Development of visual display and data transmission system for patients with chronic disorders of consciousness

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Abstract. The monitoring is integral part for patients with chronic disorders, as such cases require serious attention to save their life and predict recovery. Physiological signs such as heart rate, hemodynamic, temperature, saturation are collected from biomedical sensors to bedside monitors that medical staff could detect unexpected life-threatening conditions being around the patients. However, it is a tough job to being stuck at monitor for every person. Furthermore, such continuous supervision may lead to difficulties due to human error. Thus there is a need to capture, display all physiological changes visually and give a medical emergency about health conditions when they are out of the normal range. The main objective is the development of the optoelectronic system for visual monitoring and data transmission of patients in a coma by optical wireless communication.

1. Introduction

A coma is a deep state of prolonged unconsciousness as a result of traumatic brain injury, stroke, brain tumor, diabetes, hypothermia or an infection. The number of accidents happens very high when the patients are admitted in the Intensive Care Unit (ICU) [1]. Coma usually lasts for less than 2 to 4 weeks in itself, then a patient may wake up into a vegetative state/unresponsive wakefulness state (VS/UWS) or minimally conscious state (MCS). It requires operative action to preserve their life and brain function as well as visual controlling of basic physical cues.

Diagnosis of chronic disorders of consciousness is a threat to the patient's life and requires a continuous monitor of the values on bedside monitors, even in the face of the increased workload of medical personnel. In the meantime, patients are admitted to the rehabilitation unit after without any monitoring system after ICU, cause he or she is considered stable. Nevertheless, the need to monitor the physiological parameters remains.

Imaging techniques, including functional magnetic resonance imaging, EEG, and FDG positron emission tomography have great potential to predict the diagnosis of VS/UWS and MSC [2-5]. They can be used to investigate metabolic and functional impairment of the brain. However, diagnosis of the VS/UWS and MSC should be based on a patient’s clinical history and on simple visual observations as well. Therefore, monitoring systems should be applied.

Recently developments provide more convenient and comprehensive medical monitoring. Some of them are focused on system that collect health parameters [6-7]. Other developments are dedicated to
wireless patient monitoring systems [8-9]. However visual module is not implemented to monitor physical changes in real-time. Thus, there is a need to develop a system that helps to read vital physiological parameters, display their changes in real-time and indicate a deterioration or improvement of the patient’s internal state. The development of a visual display object with established light-emitting diodes allows to represent physiological changes by controlling parameters and send them by optical wireless communication immediately.

2. Methods
A current system has 2-3 sensors on the patients. It is designed to collect the values of physiological parameters from sensors, display received data according to specified scenarios of light-emitting diodes on a visual object, and transmit data to a server or personal computer using optical wireless communication technology for viewing. The system will help to read the state of patients with chronically impaired consciousness, such as the vegetative state (such vital functions as heart activity and breathing are preserved), the state of minimal consciousness (pain stimuli, environmental eye-tracking persist) the syndrome of unresponsive wakefulness (cognitive functions are preserved).

![Diagram of the visual display and data transmission system.](image)

The most important indicators of patient physiological state as measured signals were selected: heart rate (sensor working range 60-120 beats per minute), arterial oxygen saturation (sensor working range 95-99%), body temperature (sensor working range 36 - 38 degrees).

Under signs of these types of depression of consciousness, the most important indicators of the physiological state of patients as pulse rate, arterial blood oxygen saturation, and body temperature were selected as measured signals. The block diagram is presented in Figure 1 below.

A working principle is shown in Figure 2.

A bracelet with established light-emitting diodes is currently offer as a visual object. It visualizes the physiological parameters of patients in several scenarios: the values of physiological parameters are normal, the values of physiological parameters are lower than normal values, the values of physiological parameters are higher than normal values. If the values are in the range of normal values, the scenario is implemented in the form of pulsating green color. When the values are outside
the normal range on the lower bound, the LEDs have a chromaticity in the range of cold colors. When the values are outside the normal range on the upper bound, the LEDs have a chromaticity in the range of warm colors.

Figure 2. Working principle of the visual display and data transmission system.

Figure 3. Scenarios of light-emitting diodes on the visual display object: a) The values are below the normal range, b) The values are in the normal range, c) The values are above normal range.

Figure 4 presents a color scale of possible scenarios of light-emitting diodes for given parameters which is bounded by a triangle on the CIE color space diagram.

It has vertices in the chromaticity coordinates, reflecting a wide range of colors for specifying all necessary parameters: $x_r = 0.71, y_r = 0.29$; $x_g = 0.18, y_g = 0.72$; $x_b = 0.16, y_b = 0.03$.

Technical parameters are presented on a table 1.

Arlight light-emitting diodes in the wavelength range of 930-940 nm were selected as a data transmission source. The main criterion for choosing was the spectral sensitivity since the peaks of the LEDs and the photodetector must coincide. A FDS100 silicon photodiode with a spectral sensitivity of 950 nm was selected as a receiver. The spectral sensitivity $R(\lambda)$ is shown in Figure 5.

3. Conclusion

The healthcare industry has perpetually been on the forefront in the adoption and utilization of information and communication technologies for the efficient healthcare treatment. Most of the patients with chronic disorders are young people who were injured, got sunstroke, or hypothermia. The question of their recovery is extremely important, although the chance is quite low, but it is there. The probability is dependent on the extent of structural brain damage, which is difficult to assess by clinical, laboratory, or functional tests. The development of visual display and data transmission system is a critical step towards regaining consciousness, because the goal of this project is to learn how to catch and notice some glimmers and influence them so that the brain wakes up. The use of
visual display and data transmission system will help medical staff monitor the comatose regularly to see if there are any changes in emergency cases.

![Figure 4. Light-emitting diodes chromaticity scenarios on color space diagram.](image)

Table 1. Technical parameters of light-emitting diodes.

| Parameter                                           | Value                  |
|-----------------------------------------------------|------------------------|
| The emission angle of RGB LEDs, deg                | 120                    |
| Luminous flux of RGB LED strips, lm/m               | 150                    |
| LED strip power supply voltage, V                   | up to 12               |
| Peak wavelength of red chip radiation, nm           | 600-670                |
| Peak wavelength of the green chip, nm               | 510-570                |
| Peak wavelength of blue chip radiation, nm          | 420-480                |
| Coordinates of the radiation chromaticity, the normal range | x - 0.1-0.4, y - 0.5-0.8 |
| Coordinates of the emission chromaticity, below the normal range | x - 0.1-0.3, y - 0,0-0,3 |
| Coordinates of the emission chromaticity, above the normal range | x - 0.5-0.7, y - 0,2-0,4 |

![Figure 5. The spectral sensitivity of photodiode.](image)
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