Oxygen Sensor Module with Majority Sensing for Monitoring Wide Area at Disaster

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***Abstract*—This work presents a new sensor module with majority sensing which improve an accuracy by multiple sensor devices. The sensor modules are distributed over disaster region for monitoring environmental information such as a temperature of the surface and oxygen concentration. Each sensor module is connected by a wireless network and transmits the information to a monitoring server. In this work, we focus on sensing oxygen concentration in case of forest fire. To improve an accuracy of the sensing value, we introduce a new sensing mechanism called majority sensing with multiple sensor devices. In experiments, we demonstrate 8.4-14% improvement for the oxygen concentration sensing.**

I. INTRODUCTION

In recent years, a sensor network is used in various places and cases such as crime prevention and disaster prevention. In this work, we tackle to develop a sensor network for monitoring environmental information in case of forest fire. Unlike a house or building fire, a forest fire affects to a wide region. Therefore, it is important to collect information at various locations in real-time. Plus, many sensor modules are scattered over fire field. Thus, the module must be small, low cost, and low-power.

This work focuses on sensing oxygen concentration which is the most important information for life living.

Unlike an expensive measurement instrument for oxygen concentration, we use a low cost oxidation exothermic agent and measure it by a temperature sensor to calculate oxygen concentration. However, the measurement method by the oxidation exothermic agent is not so accurate, because the accuracy depends on the material variability.

In this work, we propose a new sensing mechanism called majority sensing. In the mechanism, one sensor modules has three or more than sensor devices, that is, three or more sets of temperature sensor and oxidation exothermic agent. By calculating the majority among sensing results, we determine the sensing value in a reasonable way. In experiments, we demonstrate more than 10% improvement for the oxygen concentration sensing.

Furthermore, we develop a sensor module along with a visible light communication function by LED and a wireless networking function based on ZigBee.

II. SENSOR NETWORK

We depict an image or our sensor network used in forest fire in Fig 1. The environmental information collected by the sensor network is transferred to database, analized by “big data technology”, and translated as the fire-fighting tactics.

Plus, Fig. 2 illustrates an overview of our proposed sensor network system. A set of sensor modules is distributed over the fire field. Each module has a function to organize a wireless network and it can connect to a monitoring server. In addition, the module has LEDs of multiple colors, and it can notify the oxygen concentration level to the sky where a helicopter is recording the picture of the field. The LED map information is used for identifying the sensor module location. We have an idea for this identification, but we would like to introduce it in the next work.

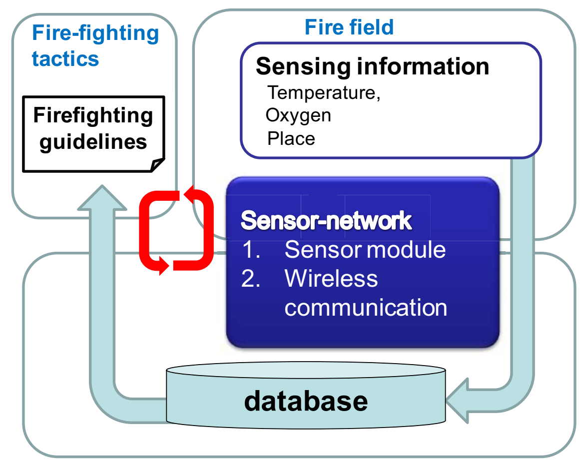

Fig. 1. Sensor network for monitoring disaster region.

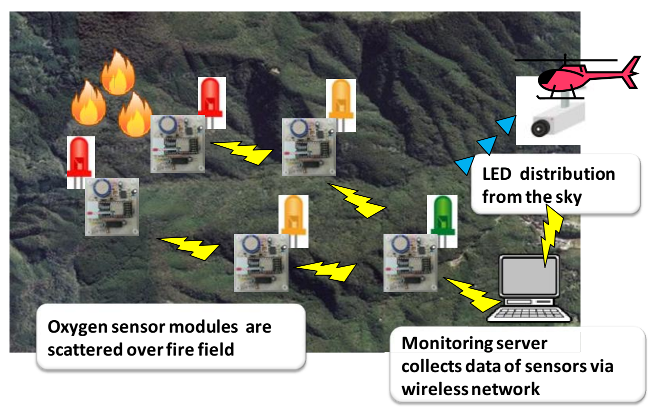

Fig. 2. Functional overview of our sensor network system.

III. OXYGEN SENSOR MODULE

In this work, we use the oxidation exothermic agent to measure the oxygen concentration. As shown in Fig. 3, we make use of heat of the oxidation reaction. We make a model among the heat, reaction time and the oxygen concentration in the prior experiments. Then, we convert the heat to the oxygen concentration according to the model.

Fig. 4 and Fig. 5 show an architecture of our sensor module and its prototype. Each function of the sensor module is controlled by a micro-controlloer which has a function to organize a tree-type or mesh-type network based on ZigBee. The size of the prototype is 4cm x 5cm, but we are challenging of downsizing the module up to a coin.

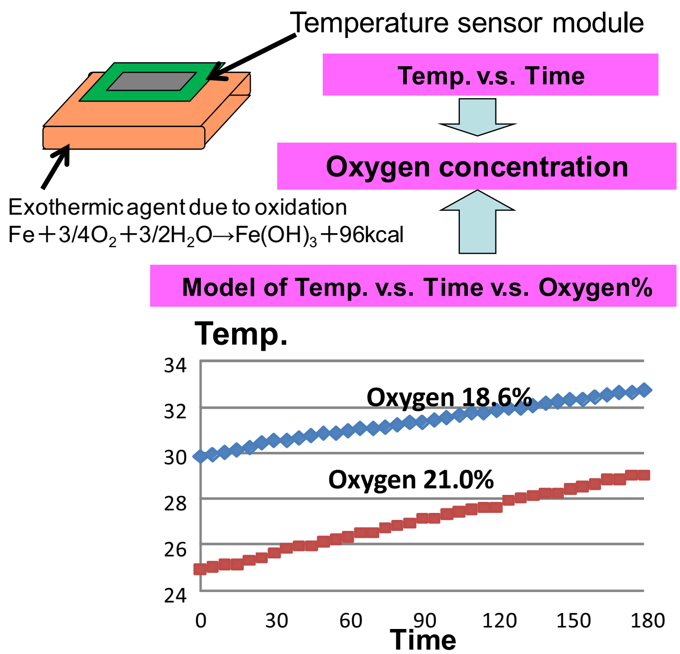

Fig. 3. Oxygen concentration measurement by oxidation exothermic agent

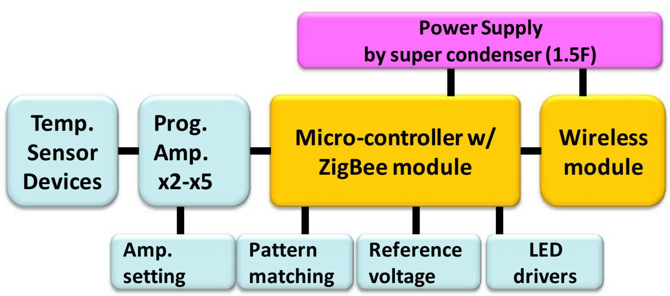

Fig. 4. Architecture of sensor module


Fig. 5. A prototype of sensor module

By using the prototype, we experiment to measure the oxgen concentration. In practice, we must distinguish 18% and 21% oxygen , because a human cannot act safely in the air of less than 18% oxygen. However, it is difficult to distinguish 18% and 21% oxygen by one sensor device as long as we use the oxidation exothermic agent.

Then, we introduce the majority sensing as shown in Fig. 6.In this sensing, we employ three or more sensor devices. Dividing the results into two patterns (X or Y in the figure) by a certain threshold, we determine the sensing value according to the number of patterns.

In the experiment, we obtained the results as shown in Fig. 7. The experiment includes 10 measurements. With respect to 21% and 18% oxygen sensing results, the number of measurements exceeding 75mV (the output voltage of temperature sensor) are 7 and 2, respectively. This means one sensor device provides 0.7 and 0.8 reliability for 21% and 18% oxygen if we use 75mV as the threshold to distinguish the 21% and 18% oxygen. The majority sensing can improve the accuracy of the sensing if we introduce (a) 3 sensor devices or (b) 5 sensor devices as follows;

(a) case for Oxygen21%

3 dev: ${}_3C_2*0.7^2*0.3+{}_3C_3*0.7^3=0.784$

5 dev: ${}_5C_3*0.7^3*0.3^2+{}_5C_4*0.7^4*0.3+{}_5C_5*0.7^5=0.83692$

(b) case of Oxygen 18%

3 dev: ${}_3C_2*0.8^2*0.2+{}_3C_3*0.8^3=0.848$

5 dev: ${}_5C_3*0.8^3*0.2^2+{}_5C_4*0.8^4*0.2+{}_5C_5*0.8^5=0.94208$

Hence, the majority sensing can improve the reliability by 8.4%-14%.

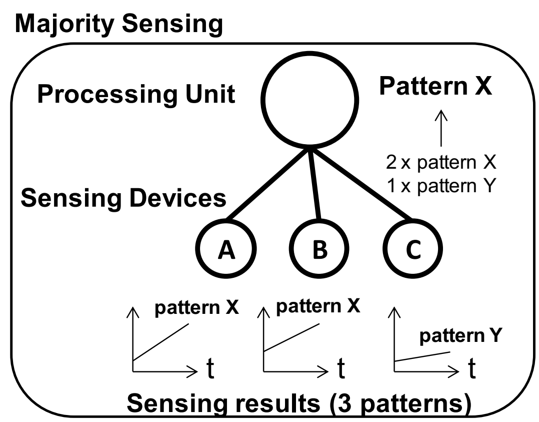

Fig. 6. Majority sensing with three sensor devices

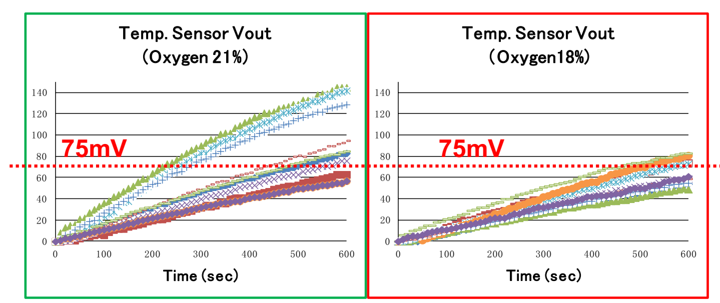

Fig. 7. Measurements of 18% and 21 % oxygen

IV. Conclusion

In a sensor network for monitoring forest fire field, we focus on sensing oxygen concentration, and develop sensor module with a new sensing mechanism, majority sensing. In the experiments by using the prototype, we demonstrated more than 14% improvement for the oxygen concentration sensing.