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MEMS Sensors to Assess Pain Sensitivity of Human

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Abstract

This article considers the possibility of creation of microelectronic systems to assess human pain sensitivity. The focus is devoted to the description of the known methods of pain sensitivity evaluation, the structure of the system to assess human pain sensitivity, as well as the description of the concept of the individual parts of the system with the use of MEMS sensors. A substantiation is presented of the use of the selected field type to create the impact of pain, as well as increased ease of use when using MEMS sensors for removal of photoplethysmogram, which is used in the evaluation of human pain sensitivity. The model of the device for readout photoplethysmogram data with the use of MEMS sensors is presented.

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1. Introduction

The development of methods for determining the pain threshold for various people based on medical records (electrocardiogram [1], photoplethysmogram [1], pressure, etc.) is an important tasks. Now, the only individual approaches are known to solve the problems of automatic evaluation of human response to exposure to standard pain. Another problem is the microminiaturization of devices for estimating the impact of pain, which is associated with methods of determining the level of pain.

For example, the problem of the readout of medical records at the same time as the influence of pain in dentistry considered in [2, 3]. It is proposed to assess pain sensitivity using blood tests and of interleukin in blood.

Gorbonosov and Semenov proposed to use photoplethysmogram to assess pain sensitivity in article [4], however, the problem remains unsolved because the source of pain is the object. On the one hand, this creates objectivity in the study because it is difficult to endure the pain, but at the same time complicates the investigation.

In article [5], a variety of options that are used in the evaluation of the impact of pain and pain sensitivity are presented. The main drawback is the use of subjective methods of measurement because in all the given methods, the man assesses the level of pain himself, but for this he uses different scales. For such a measurement method as in [6], consider the dependencies that are associated with sex, age, race and others. The main disadvantage of these options remains the use of people with chronic pain sensations to reduce the error in the subjective measurement of pain, and general measurement subjectivity.

This work presents an approach to the development of MEMS devices that are able to control the effects of pain and evaluate them by means of intelligent software functions for complex medical criteria: the area of the wave of photoplethysmogram, the value of the area of the wave of photoplethysmogram to the impact of pain, during and after the impact of pain, as well as the average values for the wave amplitude and also increase time of photoplethysmogram before, during and after the impact of pain.

The purpose is to assess the possibility of design of microelectronic systems for assessing pain sensitivity based on a typical human response to painful effects.

The use of microelectronic systems in this area will reduce the size of known devices for evaluating the impact of pain, simplifying, and speeding up the results for pain sensitivity analysis due to the minimal number of devices with wired connections and use of wireless connection to other devices.

2. Materials and Methods

2.1. The general structure of human pain sensitivity acquisition and evaluation system

The structure of the human pain sensitivity analysis system includes the following components:

- pain impact device;
- MEMS sensors for the readout of medical conditions and a device for transmission; and
- a device for data processing (computer and software).

A person is exposed to the impact of pain from the source of pain impact. Throughout the painful effects, medical records (photoplethysmogram, electrocardiogram, blood pressure and others) are read by a readout device for medical records and transmitted to the processing device (computer with software for data processing). Upon reaching the threshold of pain, a person clicks on the button and press time data is transmitted through the pain impact device to the processing device.

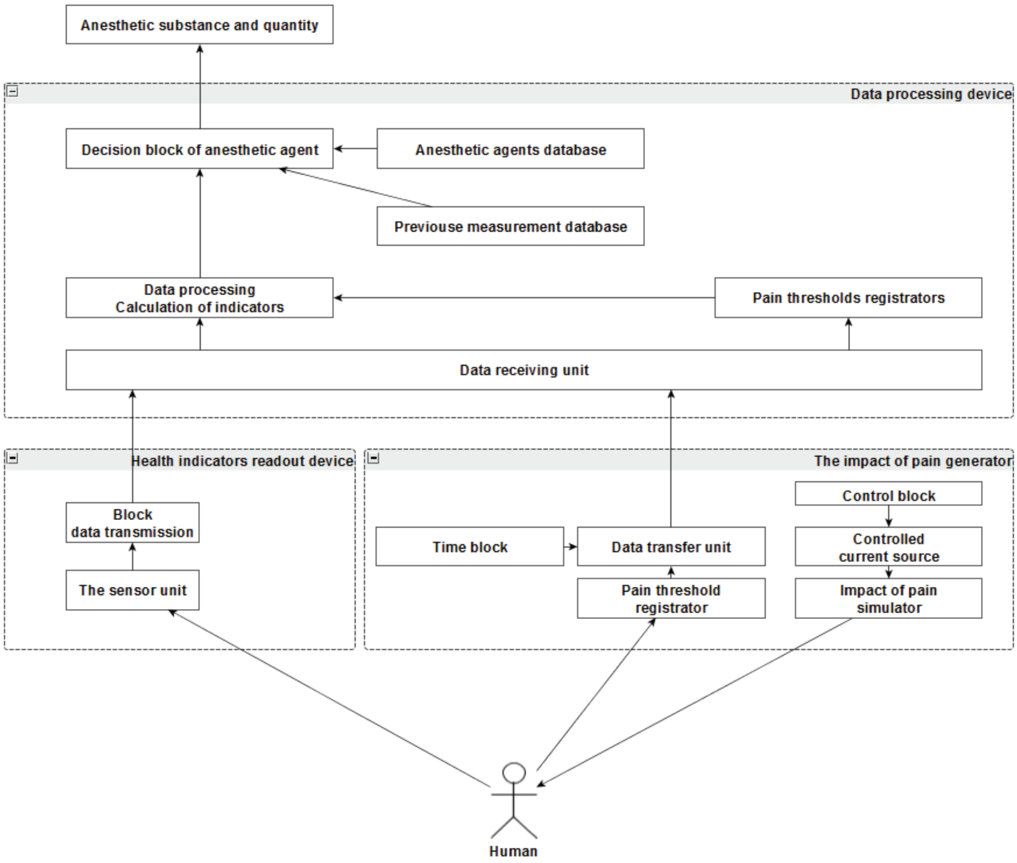

Figure 1: Block diagram of the human pain sensitivity acquisition and analysis system. Anesthetic agent database. Data transmissions block.

3. Classification Methods of Pain Impact

When implementing block simulation of pain impact, it is necessary to implement a controlled source of pain. Consider the basic techniques that can be used to create pain impact [7]. In terms of the physical nature of pain, impacts generators are based on the usage of the properties of different physical fields (mechanical, electromagnetic, etc.) to impact human pain.

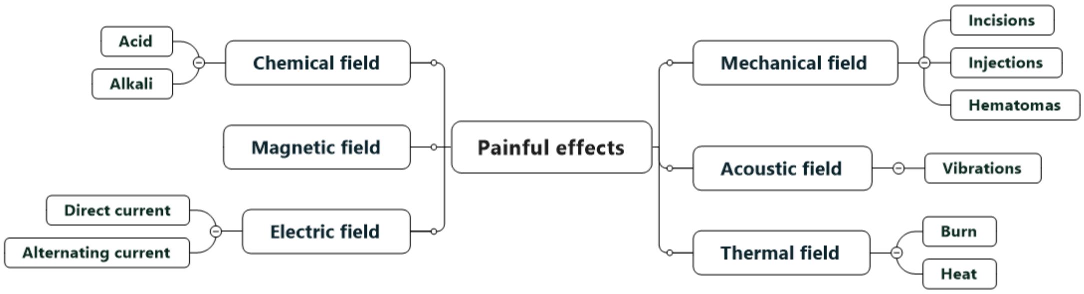

Figure 2: Classification of physical fields by type of painful effects.

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The mechanical (force) field is presented by various cuts, injections, hematoma, and similar effects [7]. The main disadvantage is the possibility of skin disorders, as well as the inability to accurately manage the impact of pain. It can be used in conjunction with a magnetic field to increase the exposure control, however, this will complicate by several times the system and pain impact procedure (impact tool will be sterilized, or be disposable). This field is difficult to manage in terms of electronic systems, and the use of different tools for applying physical effects requires good fixation, which impedes miniaturization together with the creation of a sufficient level of pain exposure.

The acoustic field is presented by acoustic impact at different frequencies [8]. The nature of the impact is such that it may affect the organs of hearing, as well as on the state of internal organs. At certain frequencies, there may be a resonance with the internal organs, which adversely affects the health of people, and sometimes leads to death. From the standpoint of use in microelectronic systems, this method is interesting because it requires a small amount of energy to create certain frequencies of impacts, nevertheless the possibility of resonance with the internal organs makes this method inapplicable for the purposes at hand.

The thermal field is presented by the impact of temperature. During imitation, it is easily adjustable, however, there is the possibility of thermal destruction of the places of contact. In the absence of anesthetic means, the limit of pain sensitivity is likely to be reached before the skin is destroyed, however, whilst using anesthesia a subject cannot even feel the burning of the skin and the integrity thereof will be destroyed, which is unacceptable in this case. Thermal effects require a large amount of electricity, which makes it impossible to use wireless systems.

The electric field is presented by the effect of electrical discharge or current. This method allows to create an adjustable painful effect simply, without damaging the object, and makes it easy to produce a level of measurement created by the impact of pain (electric current intensity). It is ideal for use in electronic systems. The main problem is the difficulty in implementing wireless systems, as to assess the needed level of pain it is required to create a voltage of 200V and a current of up to 10mA, which either hinders the creation of wireless systems or requires the use of a sufficiently large battery pack.

The magnetic field up to a certain point does not affect the object, and after the exposure can be deadly and causes irreparable harm to the object.

The chemical field is presented by the impact of various chemically active substances. It is the main drawback in (замечание: может быть, amidst, «среди») the difficulty of the impact of regulation and material consumption to create these effects. Also, this effect in the majority of the reactions will be destructive, which is unacceptable.

Based on the nature of the discussed effects, it can be concluded that the best way to create controlled impact of pain is the electric field, as electric shock is easy to operate (continuously adjust) (замечание: continuously – это в течении время, может быть, следует использовать слово smoothly), and can be quickly turned off by a fuse in case of emergency.

The source of the impact of pain is a controlled current source. At this stage, the source can be attached to the human skin. Also, this device sends a signal to the processing unit to terminate the painful impact strength of the current at the end of the exposure and end time.

4. The Concept of the Pain Impact Device and Photoplethysmogram Measuring Device

These devices are the only ones that are in the known analogues connected directly to the device using a wired connection, which creates additional inconvenience for the patient and slows downtime measurement response.

The only required information is that of a photoplethysmogram, for which is required a source of infrared radiation and a photoresistor/phototransistor. Also required are a battery pack, the microcontroller unit and wireless information transmission block, for example, Bluetooth.

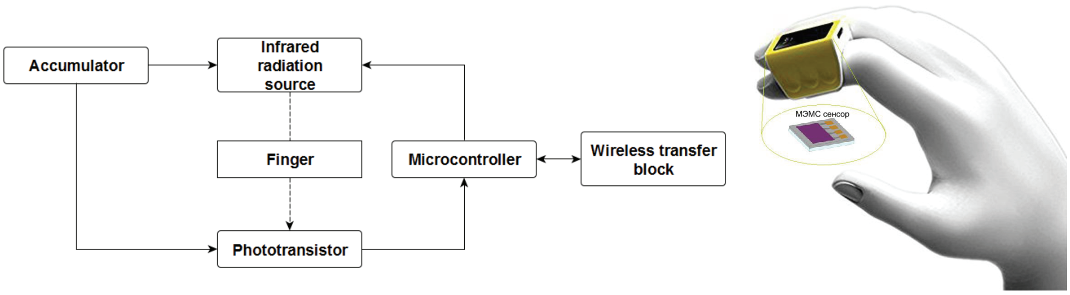

Figure 3: Wireless photoplethysmogram unit of measurement.

This unit may be manufactured in a compact package, analogues of such devices being on the market, however, the data transfer protocol is closed, which prevents the use of these devices for third-party projects and restricts their scope to only earmarked values.

5. Results and Discussion

The main problem may be the device for creating the pain impact because a sufficiently large amount of energy is needed to create the pain impact, which requires quite a bulky battery pack, as well as the use of the pulsed power supply for 200V output voltage. Based on the calculator from Texas Instruments [9], for 200V, a battery of 12V 0.5A is needed, which takes a moderate amount of space that will allow their use for the wireless measurement.

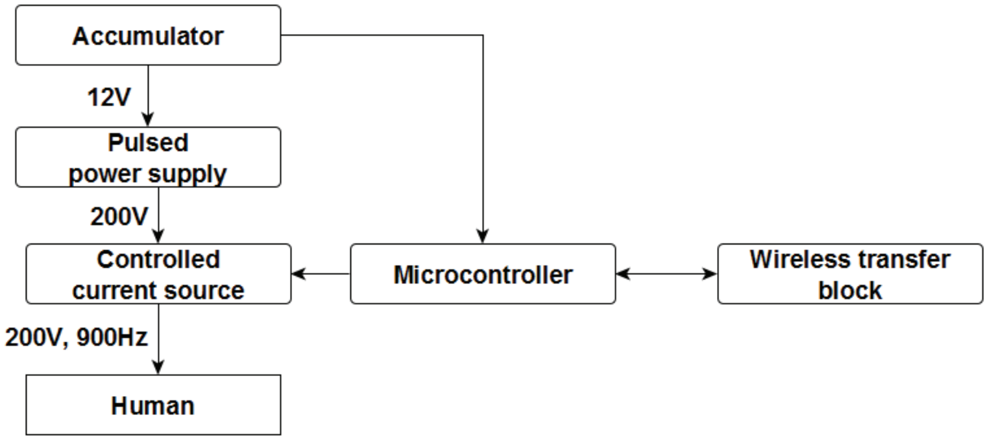

Figure 4: Wireless unit of pain impact.

The rest of the device blocks do not interact directly with the patient and their dimensions do not affect the convenience and speed of the procedure.

6. Conclusion

Assessment of pain sensitivity is currently an uncharted area, and known methods of evaluation are subjective and do not give the opportunity to link quantitative indicators with the required number of anesthetic agents to relieve pain in certain medical operations. The difficulty in estimation lies in the use of subjective data, however, the use of large amounts of information reduces the statistical error, and with enough information to move from subjective to objective parameters (photoplethysmogram amplitude, frequency, etc.).

The most simple, accurate and efficient way to create pain is electric current. It is easy to manage and creates a stable pain exposure. The only disadvantage is reduced sensitivity to electrical current for a short time, which is easily eradicated by a change in the measurement site, if re-measurement becomes necessary.

The usage of microelectronic systems makes it possible to reduce the time of measurement, as well as to increase patient comfort by reducing the number of wired connections to the pain sensitivity evaluation unit, nonetheless requires the use of batteries for the wireless data module, which creates some difficulties.

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