2), heart rate (HR), respiratory rate (RR), and body temperature (BT).

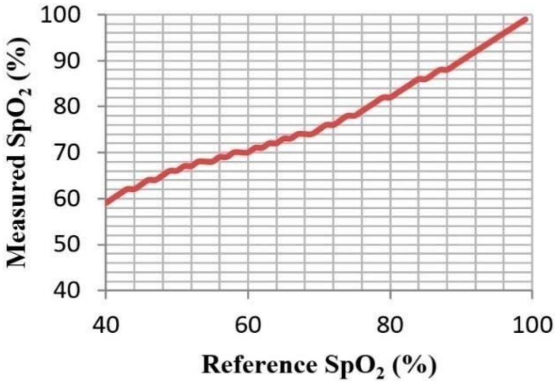


3.1.1. Testing the Telemonitoring Function

The number and type of monitored parameters can be adapted to the patient's medical needs and can be selected according to medical recommendation. The head-mounted eye-tracking interface illustrated in Figure 3a consists of an infrared video camera mounted on an eyeglasses frame placed close to the eyes and connected to a Patient Subsystem (laptop) for eye image acquisition and processing. The tests performed on the telemonitoring subsystem in laboratory conditions included two stages: assessing measurement accuracy and testing energy consumption. The accuracy of temperature measurement was assessed using a high-precision medical thermometer as a reference. The reference thermometer was placed in a thermally insulated enclosure with the body temperature monitoring device. The results obtained are presented graphically in Figure 21a. The data in Figure 21a show that the body temperature telemonitoring device measures the temperature with an error of less than ±0.15 ◦C, a tolerance suitable for medical measurements.







PROPOSED SYSTEM:

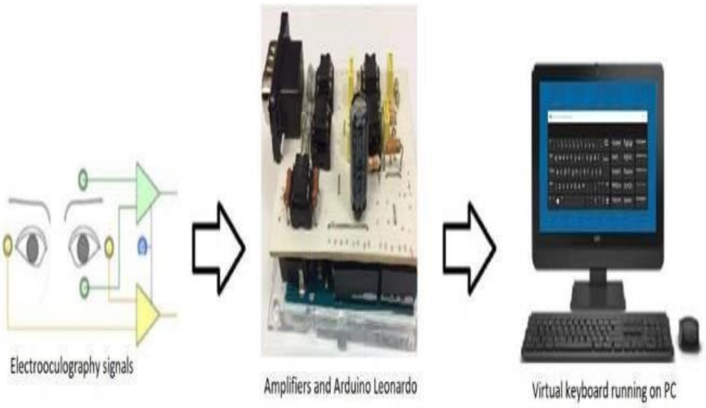
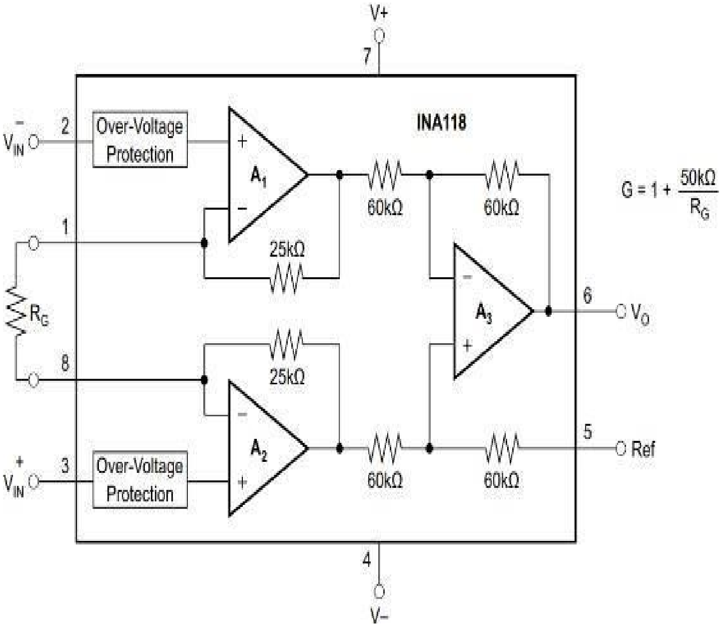
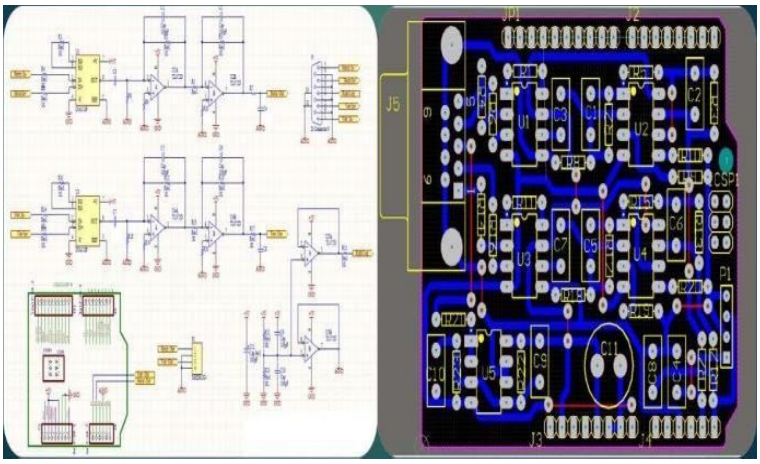


Fig. 1. The proposed device architecture





EOG signal has been acquired by using Ag/AgCl disposable electrodes through a custom developed board, a two channel device (comprising of a horizontal and a vertical channel) developed for signal amplification (x20.000) and band pass filtering (0.1- 20Hz). The signal collected from the electrodes is fed to the first stage of the amplifier that is implemented by using instrumentation amplifiers (INA 118 – Fig.2), followed by a second and third stage -a low pass filter with a cut off of 20Hz and a high pass filter of 0.1Hz cut off to eliminate the DC component. The INA118 is a differential, low-power, high input impedance, general- purpose, low offset voltage instrumentation amplifier offering excellent accuracy in biomedical signal conditioning. The amplified EOG signal is fed to the A/D inputs of the Arduino Leonardo module, that is also responsible for providing power supply (+5V) to the developed board. The schematic and PCB design of the custom developed board has been represented in Fig.3

EXPERIMENTAL RESULTS

The prototype of medical device for communication with disabled patients is presented in Fig.6.The character selection method used in communication between patient and clinicians is performed by selecting characters from an alphabet list and building free sentences using them. This method results in complex messages, but, in order to obtain good results, the method requires patient skills for working properly with this device.

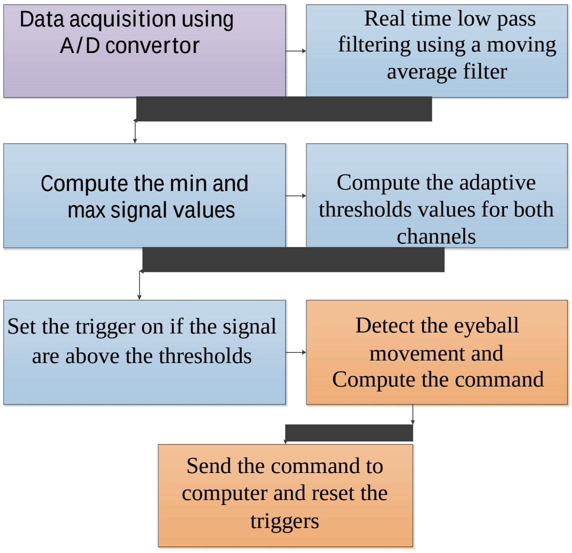


Fig. 5. The flowchart of the software running on Arduino Leonardo
Fig. 6. Medical device for communication with disabled patients.

CONCLUSIONS AND FUTURE WORKS

This paper describes the design, implementation and testing of a custom developed medical device, as a part of assistive system, and used for communication with patients having neuromotor disabilities. The proposed device is both inexpensive and implements robust, simple facilities for a dialogue between patient and clinician by using a PC. The obtained results on simulated patients are promising, making the device suitable to be used in practice. Other applications of the device will include games controlling, interfacing with smartphones / tablets or e-book reading. In order to make the device wearable, the device should be implemented by using wireless technology.

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