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NOISE CONTROL FOR A BETTER ENVIRONMENT

IoT-based system for monitoring and limiting exposure to noise, vibration and other harmful factors in the working environment

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ABSTRACT

There may be various agents harmful to employee health in the work environment. One of the most common is noise. For example, in Poland in 2017, over 187 thousand people were working in the noise hazard, while in industrial dusts hazards about 50 thousand. The protection of workers' health from the effects of exposure to these agents requires the measurement and assessment of exposure. This task can be particularly difficult in the case of a changing work environment or non-stationary workplaces. The article presents a system being developed for monitoring and limiting worker exposure to harmful agents in the work environment. It consists of a network of intelligent sensor (measuring) devices and wearable warning devices worn by employees. The system uses two types of popular wireless data transmission protocols: Bluetooth LE to determine the position of an employee in a working environment and Wi-Fi for data transmission between network devices. Thanks to the use of Wi-Fi devices, the network can send data via the Internet, which enables remote supervision of working conditions. The article discusses the structure and operation of the system following the example of monitoring of noise and vibration hazards.

Keywords: Noise, Monitoring, Wireless Sensor Network
I-INCE Classification of Subject Number: 71

1. INTRODUCTION

The working environment is an environment in which there may be various agents harmful to the health of employees, such as noise, vibrations, industrial dusts, optical radiation, chemicals and other [1]. According to the data of the Statistics Poland [2], in Poland in 2017, the number of people employed in hazardous conditions caused by these harmful agents exceeds 262 thousand. The most common harmful agent is noise. Over 187 thousand people were working in the noise hazard, while in industrial dusts hazard about 53 thousand and in vibration hazard about 14 thousand. These statistical data do not include companies employing less than 10 people, therefore it is estimated that the number of people employed in hazardous conditions caused by harmful agents can be twice as large.

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Health effects of exposure to a given agent depends on its intensity or concentration and duration of exposure. For this reason, the protection of workers' health requires the assessment of the intensity or concentration of harmful agents and the assessment of exposure. However, the classical approach to exposure assessment may be difficult or insufficient for non-stationary, mobile workplaces or for work environments in which the concentration or intensity of harmful agents may vary over time. In such cases, the detection of excessive exposure of the employee and taking effective preventive actions is possible only if parameters of the work environment are constantly monitored. For this purpose wireless sensor networks can be used.

Wireless sensor network (WSN) [3] can be defined as a group of specialized sensing and actuating devices with the infrastructure for wireless communication, forming a network, intended for monitoring and controlling the state of the environment or physical systems. Devices forming a wireless sensor network are called nodes. The node structure includes a suitable transducer (sensor or actuator), a microcontroller and a radio communication module. Devices of sensor networks using the Internet Protocol (IP) can communicate directly through the Internet with other devices, thus creating the Internet of Things [4, 5]. Nowadays wireless sensor networks find applications in such areas as smart buildings and cities, industrial automation, health care, environmental monitoring, weather monitoring, construction monitoring, agriculture and forestry and so on [6]. Monitoring of environmental noise [7, 8] is such an example of the use of wireless sensor networks. Such applications are most often based on low-cost measuring devices, which have lower accuracy than commonly used measuring devices, but thanks to a much lower cost, they enable long-term, continuous noise monitoring in many locations. It gives better insight into the processes occurring in the acoustic environment.

One of the possible applications of wireless sensor networks is the monitoring of the work environment in terms of the hazards to the health of employees. The further part of the article discusses the structure and operation of a system for monitoring and limiting worker exposure to harmful agents in the work environment being currently developed in the Central Institute for Labour Protection – National Research Institute.

2. STRUCTURE OF THE SYSTEM

The system being currently developed is a wireless sensor whose main objective is to monitor the working environment and preventing exposure of workers to agents harmful to health. This system must therefore consist of at least two types of components: measuring devices and employee warning devices. The measuring devices monitor the work environment by measuring concentrations or intensities of harmful agents. An employee warning device is a wearable device worn by an employee, which warns him about hazards in a given area. Hazards in various parts of the workplace may be different. Therefore, the correct operation of the system also requires determining the position of employees in the area of the workplace.

The basic method of determining the position of objects in wireless sensor networks is based on the measurement of the received signal strength [3, 9]. For a given transmitter power, the strength of the received signal depends on the distance between the receiver and the transmitter. In wireless communication standards such as Wi-Fi or Bluetooth LE, information on the strength of the received signal is available in the form of a Received Signal Strength Indicator (RSSI). At least three RSSIs from transmitters of a known location are needed to determine the location of the receiver. In the proposed system, small Bluetooth Low Energy transmitters (known as beacons) were used to determine the location of employees. The basic structure of the system is shown in Fig. 1.

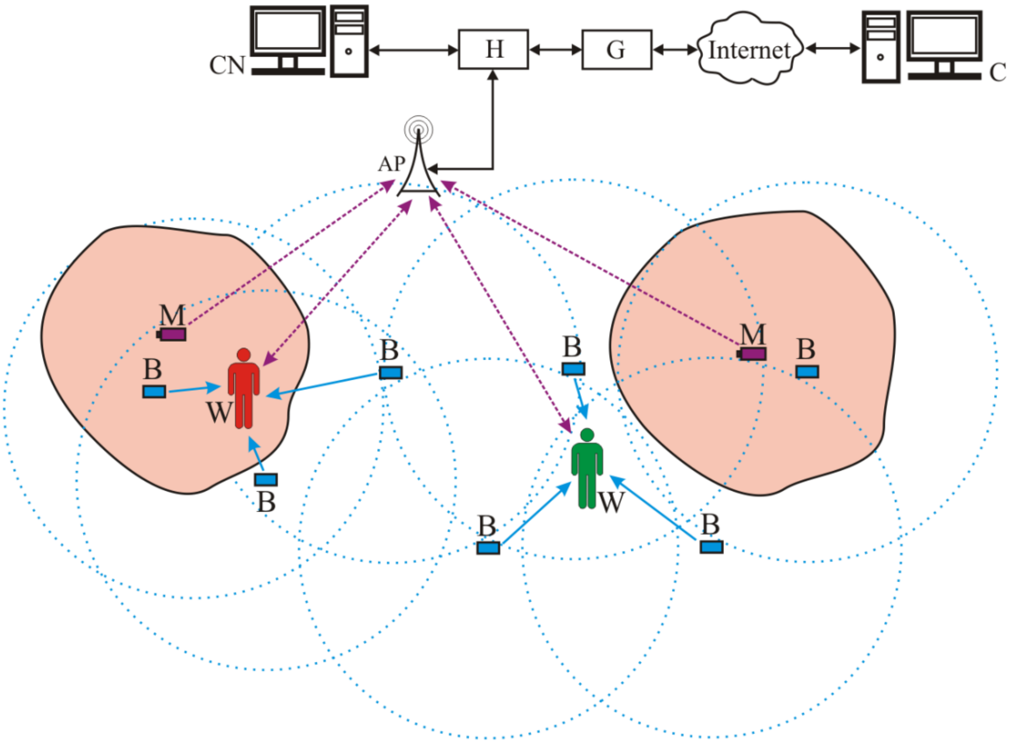

Figure 1. Basic structure of the system (M – measuring device, W – person with wearable device, B – beacon, AP – Wi-Fi access point, H – Ethernet hub, G – network gateway, CN – main unit, C – computer, blue arrows – Bluetooth LE transmission, violet arrows – Wi-Fi transmission, black arrows – Ethernet connections, pink areas – hazard zones, blue dashed circles – beacon radio transmission range).

In the proposed solution, data on hazards and location of network devices, hazard zones and employees are collected and processed in the computer being the system's main unit (CN in Fig. 1). Transmission of data from measuring devices and from and to garments is based on the Wi-Fi standard. The use of the Wi-Fi standard allows easy use of the existing network structure of the company and access to measurement through the Internet. The system uses iNode Beacons [10], supplemented by additional power systems extending their operation time. The wearable device (Fig.2) was developed based on the ESP-WROOM-32 radio module. This radio module supports data transmission in both Wi-Fi and Bluetooth LE standards.

Figure 2. The model of the wearable device.

A wearable device reads the RSSI values of radio transmissions from the beacons and sends them to the main unit of the system. The main unit determines the location of the employee and sends information about hazards to its wearable device.

3. MEASURING DEVICES

The measuring systems are an important part of the system currently being developed. Since the system is designed to monitor various hazards in the work environment, a modular construction of measuring systems has been proposed. It consists of a communication module and a sensor module connected with each other using a modular interface. The communication module contains components that are the same for all measuring devices: the ESP-WROOM-32 radio module, the STM32 family microcontroller and the power supply systems. The sensor module includes a sensor and circuits for pre-processing of the measurement signal. The sensor module can be constructed in analogue or digital technology. The modular interface provides electrical and mechanical connection of modules. Multi-pin signal connector enables transmission of measurement and control signals. Simple binary code and data in the EEPROM memory of the sensor module allow automatic recognition of the attached sensor module by the communication module.

Measuring devices using for monitoring noise in work environment should enable the determination of the quantities characterising noise in the work environment or at least to determine whether admissible values have been exceeded. The output quantities from the noise measuring devices are the RMS value of A-weighted sound pressure, as well as the information on exceeding admissible value of the C-weighted peak sound pressure level. On the basis of the RMS value of A-weighted sound pressure, the daily noise exposure and A-weighted maximum sound pressure level values are determined by calculation in later phases of data processing.

Fig. 3 shows the noise measuring device consisting of the communication module and the digital noise sensor module. The digital sensor module is based on MP34DT05A digital MEMS microphone connected to the STM32 microcontroller. Fig. 4. shows the developed analogue noise sensor module. This module uses the 6 mm electret microphone ABM-713-RC. The design of the digital sensor module is much simpler, but the analogue circuit has less electricity consumption, which is of great importance in sensor networks. The correct calibration of the measurement devices will be of great importance for the correct operation of the system [7, 11].

Figure 3. The model of the noise measuring device consisting of communication module (white) and digital noise sensor module (yellow).

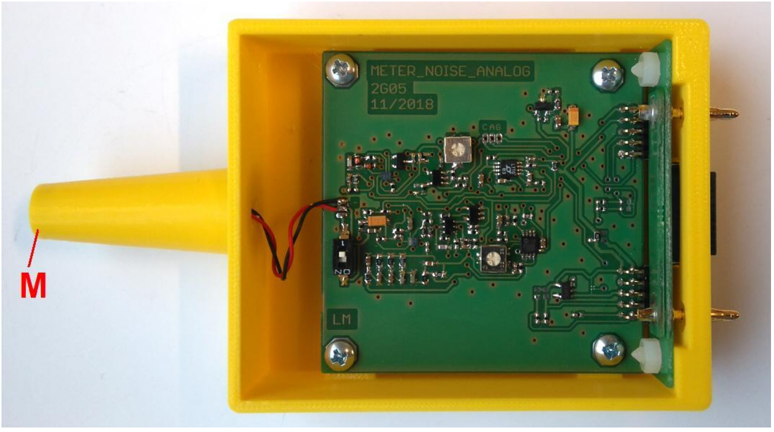

Figure 4. The model of the analogue noise sensor module.

Vibration measuring devices were developed in a similar way. Fig . 5 shows the vibration measuring device consisting of the communication module and the analogue vibration sensor module. This module has three measuring paths for each of the vibration directions. The MEMS accelerometer is placed in a separate housing, connected to the module by a cable.

Figure 5. The model of the vibration measuring device.

4. SUMMARY

Wireless sensor networks, including those using the Internet of Things, can be an excellent tool to monitor the work environment and warning employees about hazards. Such monitoring will enable immediate reaction to emerging new hazards or changes in the already existing intensity. Data on hazards present in the workplace, collected at many of its points and in longer periods of time, will also enable appropriate design of work processes or preventive activities, limiting the exposure of employees to harmful agents in the work environment. The system for monitoring and limiting worker exposure to harmful agents described in this article is one of the possible examples of such solutions. Further works planned as part of the system development include its tests in laboratory conditions and then in real conditions.

5. ACKNOWLEDGEMENTS

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