Supersensory computers for measurement and analysis of biologically dangerous factors of environment

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Development questions of gathering, storage and data processing systems with a considerable quantity of the sensors metering various environmental factors which can represent danger to human health and biosphere are considered. The construction of a system prototype which includes directly the supersensory data collection system and client-server architecture is offered. Also questions of the supersensory networks construction and a complex data analysis are considered.

Introduction

One of actual problems of the modern world today is environment pollution by the factors which are a result of human activity and the measurement of these pollutions. Such factors may include acoustic noise, vibration, electromagnetic radiation, ionizing radiation, toxic gas emissions, biological pollution, effects on weather and climate. For measurement of some parameters bulky expensive devices are required. Many parameters are measured separately and frequently complex estimations of influence of these parameters on environment are not spent and correlations between them are not investigated.

The purpose of this work is to describe the possible ways to solve the problems described above.

The main idea of this work is creating a universal supersensory computer and building a network of these devices for data analysis, prediction and conclusions about the suitability of the environment for humans and other living organisms.

The relevance of tasks in view proves to be true that daily we are exposed to influence of external factors of environment and we have even no slightest representation about influence of these factors on our organism.

Scientific novelty of work consists that the developed system will analyze in a complex arriving data from multiple sensors, to find correlations between them, to make an estimation of the influence of environmental factors on the human body, and also to be mobility and the cheapness comparable to modern mobile devices, such as smartphones, PDA or satellite navigators.

The main parameters of the supersensory computer

Universality, the presence of a different digital interfaces and ADC allows connecting both analog and digital sensors, which measure various parameters of the environment and have different accuracy and precision of measurements (table 1). The modular design (figure 1) of the device makes it easy to replace the sensors.

Supersensory computer has multiple interfaces for data exchange with other devices and the central server: USB, serial port, Bluetooth, GSM modem.

It also contains a built-in non-volatile memory, real time clock, and allows connecting external storage devices such as memory cards. It powered by the built-in lithium-ion or lithium-polymer battery, an AC adapter or a port USB.

Hardware architecture of supersensory computer

Supersensory computer (figure 1) consists of the following modules (using the simple modular architecture that allows quickly replace any of the modules or sensors):

1. Micro Controller Unit (MCU)
2. Analog-to-Digital Converter (ADC)
3. Impulse-to-Digital Converter (IDC)
4. Frequency-to-Digital Converter (FDC)
5. Connection Module (CM)
6. Memory Module (MM)
7. Power Module (PM)
8. Real Time Clock (RTC)

Table 1. Main parameters measured by supersensory computer

Instrument parameter	Measuring range	Error
Temperature	-55…+125 °C	±0.5 %
Relative humidity	0…100 %	±2 %
Atmospheric pressure	300…1100 hPa	±0.1 %
Illuminance	0…70000 Lux	±10 %
Mechanical vibrations	-16…+16 g (3 axes)	±2 %
Acoustic noise	0…150 dB	±10 %
Ionising radiation	0…100000 μR/h	±10 %
Magnetic field	0…1000 Gauss	±1.5 %
Electromagnetic radiation	0…4000 $\mu W/cm^2$	±10 %
Lightning detector	0…100 km	±50 %
Concentration of ozone	0.01…1 ppm	±50 %
Concentration of carbon monoxide	1…1000 ppm	±50 %
Concentration of ammonia	0.1…100 ppm	±50 %
Concentration of nitrogen dioxide	0.05…5 ppm	±50 %
General concentration of harmful gases and steams	0…1000 ppm	±50 %
Electronic compass	0…360° (3 axes)	±1 %
GPS navigation	18000 m, 515 km/s, 66 channels	±0.01 %

9. Navigation Module (NM)
10. Analog Sensors (AS)
11. Digital Sensors (DS)
12. Impulse Sensors (IS)
13. Input Devices (ID)
14. Output Devices (OD)

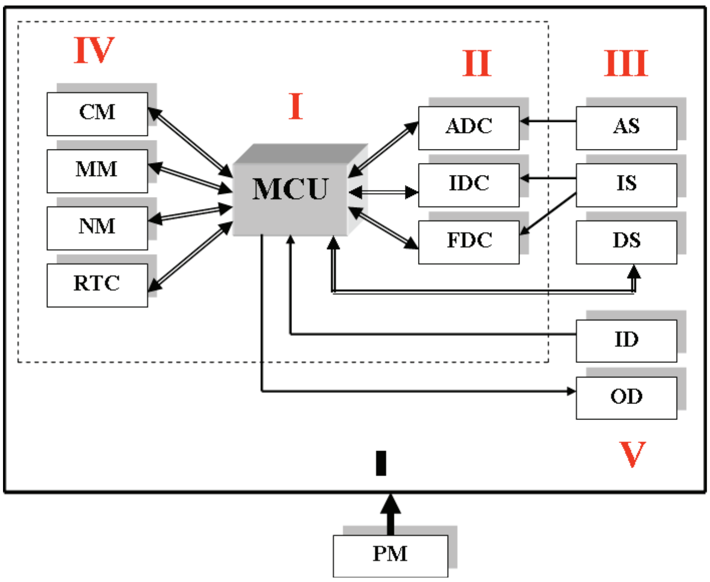

Figure 1. Block flow diagram of supersensory computer

Micro Controller Unit (MCU) — is the main device, without which supersensory computer can not function. MCU consists of a microprocessor, a clock circuit and additional items. The microprocessor is a chip that includes a memory, an arithmetic logic unit (ALU), the control unit (CU), the data bus, and so on, that is the basic building blocks that are part of common processors. If the microprocessor also contains modules ADC, IDC, FDC, RTC, CM, MM and NM — it's already called a microcontroller. The clock scheme sets a clock speed of the processor; the additional elements determine the proper functioning of the processor.

MCU module performs the following functions:

1. Controls the operation of peripheral devices — modules ADC, IDC, FDC, RTC, CM, MM, NM, PM, ID and OD.
2. Performs mathematical processing of the measurements from the sensors.
3. Provides storage of the data.
4. Outputs the data to the output devices (OD) and transmit it through a module CM to external devices for storing and processing.

Signal conversion modules (ADC, IDC, FDC) — required to convert signals from analog to digital form, clear for the microprocessor. Most analog sensors have an output voltage is directly proportional to the measured value, such as temperature, humidity, pressure. To work with them requires an analog-to-digital converter (ADC). The developed device has a built-in microcontroller, 10-bit ADC. Also, an external 24-bit sigma-delta ADC with integrated digital filter is used for very accurate measuring. Some sensors such as anemometers, Geiger's counters outputs the pulses. To measure the amount of pulses or pulse frequency – frequency converters (IDC, FDC) are used. But, as a rule, no longer necessary when using modern and fast microcontrollers.

Connection module (CM) — provides data exchange between supersensory computer and any other device that can store and process information. This could be a mobile phone, a personal computer, a centralized server, and so on as the interface can be used as a wired (LPT, RS-232, RS-485, USB, FireWire, Ethernet), and wireless (IrDA, Bluetooth, Wi-Fi, GSM) communication interfaces. First experimental devices use an USB interface.

Memory Module (MM) — consists of the internal and external memory. It required storing the information obtained from the sensors to be processed. As a non-volatile internal memory, memory of the microcontroller is used, as external — can be used memory cards, USB-drives and hard disk drives (HDD).

Real-time clock (RTC) — needed for accurate time measurement of recording information from sensors. RTC module is synchronized with the atomic clock installed on the navigation satellites through GPS module.

Navigation module (NM, GPS) — determines the geographical location of supersensory computer. This is necessary for the subsequent analysis of data sensors, focused on particular geographic coordinates and object definitions that create a negative impact on the environment.

Power Module (PM) — provides a stable power supply by different voltages of all modules of supersensory computer, monitors battery charge and protects chips from interference and harmful impulses.

Input/Output device information (ID/OD) — are buttons, keyboard, controllers, display, LEDs and sound indicators, printers, needed to control a supersensory computer and display the value of the measured parameters [1].

Sensors

Sensors that can be connected to supersensory computer divided into analog, digital and pulse sensors. Analog sensors, for example, include temperature, humidity, pressure, thermocouples, photoelectric sensors, acoustic, gas sensors, etc. Supersensory computer contains two independent ADCs with different resolutions, processing speed and the presence of built-in filters and amplifiers, and therefore allows you to connect any of these sensors.

Pulse sensors are wind speed, flow, particle counters. They directly or through a matching device connected to the MCU module.

Digital sensors are components that already contain an analog sensor, amplifier, filter, ADC, microcontroller, memory, registers and a digital interface that is compatible with microcontrollers. Supersensory computer supports both parallel communication with the sensor, and serial interfaces, such as 1-wire, SPI, I^2C, and others [1, 2].

Intelligent supersensory computer networks

Sensor network — a distributed adaptive wireless network of small intelligent sensor devices. Appointment of intelligent sensor networks is collecting, processing and transmission of information with high demands for autonomy, reliability, scalability, and distributivity of network.

The main application areas of intelligent sensor networks include next industry research and production:

- Security systems and access control
- Building Automation
- Diagnostics of industrial equipment
- Remote collect readings from meters
- Telemedicine and Health
- Military applications
- Environmental Monitoring

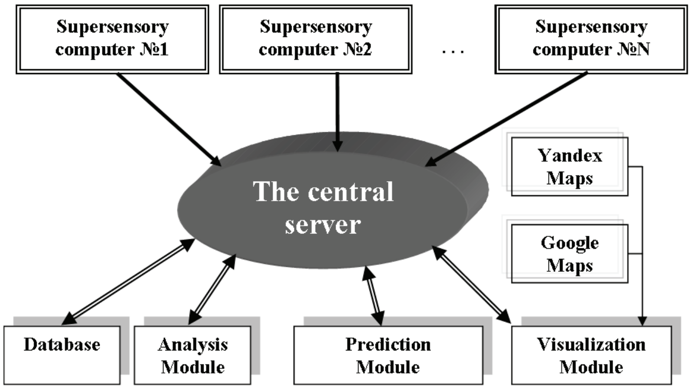

Figure 2. A structural block diagram of intelligent supersensory computer network

The architecture of such network which can unite in itself a large quantity of the supersensory computers that will allow to solve following problems is now developed:

1. Accumulation and storage of information from handheld supersensory computers.
2. Analysis of the recorded data, find correlations between them.
3. Visualization of the information with the use of GIS technologies.
4. Forecast future changes of the measured parameters and their impact on the environment.
5. Formation of conclusions about suitability of environment on human health and biosphere.

Use of client-server architecture in which portable supersensory computers will be clients is supposed. Information from them will come to a central server [1, 3, 4].

Figure 2 shows the block diagram of client-server architecture of intelligent supersensory computer network.

Complex parameters and indexes

Now for an estimation of external environment factors on the human, complex indexes which simultaneously consider some parameters are used. These indexes are commonly used in weather stations and based on several parameters (temperature, humidity, wind speed, etc.). For example, they expect the ambient temperature, which people will actually feel the skin and not something that shows only a thermometer.

These indexes, for example, are [6]:

1. *Heat Index (humiture)* — considers the relative humidity and temperature
2. *Humidex* —- considers temperature, humidity, a dew-point
3. *Wind Chill* — considers temperature and wind speed
4. *Wet-Bulb Globe Temperature (WBGT)* — the complex index which considers also radiating and convective heat transfer, but also and air humidity
5. *THC index* — is an empirical measure of the combined effect on the human microclimate parameters (temperature, humidity, air velocity and thermal radiation)

Let's consider, for example, the Heat index. It's calculated only on the two characteristics - temperature and relative humidity, because humidity affects the secretion of sweat from the skin, and thus the entire heat transfer in general. Equation 1 of Heat index calculation is as follows [5]:

$$\begin{aligned}&HI = c_1 + c_2T + c_3R + c_4TR + c_5T^2 + c_6R^2 + c_7T^2R + c_8TR^2 + c_9T^2R^2\\&c_1 = -42.379,\ c_2 = 2.04901523,\ c_3 = 10.14333127,\\&c_4 = -0.22475541,\ c_5 = -6.83783 \times 10^{-3},\\&c_6 = -5.481717 \times 10^{-2},\ c_7 = 1.22874 \times 10^{-3},\\&c_8 = 8.5282 \times 10^{-4},\ c_9 = -1.99 \times 10^{-6}\end{aligned} \quad (1)$$

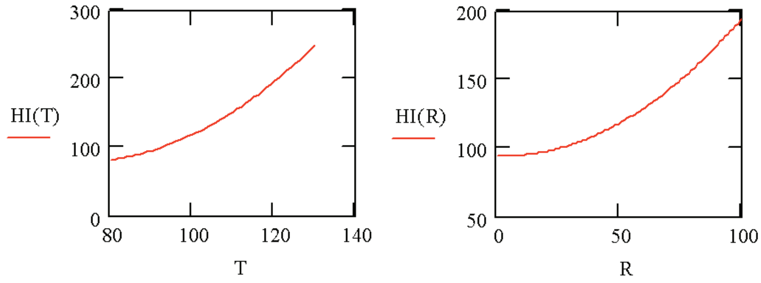

Figure 3. Plots of the heat index of temperature and relative humidity

Figure 3 shows the dependence of the Heat index from the temperature (R = 50%) and the relative humidity (at T = 100 degrees Fahrenheit). As can be seen from the graphs, the Heat index value is directly proportional to the two parameters, and these two parameters are indeed complex effect on the human body.

For example, all know that too loud noise negatively influences working capacity of the person but if to it still to add the raised temperature, and frequency of noise to shift in the area of noise subsonic frequencies only these two factors can make the person totally unworkable and affect his mental state.

It is proposed, to introduce the so-called general hazard index that takes into account not only the atmospheric parameters, but also ionizing, electromagnetic influence, acoustic noise, vibration and air pollution.

Conclusions

In this paper the basic principles of supersensory computers, intelligent supersensory computer networks and computing the values of the complex indexes have been described. It is possible to draw the following conclusions:

1. Modularity, ease of use, the ability to replace individual units and sensors and mobility make the system accessible to a wide range of users.
2. Target price of such devices will be a range from 100 to 1000 $, depending on the equipment that is less than the average price of mobile phones and GPS.

Experimental model of supersensory computer with eight measures of environmental parameters and USB-connection to PC was developed. In the future it is planned to solve following problems:

1. Development of a series of experimental devices.
2. Development of low-cost, compact supersensory computer, equipped with the maximum number of sensors.
3. Research the combined effect of various parameters on the human body and the development of mathematical models.
4. Software development for the central server, which will be able to collect and analyze information received from devices in real time.

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