Wearable Care System for Elderly People

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***Abstract*—A growing number of elderly persons in Poland and Europe forces us to looking for new solutions for the continuous monitoring of their health state. This approach allows for early action in case of dangerous situations for elderly person life (state before heart attack or stroke, etc.). The system for continuously monitoring the health state also allows for quick action of first contact doctors in the case of emergency situations. This described system also allows the remotely monitoring of elderly people in their home by their relatives. The monitoring system is portable, comfortable to use and uses non-invasive measurement methods. This kind of clothing is full user-friendly product. The textronic system is a new product for monitoring selected human physiological parameters, such as: pulse, frequency of breathing, underclothing temperature, positioning inside and outside the house. Textile sensory elements and signal lines are implemented in the structure of the clothing and it is a main innovation of this kind of systems. System of a textile sensor is part of a garment, the monitoring system is fully portable, easy for using, does not require specialized medical services. Furthermore, measurement of physiological parameters is non-invasive which means that does not interfere directly in the human body. The system is completely safe, because it is supplied by a miniature battery such as the one that are used in mobile phones. The combination of textile clothing interface with specialized software for data acquisition and generation of alarm signals provides a continuous overview of the health status of the monitored person.**

***Index Terms*—monitoring, measurement, textronic, smart textile, sensors, textile electrodes, pulse measurements, breath measurement, IPS, GPS, software**

I. Introduction

State of art presents a systems for mobile monitoring of vital signs, but these solution uses typical electronic sensor that are implemented in shirt structure [1], [2].

The other approach is to use care systems that has textile sensor inside their structure [3]. This kind of system is called textronicsystem.

The term textronics refers to a synergic connection of textile science and engineering, electronics and informatics with the use of knowledge from the area of automatic and metrology. The synergy of such a connection is displayed in creation of a new quality, in which the component elements enhance mutually their action. This is achieved by physical integration of microelectronic with textile and clothing structures. The aim of textronics is obtaining multifunctional, intelligent products of complex internal structure, but of uniform functional features. As textronic system it is called measuring and control system, which includes fibrous sensors and actuators, or other elements inserted in the fibrous structures, as well as electronic micro-circuits connected with these structures or formed with the use of them. Fig. 1 presents the idea of textronic field.

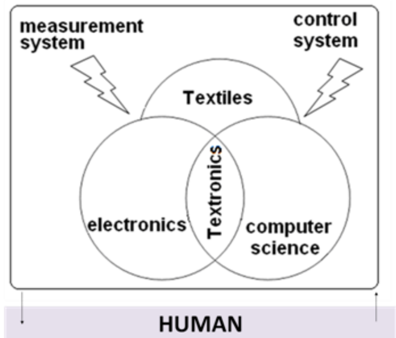

Figure 1. The textronic field of knowledge

The elderly are a group of people who need special care. Concerning for their safety, textronics clothing for monitoring physiological parameters was designed. This system is a new product for monitoring selected human physiological parameters, such as: pulse, frequency of breathing, underclothing temperature, positioning inside and outside the house. If one of those parameters changed in a life-threatening way, the appropriate services would be notified.

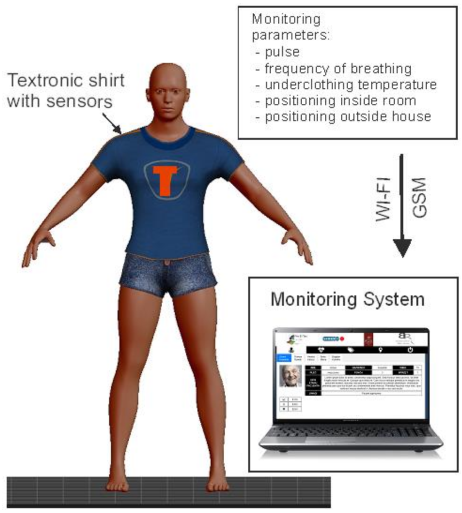

Figure 2. The block scheme of the textronics system for protecting of elderly

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Presented textronic system (Fig. 2) does not require specialized staff to support it. Compatible software will provide continuous data acquisition and generation of alarm signals in the form of reports such as sms or e-mails for carers of older people. This system also allows remotely the monitoring of elderly people in their homes by their family.

Textile sensory elements and textile signal lines are implemented in the structure of the clothing and it is a main innovation of this kind of systems. Furthermore, measurement of physiological parameters is non-invasive which means that does not interfere directly in the human body. The system is completely safe, because it is supplied by a miniature battery such as the one that are used in mobile phones. The GPS function activated after leaving the predetermined area provides the possibility to find an elderly with fading memory. The IPS system indicates user's positions inside building.

II. Construction of Textronic System

The invention of prototype would be the textile construction of sensing and active system. Authors use only textile sensors. The overall concept of wearable system to for elderly is presented in Fig. 3.

Figure 3. The scheme of the textronics system for protecting of elders

The biosignals measurement will take place on a textronic shirt with textile electrodes. These electrodes adhere well to the human body and can be washed. Theelectronic setup is implemented in shirt structure and includes: measurement circuits of biosignals, microcontroller unit, communications modules working in WiFi, RFID, GPS/GSM technologies.

III. Pulse Measurement System

The flexible form of textronic measurement system provides a measure of the pulse using dry textile electrodes. The system will consist of a textronic measuring module and a transmitter module. Measurement data will be sent by wireless transmission methods to the computer or smartphone using WiFi technology. The block scheme of pulse electronic system is presents in Fig. 4.

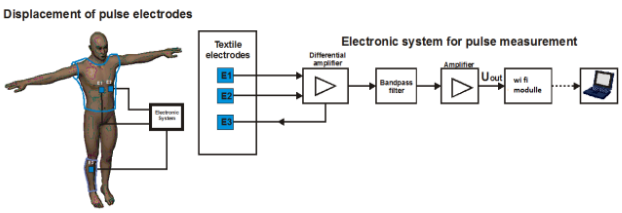

Figure 4. Electronic system to pulse measurement

Pulse measurement requires textile electrodes. The electrodes must be characterized by low surface and volume resistance and should be also characterized by uniform distribution of contact resistance between the materials surface and the human body. Textile electrode realization presents Fig. 5 [4].

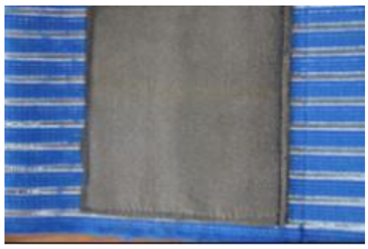

Figure 5. The component textile electrode made of the nonwoven fabric layer and the electrically conductive outer layer

The basic parameters of electrode are collected in Table I.

TABLE I. The Parameters of Textile Electrodes

No	Properties	value
1	Thickness of electrode	1.5 mm
2	Surface mass	219 g/m
3	Surface resistivity	0.05 Ω/m
4	Volume resistivity	5 mΩ

First electronic pulse setup with electrodes was tested by phantom pulse [5]. It ensures repeatability of measurement, because real time pulse read from human body is stochastic signal. It consists of special electroconductive gel that imitates a human's skin and tissues [6]. Two supply electrodes introduces a pulse signal from arbitrary generator and other two electrodes (traditional or textiles) read this signal in certain place on phantom.

In the case of the pulse sensor comparative analysis with traditional measuring electrodes was carried out. Various electrodes placement configurations were studied. Chosen waveform of pulse shows Fig. 6 and Fig. 7 presents its periodogram for traditional ECG electrodes.

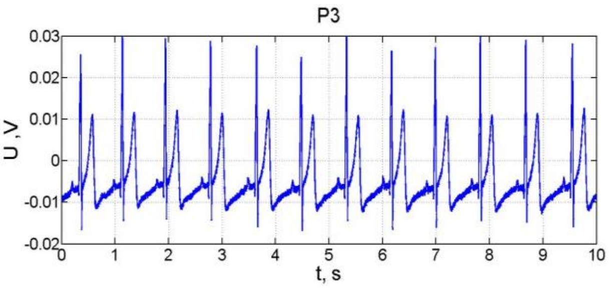

Figure 6. The timing diagram of a pulse signal obtained from traditional electrodes

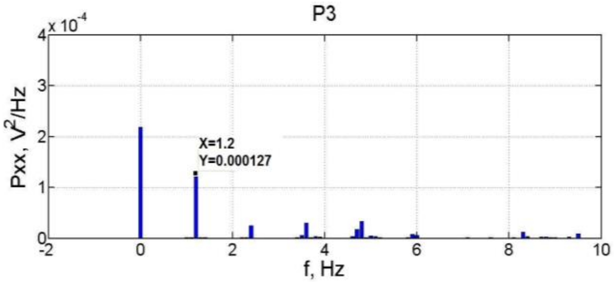

Figure 7. The periodogram of a pulse signal obtained from traditional electrodes

Periodogram can specify the number of heartbeats per minute. Modulus P_{xx} for the periodogram were calculated as a complex formula (1) [7]. The maximum value of spectral density P_{xx} can indicate pulse value expressed in Hz, what can be simply calculated in beats per minute.

$$S(f)=\frac{1}{F_S N}\left|\sum_{n=1}^{N} x_n e^{-j(2\pi f/F_S)n}\right|^2 \qquad (1)$$

where $S(f)$ is a complex form of periodogram, f- frequency spectrum of the signal, F_S - the frequency of sampling, N- number of samples analyzed signal [x_1, ..., x_n], n another sample.

The value presentation by the periodogram match the number of waves calculated over 10s and has been translated into the period 1 minutes. If the foregoing is 1.2Hz, or 72beat/min. The Fig. 8 and Fig. 9 present time pulse obtained for textile electrodes with its periodogram.

The frequency for the course of time or with periodogram, which is presented at the highest power density (do not take account of fixed component) is 0.9hz, or 54 beats/minute.

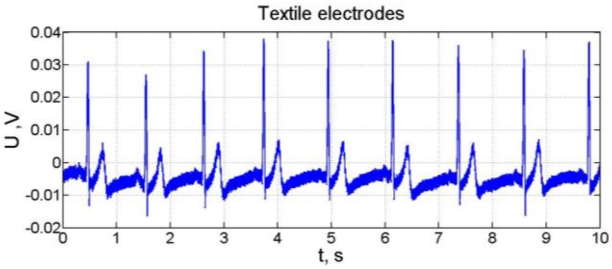

Figure 8. The timing diagram of a pulse signal obtained from textile electrodes

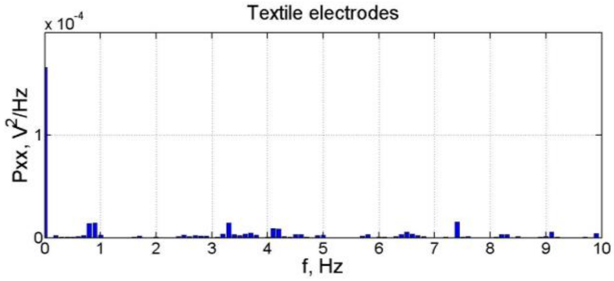

Figure 9. The periodogram of a pulse signal obtained from textile electrodes

IV. Breath Rythm Measurement System

It was also made textile testing sensor for measuring the frequency of breathing rhythm. It is possibility to create different kind of textile sensors to breath frequency measurement [8]-[11]. The most interesting from authors point of views is technology where textronics shirt can be create in one technological process [12]. T-shirt with flexible knitted sensor to measure breathing rhythm was used during presented research. The construction of measurement shirts is shown in Fig. 10.

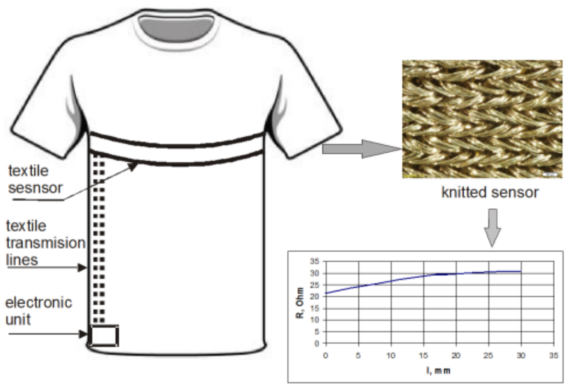

Figure 10. Scheme prototype textronic shirts to measure the incidence of respiratory rhythm; Photos of electrically conductive microscopic elastic fabric

The textronic sensor advantage is that enable noninvasive breath rhythm measurement and their textile form does not cause discomfort of use.

First test of textile sensor was performed on breathing phantom. Phantom allows obtained repeatability and reproducibility conditions. It is important to determine the measurement accuracy and development of frequency measurement algorithm of breathing rhythm. It should be noted that the signal sensor tested in real conditions on human body is stochastic waveforms and elaboration of suitable algorithm would be impossible without phantom. The scheme of breathing phantom is shown in Fig. 11.

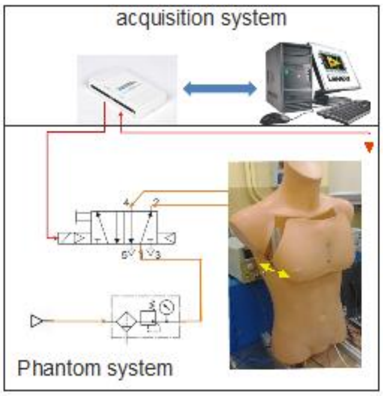

Figure 11. The schematic view of breathing phantom [13]

Phantom also enables calibration of textile sensors in relation to the reference spirometer. It enables:

- Changing the depth of breathing,
- Change the frequency of breathing,
- Monitoring the breathing process.

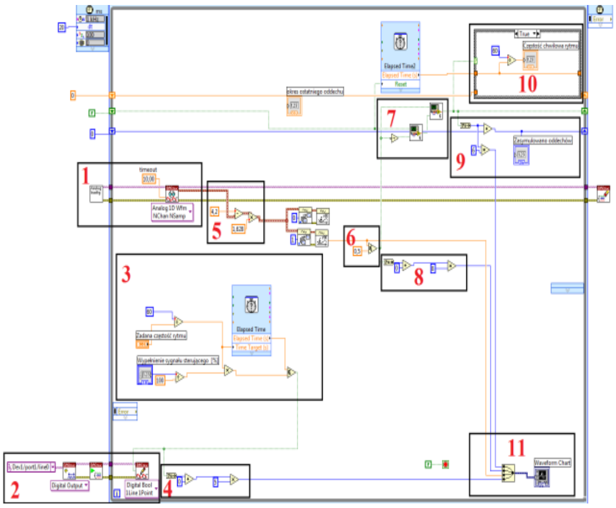

Figure 12. The schematic view of LabView diagram software to control human breathing phantom

Phantom includes a part of the torso imitating humans. The whole phantom structures is based on aluminum profiles. Actuating system is provided with pneumatic actuators and electrovalves for simulating movement of the chest. Electrovalves are connected to the system of preparation of compressed air with working pressure max. 6bar. This system consists of a compressor, filters and dehumidifiers. The pneumatic actuator is controlled by a control signal derived from the digital output measurement card. This card is connected to the PC. Furthermore, the actuation system is equipped with an optical path of infrared light to measure the position of the actuator pistol. The output of this circuit is also connected to the input measurement card. This allows to adjust the frequency and amplitude of the rhythm of breathing. Phantom is characterized by repeatable movements of the chest. It has also developed software in LabView environment to control and monitor the process of breathing. The Fig. 12 shows a program to operate the breathing phantom.

The Fig. 13 presents example waveform of pistol movement of phantom monitored by optical sensors and Thetextronic breathing sensor is placed on the phantom during tests. The Fig. 14 shows waveform voltage from textronicsensors in the same time. The frequency of both signals are the same. The signal of tested sensor is only delayed (inverted) according to optical sensor. It results from electronic structure of measurement setup of this sensor. Noise signal sensor results from measurement card used for data acquisition.

In a next step of research the measurements were done on volunteer. The Fig. 15 and Fig 16 show a time diagram of breathing rhythm and its periodogram.

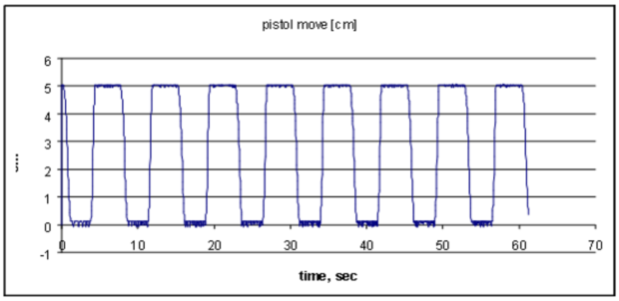

Figure 13. An example of the chest phantom movements, 8 breaths

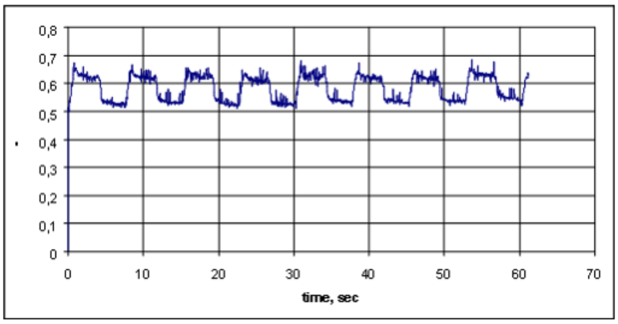

Figure 14. An example of the textronic sensor changes during the chest phantom moves, 8 breaths per minute

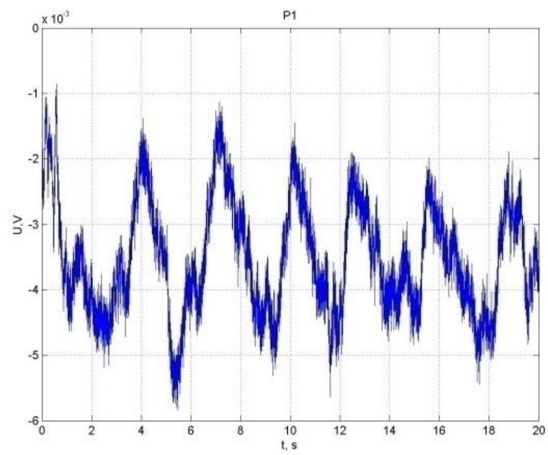

Figure 15. An example of the textronic sensor changes during the volunteer research

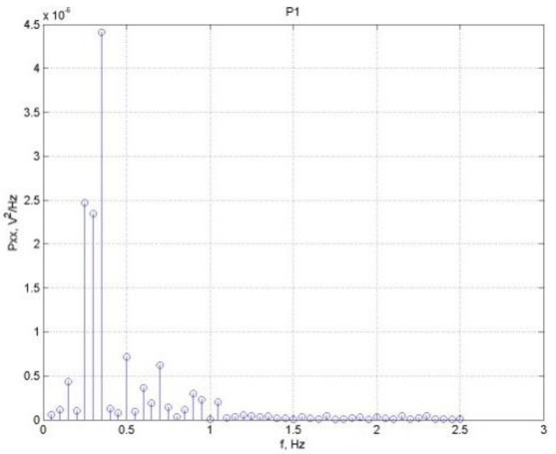

Figure 16. Periodograme for breathing tests

The frequency at which the periodogram has the highest value is 0.35 breaths/s or 21 breath/min. This is the true frequency running breath. This value was proofed with reference spirometer.

V. Temperature Measurement System

This system uses temperature sensor to measure underwear temperature in space between skin and shirt with sensors. The real body temperature is difficult to evaluate, but placement in this way can warn against overheating and perform non-invasive measurement.

The platinum PT100 temperature sensor was used in wearable system. It has reproducible and linear static characteristics, it is often used to calibrate other sensors. Its disadvantage is low sensitivity, it means low resistance increase in function of temperature rise. The presented sensor uses sensor without the metal housing, it ensure much smaller time constant. The PT100 sensor requires a suitable measuring system that introduces a small error measurement and is independent on resistance connection between sensor and measurement electronic setup. The temperature sensor was connected to three wired measurement system presented in Fig. 17.

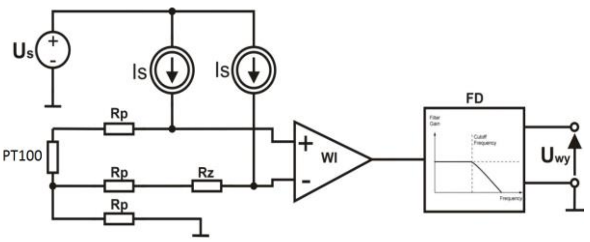

Figure 17. Threewired measurement seteup for temperature sensor

The PT100 temperature sensor is connected to aplifier WI by textiles wires, with R_p value. This connection configuration reduces to zero error caused by wires. Output voltage from amplifier WI is processed by lowpass filter FD.

PT100 sensor with measuring system was calibrated using a calibration stove. The stove temperature was adjusted after settling indications read oven temperature and the output voltage of the sensor measuring system under test. Research carried out for the rise and fall of temperature.

VI. PS System

Authors presented one type of Real-Time Location System (RTLS) based on the location of people inside the buildings (IPS - Indoor Positioning Systems). The presented system uses RFID technology. RFID is the general term which is used to describe the technology that allows automatic identification of an object with the use of radio waves. The system includes an RFID tag (also known as transponders, RFID label, chip RFDI, tag RFID) and an RFID reader antenna. A typical RFID tag is a microchip (integrated circuit) connected to the antenna, mounted on a support (paper, plastic or a garment). The microchip with a few hundred bits of user memory can store data, usually written only a number that applies to a specific user database. For reading the data from the RFID tag reader antenna is required. The reader is able to read more than a thousand tags. i That number depends on the model of the reader. Then the reader can send its data to the computer, where it will be used properly. The part of memory in a microchip is a TID (identification tag memory) - a unique serial number that identifies the tag. Access to the memory is protected by password and it is required to read, write and change the tag data. The separate password allows the destruction of the marker. Patient identification is possible through the implementation RFID tags, within specialized textronics clothing. The general principle of the IPS system is shown in Fig. 18. The main elements of the system are the RFID readers with integrated DL920antenna installed in frame door of patient's rooms. These readers were selected on the basis of market analysis from a broad range of RFID readers with integrated antennas. They are characterized by compact dimensions (24x24cm), the possibility of connecting to the Ethernet via TCP/IP and reading range up to 5 meters.

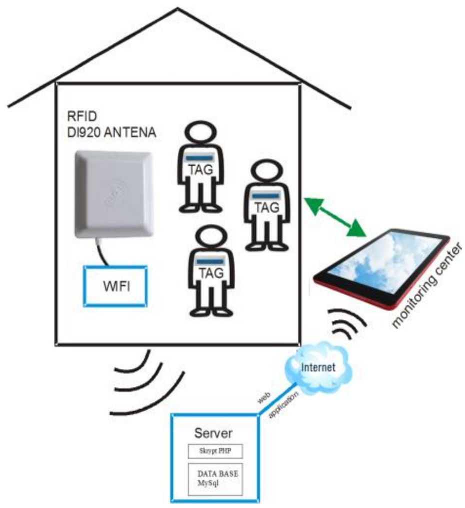

Figure 18. The structure of a IPS system for monitoring patients in hospitals or nursing homes

For the patient diagnosis there is used one of the types of tags with the symbol VT-85C. Tag VT-85C has a sealed housing for its protection from harmful agents such as water, sweat or mechanical damage due to its normal operation. The tag has an IP-67 class resistance. It is flexible and can withstand high temperatures up to 180℃. It is characterized by compact dimensions (101mmx14mmx1.5mm) which allows its implementations in the clothing without worrying about its damage.

VII. GPS System

The GPS function activated after leaving the predetermined area provides the possibility to find an elderly with fading memory. This system is dedicated for patient location outside buildings. The GPS system is based on SIM908 setup. This module has integrated two technologies GPS/GSM. It is necessary because GPS module has only receiving function. It communicates with satellite and gather information about position. In this case GSM module sends to the webserver information about actual position of user. It uses GPRS service to data sending. Microcontroller uses UART interface to change data between appropriate modules. The general concept of GPS system is presented in Fig. 19.

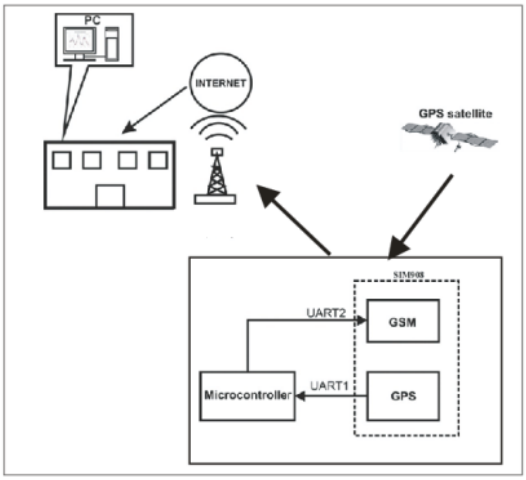

Figure 19. The structure of a GPS positioning system

VIII. Software

The whole system for elderly protection is managed by a web application embedded on the server Synology DS1010+. It is an application which can be accessed on various mobile devices such as Smartphone, tablet or notepad. The requirement of using it is that the devices have a web browser. In that case the type of operating system (Android/iOS/Windows) does not matter. The simplification diagram of web application structures divided into programming languages like PHP, MYSQL, HTML, CSS, JS is presents in Fig. 20. The web application allows tovisualize measurement of phisiological parameters (pulse, breathing rate and undwear temperature) and graphical patent's identification inside and outside building.

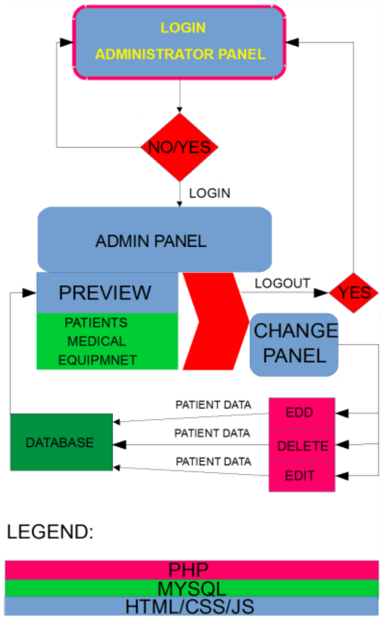

Figure 20. The simplification structure of web application divided into programming languages

The main panel of the application that supports the login pages is shown in Fig. 21. The home application is a login page.

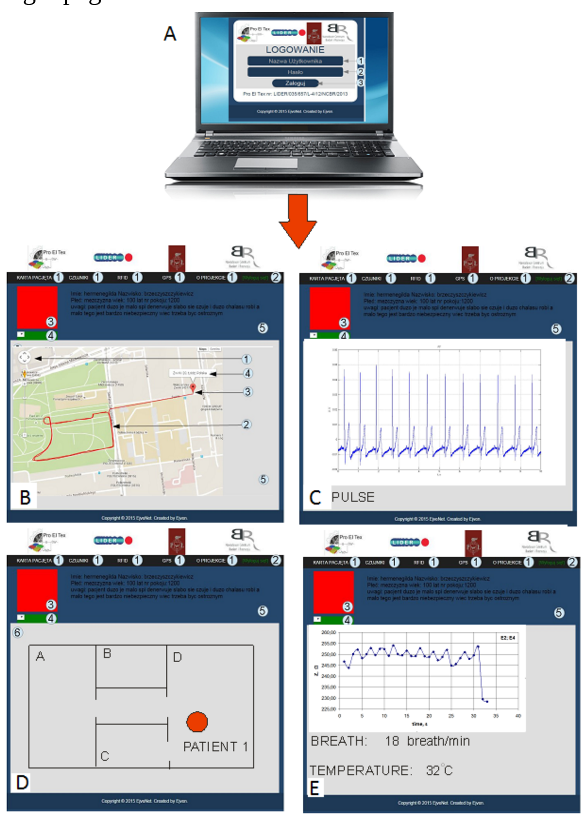

Figure 21. The structure of a software for monitoring patients

A. Login panel for web application; 1 login name; 2 – password; 3 – log in button
B. GPS tracking panel
C. IPS tracking panel
D. Pulse measurement panel
E. Breath and temperature measurement panel

IX. Discussion

In the paper authors presented the specialized textronics clothing system especially dedicated for elderly Thesegarments can monitor physiological parameters of the patient. System of a textile sensors is part of a garment, the monitoring system is fully portable, easy for using, does not require specialized medical services.

The system itself is a modular system. It consists of two parts: a hardware and a software. That structure of the system enables, after logging in to the website, monitoring of the patients in the building with a various mobile devices such as the smartphone, tablet or by traditional desktops. Information about the patients' moving around is shown in mobile device, with the current date and time of entering into the room. Lack of physical activity of the patient is also indicated by changing the color of a website. The combination of textile clothing interface with specialized software for data acquisition and generation of alarm signals provides a continuous overview of the health status of the monitored person. Textile sensors was proofed and calibrated in specials stand like a breath rhythm phantom.

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