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AUTOMATIZED MULTI-ELECTRODE VOLTAGE MAP MEASUREMENT OF ACTIVE POINTS ON SKIN

Our contribution deals with the human skin voltage chart measurement. We have concentrated our effort on finding and following the measurement of active points on different parts of the skin's surface, to acknowledge their existence and position through a measuring process. The human skin has a certain impedance or resistance - it can be easily described and simulated using a substitute electric circuit. But the skin also contains parts with measurably lower impedance and different electric properties - we can show them clearly by measurement of voltage chart.

1. Introduction

The human skin has very interesting properties, especially from an electrical point of view. We can read about it in many literary sources. It has a certain impedance or resistance; it can be easily described and simulated using a substitute electric circuit. But the skin also contains parts with measurably lower impedance and different electric properties - we can see them clearly by a measurement of voltage map. These small parts on the skin's surface are called active points (acupuncture points) and they are known and have been used in acupuncture centuries ago. For many years a number of authors concentrated their efforts to measure them, to describe them and to learn about new properties of them. They are used in different new diagnostic and therapeutic medical devices nowadays. We would like to reveal exactly and with reproducibility through measurement some of those interesting properties of the human skin and the human body and bring something new into this area of our knowledge.

2. The electrical Model of Human Skin

The characteristic impedance of the skin and its capacity allows us to create an equivalent electric circuit of the human skin. But the skin also has other properties which we cannot easily include into that simple model. In 1988 Rosell found out that the skin, lightly impregnated with gel, has an impedance in the range approximately from 100 Ω to 1 M Ω in accordance with the frequency of input pulses [6]. In the lower area of the frequencies about 1 Hz, the impedance alternated from 10 k Ω to 1 M Ω and at higher frequencies from 100 kHz to 1 MHz impedance was in the range about 120 Ω to 220 Ω . Mechanical deformations also influence the skin impedance, except electrical parameters. The stretching of the skin's surface causes a drop of the skin's potential between

the inner and the outer barrier of the layer from about 30 mV to 25 mV. It is approximately 50 k Ω impedance for 1 cm² barrier layer of the skin. The change of the skin's potential is a consequence of alternating the skin impedance considering the skin tension. The capacity of the skin alternates in borders from 0.02 to 0.06 $\mu\text{F}/\text{cm}^2$. A large part of this capacity is in the scleroderma. If this layer thins away, then the skin's capacity becomes smaller (as layers of skin fade away [8]). If this layer is completely eliminated, then the skin's capacity comes down almost to zero. The cell membranes as parts of the skin layers cause high skin capacity.

The equivalent model of human skin impedance cannot be expressed using a simple passive circuit only because the properties of the skin are nonlinear and alternating in time. The simplest model for the skin impedance interpretation is a parallel circuit containing a capacitor and a resistor and a serial resistor. This

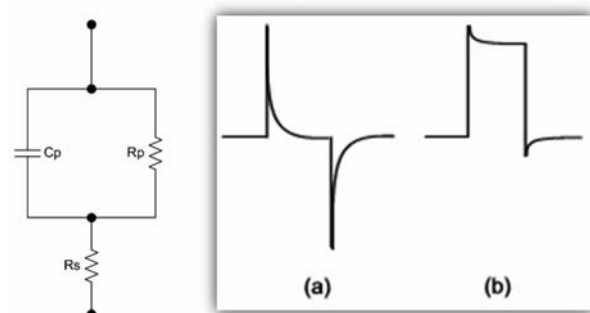


Fig. 1 The equivalent impedance model of the human skin; the response of the human skin to pulses of rectangular voltage connected to the skin's surface: a) skin with a scleroderma layer; b) skin without a scleroderma layer [8]

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model we can see on Fig.1. The parallel connection of the capacitor C_p and the resistor R_p in this model represents influence of the skin capacity and the serial resistor R_s represents the impedance of subcutaneous tissue [8]. Image on the Fig. 1 displays the reaction of the skin with rectangular voltage. It is plain to see from the reaction, that if the skin is without scleroderma then the electric current flowing trough is limited by the R_s resistance. Setting values for an equivalent model of human skin was difficult, because these values are closely dependent on the kind of skin and on the position of the measurement. For 0.8 cm^2 dry and clean skin, cleansed by ethanol and water values for the resistors and capacitor were established as follows: $R_s = 2 \text{ k}\Omega$ to $200 \text{ k}\Omega$, $R_p = 100 \text{ k}\Omega$ to $500 \text{ k}\Omega$ and $C_p = 50 \text{ pF}$ to 1500 pF .

3. Electro-Acupuncture and Physical Structures Called Meridians

Physical structures meridians are objectively measurable, identifiable and describable specific paths in human body. They have special physical features and significance. They contain so called active points which are significant with: skin impedance between these points ($100\text{--}200 \text{ k}\Omega$) and surrounding skin ($1 \text{ M}\Omega$) is different, the electric capacity of these points is greater – within the limits 0.1 to $0.5 \mu\text{F}$, in comparison with non active points where the capacity reaches only about $0.01 \mu\text{F}$. Various authors in their works consider meridians as channels that lead electric charge in extracellular space [7]. The blockage of the flow of these currents leads to a higher concentration of positive or negative charge and a physical manifestation of that can be pain or some disease symptoms. Namely here are various qualitative indications on the skin’s surface of significant meridian points, which are interesting from a technical point of view: high electric potential (to 300 mV), high electric capacity (0.1 to $0.5 \mu\text{F}$), low electric resistance, higher skin respiration, higher local temperature, generation of infrasonic waves (from 2 to 15 Hz). Some qualitative indications of deeper layer of the skin in significant meridian points: lower level of sensitivity for electric stimulation, higher electric capacity, higher conductivity of isotopic tracers. The measurement of electric parameters of the skin on meridians was described in various literal sources [5], [6]. Meridians have an important information, energetic and regulative function in the human organism and have been used since centuries in acupuncture prevention, diagnostics and therapy. Disorders in energy flow in the body then manifest in whole body form and state of the organism. They express in their primary energetically-information level and also in the psycho-regulation. The system of active points and meridians contains a multitude of information about the actual state of the organism. The problem is to find the appropriate key to evaluate this information. We have to respect the knowledge and laws of classic acupuncture when solving it.

In this paper we focus on physical verification or denying the existence of those points on the human body, using potential chart measurement on certain areas of the human body.

4. Structure chosen for measurement

Literature and various web sources describe in a wide range positions and properties of these physical body structures. Because of accessibility and position we have chosen the following one: *Large Intestine Meridian (Li)*. General distribution of Large Intestine Meridian [4] – it starts from the hand and goes to the head, along the anterior lateral side of the upper limb, then connects with the large intestine, lungs, teeth (especially the lower teeth), mouth, nose, and face. It meets the Lung Meridian of Hand Taiyin at the radial side of the tip of the index finger, the Stomach Meridian of Foot Yangming at the areas lateral to the wings of the nose, and the Du Meridian at DU14-Dazhui.

The main indications are:

disorders along its external course, including upper hemiplegia, tennis elbow, frozen shoulder, toothache; facial pain, spasm or paralysis; nasal discharge or obstruction, headache, pain conditions, either along its external course or on the other parts of the body, exterior patterns, both wind-cold and wind-heat.

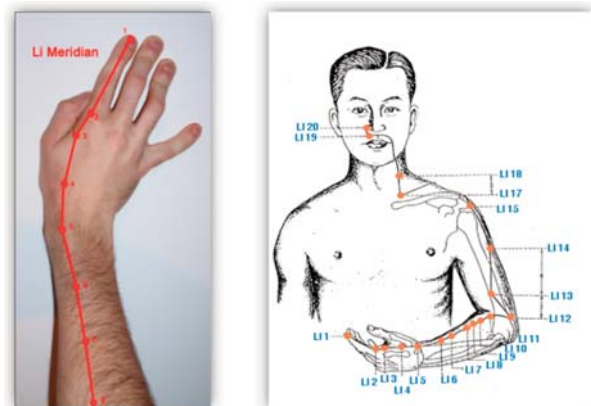


Fig. 2 Large intestine meridian path (Li Meridian)

5. Experimental Measuring Device

The basic construction element of the designed and realized measuring device is a processor from Atmel – ATmega16. The processor contains one serial port, eight 10-bit A/D converters and one SPI – Serial Peripheral Interface. For the controlled connection of measuring electrodes multiplexers DG406 were used. The device also contains a modified version of a peak detector. In addition, the device was extended by DDS – Direct Digital Synthesis generator from Analog Devices AD9833 which is controlled via a SPI bus by a microprocessor [2]. The communication with the PC covers the module DLP-USB232M which serves as a converter of the USB interface to UART – Universal Asynchronous Receiver/Transmitter. This module and the connected computer are separated from the measuring device by a two channel insulator ADUM1201 from Analog Devices, because of the safety of the patient. Supplying the device from accumulators is the way how

to protect the human operator or the measured object from potential electric injury.

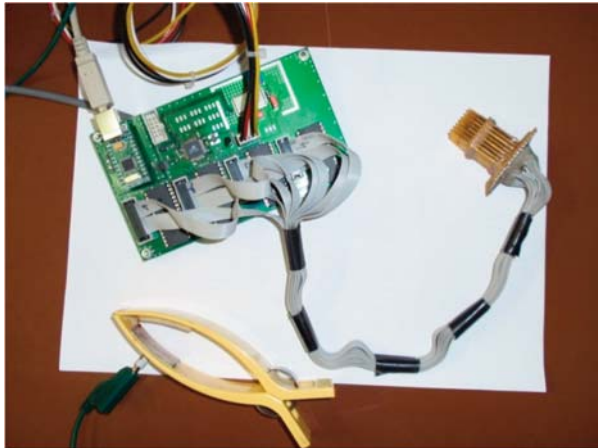


Fig. 3 Measuring device with connected electrodes

Our measurement was realized using needle electrodes [2], [3] (Fig.4.). There are 64 electrodes placed into a 8×8 matrix on an isolative holding construction. Each of the electrodes is created by a brass needle located in a cavity shell with a nib which allows fitting each of the electrodes to the surface of the human body and make the contact. All the electrodes measure the change of voltage with regard to a reference electrode placed on the chosen suitable position on the body. The distance of needle peaks is 2.5 mm.

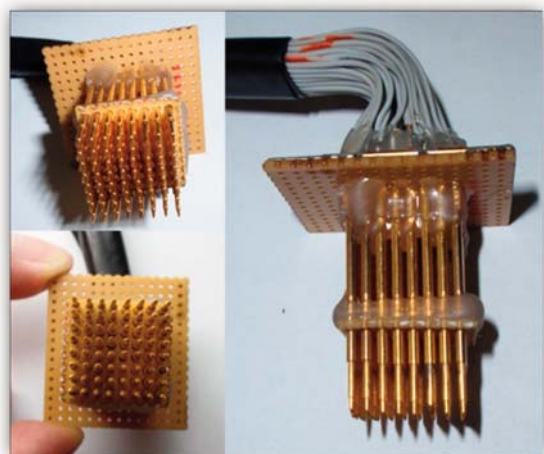


Fig. 4 Measuring 8×8 needle electrodes

6. Searching for Active Point Position

Before the measurement we had to choose a meridian appropriate to our technical abilities for measuring. We had two suitable options. One was to find an active point on the LU meridian

of the lungs or the second one on the large intestine meridian – the LI meridian. We finally decided for the large intestine meridian because of its path by the outer side of the hand perfectly accessible for our needle sensor. We started to measure according to the marked positions for the measuring probe on Fig. 5.



Fig. 5 Searching for active point No.4 on Li meridian, experimentally chosen positions for measuring electrodes from 1 to 10, along the Li meridian

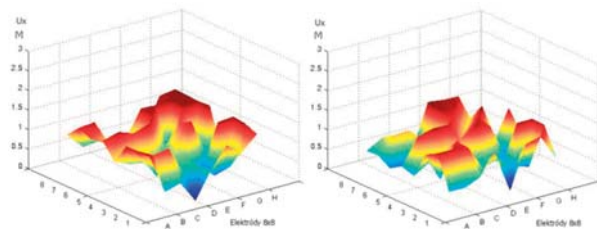


Fig. 6 A voltage chart measured on positions 1 and 2.

All ten points were measured a few times, an example of obtained voltage charts we can see visualized in 3D on the picture Fig. 6. During the measurement process on the large intestine meridian we found a point which showed a significant change in comparison with previous measurements. It was the active point No.4 on the large intestine LI meridian. This point was precisely analyzed many times. The measuring probe was positioned as we can see on Fig. 7. The point was measured repeatedly, each measurement was performed in a different time and all the measurements proved the existence of that active point.

From the measurement with electrodes placed on A position (Fig. 7.) the area of lower values of measured voltage U_x in lower left quadrant is visible (Fig. 8.).

After a change of electrode position to B position (Fig. 7.) it is clearly visible that the area of the lower measured voltage U_x moved into the center of chart (Fig. 9.).

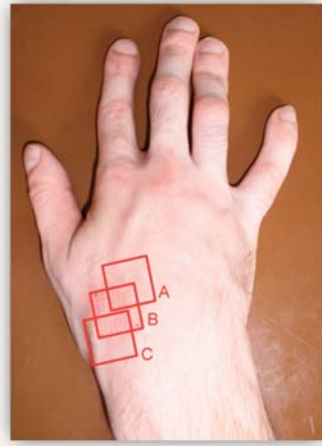


Fig. 7 Localization of active point No.4 on Li meridian, in B position

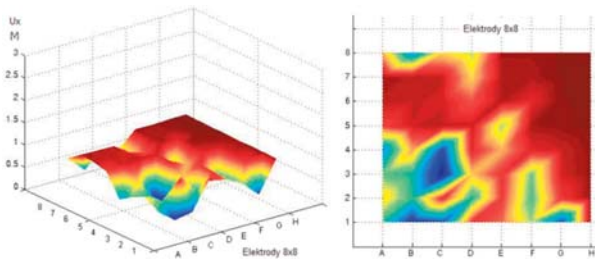


Fig. 8 Measuring voltage chart on A position in 3D and 2D visualization

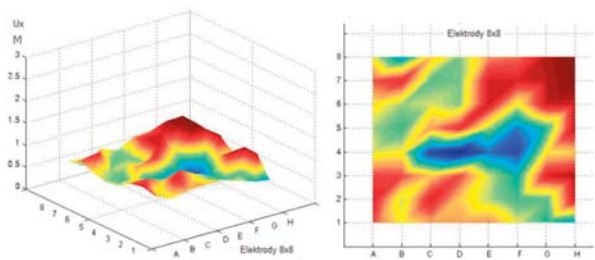


Fig. 9 A voltage chart measured on B position in 3D and 2D visualization

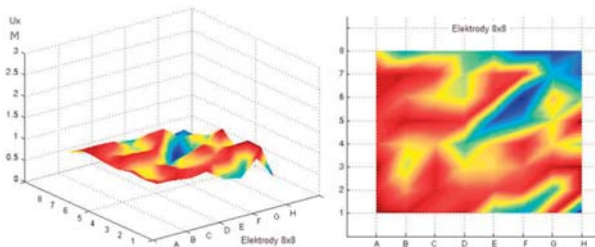


Fig. 10 A voltage chart measured on C position in 3D and 2D visualization

We continued with the measurement in a diagonal positioning of the probe. We placed the electrodes on the C position (Fig.

7.) and the area with a lower measured voltage U_x moved into the right upper quadrant of chart (Fig. 10.). After performing these measurements we located the active point No.4 on the Li meridian in the centre of the B position (Fig. 7.).

7. Comparison of Measured Results

For quite a long time, people believed that the active point of a meridian was a pipeline like a blood vessel or nerve fiber and the active point was like neuroganglion or hole, and expected that we would find them through dissection one day [1]. Unfortunately, this belief failed to be proven by anatomy or histology after half a century of research. On the other hand, however, the objective existence of active points and meridians was proved by means of electronic measurement with excellent reproducibility. Then, we have to ask what the meridians and active points look like - from the data from electronic measurement and whether they are similar to invisible pipelines or knots or holes. From Fig. 11, we can see the shape of the active point measured by the American scientist Becker [5], electronically. The picture shows that the active points are not similar to nerve knots or holes with a clear boundary, but more like a small and invisible hill or hole without clear borders.

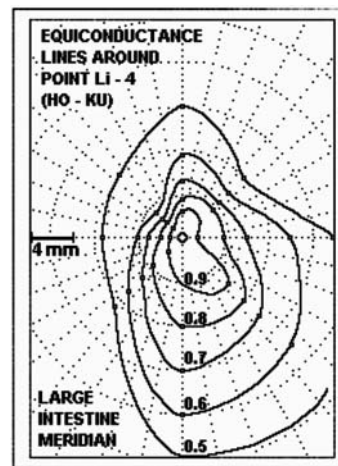


Fig. 11 The shape of active point No.4 on Li meridian from [1], [5]

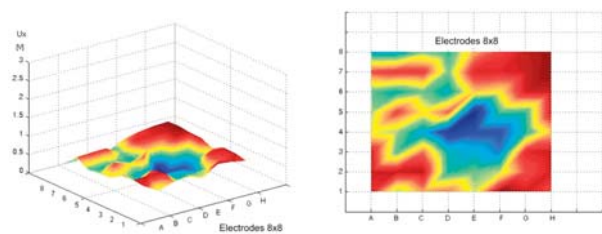


Fig. 12 Voltage chart measured on position of active point No.4 on Li meridian in 3D visualization and 2D visualization.

Our measurement also confirmed these investigations. Here we offer for comparison the following chart on active point surface

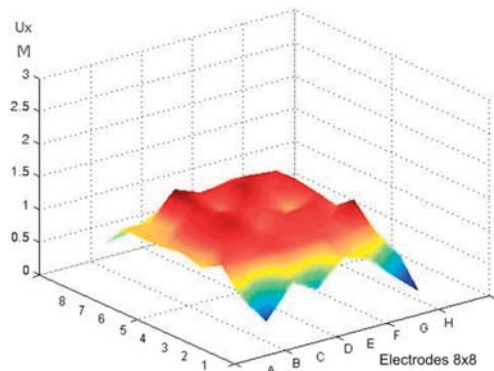


Fig. 13 Voltage chart measured on position of non-active point in 3D visualization

achieved by measuring device (Fig.12), the dark blue color represents the center of an active point, the pale blue color its a narrower border and boundary yellow color is its contour.

We can also see a non active point (Fig. 13) measured for comparison with the active one.

8. Conclusion

Methods and electronic measuring devices used for measuring of 3D voltage charts of human body surface offer a wide space for practical research and can be useful in medicine, diagnostics and therapeutic process as well.

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