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Dohledové monitorovací systémy v domácí péči

Supervisory Monitoring Systems in Home Care

Souhrn

Evropská populace dlouhodobě stárne a bude potřeba zvýšené zdravotní a gerontologické péče. S nárůstem množství takovýchto pacientů, kteří mají zdravotní nebo pohybové problémy bude potřeba řešit jejich umístnění ve zdravotnických zařízeních anebo v domácnosti. Pacienti pak mohou být monitorováni technickými prostředky pro sledování jejich zdravotní stavu a životu ohrožujících situací. Tento problém řeší nově navržené technické řešení dohledového systému monitorování v domácí péči. Toto řešení popisuje jak koncepci činnosti systému jako celku, tak rozbor jednotlivých původních návrhů souvisejících praktickou realizací monitorovacího systému. Takto navržený systém eliminuje riziko vzniku a prodlevy při zjištění a nápravě krizových a životu ohrožujících situací a rovněž umožňuje dlouhodobé monitorování zdravotního stavu a jeho změn v přirozeném prostředí.

Summary

The European population is getting older in the long term period and that is the reason we need to focus on increased and improved health and gerontological care. With a growing number of such patients who have medical or physical problems, we will need to deal with their placement in health care facilities or at home. Patients then can be monitored by technical means for monitoring their health status and life-threatening situations. This problem is solved by a newly designed technical solutions of the supervisory monitoring system in the home care. This solution describes the concept of system as a whole, and also analysis of each of the original proposals related to practical implementation of the monitoring system. The proposed system eliminates the risk of its origin and delays in the detection and correction of emergency and life threatening situations and also provides long-term monitoring of health state and its changes in the natural environment.

Klíčová slova:

monitorovací systém, domácí péče, měření biosignálů, bezdrátová komunikace, zpracování signálů, decentralizované zpracování

Keywords:

monitoring system, home care, biomedical measurements, wireless communications, signal processing, decentralized processing

Content:

1 Introduction

The concept of biotelemetry is extremely topical in terms of them trends seen in the demographic curve and prolonging of the population's age; however, it is also interesting because we can combine the knowledge of electrical engineering, technical cybernetics and biomedical engineering, resulting in sophisticated and mostly beneficial solutions. This knowledge benefits the selection or design of sensors and devices that measure and transmit data for further processing and evaluation. Biotelemetry combines the knowledge and skills of many fields of science; for individuals or small teams, it is usually not possible to completely comprehend this entire area. Problems include the biophysical basis related to the generation of signals and their measurement as well as the subsequent data transmission, protection, encryption and storage; the resulting information about the behavior and health status of individuals outside the medical facility cannot be obtained without processing and evaluating relevant data.

This work includes an analysis and description of some areas of the biotelemetry concept that is address with regard to professional orientation and knowledge. The work starts with an analysis of the design concept of biotelemetry systems in relation to the ways and methods of sensing biosignals through the use of existing technology, but also with a design of new solutions for measuring bioelectric signals in home care. Part of the work include mobile wearable devices for measuring, collecting and transmitting the data necessary to process and evaluate these biosignals. There is proposed one possible way to process and store data that would significantly contribute to providing a rapid and reliable evaluation of potential crisis situations in which we may all eventually find ourselves.

2 The Concept of Remote Home Care

Increasing demands on the quality of health care services and the related growth in the prices for these services in the respective healthcare facilities monitoring older patients will require the use of information and communication technologies, especially various types of embedded (built-in) systems with different levels of critical safety for the persons being monitored. From this perspective, it is possible to divide health care into three main categories. The first category includes ill patients with a partial emphasis on chronic problems. The second category includes patients at risk of health problems due to their age or current posttraumatic condition. The final category includes health care with clinical support of primary services for acute and clinical care, ensuring communication between other home care and social services

In these health care categories, it is expected that personal telemedicine embedded systems based on the principle of wireless sensing elements enabling a user-accessible interface when accessing current medical information will be used. A part of these systems is the need for the connection between superior elements of the wireless communication to the supervisory centre. Patients themselves can easily control their health; based on the type of biosignals being monitored for each person, the embedded system is connected to different types of medical transducers with a corresponding interface. The obtained digitized biomedical signals from the new built-in medical transducers allow us to determine appropriate parameters using new signal processing and extraction techniques in order to support making a diagnosis and prescribing subsequent treatments (Horak et al., 2007; Chan et al., 2012; Noury et al., 2014; Srovnal, Penhaker, 2006).

2.1 Concepts of Remote Healthcare Systems

The embedded system must be portable and unobtrusive for the user; its weight must be low and the system must also be affordable. The main objective of the sensor network's design is to avoid any obtrusion for the user and provide relevant data on the patient's health status and critical situations.

Using the technology of intelligent environment changes close relationships between the process of health care and home care system, and the depth of embedding the technology of wireless sensors and actuators into this environment. This is a partial important benefit of embedded systems because they provide the technological infrastructure for the implementation of intelligent environments.

The existing proposed solutions envisage the use of basic biological function sensors in home or hospital care; however, they also contain sensors for measuring the values of specific biological variables.

In the context of demands for measuring biological variables and their transfer set out by experts, the proposed telemetry system for gathering information should meet the following requirements:

- Possibility for a modular measurement of biological parameters
- Mobility and modularity of the embedded system
- Easy applicability and transferability
- Discreetness of the sensors used
- Minimum energy demands
- Minimum weight
- Noiseless
- The use of commercially-available devices
- Price affordability

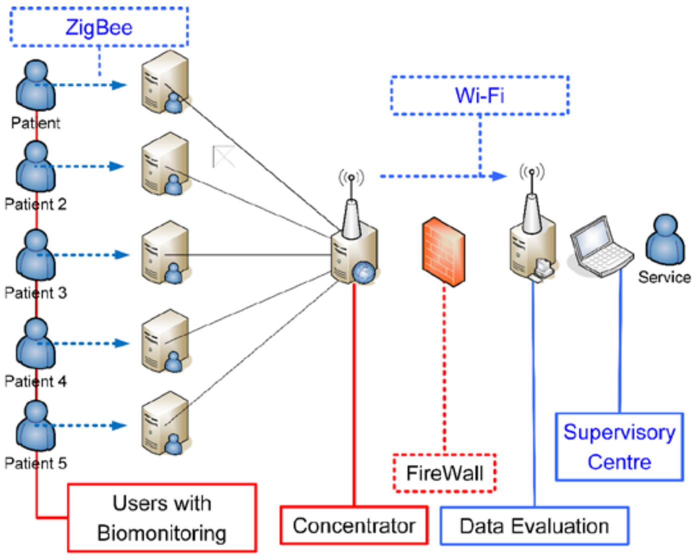

Figure 1: Design of communication and data transmission to the central console or supervisory centre

The system was also designed in order to allow for the utmost adjustability of the number of sensors and monitored persons, to ensure the proper identification of each user of the telemetry system and to always guarantee the transfer of information and alarm events to the supervisory centre see figure 1. Therefore, this solution takes into account both indoor (e.g. for home care) and outdoor use by ensuring the continuity of data transmission through switching between data channels (Srovnal, 2005).

2.2 Selection of Measured Variables

A priority aspect of home care systems is to be able to select the variables for monitoring the selected parameters. Since these variables are based on human activities, we call them biosignals. These biosignals can be divided as follows: biosignals related to the measurement of acute information showing the immediate condition of monitored persons, and biosignals that carry information about their long-term activity and condition. Selecting the right biological parameters to be sensed was consulted with experts and doctors. Based on their recommendations, the following criteria for these parameters were determined:

- Ease and efficiency of measurement
- The parameters should comprise vital body functions
- The predictive value of individual biological parameters
- Possibility of further processing and information extraction
- Willingness in clients regarding practical installation
- Observance of personal data confidentiality and protection

An important home care parameter is the detection of falls. Falls are a common hazard for older people and cause frequent and severe health complication. It is well known that the consequences of falls increase with age. Obviously, falls are a serious problem for the elderly. It is necessary to realize that falls are the result of a fear of falling; they indicate a loss of confidence and limited mobility and independence, which can be either voluntarily accepted or be a result of the care provided (Reichman, 2009).

The possibility to monitor the position and movement of people can either help in the identification of persons in the event of a fall or reduce the risk of falls if this risk is detected in a timely manner. The ability to detect falls in old people living alone and simultaneously activate a rescue system is a huge benefit that allows us to shorten the time until the arrival of the first responders and thus reduce both the physical and psychological traumas of such events (Penhaker, Černý, 2008).

2.2.1 Wireless Transmission of Data from Sensors

Measuring the biosignals occurs by using wireless technology incorporated in all embedded devices, with the exception of measuring human movements in an enclosed space.
To compare and evaluate all wireless technologies, it is necessary to select relevant criteria. The main criteria used in our project included bandwidth, range, power consumption, reliability, availability, usability and security. Depending on the sub-requirements, there may be also other criteria or special weighing or simple criteria. After defining these criteria, different technologies for use in a medical environment were considered and compared (Srovnal, 2005).

2.2.2 Embedded System

The embedded system performs several functions in the measuring chain. First, it primarily ensures data collection from sensors and performs signal pre-processing; at the same time, autonomously or indirectly, it also provides the position localization and sends all data on alarm situations to the supervisory centre.

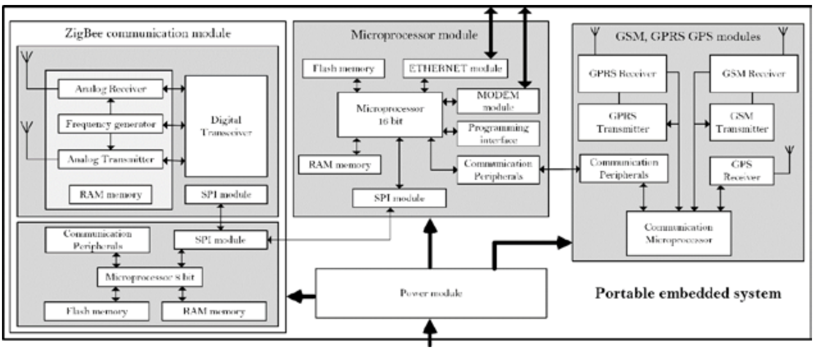

Figure 2: Block diagram of portable embedded system

On one hand, the portable embedded system can wirelessly communicate with the network of sensors; on the other hand, the embedded system can make decisions based on the sensed data and transfer the decision outcome through the wireless GSM/GPRS network or using a wired connection via an Ethernet port or modem. GPS-based GSM/GPRS communication is very useful on the street in the case of a user falling. Both ways of communication can be used in the user's residence since standard communication over a phone or cable line for sending data to the medical centre is often still cheaper than GSM/GPRS. The parameters for the decision-making process can also be adjusted remotely.

When the patients leave their home, they take their embedded system along with them. After they return, they simply connect the device to an external power source in order to recharge battery.

The type of processor depends on the configuration of the sensor network. We used a DSP signal processor or a 32-bit microprocessor. The figure (Figure 2) shows the configuration for the basic sensor network without ECG signal processing (Caldara et al., 2013; Campo et al., 2013; Cerny, Penhaker, 2011).

2.2.3 Wired and Wireless Data Transmission to the Dispatch Centre

The data concentrator allows us to have a mobile part that collects data from biosensors via Bluetooth and ZigBee or other technologies to communicate with the central console via a GSM/GPRS modem while the patient moves outside and a stationary part that is permanently connected to a local area network (LAN). During the period in which the patient is present within the area covered by the LAN, the mobile part can be inserted into the stationary part. The stationary part communicates with the mobile part via a USB interface and is connected to the data network either via an Ethernet 10BaseT (for example) or wirelessly using Wi-Fi IEEE 802.11 (Figure 3).

Although the issue being discussed is already a standard technical implementation of LAN integration into a wide computer network, it is necessary to bear in mind the absolute need for data security as well as the need for the guaranteed delivery of information on any critical states to the central console, even in the case of communication path failures.

Alternative transmission routes were therefore considered with regard to the provision of communication even in the event of failure of some of the paths, respecting maintaining a reasonable price for the applicable routing element between LAN and WAN (Ali, Khan, 2014; Li, Lou, Ren, 2010).

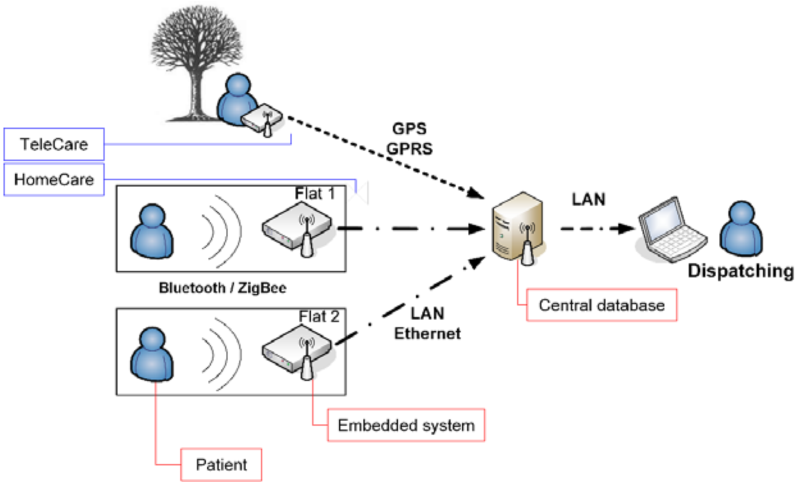

Figure 3: Scheme of using the embedded system for monitoring

2.2.4 Dispatching of Data Processing, Evaluation of Data from the Database

In accordance with the focus on having the entire telemetry system based on open systems, it seems appropriate to use a Linux OS with data storage in the freely available SQL database MySQL, which also supports triggers (starting with version 5.0) and is easily utilizable for evaluating alarm conditions based on stored data and for the respective responses. Receiving data through the TCP connection from the data concentrator and their storage in the SQL database will be ensured by a rather simple program most likely written in some commonly used programming language. Operator access to the central console database is proposed through a web application. Using Linux in the central console server is advantageous as it also enables the direct implementation of IPSec technology for terminating the encrypted tunnel for secure data transmission from the router to the LAN interface with patient data concentrators (Yang, 2014).
Although there are many similar as well as very different design concepts for biotelemetry systems for monitoring a patient's condition, the above concept is the concept that we developed with colleagues over a long-term basis and also implemented in the form of a biotelemetric flat. Each journey begins with the first step; similarly, the subsequent

reflections on the system's implementation were built on the selection of measured variables carrying relevant information about the current state of the person being monitored. Therefore, the following chapter deals with biosignals and their measurement.

3 Measuring Biosignals

3.1 The Essence of Biological Signals

The human body is composed of many cells, fibers, tissues and organs, which are all sources of biological signals. A biological signal is a carrier of information about an observed or researched biological system. The most commonly measured and used signals in diagnostics are those with spontaneous activity in the biological system, called natural signals. These signals may be of different types depending on the principle of their formation. Impulses and chemical processes in the membranes of nerve and muscle cells generate electrical action potentials. The electric field easily spreads through the biological environment; it is therefore possible to sense bioelectric signals at appropriate locations on the body's surface. Bioelectric signals are the most important signals from the group of biosignals transmitted via biotelemetry.

3.2 Sensors of Biological Variables

Measurements provide a source of information about the properties, condition and behavior of a system, which in our case is a living body. Depending on the type of sensor, we can also distinguish between inherent and mediate types of biosignals as well as their manner of sensing and examples of their application in medical diagnostics.
A substantial and very important group of sensors are the sensors of electrical activity of living organisms. Specific differences from the sensors used in technical cybernetics are described in many literary sources such as (Bronzino, 2000a, 2000b, 2006; Enderle, Blanchard, Bronzino, 2000; Penhaker, 2004; Webster, Clark, 2010; Webster, Eren, 2014a, 2014b); these differences result in different demands on their design, construction and use. This mainly relates to completing the existing criteria imposed on sensors as well as on the measuring and evaluating circuits that are affected by the emergence of half-cell potentials (voltages) and the oxidation of electrodes used to take measurements on biological organisms (Liu et al., 2013).

3.3 Biopotential Electrodes

Biopotential electrodes are active sensors, i.e. the source of electricity. In terms of their ability to adapt to input measuring circuits, the properties (characteristics) of this source of electrical signals are essential. These properties are not determined only by the design parameters of the electrode, but also by the place of sensing.

The electrical properties of the electrode-electrolyte interface or the consecutive electrolyte-skin interface are affected by the design parameters of the electrode (the material used, dimensions, etc.), the physical and chemical properties of the electrolyte and the tissue. These effects must be known in order to construct and effectively use the electrodes. When using electrodes, it is also necessary to consider the movement of tissue, known as the artefact, which can completely destroy biopotential records and the change of parameters of electrodes and electrolytes over time. The general requirements for biopotential electrodes are as follows:

- Provision of a high-quality conductive connection between the body and the measuring circuit
- Non-irritating to the skin and tissue
- Electrode material must not degrade due to the reaction of electrolytic solutions
- It must be possible to clean and disinfect the electrodes (Penhaker, 2004)

Regarding prolonged or home applications, the use of standard biopotential electrodes is limiting or improper due to the degradation of the electrode conductive gel and the irritation of tissue found with the long-term wearing of self-adhesive electrodes. For this reason, it is necessary to consider other types of electrodes that are wearable in the "Wear and Measure" sense without the need of knowledgeable installation our use in personal hygiene. Sensors used for long-term recording of a person's electrical activity while sleeping or at rest at night are also needed. For this purpose, the electrodes and pyjamas with interwoven silver threads or capacity systems for sensing electrical activity of the heart are very suitable (Amjadi et al., 2014; Komensky et al., 2012; Migliorini et al., 2014; Weder et al., 2015)

3.4 Implementation of Biopotential Electrodes

The range of sensors that can be used to measure individual biosignals is currently very broad and fully meets the needs of conventional medical diagnostics. At the same time, however, these sensors do not meet the requirements imposed on them in applications for home and wearable sensors.

Therefore, it is necessary to deal not only with issues of development, testing and application use of the existing and new biotelemetric sensors, but also with the design of their appropriate implementation into telemetry chains. The result of the implementation analysis and related tasks was the need to design a new type of sensor that provides valid and reliable monitoring of bioelectric signs in people in home care.

3.4.1 Conductive Polymers

Synthetic polymeric materials have been known for a long time and have been used in experiments since the mid-nineteenth century. Polymers have many synthetic modifications; from the perspective of biomedical engineering, the most interesting polymers are conductive polymers and their use for measuring biosignals.

Among others, conductive polymers also include polyaniline, which is probably the oldest man-made organic polymer. This green product obtained by the oxidation of aniline was described as early as 1840 by J. Fritsche, who tried to develop new synthetic dyes shortly after obtaining aniline (as a decomposition product of indigo).

It is known that typical chains are composed of many aniline constitutional units. The electrical conductivity of polyaniline (in the order of units of S.cm-1) is comparable to conductivity of conventional semiconductors and was known already in the 1960s when research for use in electronics was implemented. Nevertheless, polymers were not very used as scientists knew many other materials conducting electric current. Interest in conductive polymers increased in the late 1970s when three scientists, A. J. Heger, A. G. MacDiarmid and H. Shirakawa, published their beneficial results. (Chiang et al., 1978) (Rahman et al., 2008) (JAN PROKEŠ, 2001; Nešpůrek, 2001; Prokeš, Stejskal, Omastová, 2001)

Figure 4: Ready underlying textile material coated with a layer 100 nm layer of electrically conductive polyaniline

In addition to conductive composites, there are also conjugated polymers which can exhibit high inherent electrical conductivity. This is due to the regular alternation of single and double bonds, the so-called conjugation, in their molecular structure. Except the system of these bonds, a prerequisite is the presence of moving charge carriers mediating the transport along the conjugated chain see figure 4 and 5. (Prokeš, Stejskal, Omastová, 2001)

Figure 5: Implemented flat electrode and textile polymer-based conductor on elastic material

Polyaniline is prepared by oxidation of aniline, usually using ammonium peroxydisulfate, i.e. from common and inexpensive chemicals, in an acidic aqueous environment, in air; at room temperature, the reaction takes several tens of minutes and the yield is almost 100%.

The product is isolated by filtration and dried. Thus prepared polyaniline in an amount of about 2 g has a conductivity of 5 Scm-1. When stored, it has time-unlimited stability.
Simple preparation and stability of the product is one of the reasons for increasing attractiveness of this polymer. If we immerse any object stable in the acidic environment in the reaction mixture during the aniline oxidation, its surface will be covered with a conductive polyaniline film having a thickness of about 100 nm. In this way, it is possible to modify virtually any surface, e.g. glass or textile fabric. (Nešpůrek, 2001; Prokeš, Stejskal, Omastová, 2001; Stejskal, 2006)

3.4.2 Polyaniline Deposition

When implementing biopotential electrodes, the motivation was to create a wearable shirt containing conductive electrodes on its internal fabric and exerting a sufficient downforce of deposited polyaniline electrodes on the skin due to sufficiently elastic base material see figure 6. During tests, it is not necessary to use electro conductive gels containing free ions; natural moisture of the skin is adequate for transporting the electrical charge to the conjugated polymer. (Rosulek, 2007) (Stejskal, 2006; Stejskal, Sapurina, Trchova, 2010)

Figure 6: Polymeric electrodes with conductors placed on the elastic shirt

Production of one polymer electrode takes approximately fifteen minutes and approximately additional twelve hours, depending on air humidity and perfect spontaneous drying. To produce one electrode, it is necessary to have several commonly available chemicals; the final price is predominately determined by the amount of substances in admixture, totally up to 2 g, which means that the price level of these polymeric electrodes is approximately hundredfold lower than in conventional metallic electrodes. Therefore, the electrodes can be used as removable or disposable. The use of polyaniline for biopotential electrodes is also suitable due to another fact: so far, not a single evidence of its toxicity or irritativeness has been found. (Humpolicek et al., 2012)

Another advantage of this material is that it can be used to create electrodes from a vast majority of materials resistant to acidic environment. Therefore, the use of fabrics is absolutely reasonable. We used both of these benefits; electrodes were made of fabric and are also removable. (Rosulek, 2007) (Mirmohseni, Valiegbal, Wallace, 2003; Stejskal, Gilbert, 2002; Valentova et al., 2013)

3.5 Complexity of Sensed Variables

Considering the fact that the monitored persons occur in the monitoring area for a long time and their physical activities outside the relaxation zone during the day are minimal, can be viewed as a high probability of life-threatening situation. This conclusion cannot be unambiguously achieved using one information, e.g. from ECG sensors, if one has a traumatic injury. The same applies when all physiological functions are in order but the monitoring area is hit with fire or gas leak. It is therefore fundamental to have information about the movement and position of the person; then, for example, a sudden change in the position of the monitored person evokes suspicion of a critical situation. Therefore, it is necessary to combine sensing systems enabling us to relevantly determine the problem and assess the requirement for possible assistance to the user of the monitoring object see figure 7.

For this purpose, it is necessary to select an appropriate combination of sensors in monitoring areas and wearable sensors using the implementation analysis and its contribution to the objective data acquisition and subsequent evaluation of events. When combining these selected sensing elements, we create monitoring systems in home and wearable healthcare which must reliably communicate with each other and transmit the data further to the evaluation centre.

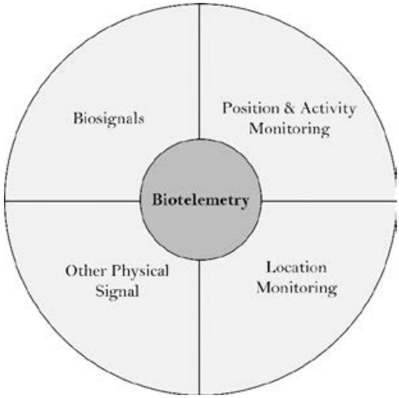

Figure 7: A comprehensive scheme of sensed variables in biotelemetry

Sensed biological signals, as primary elements of the concept of biotelemetric measurements, must be recorded by circuits that convert the physical quantities into electrical signals and thus allow their subsequent amplification and transmission by other elements of the measuring chain. The next chapter describes the design and implementation of such a wireless monitoring system usable in home care.

4 Wireless Monitoring Systems for Home Care

Monitoring systems that should be used for the monitoring of health conditions and potential health risks must conform to users regarding the convenience of biomedical sensing as mentioned above; in particular, these systems should allow for the simple installation of additional sensors in the monitored location. This assumption of simple installation can be achieved primarily through wireless technologies and possibly through data transmissions using electricity networks.

4.1 The Design of Distributed Monitoring Systems

A distributed monitoring system used in home or wearable healthcare is composed of elements distributed throughout the monitored area. These include wearable elements that must be constantly positioned on the body of the monitored person, such as ECG sensors, body temperature and actimetry sensors. In these elements of the monitoring system, it is practical to process data obtained from the respective sensors in a single

mobile hardware device which may additionally serve as a platform for facilitating communication with the patient or may display biometric data to the patient.
The second category of sensing elements is sensors that may not be in constant contact with the body of the monitored person because it would be unnecessary or impractical. This category includes all other sensors, such as those sensing the person's position in a building, personal weight and blood pressure, saturation, fire and gas sensors, sensors that detect lighting, ambient temperature and air humidity.

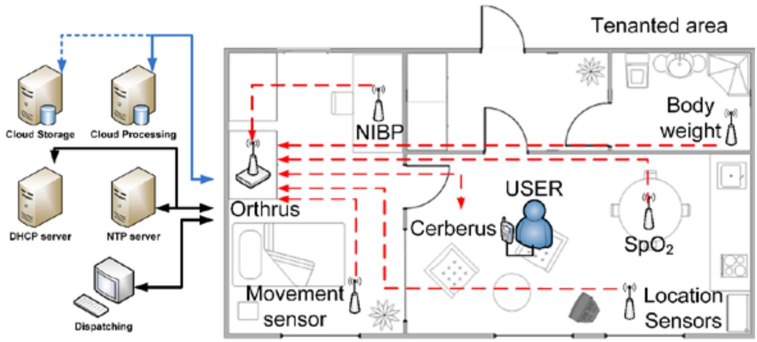

Figure 8: A scheme of the monitoring area with installed home care sensors

The figure 8 shows the proposed scheme of the monitoring area in a dwelling unit occupied by one monitored person. For reasons of clarity, the scheme does not include all the possible sensors in a wireless network. The architecture and protocol of the system for monitoring in home and wearable healthcare (SMS&HC) allow us to determine a specific set of sensors used for each monitored person. Communication of SMS&HC sensors located in the monitored person's apartment takes place through wired and wireless networks; it particularly uses of short or medium-range communication technologies such as Bluetooth, ZigBee, WiMAX and others. There are two key elements of the SMS&HC system. The first key element is a mobile unit that can be equipped with a display and keyboard enabling interaction with the entire system; this unit also measures and evaluates data from sensors that are located on the body of the monitored person. The second key element is a stationary base station that concentrates all measured data and forwards information through the network for evaluation to the supervisory centre. Data transfer to the supervisory centre can be implemented through wired communication technologies such as Ethernet and TCP/IP; shown in blue in Figure 9 (Poujaud et al., 2008; Stankus, Penhaker, Cerny, 2010; Stankuš, 2009).

4.1.1 Design Topology

A stationary collecting unit is a base station operating as an interface between wireless communication and wired communication with the supervisory centre. It performs the role of buffer memory if the connection with the supervisory centre is temporarily unavailable. It also allows remote management and configuration of the SMS&HC system. A stationary unit is always present in the given installation only once. The stationary system is powered from the electrical network and can serve as a charging basis for the mobile part of the system during sleep or relaxation.

The mobile unit located on the monitored person measures and processes ECG, actimetry and thermometer data. It performs the role of buffer memory for these data if the wireless connection with the stationary unit is temporarily out of service. The mobile unit of the SMS&HC system looks like a mobile phone and is always present in the immediate vicinity of the monitored person.

Sensory elements distributed within the system provide dedicated measurements of variables and send the obtained data to the stationary system. A flawless functioning of the communication system requires introducing an explicit identification and indication of sub-elements of such a system (Cerny, Penhaker, 2010; Penhaker et al., 2011; Stankus et al., 2010b).

4.1.2 Communication within the System

The technical means used to communicate within the SMS&HC system form an inhomogeneous environment; therefore, the proposed protocol mainly addresses the solution’s complexity. When designing the protocol, it was necessary to accommodate a large number of requirements for the system’s function and structure. Since the SMS&HC system is a biotelemetric system on which the life of the monitored persons may depend, the primary requirement is to prevent the loss and inhomogeneity of measured data while delivering these data promptly to the supervisory centre. The proposed protocol must also reflect the possible different configurations of sensors in particular installations. At the hardware level, communication within the SMS&HC system is implemented through standard technologies for both wireless and wired data transfers. The software uses technologies such as Bluetooth, ZigBee, etc., and obviously the TCP/IP protocol and specific protocols for communication on the SPI bus in the system's sub-elements (Stankuš, 2009).

4.1.3 Data Transfer

Data transfer with respect to wireless communications, e.g. from ZigBee sensors in the SMS&HC system, are shown in Figure 9 and are marked in red. The measured data are transmitted through the wireless network to the stationary element, which forwards them further to the supervisory centre. At the same time, there is an information connection between the stationary and mobile unit allowing the visualization of all measured data by the user.

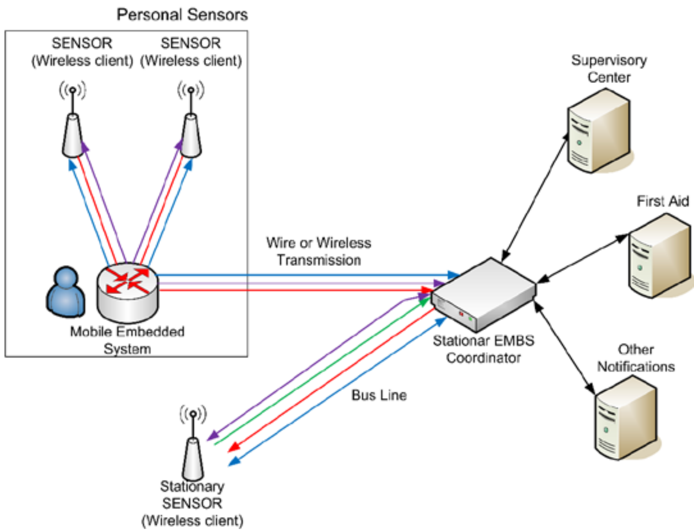

Figure 9: Data communication between the sensors within the health care monitoring system

Mobile data elements are marked in green. This data stream contains two categories of information. The first category includes ECG, actimetry, thermometer data, etc. The second category is a requirement

for providing first aid. The stationary element transmits both data categories to the supervisory centre.
In the scheme, the information transmitted within the internal network is marked in blue. In the ZigBee wireless network, there are special administrative channels between the stationary unit and any other wireless ZigBee devices. The stationary unit acts as an agent subject to an external remote message console.
In Figure 9, the "keep alive" data stream is marked in purple. This data stream flows only through the ZigBee network in which it is spread in all directions. Since the "keep alive" data stream is generated by all units in the ZigBee network and all units also hear it, it is primarily intended for mutual synchronization of sending operational data in wireless units.
In Figure 9, auxiliary data streams are marked in black. Their task is to enable the stationary unit to obtain the IP address and synchronize the system's time via the NTP protocol (Ali, Khan, 2014; Behan, Krejcar, 2013; Krejcar et al., 2010; Krejcar, Penhaker, 2012; Stankus et al., 2010a; Stankuš, 2009; Sye Loong, Lupu, Sloman, 2009).

4.2 Use of the Monitoring System

From the perspective of the home care monitoring system's use, a majority of particular solutions depends on when they were produced. They are mainly suitable for verifying the technology and accuracy of the concept as a whole. I have seen several interesting applications for monitoring the health condition of patients at many conferences and even in practical use, but they always reflect the historical value of the respective design. One of them was a monitoring system from 2001 from Iceland that measured leakage values through PDA ECG 3 and sent the information about the patient's condition via a mobile phone using GPRS. Another example is systems based on a wired connection between user elements in the monitored area that did not provide a promising platform for mass deployment in terms of portability. Other systems enabled a simple call for help using a user button or automatic connection with the operator when detecting a fall – see CleverTech. Nevertheless, there are plenty of applications that work either as partial or comprehensive elements, and their viability in practice will be shown in the future.
We have designed a system for monitoring the health condition of patients in home care so that it best reflects the requirements of the

elderly and doctors to verify the patient’s health condition and to notify the supervisory centre of any particularly critical or unexpected situations. Probably the most important unit is the mobile unit called Cerberos, from Greek mythology. Its role is crucial; it is a wearable technology that is able to sense biosignals directly from the human body and send this information to the supervisory centre, either through a stationary unit (Orthrus – from Greek mythology) located in the monitoring object or directly via 3G networks in the case of movement outside the monitoring object.

4.2.1 Concept Description

A human can be monitored by a user adaptive visualization system located in the home. The information obtained by measured data can be provided to the patient by several ways, such as visualization on a TV screen. The user would select the kind of vital function data to be displayed on the TV screen through a wireless input device. The disadvantages are the low portability of TV, the necessity of creating a special data channel for connecting to the TV video input and a special wireless TV driver design.

Visualization of the new measured values through a mobile phone would be transmitted by SMS. The disadvantage is the reduced visualization option.

The best method would be to develop a special mobile device (a mobile unit for measuring data and visualizing) with a user interface (LCD and keyboard) which is suitable for the visualization requirements. The device allows wireless transmission of vital function data. The advantage is great stability compared to PC, PDA or smartphone as the application does not depend on any operating system. The device is useful for making emergency calls (emergency medical service calling), for example after the given keyboard button is pushed. In the following chapters, we will describe the mobile unit and user communication interface.

4.2.2 The Mobile Unit

The Cerberos mobile unit is a device that can monitor basic human vital functions and provide communication with its surroundings through wireless networks. The mobile unit integrates all the measuring and visualization functions into one compact mobile device, which is capable of ZigBee wireless communication. The device is embedded into a case that is the size of a small mobile phone. The LCD, keyboard and power button can be used to create the user interface. The output connector is used for attaching measuring and programming wires and for and for connecting the battery charger. The device is powered by a common Li-Ion 3.3V battery used in mobile phones. All components of the device are designed for this voltage.

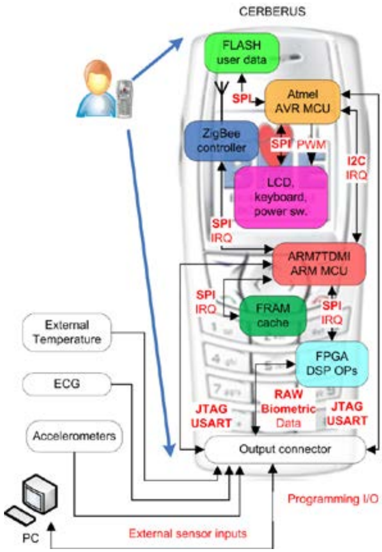

Figure 10: A block diagram of the Cerberos mobile unit

The block diagram of the Cerberos mobile unit is in Figure 10. It shows the inner structure and how the individual blocks and communication function within the unit. An individual description is given for the blocks of the user communication interface.

Cerberos's "heart" is a microprocessor based on the ARM architecture. It transmits all the visualization data to the user interface microprocessor control unit based on the AVR architecture. The user interface control unit processes the received data.

Cerberus control MCU – it transmits a continual data stream that contains a vital measured data function, actual time, and actual event data. There is defined sampling frequency for ECG, plethysmography, temperatures and time; a single-shot value for weight, pressure, position, and event data. User Interface Control MCU – it receives a continual data stream; transmits the event data (emergency calling, power down request). The transmitter mode is activated by an interrupted line.

4.2.3 Graphical User Interface

Because the Cerberos unit is a user-configurable compact mobile unit for measuring data and providing visualizations of the measured data, the system design was based on parts of the case and modules from Nokia 6610 phones. The case and visualization system used from Nokia includes the LCD, numerical keyboard, buttons, communication connector, and the case.

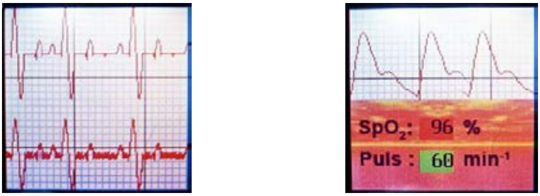

Figure11: Visualization of actual measured ECG and PPG, SpO2a data on a Cerberos mobile unit

Better communication between the user and the Cerberos mobile unit occurred when color menus and information were incorporated. Interaction occurs through keys on the keyboard. The user can display actual measured data and trend data from any recorded timeline (see Figure11). There is also the very important ability to select making an emergency call from the unit.

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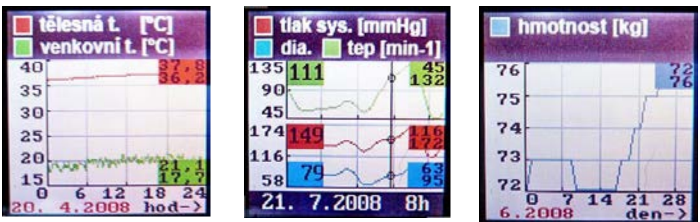

a b c

Figure 12: Displaying the trend data on a Cerberos mobile unit a) body and surrounding temperatures b) pulse, systolic and diastolic pressures c) body weight

The measured waveforms imaging an ECG with a maximum 3 channels and plethysmography are stored in the user data Flash memory to be examined in the trend data

To display the historical trend data of the body and surrounding temperatures, systolic and diastolic NIBP pressure, pulse and SpO2, body weight and the position in the occupied area. There is the possibility to arrange the common or user scales for temperature and other specific values in the chart (see Figure 12).

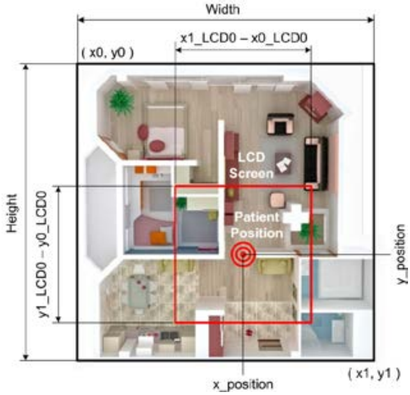

Figure 13: Layout plan of the occupied area displayed on the LCD display with the information about the actual position of the user.

The LCD controller is able to also visualize the layout plan and the actual position in the monitored area (Figure 13). The layout plan is an image stored in the Flash memory with illustrated coordinates (x0, y0) and (x1, y1),

The above biotelemetric wireless system allows for the measurement and transmission of biosignals reflecting the actual health condition of the monitored person and becomes a kind of “electronic guardian angel” who selflessly monitors critical and crisis situations of its owner. In order to achieve a fully operational system, it is necessary to complete the system with a measured signal processing and evaluation. This can be performed in the supervisory centre where the data are transmitted, or implemented directly into the mobile unit so that the reliability of detecting life-threatening situations and calling for help is maximal.

5 Processing Biosignals to Support Diagnostics

With regard to biosignals measured by the supervisory monitoring systems as in the proposed SMS&HC system, the determining signals are mainly those that monitor cardiac and physical activity. These signals contain information on critical health conditions such as myocardial infarction, cardiac arrest, cardiac irregularities, etc. Regarding actimetry data, these provide valuable information about sudden changes in the position and subsequent movement or inactivity, which can clearly detect life-threatening conditions, whether as a result of a brain injury from falling or following a traumatic injury.

One of the methods that we examined in the evaluation of real records from the monitoring system was the analysis of the variability and shape of the heart vector trajectory serving as a relevant diagnostic method in cardiology. Most often, the electrocardiogram is evaluated over short periods (5 - 10 seconds) or long periods (e.g. 24 hours).

5.1 Vectocardiography in Home Care

In terms of assessing ECG recordings obtained from measurements obtained by the SMS&HC system in home care, it is relatively time-consuming and computationally exacting to focus only on the time record and search for record sub-segments. This complicates operations during filtration and segmentation as well as hinders the detection of individual segments. Research in assessing the heart electrical activity from a holistic perspective has already been carried out. The respective approaches, however, considered various leakage systems for measurement as well as different methods for evaluating the records. From the viewpoint of today's technology, one of the perspective approaches appears to be the work by Prof. Lauferger, who described and defined his octant theory for evaluating the course of the end of the cardiac vector by the spatial system (1967; Laufberger, 1981; Laufberger., 1082, 1975, 1980, 1981; Ruttkayn.I, 1966).

In order to apply the octant theory to diagnostic purposes, it is necessary to use transformation systems for converting signals from the leakage system determined by Franco’s leads into classic 12-lead systems. For example, in comparison with conventional 12-lead ECG systems, the hybrid leakage systems have only two extra electrodes. Due to technical shortcomings in earlier times, the actual measurement and visualization of VCG was quite complicated; today, it is employed only in special

workplaces while the use of conventional ECG is already so ingrained that the VCG measurement almost does not exist in clinical practice.
New approaches to signal processing and mainly the need to evaluate the electrical behavior of the heart in wearable applications resulted in creating a transformation system of orthogonal leads derived from the 12-lead ECG. This approach was named as Macfarlane 12-lead vectocardiography. (Edenbrandt, Houston, Macfarlane, 1994; Frank, 1954, 1956; Guldenring et al., 2012; Macfarlane, 1979; Macfarlane, Edenbrandt, 1992)

5.2 Segmentation of Records

Even in this case, similarly to conventional records, the segmentation of parts of the records can be done using wavelet transformation. In experiments, the real signal contained much information - interference which should have been missing in the records; therefore, a representative averaged curve of the records of multiple sequences of cardinal evolution was implemented.

Table 1 Numeric identification of octant numbers

	1	2	3	4	5	6	7	8
x	+	+	-	-	+	+	-	-
y	+	+	+	+	-	-	-	-
z	+	-	-	+	+	-	-	+

Then, the VCG record as well as just certain segments can be expressed as a sequence of octant numbers that were defined by professor Laufberger. Each of the orthogonal leads X, Y and Z has a positive part and negative part which results in eight combinations numbered from one to eight.
Each of the combinations of numbers represents a certain part of the space which is called octant. All octants together form the cardiac electrical space. Together with individual octants, this space can be schematically represented as a cube (Figure 14). The theory of octants was invented and examined by prof. Laufberger, a significant Czech scientist. Unfortunately, due to the former technical possibilities, he compiled the octant numbers manually and subsequently determined the diagnostic failures from VCG records. His attention was particularly

attracted by numbers representing the QRS complex, describing the evolution of the depolarization wave of ventricles in space. (Abeysekera, 1991; Aro et al., 2012; Laufberger, 1981; Laufberger., 1975, 1980, 1981)

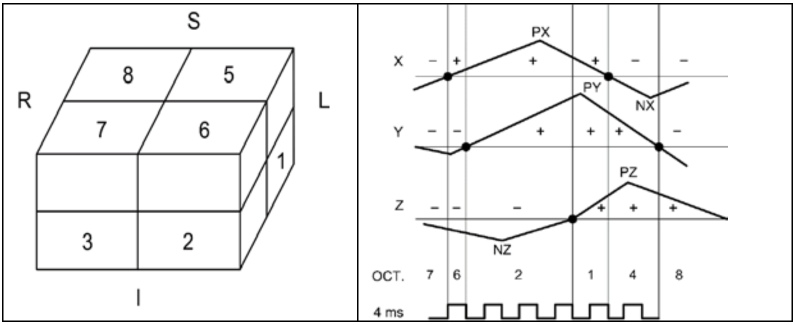

Figure 14: The principle of constructing the octant space from x,y,z record

When expressing the passage through a loop as a sequence of numbers of individual octants, we obtain a numerical representation of the given VCG segment; we generally talk about the so-called sequence of octant numbers.

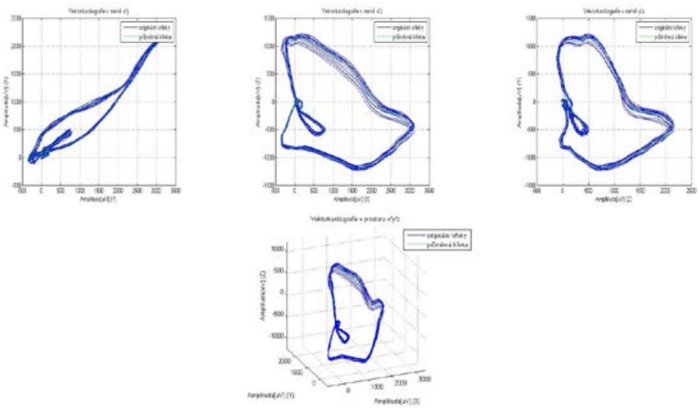

Figure 15: Visualization of VCG projections and spatial representation in a longer period of time with visible heart evolutions marked with a representative average.

In the measured patient records on figure 15, the VCG record was subsequently created through a simultaneous display of curves from different leads. In this way, it is possible to observe VCG representation in x/y, y/z, z/x planes as well as the overall representation in space. The average VCG loop of cardiac cycle can also be visualized spatially.

When prepared in this way, the records of individual channels from particular patients can be used for evaluating the VCG inter-individuality already now. Various average VCG curves can be compared with each other.

5.2.1 Intra-individuality of the Records

There were always evaluated records with the same time length in order to preserve their informational value. Intraindividual comparison of uniqueness and variability of the records over time discriminates individual persons from other individuals. As the record of each person is unique, it can be stated that these records can unambiguously identify the respective information carriers. For this reason, every cardiological record must be assessed from the perspective of personal individuality. In each processed record, we evaluate the average and adjacent values of record samples.

In the VCG record, we evaluate the duration of individual loops, direction of rotation of the heart vector and shapes of individual loops. From a practical point of view, the most important VCG is in the frontal plane. The observed maximum deviations from the average VCG record of individual cardiac cycles in a patient range up to 7.5%. Deviations of individual cardiac cycles in a patient may therefore be considered as not very significant and we can work with an average representative curve of the record for further comparisons. (Babusiak et al., 2014; Darebnikova, 2012; Ishizawa, Yokoyama, Okada, 1978; Man et al., 2009; Silverberg, 1966).

5.2.2 Inter-individuality of the Records

Interindividuality of ECG records is caused by differences in resulting conclusions for each individual in the given diagnostic group. This knowledge of similarity of waveforms in the respective diagnostic group subsequently allows the deployment of comparative algorithms and classification of measured records into classification groups corresponding to any disease.

After making the experiments and processing of the measured signals, it was possible to assess interindividuality of ECG records. The supposed goal was to keep the variances of individual maximum and minimum values as close as possible to the average values. Significant reduction in the variance was achieved through a correction to isoelectric zero in a defined point of the course of each lead. Based on the data observed, it is also possible to state that there is a significant statistical difference between individual curves, primarily in the lead y.

On average, the analysed data showed a variance of 15.5% from the mean value. In the case of assessing pathophysiological records (Right Bundle Branch Block), the relative variance of data interindividuality is 18% on average. However, the result and observed assumptions must also be verified on a large sample of data. (Biel et al., 2001; Borovička, 2014; Correa et al., 2013; de Chazal, Lim, Celler, 1997; Israel et al., 2005; Malik et al., 2008; Medhat, Abdelraheem, 2011)

Processing and evaluation of measured signals imaginarily closes the circle of biotelemetric applications whereas the respective obtained data lead to contingent interventions in life-threatening situations. The number of partial biotelemetric applications involving large quantities of transmitted data is growing; therefore, a promising way can be the transfer of large volumes of data and their subsequent processing in cloud repositories, using decentralized computing and storage facilities.

6 Cloud Computing in Home Care

For the purposes of medical practice, it is important that biomedical records can be accessed from various Internet sources and networks without the need for any specialized software to retrieve them. To this goal, the system of storage and management of biomedical data has been designed as a web application which also allows data processing.

In addition, the system was expanded to evaluate biomedical data with on-line detection of signals with ultra-fast response and calculation accuracy. Realistically, these calculations and data storage can be performed using supercomputing centres and data repositories or using FPGA with a parallel system of operation equipment. Systems based on

FPGA devices allow data exchange with a data server; however, they can also measure the analogue signal from on-line inputs and implement biological signal processing. (Penhaker, Kasik, Snasel, 2013)
In cases where the digitized signal is processed in several steps, it is preferred to use a computer controlled processing. Typically, such calculations are solved with a computer that is not able to perform these operations simultaneously but in a sequential manner. Such a standard procedure requires higher computing power of the processor. Furthermore, it is difficult to predict the time required for the calculation, and the whole situation affects the security of this calculation. Solution, that better reflects the computational structure for signal processing, consists in a distributed architecture of the system as well as the unit inside the chip. Therefore, the FPGA technology is utilized in which the calculating phases are designed in separate processing modules (Kasik et al., 2011; Krawiec et al., 2010; Penhaker, Kasik, Snasel, 2013)

6.1 Processing Design

The processing of biomedical data often requires the detection of various events in recorded measurements. These events are evaluated in both qualitative parameters and the time parameters. Proper evaluation of caused events is usually not often easy, because the biomedical signals are strongly unsteady non-periodic and often stochastic in nature and may also be changed by parasitic physiological effects of interference. This is connected with the computing demands of data processing. The requirements for computing power increases mainly in the evaluation of biomedical signals in real time, which is the also thr domain of home care applications and wearable systems.
Implementation of this option can be currently done with only two possible architectural designs. One of them is a supercomputer and the second solution is parallel computing with FPGA structures, which is comparable for these purposes with supercomputer performance. In this case, there seems to be three alternatives for fast signal processing as shown in Figure 16.
That figure represents a system that transmits stored biomedical data to the coprocessor unit for processing upon user request. The data is returned after processing in a data server, from which it can be visualized in a web application (Kasik et al., 2011; Penhaker, Darebnikova, Cerny, 2011).

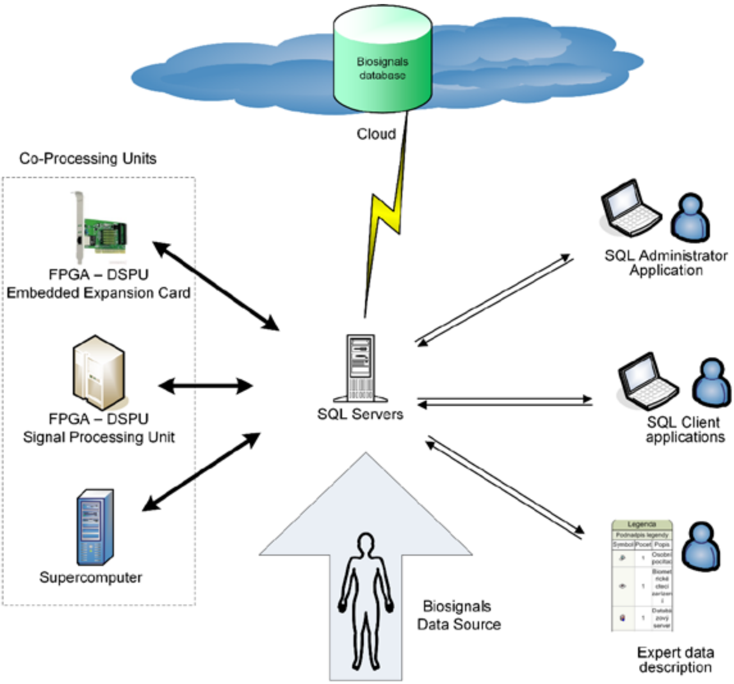

Figure 16: Overall system for cloud computing structure

Dataflow between the FPGA and DSPU co-processing unit constitutes a second link between the web server and the SQL server see on figure 17. The sequences of FPGA calculations is controlled by a web application that sends commands to the unit. Each biosignal processing algorithms operate on data from the SQL Server. The resulting data are processed by web applications and offered to the authorized user's web browser on the user terminal.

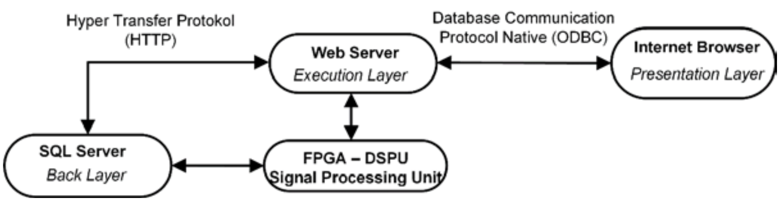

Figure 17: Dataflow paths inside the system.

6.2 Implementation of Remote Calculations

One of the projected features of the system was an EEG evaluation of patients and their association with epileptic attacks. Moments of epileptic attacks were evaluated by a detection algorithm that was trained to locate some reference points in the image. Placement of these points and their movement is the basis for subsequent classification of the patient. The left image in Figure 18 is an input image and the right image is updated with discovered reference points. In another analysis, the arm angles, hand position and movement, posture and movement of the head are observed. The result is an estimation of the overall condition of the patient, focusing on the pathological states of the brain.
This application serves to test the system of distance computing and storing data in medical practice. Processing these data in real time is very difficult to implement because the task requires high computational and financial demands at the workplace. The presented solution of treatment and detection of signals in real time using FPGA brings new possibilities that are not only suitable for particular workplaces, but also for users of web applications for visualizing and processing distance signals in real time.

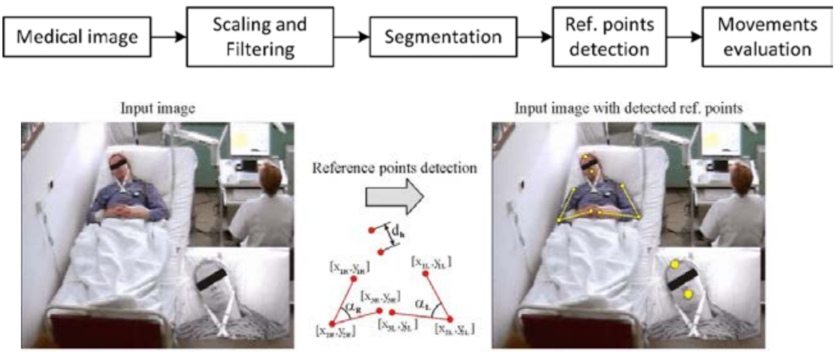

Figure 18: Evaluation of a Medical Image. Real-time processing of input image gives a result in terms of reference points, whose position is further evaluated.

The proposed system was tested on specific polysomnographic recording video data and an epileptic seizure and subsequent levels of nerve-muscle movements were successfully detected using this system which then helped to determine the strength of muscle contraction with respect to the degree of fitness (Kasik et al., 2011; Krawiec, 2009; Krawiec et al., 2010; Penhaker et al., 2010; Penhaker, Kasik, Snasel, 2013).

7 Conclusion

Regarding to the demographic curves of the Europe and America, where a long run tendency of increasing number of the elderly population is noticeable, it is logical and necessary as well as the development of health – technical courses who wish to to ensure men´s health and quality in his natural environment in the future. For this purpose, gradually arose a separate scientific branches such as Smart Home Care and Personal Health Care, which aim to address the conceptual and sub-tasks for monitoring the health condition of a person in the day to day running and burdening him too, knowing that the man must think on the sensors, methods, and principles of this monitoring, which should ideally take place without the interference and restrictions into the activities of an individual.

The success of such systems is mainly in the fact that, in their development will participate together in multidisciplinary teams that take into account the various aspects in the development of such systems. And therefore most of the publications submitted by the author there are also other members of the team listed, who for the mutual cooperation implemented these ideas and reshaped them to the real biotelemetry apartment used already since 2009, jointly between the VŠB – Technical University of Ostrava and Ostrava University – Faculty of Medicine to the verification of the proposed procedures and methods.

In this work there are described the procedures, methods and the implementation that could lead to the introduction of such a system of health monitoring in the home-based care into the practice. Among the original benefits of the author's work there are primarily new textile electrodes for biopotentials scanning based on conductive polymers, which among others can be used for the electrical activity from the surface of the human body in examination of imaging methods, where an existing electrode cannot be used.

The one of the benefits of work is the design and implementation of a miniature of a mobile monitoring system of health status of the person with the wireless communications between the supervision centre and the person monitored.

The next benefit and as the original contribution of the work is also described the design and partial implementation of the methods of storing and processing the uncritical wholesale volume data in the cloud deposits with the use of the processing using an autonomous unit with the high speed equipment of the information on the basis of the FPGA (Cloud Computing in Home Care) comparable with the performances of the current supercomputing centers. These units can be used not only for analysis of the information of coherent structures of the smart home care units, but also of whole areas, where there may be a home care monitoring embattled and will need to be decentralized collection and processing of information, while maintaining the safety of the data of the patient is apparent.

Most of the annotated articles and their physical outputs, were used in the educational process at all levels of higher education and also formed the basis for the implemented protection of intellectual property in the form of several patents and utility models.

References

1. LAUFBERGER,V - SPATIOCARDIOGRAPHY - TEXTBOOK AND ATLAS. *American Journal of the Medical Sciences*, 1967, vol. 253, no. 2, s. 244-&. ISSN 0002-9629.
2. ABEYSEKERA, R. M. S. S.: Some physiologically meaningful features obtained from the vectorcardiograph. *IEEE Engineering in Medicine and Biology Magazine*, 1991, vol. 10, no. 3, s. 58-63.
3. ALI, A., KHAN, F. A.: A Broadcast-Based Key Agreement Scheme Using Set Reconciliation for Wireless Body Area Networks. *Journal of Medical Systems,* 2014, vol. 38, no. 5. ISSN 0148-5598.
4. AMJADI, M., PICHITPAJONGKIT, A., LEE, S., RYU, S., PARK, I.: Highly Stretchable and Sensitive Strain Sensor Based on Silver Nanowire-Elastomer Nanocomposite. *Acs Nano,* 2014, vol. 8, no. 5, s. 5154-5163. ISSN 1936-0851.
5. ARO, A. L., HUIKURI, H. V., TIKKANEN, J. T., JUNTTILA, M. J., RISSANEN, H. A., REUNANEN, A., ANTTONEN, O.: QRS-T angle as a predictor of sudden cardiac death in a middle-aged general population. *Europace,* 2012, vol. 14, no. 6, s. 872-876. ISSN 1099-5129.
6. BABUSIAK, B., GALA, M., PENHAKER, M., CERNY, M., KRAUS, J.: Dry contact less surface electrodes for bioelectrical measurements. In *12th IEEE International Symposium on Applied Machine Intelligence and Informatics, SAMI 2014*. Herl'any: IEEE Computer Society, 2014. s. 357-360.
7. BEHAN, M., KREJCAR, O.: Modern smart device-based concept of sensoric networks. *Eurasip Journal on Wireless Communications and Networking*, 2013. ISSN 1687-1499.

8. BIEL, L., PETTERSSON, O., PHILIPSON, L., WIDE, P.: ECG analysis: A new approach in human identification. *IEEE Transactions on Instrumentation and Measurement,* 2001, vol. 50, no. 3, s. 808-812.
9. BOROVIČKA, J.: *Analýza interindividuality EKG v populaci.* Ostrava, 2014. 57 s. VŠB - TU Ostrava.
10. CALDARA, M., COLLEONI, C., GUIDO, E., ROSACE, G., RE, V., VITALI, A.: A wearable sensor platform to monitor sweat pH and skin temperature. In *Body Sensor Networks (BSN), 2013 IEEE International Conference on*. 2013. s. 1-6.
11. CAMPO, E., HEWSON, D., GEHIN, C., NOURY, N.: Theme D: Sensors, wearable devices, intelligent networks and smart homecare for health. *Irbm,* 2013, vol. 34, no. 1, s. 11-13. ISSN 1959-0318.
12. CERNY, M., PENHAKER, M.: Notice of Retraction
Plethysmography Bluetooth measurement. In *Mechanical and Electronics Engineering (ICMEE), 2010 2nd International Conference on*. 2010. s. V1-337-V331-339.
13. CERNY, M., PENHAKER, M.: Wireless Body Sensor Network in Health Maintenance Systems. *Elektronika Ir Elektrotechnika,* 2011, no. 9, s. 113-116. ISSN 1392-1215.
14. CORREA, R., ARINI, P., CORREA, L., VALENTINUZZI, M., LACIAR, E., IOP: Analysis of vectorcardiographic dynamic changes in patients with acute myocardial ischemia. *19th Argentinean Bioengineering Society Congress (Sabi 2013),* 2013, vol. 477. ISSN 1742-6588.
15. DAREBNIKOVA, M.: *Vyhodnocení biologických signálů.* Ostrava, 2012. 67 s. VŠB-TU Ostrava.
16. DE CHAZAL, P., LIM, K. G., CELLER, B. G.: *An analysis of the planarity of the vectorcardiographic*

QRS loop characterised by disease condition. 18. 1997. 1401-1402 s. Proceedings of the 18th Annual International Conference of the Ieee Engineering in Medicine and Biology Society, Vol 18, Pts 1-5. ISBN 0-7803-3812-X.

17. EDENBRANDT, L., HOUSTON, A., MACFARLANE, P. W.: VECTORCARDIOGRAMS SYNTHESIZED FROM 12-LEAD ECGS - A NEW METHOD APPLIED IN 1792 HEALTHY-CHILDREN. *Pediatric Cardiology,* 1994, vol. 15, no. 1, s. 21-26. ISSN 0172-0643.
18. FRANK, E.: GENERAL THEORY OF HEART-VECTOR PROJECTION. *Circulation Research,* 1954, vol. 2, no. 3, s. 258-270. ISSN 0009-7330.
19. FRANK, E.: AN ACCURATE, CLINICALLY PRACTICAL SYSTEM FOR SPATIAL VECTORCARDIOGRAPHY. *Circulation,* 1956, vol. 13, no. 5, s. 737-749. ISSN 0009-7322.
20. GULDENRING, D., FINLAY, D. D., STRAUSS, D. G., GALEOTTI, L., NUGENT, C. D., DONNELLY, M. P., BOND, R. R., IEEE: Transformation of the Mason-Likar 12-Lead Electrocardiogram to the Frank Vectorcardiogram. *2012 Annual International Conference of the Ieee Engineering in Medicine and Biology Society (Embc),* 2012, s. 677-680. ISSN 1557-170X.
21. HORAK, B., KOTZIAN, J., KOZIOREK, J., SROVNAL, V., PENHAKER, M.: Structure proposal of hydrogen powered car control system use multiagents. In *Management and Control of Production and Logistics*. 2007. s. 163-168.
22. HUMPOLICEK, P., KASPARKOVA, V., SAHA, P., STEJSKAL, J.: Biocompatibility of polyaniline.

Synthetic Metals, 2012, vol. 162, no. 7-8, s. 722-727. ISSN 0379-6779.

23. CHAN, M., ESTEVE, D., FOURNIOLS, J.-Y., ESCRIBA, C., CAMPO, E.: Smart wearable systems: Current status and future challenges. *Artificial Intelligence in Medicine*, 2012, vol. 56, no. 3, s. 137-156. ISSN 0933-3657.
24. CHIANG, C. K., DRUY, M. A., GAU, S. C., HEEGER, A. J., LOUIS, E. J., MACDIARMID, A. G., PARK, Y. W., SHIRAKAWA, H.: Synthesis of highly conducting films of derivatives of polyacetylene, (CH)x. *Journal of the American Chemical Society*, 1978, vol. 100, no. 3, s. 1013-1015. ISSN 0002-7863.
25. ISHIZAWA, K., YOKOYAMA, H., OKADA, M.: The diagnostic usefulness of the vectorcardiogram. II. Comparison between the aVF lead of ECG and the Y lead of VCG (Frank system). *Journal of Transportation Medicine*, 1978, vol. 32, no. 2, s. 98-101.
26. ISRAEL, S. A., IRVINE, J. M., CHENG, A., WIEDERHOLD, M. D., WIEDERHOLD, B. K.: ECG to identify individuals. *Pattern Recognition*, 2005, vol. 38, no. 1, s. 133-142.
27. JAN PROKEŠ, J. S., MÁRIA OMASTOVÁ: POLYANILIN A POLYPYRROL DVA PřEDSTAVITElé VODIVýCH POLYMERů. *Chem. Listy*, 2001, vol. 2001, no. 95, s. 484 ñ 492.
28. KASIK, V., PENHAKER, M., NOVAK, V., BRIDZIK, R., KRAWIEC, J.: User Interactive Biomedical Data Web Services Application. In Yonazi, J. J. et al. *E-Technologies and Networks for Development*. 2011. vol. 171, s. 223-237. ISBN 1865-0929, 978-3-642-22728-8.
29. KOMENSKY, T., JURCISIN, M., RUMAN, K., KOVAC, O., LAQUA, D., HUSAR, P., IEEE: Ultra-

Wearable Capacitive Coupled and Common Electrode-Free ECG Monitoring System. *2012 Annual International Conference of the Ieee Engineering in Medicine and Biology Society (Embc),* 2012, s. 1594-1597. ISSN 1557-170X.

30. KRAWIEC, J.: *Systém pro sdílení a výměnu elektrofyziologických dat*. Ostrava, 2009. 45 s. VŠB-TU Ostrava. Vedoucí práce Penhaker, M.
31. KRAWIEC, J., PENHAKER, M., KREJCAR, O., NOVAK, V., BRIDZIK, R.: System for Storage and Exchange of Electrophysiological Data. *Proceedings of 5th International Conference on Systems, ICONS,* 2010, s. 11-16.
32. KREJCAR, O., PENHAKER, M., JANCKULIK, D., MOTALOVA, L.: Performance test of multiplatform real time processing of biomedical signals. In *8th IEEE International Conference on Industrial Informatics, INDIN 2010*. Osaka: 2010. s. 825-830.
33. KREJCAR, O., PENHAKER, M.: Remote measurement and control with sensors via the BT interface. In *IEEE 16th International Conference on Intelligent Engineering Systems, INES 2012*. Lisbon: 2012. s. 161-166.
34. LAUFBERGER, V.: Octant vectorcardiography-the evaluation by peaks. *Physiological Bohemoslovaca,* 1981, vol. 31, no. 1, s. 1–9.
35. LAUFBERGER., V.: Octant vectorcardiography and automatic diagnosis of coronary artery disease. *Physiological Bohemoslovaca,* 1082, vol. 31, no. 6, s. 486–495.
36. LAUFBERGER., V.: Teorie elektrického prostoru srdečního. *československá fysiologie,* 1975, vol. 24, no. 6, s. 551–554.

37. LAUFBERGER., V.: Octant vectorcardiography. *Physiological Bohemoslovaca,* 1980, vol. 28, no. 6, s. 481–492.
38. LAUFBERGER., V.: Octant vectorcardiography. *Physiological Bohemoslovaca,*, 1981, vol. 30, no. 6, s. 481–495.
39. LI, M., LOU, W., REN, K.: DATA SECURITY AND PRIVACY IN WIRELESS BODY AREA NETWORKS. *Ieee Wireless Communications,* 2010, vol. 17, no. 1, s. 51-58. ISSN 1536-1284.
40. LIU, J. J., HUANG, M.-C., XU, W., ALSHURAFA, N., SARRAFZADEH, M.: On-bed monitoring for range of motion exercises with a pressure sensitive bedsheet. In *Body Sensor Networks (BSN), 2013 IEEE International Conference on*. 2013. s. 1-6.
41. MACFARLANE, P. W.: *A hybrid lead system for routine electrocardiography*. London, UK: Pitman Medical, 1979. 1–5 s. Progress in Electrocardiology.
42. MACFARLANE, P. W., EDENBRANDT, L.: 12-LEAD VECTORCARDIOGRAPHY IN ISCHEMIC-HEART-DISEASE. *Journal of Electrocardiology,* 1992, vol. 24, s. 188-193. ISSN 0022-0736.
43. MALIK, M., HNATKOVA, K., SISAKOVA, M., SCHMIDT, G.: Subject-specific heart rate dependency of electrocardiographic QT, PQ, and QRS intervals. *Journal of Electrocardiology*, 2008, vol. 41, no. 6, s. 491-497. ISSN 0022-0736.
44. MAN, S., VAN ZWET, E. W., MAAN, A. C., SCHALIJ, M. J., SWENNE, C. A.: Individually Improved VCG Synthesis. In Murray, A. *Cinc: 2009 36th Annual Computers in Cardiology Conference*. 2009. s. 277-280. ISBN 0276-6574, 978-1-4244-7281-9.

45. MEDHAT, M., ABDELRAHEEM, T.: Human identification using main loop of the VCG contour. In *ECTI-CON 2011 - 8th Electrical Engineering/ Electronics, Computer, Telecommunications and Information Technology (ECTI) Association of Thailand - Conference 2011*. 2011. s. 1011-1014.
46. MIGLIORINI, M., KORTELAINEN, J. M., PARKKA, J., TENHUNEN, M., HIMANEN, S. L., BIANCHI, A. M.: Monitoring Nocturnal Heart Rate with Bed Sensor. *Methods of Information in Medicine*, 2014, vol. 53, no. 4, s. 308-313. ISSN 0026-1270.
47. MIRMOHSENI, A., VALIEGBAL, K., WALLACE, G. G.: Preparation and characterization of a polyaniline/poly(butyl acrylate-vinyl acetate) composite as a novel conducting polymer composite. *Journal of Applied Polymer Science*, 2003, vol. 90, no. 9, s. 2525-2531. ISSN 0021-8995.
48. NEŠPŮREK, S., PROKEŠ, J., STEJSKAL, J.: 2001. *Vodivé polymery - Inteligentní materiály pro nové století: Vesmír*. 2001. s. http://www.vesmir.cz/clanek/vodive-polymery.
49. NOURY, N., PERRIOT, B., ARGOD, J., PEPIN, J. L.: Monitoring physical activities of COPD patients with a network of sensors. *Irbm*, 2014, vol. 35, no. 6, s. 329-333. ISSN 1959-0318.
50. PENHAKER, M.: *Lékařské diagnostické přístroje: Učební texty.* VŠB-Technická univerzita Ostrava, 2004. ISBN 8024807513.
51. PENHAKER, M., ČERNÝ, M.: Telemetrické systémy pro monitoring seniorů. *Medical Tribune*, 2008, vol. III, no. 31. ISSN 1214-8911.
52. PENHAKER, M., KRAWIEC, J., KREJCAR, O., NOVAK, V., BRIDZIK, R.: Web System for Electrophysiological Data Management. In *Computer*

Engineering and Applications (ICCEA), 2010 Second International Conference on. 2010. s. 404-407.

53. PENHAKER, M., DAREBNIKOVA, M., CERNY, M.: Sensor Network for Measurement and Analysis on Medical Devices Quality Control. In Yonazi, J. J. et al. *E-Technologies and Networks for Development*. 2011. vol. 171, s. 182-196. ISBN 1865-0929, 978-3-642-22728-8.

54. PENHAKER, M., KASIK, V., STANKUS, M., KIJONKA, J.: 2011. *User adaptive system for data management in home care maintenance systems: 3rd International Conference on Intelligent Information and Database Systems, ACIIDS 2011*. Daegu: 2011. s. 492-501. Scopus. http://link.springer.com/chapter/10.1007%2F978-3-642-20042-7_50.

55. PENHAKER, M., KASIK, V., SNASEL, V.: 2013. *Biomedical distributed signal processing and analysis: 12th IFIP TC8 International Conference on Computer Information Systems and Industrial Management, CISIM 2013*. Krakow: 2013. s. 88-95. Scopus. http://www.scopus.com/inward/record.url?eid=2-s2.0-84885222389&partnerID=40&md5=019d0c46556faca546ba098f596efda9.

56. POUJAUD, J., NOURY, N., LUNDY, J. E., IEEE: Identification of inactivity behavior in Smart Home. In *30th Annual International Conference of the IEEE-Engineering-in-Medicine-and-Biology-Society*. Vancouver, CANADA: 2008. s. 2075-2078.

57. PROKEŠ, J., STEJSKAL, J., OMASTOVÁ, M.: Polyanilin a polypyrrol - dva představitelé vodivých polymerů. *Chemické listy*, 2001, vol. 95, no. 8, s. 484-492.

58. RAHMAN, M. A., KUMAR, P., PARK, D.-S., SHIM, Y.-B.: Electrochemical sensors based on organic conjugated polymers. *Sensors*, 2008, vol. 8, no. 1, s. 118-141. ISSN 1424-8220.
59. REICHMAN, A.: Body Area Networks: Applications, Architectures and Challenges. In Dossel, O. et al. *World Congress on Medical Physics and Biomedical Engineering, Vol 25, Pt 5*. 2009. vol. 25, s. 40-43. ISBN 1680-0737, 978-3-642-03903-4.
60. ROSULEK, M.: 2007. *Soubor snímačů v Telemedicíně.* Ostrava: VSb-TU Ostrava, 2007. s. http://dspace.vsb.cz/handle/10084/60488.
61. RUTTKAYN.I: LAUFBERGER,V - SPATIOCARDIOGRAPHY. *Activitas Nervosa Superior*, 1966, vol. 8, no. 3, s. 342-&. ISSN 0001-7604.
62. SILVERBERG, S. M.: A quantitative study of the Frank vectorcardiogram. A comparison of younger and older normal populations. *The American Journal of Cardiology*, 1966, vol. 18, no. 5, s. 672-681.
63. SROVNAL, M., PENHAKER, M.: Home care and Health Maintenance Systems. *The International Special Topic Conference on Information Technology in Biomedicine*, 2006.
64. SROVNAL, V.: Using of Embedded Systems in Biomedical Applications. *3rd European Medical and Biological Engineering Conference EMBEC'05*, 2005, vol. Volume 11. ISSN 1727-1983.
65. STANKUS, M., PENHAKER, M., CERNY, M.: Low cost data acquisition system for biomedical usage. In *12th Mediterranean Conference on Medical and Biological Engineering and Computing, MEDICON 2010*. Chalkidiki: 2010. s. 883-885.

66. STANKUS, M., PENHAKER, M., SROVNAL, V., CERNY, M., KASIK, V.: Security and reliability of data transmissions in biotelemetric system. In *XII Mediterranean Conference on Medical and Biological Engineering and Computing 2010*. Springer Berlin Heidelberg, 2010a. s. 216-219. ISBN 3642130380.
67. STANKUS, M., PENHAKER, M., SROVNAL, V., CERNY, M., KASIK, V.: Security and reliability of data transmissions in biotelemetric system. In *12th Mediterranean Conference on Medical and Biological Engineering and Computing, MEDICON 2010*. Chalkidiki: 2010b. s. 216-219.
68. STANKUŠ, M.: *Systém Sledování Vitálních Funkcí*. Ostrava, 2009. 43 s. VSB- TU Ostrava, Fakulta elektrotechniky a informatiky, Katedra informatiky.
69. STEJSKAL, J., GILBERT, R. G.: Polyaniline. Preparation of a conducting polymer (IUPAC technical report). *Pure and Applied Chemistry*, 2002, vol. 74, no. 5, s. 857-867. ISSN 0033-4545.
70. STEJSKAL, J.: 2006. *Polyanilin: vodivý polymer*. 2006. s. http://www.otevrenaveda.cz/ov/users/Image/default/C1Kurzy/NH2006pdf/16.pdf.
71. STEJSKAL, J., SAPURINA, I., TRCHOVA, M.: Polyaniline nanostructures and the role of aniline oligomers in their formation. *Progress in Polymer Science*, 2010, vol. 35, no. 12, s. 1420-1481. ISSN 0079-6700.
72. SYE LOONG, K., LUPU, E., SLOMAN, M.: Securing body sensor networks: Sensor association and key management. In *Pervasive Computing and Communications, 2009. PerCom 2009. IEEE International Conference on*. 2009. s. 1-6.

73. VALENTOVA, H., PROKES, J., NEDBAL, J., STEJSKAL, J.: Effect of compression pressure on mechanical and electrical properties of polyaniline pellets. *Chemical Papers*, 2013, vol. 67, no. 8, s. 1109-1112. ISSN 0366-6352.
74. WEDER, M., HEGEMANN, D., AMBERG, M., HESS, M., BOESEL, L. F., ABAECHERLI, R., MEYER, V. R., ROSSI, R. M.: Embroidered Electrode with Silver/Titanium Coating for Long-Term ECG Monitoring. *Sensors*, 2015, vol. 15, no. 1, s. 1750-1759. ISSN 1424-8220.
75. YANG, G.-Z.: *Body Sensor Networks*. 2. Springer-Verlag London, 2014. ISBN 978-1-4471-6373-2.

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Education:

Doctoral studies at the VSB - Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science 1996 - 2000 PhD. thesis on the topic: "Developing methods for systematic diagnosis of the condition of the vascular system using information plethysmographycal record", specialization: Technical Cybernetics.

Master studies at VSB - Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science 1991 - 1996. Study: Measurement and Control.

Practice:

Date: 1999 – present
Employer: VSB - Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science
Position: Lecturer / Researcher 75% (1999- 2000), Lecturer / Researcher 100% (2000- 2011), Lecturer / Researcher 70% (2011- 2015), Lecturer /

Researcher 100% (2015- present), trainer specialist (2004 - present), deputy Head of department (200 3 -2009)

Date: 1997 - present
Employer: University of Ostrava, Faculty of Medicine (Health and Social Studies in 2010)
Position: Lecturer

Date: 2011 - 2014
Employer: Center of Excellence IT Innovations 4 OP.7801512, CZ.1.05/1.1.00 / 02.0070,
Position: young researcher 50% (2011-2013), a young researcher 20% (2014)

Date: 2014 - 2017
Employer: University of Hradec Králové (UHK), Faculty of Informatics and Management
Position: researcher 10%

Date: 2012 - 2014
Employer: Czech Technical University in Prague, Faculty of Biomedical Engineering
Position: Project worker 20%

Foreign professional experience:

- Technical University of Kosice, Faculty of Mechanical Engineering, Lecture Internship, Kosice, Slovakia 23.3 – 3.4. 2015,
- Ecole Polytechnique de l'Université de Grenoble, Lecture Internship, Grenoble, France, 20.5. – 24.5.2008,
- ST. Catharine’s College, IEEE International Summer School and Symposium on Medical Devices and Biosensors, Cambridge, Great Britain, UK, 19. – 22. August, 2007
- Bialystok Technical University, Faculty of Electrical Engineering, Lecture Internship, Poland, 31.8. - 5.9.2007
- Università degli Studi Roma TRE, Dipartimento di Elettronica Applicata, Lecture Internship, Roma, Italy, 20.- 29.7.2007,
- Université Joseph Fourier, Ecole Nationale Supérieure

d'Ingénieurs Electriciens de Grenoble, Lecture Internship, Grenoble, France, 2007

- International intensive period in Jyväskylä University of Applied science, Supervise teacher, Finland, 19.3.2007 – 30.3.2007
- European accreditation and education committee - BIOMEDEA III, Stuttgart, Member, Germany 23. – 25. 9. 2005
- Université Joseph Fourier, Grenoble, Lecture Internship, France, 8.10. - 16. 10. 2004
- Université Joseph Fourier, Ecole Nationale Supérieure d'Ingénieurs Electriciens de Grenoble, Grenoble, Lecture Internship, France, 4.5. - 15. 5. 2003
- Université Joseph Fourier, Ecole Nationale Supérieure d'Ingénieurs Electriciens de Grenoble, Grenoble, Lecture Internship, France, 18.4. - 24. 4. 2002
- Université Joseph Fourier, Ecole Nationale Supérieure d'Ingénieurs Electriciens de Grenoble, Grenoble, Lecture Internship, France, 29.3. - 10. 4. 2001
- Metropolitan University of Leeds, Department of Electronic Engineering, Leeds, Great Britain, UK, 1.3 – 30.5 1997, Researcher Project

Awards :

2013  **INVENTO Prague 2013 GOLD MEDAL** for Augustynek, M., Penhaker, M., Korpas, D., The Method of patient's vibrations for pacemaker controlling 6. – 8.6. 2013, Praha

2012 **Commemorative Award** for Penhaker M., Hlavackova M., Vavra P., Grepl J., Prokop L., Sikora T.,Lukas D., Radiofrequency Surgical Instrument for Liver Ablation RONJA, November, 2012. China Kunshan

2008 **Outstanding paper award for the paper**: Penhaker, M ., Bridzik, R., Novak, V., Cerny, M., Rosulek, M., Sensitivity Analysis in Sensor HomeCare Implementation In *13th International Conference on Biomedical Engineering,* December 2008, Singapore,

2008 **IFBME Young Investigation Competition of the paper**: Cerny, M., Penhaker, M Biotelemetry In *14th Nordic – Baltic Conference on Biomedical Engineering and Medical Physics, NBC 2008*, June 16 – 20, 2008, Riga, Latvia,

2006 **SIEMENS Werner von Siemens Excellence Award** 2006 in SIEMENS Research Category *"Study of Drive Gear at Mobile Mount with Fuel Cell"* 14th December 2006, Prague

2001 **Rector's price** of Outstanding Study Results on Ph.D study, VSB – Technical University of Ostrava, Ostrava

Membership in international organizations:

2014 - now IEEE member of the Czechoslovakia Section,
2012 - now National Coordinator in Association for the Advancement of Assistive Technology in Europe (AAATE),
2009 – now Senior Member of IACSIT - International Association of Computer Science and Information Technology
2009 – now Member of AICIT,
2008 - now Member of Institute for Computer Sciences, Social Informatics and Telecommunications Engineering,
2005 Member in European Alliance for Education Harmonization BIOMEDEA III
2004 - now Member of international alliance „European Alliance for Medical and Biomedical Engineering and Science" (EAMBES)

Teaching:
During his twenty years of teaching at the candidate he was involved in teaching ten subjects in undergraduate studies, master studies in twelve and one each in doctoral studies. Such items include: medical instrumentation, biotelemetry, digital signal processing, biophysics, biocybernetics measurement for electrical materials, and MATLAB Simulation, new methods and trends in therapeutic instrumentation. The applicant is the creator and guarantor of the twelve subjects that are taught in the fields of biomedical technology and biomedical engineering. The candidate has led more than 39 master's and 42

bachelor's theses and eight successfully defended the PhD thesis supervisor specialist. He created many labs and specification, including texts for lectures published as a textbook or book.

Another activities:

22	Impact Factor Journals
51	Articles in ISI Proceedings
92	Contributions in Proceedings in Scopus
2	Handed up Patents in USA
22	Utility Design
9	Industrial Design
24	Software
43	Functional Samples
2	Trade-Marks
25	Main Solver of the Projects
27	Co-Solver of Projects
20	Books and Lecture Notes
39	Diploma works leader (5 Dean Award-Winning , 12 Running)
42	Bachelor works leader (14 Dean Award-Winning , 4 Running)
8	Ph.D Tutor Expert (7 Running)

Selected publications:

Vavra, P., Penhaker, M., Jurcikova, J., Skrobankova, M., Crha, M., Ostruszka, P., . . . Zonca, P. (2015). Semi-spherical radiofrequency bipolar device - a new technique for liver resection: Experimental in vivo study on the porcine model. Technology in cancer research & treatment, 14(5), 573-582. doi:10.7785/tcrt.2012.500432, (Impact Factor (2013 Thomson JCR Science Edition): 1.730 , ONCOLOGY,Q4)

Honegr, J., Soukup, O., Dolezal, R., Malinak, D., Penhaker, M., Prymula, R., & Kuca, K. (2015). Structural properties of potential synthetic vaccine adjuvants - tlr agonists. Current Medicinal Chemistry, 22(29), 3306-3325. doi:10.2174/0929867322666150821094634, (Impact Factor (2013 Thomson JCR Science Edition): 3.853 , CHEMISTRY, MEDICINAL, Q1)

Kuca, K., Hrabinova, M., Jun, D., Musilek, K., Penhaker, M., Krejcar, O., & Soukup, O. (2015). Universality of oxime k203 for reactivation of nerve agent-inhibited ache. Medicinal Chemistry, 11(7), 683-686. doi:10.2174/1573406411666150407154204 (Impact Factor (2013 Thomson JCR Science Edition): 1.363 , CHEMISTRY, MEDICINAL, Q3)

Vavra, P., Nowakova, J., Ostruszka, P., Hasal, M., Jurcikova, J., Martinek, L., . . . Zonca, P. (2015). Colorectal cancer liver metastases: Laparoscopic and open radiofrequency-assisted surgery. Videosurgery and Other Miniinvasive Techniques, 10(2), 205-212. doi:10.5114/wiitm.2015.52082 (Impact Factor (2013 Thomson JCR Science Edition): **-** , SURGERY, Q3)

Frischer, R., Penhaker, M., Krejcar, O., Kacerovsky, M., Selamat, A., "Precise Temperature Measurement for Increasing the Survival of Newborn Babies in Incubator Environments". *Sensors*. vol. 14, Iss. 12, pp. 23563-23580, 2014. DOI 10.3390/s141223563. Received 12 August 2014; in Revised form 22 October 2014; Accepted 1 December 2014; Published 8 December 2014. ISSN: **1424-8220**. (Impact Factor (2013 Thomson JCR Science Edition): 2.245 , INSTRUMENTS & INSTRUMENTATION 10 of 56, Q1) Q1)

Malinak, D., Dolezal, R., Marek, J., Salajkova, S., Soukup, O., Vejsova, M., Korabecny, J., Honegr, J., Penhaker, M., Musilek, K. and Kuca, K. " 6-Hydroxyquinolinium salts differing in the length of alkyl side-chain: Synthesis and antimicrobial activity". *Bioorganic & Medicinal Chemistry Letters* . 2014, vol. 24, issue 22, s. 5238-5241. DOI: 10.1016/j.bmcl.2014.09.060. ISSN: 0960-894X, eISSN: 1464-3405 (Impact Factor (2013 Thomson JCR Science Edition):2.42, CHEMISTRY, ORGANIC 20 of 58, Q2))

Vavra, P. Nowakova, J., Jelinek, P., Hasal, M., Penhaker, M., Ihnat, P. et al., "Radiofrequency-Assisted Liver Resections: Comparison of Open and Laparoscopic Techniques," *Hepato-Gastroenterology,* vol. 61, pp. 2359-2366, NOV-DEC 2014 2014. DOI: 10.5754/hge13987 ISSN: 0172-6390 (Impact Factor (2013 Thomson JCR Science Edition): 0.928, SURGERY 145 of 198, Q3))

Vavra, P., Penhaker, M., Grepl, J., Jurcikova, J., Palecek, J., Crha, M.,Nowakova, J., Hasal, M., Skrobankova, M., Ostruszka, P., Ihnat, P., Delongova, P., Salounova, D., Habib, N.A., Zonca, P. „Technical Development of a New Semispherical Radiofrequency Bipolar Device

(RONJA): Ex Vivo and In Vivo Studies“ In Journal *BioMed Research International*. 2014, vol. 2014, pp.1 - 7., Article Number: 532792, ISSN 2314-6133, ISSN 2314-6141 (online), DOI: 10.1155/2014/532792. [online:] http://www.hindawi.com/journals/bmri/2014/ 532792/ , (Impact Factor (2013 Thomson JCR Science Edition): 1.579, MEDICINE, RESEARCH & EXPERIMENTAL 85 of 123,Q3))

Positive reactions to the publication - citations excluding self-citations:

Number of citations in ISI Web of Knowledge: 141
Number of citations in SCOPUS: 155
Number of citations out of ISI WoK a SCOPUS: 167

h-index including auto citations according to ISI WOK: 9