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The development of portable system for unobtrusive perspiration monitoring

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Abstract

Portable system for monitoring of excreted fluid through the skin during human activity has been developed and fabricated. The system consists of sensing element that is mounted close to the open skin surface and transmits information about relative humidity levels and temperature through wireless communication to coordinator unit and acquisition point which is equipped by analyzing software performing the calculation of excreted fluid through the skin surface. A special software utility is designed for data storage and user control of the main measured and stored parameters. Obtained information collected in time helps to determine the volume of fluid outgoing from the body by sweating. Basic communication with PC is realized by COM port, virtual port or Bluetooth COM port emulator. The volunteers' tests demonstrated perspective for using the system for athletes, active lifestyle people and elderly people.

Keywords: Unobtrusive perspiration monitoring; Humidity sensor; Portable system, Wireless communication

1. Introduction

During human's daily movement, sport activities and fitness, a large amount of fluid excretes through the skin surface in the form of sweat which can lead to dehydration of the body as the result. In normal conditions and standard life activity human organism can produce about 600 ml of sweat daily [1]. Besides, the monitoring of excreted fluid is very important for older people, sick persons and people living in areas with high temperatures. In case of intense stress, 0.33 l/h of sweat can be produced at ambient temperature of 27 °C while 0.58 l/h at 35 °C. Dehydration of organism leads to disruption of the cells and brain work, and reduces

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the functioning of metabolic processes. The first symptoms of dehydration appear at the loss of about 6 % of the liquid contained in the body [2]. Existing methods for measuring dehydration state are intrusive or invasive which makes their use complicated in everyday life. Thereby we have proposed and developed a portable system for control of excreted fluid through the skin during active or passive day activity.

2. Development and fabrication

The portable computer system for monitoring the fluid output through the skin consists of three main parts: wearable unobtrusive sensor unit (sweat sensor), coordinator unit and acquisition point, which are connected together by wireless data transmission technology (Fig 1). Sweat sensor and coordinator unit are placed on human body and form so called Wireless Body Area Network (WBAN), which consist of different electronic devices linked to the on body network. Next, the data from WBAN are transmitted to computer or mobile phone through Bluetooth or another wireless communication protocol.

Sensor unit is the major part of the system and consists of two resistive relative humidity sensors, a temperature sensor and a digital measuring module. One of the humidity sensors (Fig 2 a) was developed and fabricated especially for measuring relative humidity (RH) close to skin surface (5 – 7 mm) and based on the semiconducting sensitive layer of nanostructured titanium oxide (skin sensor). This sensor works on the principles of water molecules physical sorption on the surface of the sensing layer to decrease the resistance [3]. The second (commercial) resistive humidity sensor HS-15P sensors is located on the opposite side of the sensing unit and intended to measure relative humidity (ambient sensor). The DS18B20U sensor has been used for ambient air temperature measurements.

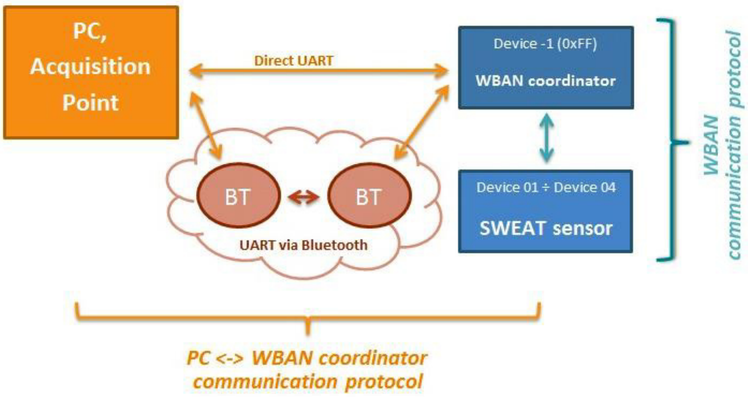
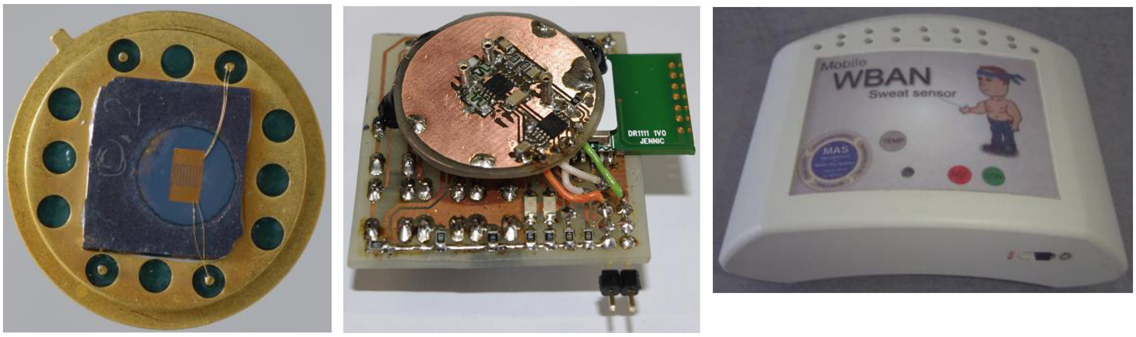


Fig. 1. Schematic view of the developed computer system for controlling fluid transport through the skin surface

A well-known mathematical model was used for calculation of the water loss through the skin surface from both humidity values [4]. This model is based on estimation of the vapour pressure gradient appear of the difference between RH on the surface of the skin and at the certain distance from it,

$$1/S\cdot(dm/dt) = -D'\cdot(\partial p/\partial x) \quad (1)$$

Where $1/S\cdot(dm/dt)$ – is the evaporation rate [$g/(m^2\cdot hour)$]; D – is a constant [$0.67\cdot10^{-3}\cdot(g/(m\cdot hour\cdot Pa))$]; $(\partial p/\partial x)$ – is the vapor pressure gradient [Pa/m].



(a) (b) (c)

Fig. 2. (a) fabricated humidity sensing element; (b) electrical module for measurements of relative humidity near skin surface; (c) prototype of the sensor unit including all sensors with electrical module and circuit for wireless data transmission

The sensors work implemented by using a special designed electronic module (Fig 2 b) that contains low power operational amplifiers, microcontroller combined with ZigBee transceiver and DA converter. All components of the sensing unit are integrated in a box, which can be fixed on the arm (Fig 2 c).

Information received from the sensor unit is stored by the coordinator unit (Fig 3 a), also coordinator unit synchronizes data transferred between PC and sensing unit. Acquisition point with specialized application software (Fig 3 b) is used for maintenance and configuration of the sensing unit. Using this program enables to set or read data, calibration constants or other parameters.

(a) (b)

Fig. 3. (a) prototype of the wearable coordinator unit; (b) PC acquisition point software for controlling of sensor unit

3. Results and discussion

First of all the portable system was adjusted and calibrated by using standard saturated salt solutions with the constant vapour pressure ensuring fixed humidity level near solution surface [3]. During electronics adjustments the signal from skin sensor was performed for better sensitive in higher humidity region and ambient sensor has been configured for equal sensitivity in all humidity range (see. Fig 4 a). Accuracy for skin sensor after calibration was determined about 10 % RH (for RH ≤ 50 %) and 3 % RH (for RH > 50 %). Error drifts over time (about 10 % RH) were detected during one month after calibration. Commercial sensor accuracy was determined about 4 % RH, in the most cases below 0.5 % RH. Then the portable perspiration system was tested with the help of 5 volunteers during standard day activity and sport actions.

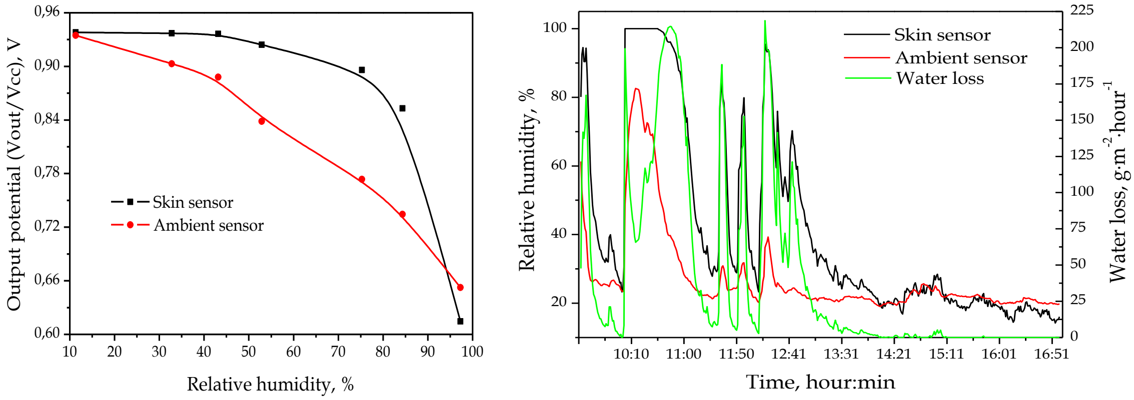


Fig. 4. (a) relative humidity sensors calibration plot; (b) portable perspiration system testing diagram

A typical measurement diagram for male person during 8-hour period is shown in Fig 4 b. As seen from the diagram for the first 10 minutes, both sensors show a high value of RH, it is the so called set up period for bedding of sensors after dry storage. After sensors stabilization we have the time of low activity of the person. At 10:00 he had a running training of about 40 min and it was the high water loss period. Then during next few hours the volunteer had alternation of physical activities and rest periods, on diagram we have few pikes of water loss. And finally after 13:00 the person showed a low activity without significant loss of fluid by sweating. The calculation of water loss for 2 m^2 skin surfaces showed losses of 740 ml of liquid by body perspiration.

4. Conclusion

The portable perspiration system for monitoring of human body water loss through the skin has been developed and fabricated. The system can be used for standard day activity, sport activity indoors or outdoors, for males or females, it has a low power consumption and low weight. The information obtained from coordinator unit can be stored on personal computer or hospital server, sent through internet to medical specialists for analysis and monitoring of dehydration state of organism.

Acknowledgements

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