Application of The “Smart Manufacturing” System to Detect a Fire in an Industrial Premises

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Abstract: The article considers the issue of identifying patterns between the readings of various sensors to reduce the number of false alarms of the fire safety system in an industrial premises. The identified rules will be used in the “Smart Manufacturing” system being developed.

Keywords: “Smart Manufacturing” system, Internet of Things, IoT, Fire safety, Sensors, Mobile application.

1. INTRODUCTION

The Internet of Things (IoT) [1] is an integrated network to which many objects are connected through communication and information infrastructure. They exchange information with each other and work without human intervention in real time [2-3]. Based on IoT, new automated control systems are being created [4-5], including the “Smart Manufacturing” system being developed. This system allows to optimize the process of maintaining a production facility, ensuring improved labor organization and cost reduction. The industrial premises for which the system is being developed belongs to the moderate fire hazard category (G)[6], where the installation of fire safety systems is not required. Due to the specific nature of the work performed in such premises, the installation of smoke detectors and a conventional fire system is not optimal: a high number of false alarm triggers and a significant number of failures of its components. However, the statistics of fires in industrial premises is high, so the fire safety system is an important and valuable component of the “Smart Manufacturing” system.

To reduce the number of false fire alarms in production (in particular, with welding work), our own fire safety system is being developed. To achieve this goal, it is necessary to solve the following tasks: select a set of sensors; conduct research in which to recreate various situations in production and analyze them; identify patterns between sensor readings for future use in the system to improve the accuracy of determining the start of a fire and reduce the number of fire alarm errors in industrial premises.

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2. SELECTING A SET OF SENSORS

There are three types of smoke detectors: optical-electronic, aspirating and ionization. The operating principle of optical sensors is based on the use of an optical system: an LED (transmitter), which emits an infrared beam of light, and a photodiode (receiver), which converts the light from the LED into an electrical signal. Optical smoke detectors are designed for use in residential and office buildings, as they are very sensitive not only to smoke, but also to dust and insects, which often cause false alarms. Ionization smoke detectors are rarely used because they contain radioactive elements that can be harmful to human health. Aspirating smoke detectors are much more expensive than all other types of sensors, which is why they are used mainly at large government facilities where a high level of fire safety is critical [7]. In this way, all available types of smoke detectors are not suitable for use in the existing production facility, since welding work is regularly carried out in it, and a large amount of production dust is also generated.

To conduct research, a linear smoke sensor IPDL-D-II/4P [8] was chosen as the most cost-effective and harmless option for human health, and a set of additional sensors: temperature and humidity sensor HTU31DI2 [9], luminosity sensor based on photoresistor GL5516 [10], Keyes KY-038 sound sensor [11], MQ7 carbon monoxide sensor [12]. This choice of sensors is due to the assumption of dependencies between changes in their readings when a fire occurs, which is proposed to be confirmed in the article.

3. DESCRIPTION OF THE “SMART MANUFACTURING” SYSTEM

The layout of the industrial premises and the location of all the IoT sensors [13-15] necessary for the research are presented in Figure **1**.

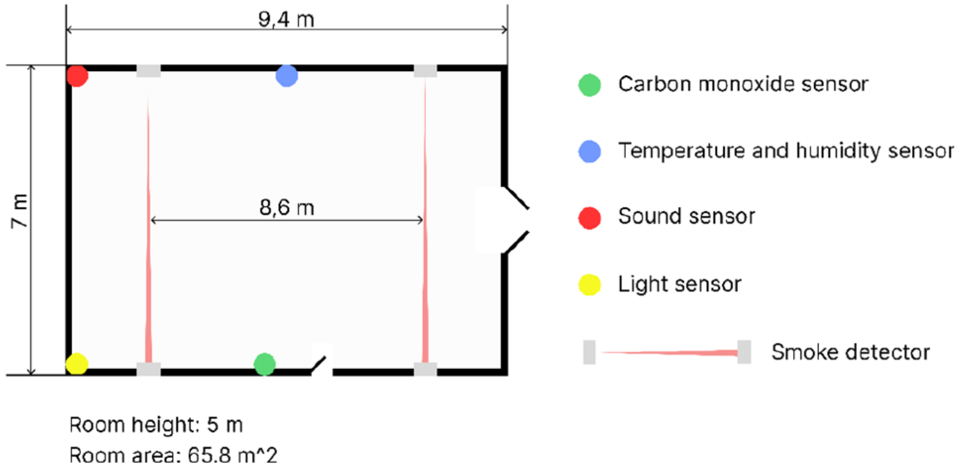

Figure 1: Sensor layout diagram.

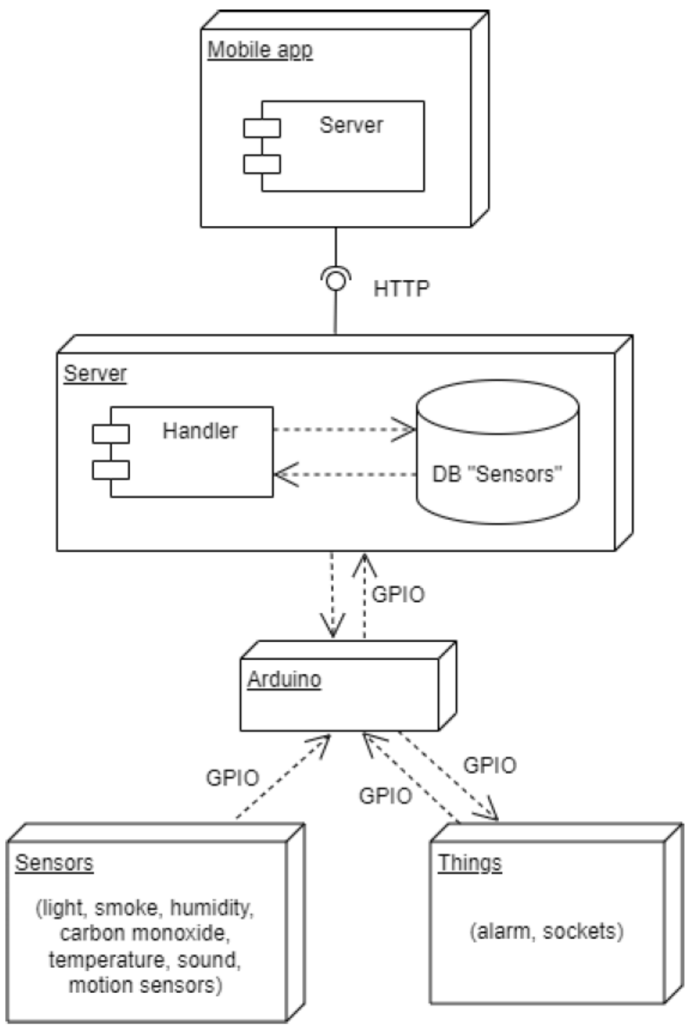

Figure 2: Diagram of components of the "Smart Manufacturing" system.

In the "Smart Manufacturing" system [16], all information about sensors is stored and recorded in the "Sensors" database (DB). Based on this data, a mobile application for the Android operating system constructs graphs of sensor values versus time. A diagram of the system components is shown in Figure **2**.

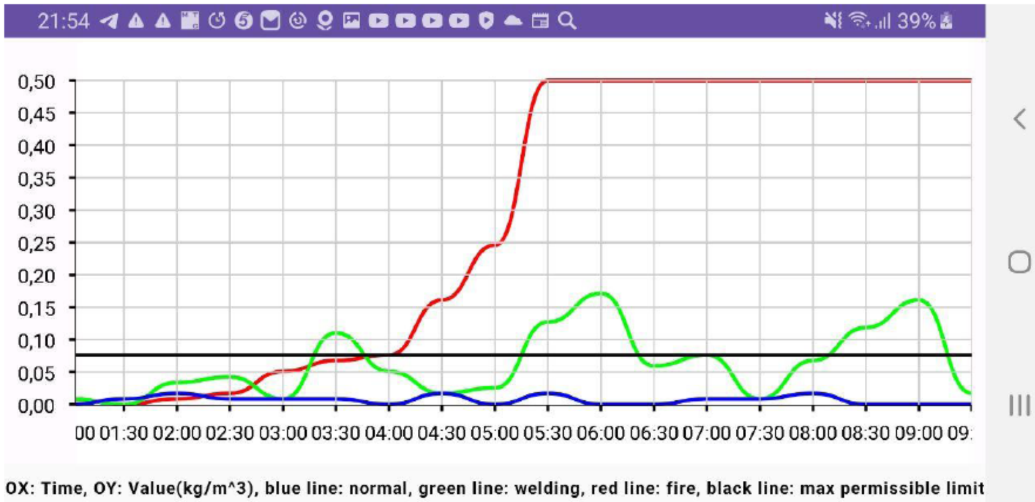

Figure 3: Graph of changes in average readings of smoke sensors under various conditions.

4. CONDUCTING THE EXPERIMENT AND ANALYZING THE RESULTS

At the research stage, measurements were taken of data obtained from sensors in the production room under three different conditions: normal, welding, and simulated fire. During each experiment, the system measured sensor data for ten minutes and recorded it in the DB, then graphs were built in the mobile application based on this data. A time period of ten minutes was chosen based on the duration of the first phase of the fire, when the ignition turns into a fire and the spread zone grows [17]. It is important to configure the system so that it can detect a fire as early as possible, which will ensure a high level of personnel safety.

Figure **3** shows a graph of changes in the average readings of smoke sensors in three different situations. From Figure **3** it can be seen that under normal conditions the sensor readings are within normal limits; during welding operations, fluctuations appear, due to which the values periodically exceed the norm; during a fire, the values first gradually increase, and after four minutes from the start of the fire, they grow exponentially to the maximum.

Changes in the carbon monoxide sensor data are shown in Figure **4**. From the graph we can conclude that during a fire, 4 minutes after the start, the density of carbon monoxide in the air sharply increases to values dangerous for humans, and during welding and under normal conditions it varies by within acceptable values.

Figure 4: Graph of changes in carbon monoxide sensor readings under various conditions.

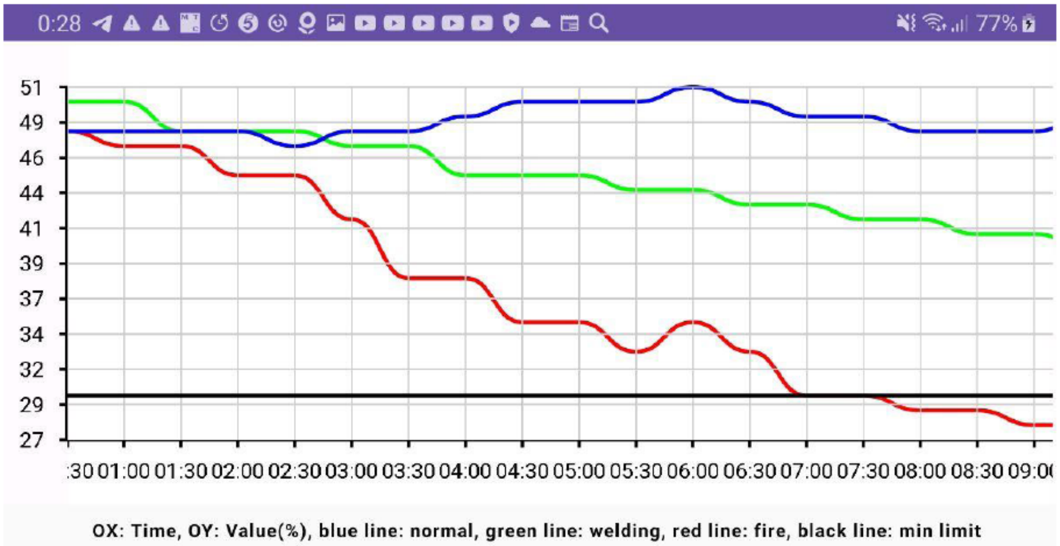

Figure 5: Graph of changes in humidity sensor readings under different conditions.

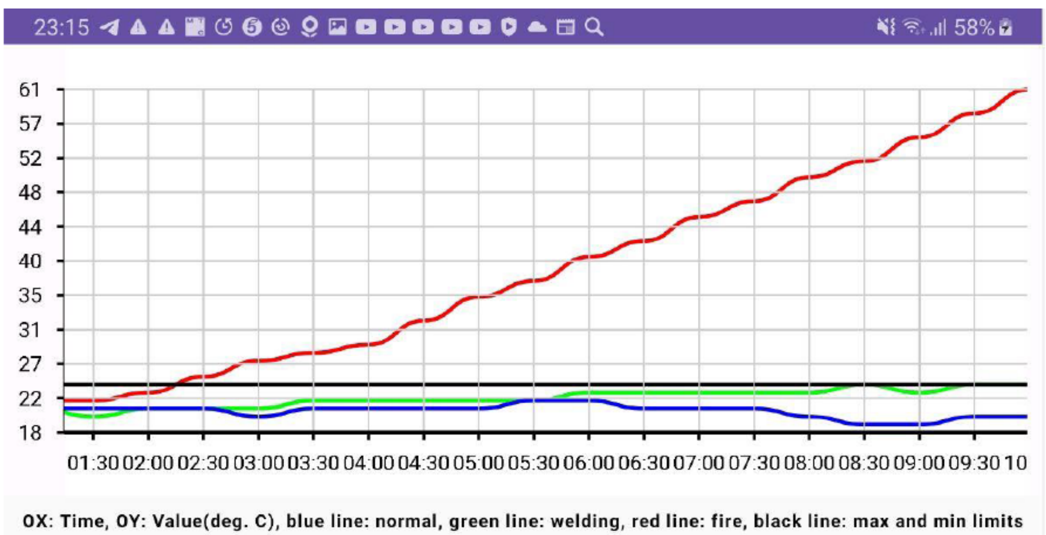

Figure 6: Graph of changes in temperature sensor readings under various conditions.

From Figures **5** and **6** you can see that temperature readings increase by an average of 5 degrees per minute, while air humidity readings drop by an average of 2% per minute during a fire [18-19]. During welding work, the dependence of humidity remains inversely proportional to temperature, but the slope of the graphs is less: humidity changes by about 1% per minute, and temperature by 4 degrees during the entire observation period. Under normal conditions, humidity and temperature values do not change significantly.

Figures **7** and **8** show graphs of changes in the values of illumination and sound. During welding operations, the functions of the observed quantities reach an extremum at the same points in time. When a fire occurs [20-22], the sound volume increases throughout the time under consideration, and the illumination values first increase, and then fall and stabilize at approximately 80 lux.

After analyzing all the graphs, the following patterns can be noted. When carrying out welding work, the smoke sensor detects minor deviations from the norm (values do not exceed 0.2 ppm), the values of carbon monoxide density and air temperature gradually increase. The humidity value changes with an inverse linear dependence on temperature. When a fire occurs in a room [23-24], it is characterized by a rapid

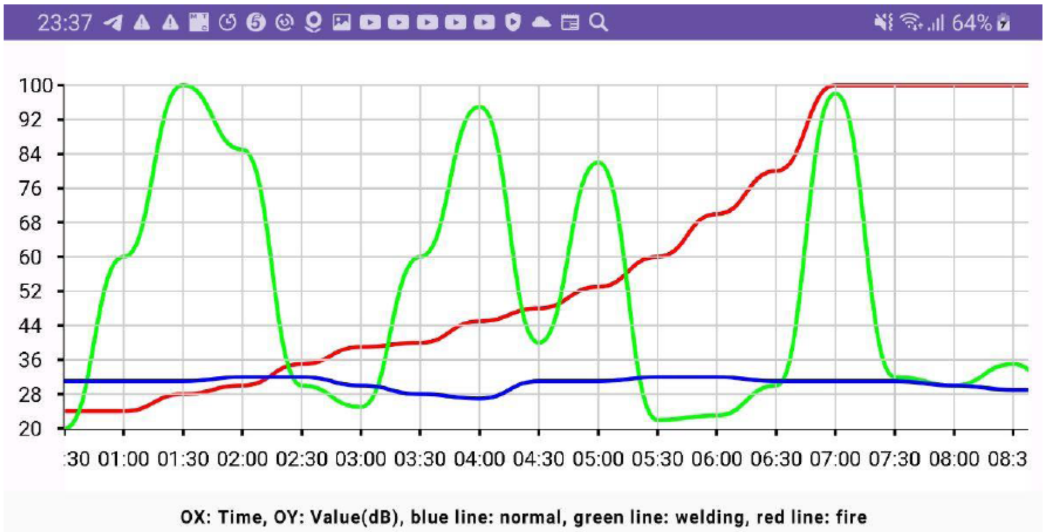

Figure 7: Graph of changes in sound sensor readings under different conditions.

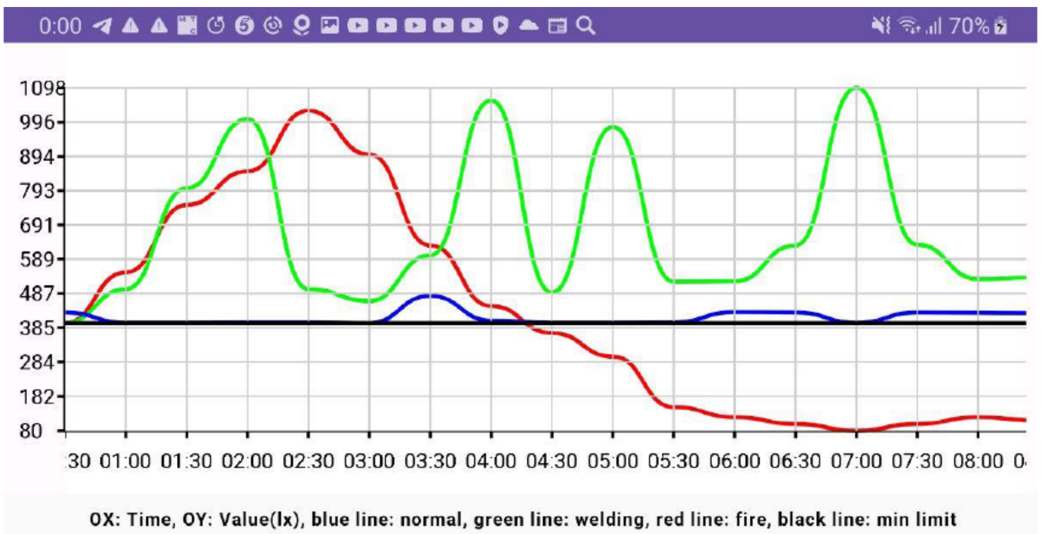

Figure 8: Graph of changes in light sensor readings under various conditions.

increase in temperature (on average, its value changes by 5 degrees per minute), smoke density, carbon monoxide, and sound; gradual decrease in air humidity; increase and then decrease in illumination.

5. CONCLUSION

In the experiment carried out under normal conditions, all sensor indicators fluctuated slightly within normal limits. During welding work, the values of sound and light simultaneously changed, the air temperature gradually increased and the humidity decreased. During a fire, the temperature quickly increased and air humidity decreased. 4 minutes after the start of the fire, the smoke density values began to increase sharply, along with them the density of carbon monoxide in the air increased and the previously increasing illumination values dropped. The sound volume gradually increased throughout the observation.

Therefore, the following rules can be formulated. The abrupt nature of changes in the values of light and sound, as well as a smooth increase in temperature and a drop in air humidity are characteristic of welding work. A rapid increase in temperature, and after a few minutes a sharp simultaneous change in the density of smoke and carbon monoxide to values dangerous for human life, as well as a steep drop in illumination, are characteristic of a fire. Using these guidelines will allow us to develop an accurate and reliable fire safety system for production.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest

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