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# An Intelligent Fire Detection Algorithm for Fire Detector

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**Abstract :** This paper presents a study on the analysis for reducing the number of false alarms in fire detection system. In order to intelligent algorithm fuzzy logic is adopted in developing fire detection system to reduce false alarm. The intelligent fire detection algorithm compared and analyzed the fire and non-fire signatures measured in circuits simulating flame fire and smoldering fire. The algorithm has input variables obtained by fire experiment with K-type thermocouple and optical smoke sensor. Also triangular membership function is used for inference rules. And the antecedent part of inference rules consists of temperature and smoke density, and the consequent part consists of fire probability. A fire-experiment is conducted with paper, plastic, and n-heptane to simulate actual fire situation. The results show that the intelligent fire detection algorithm suggested in this study can more effectively discriminate signatures between fire and similar fire.

**Key words :** fire detection, intelligent algorithm, fire detector

## 1. Introduction

Fire detection system has to alarm fire very precisely even though its detection environments change. But it often makes false alarm under similar fire condition commonly encountered such as tobacco smoke, steam, heat produced by cooking and so on. So it has become a matter of public safety when misdiagnosed alarms cause us to miss real fires by switching off fire detection system. The fire detection system often makes false alarm because it alarms at the pre-assigned value of temperature and smoke density produced from actual fire. A number of methods have been devised to reduce the probability of false alarms in such system [1-3]. However, reducing the number of false alarms is still a major challenge in developing a fire detection system.

This study presents the analysis for reducing the number of false alarms in fire detection system. To overcome above-mentioned shortcomings of fire detection system a new type fire detection algorithm is suggested in this study. Fuzzy logic is adopted in developing intelligent fire detection algorithm to reduce false alarm. It is analyzed with experiment of simulating fire to calculate fire probability. The intelligent fire detection algorithm suggested here diagnoses fire by fuzzy logic with comparison of the input signal from temperature sensor and smoke sensor.

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## 2. Intelligent Algorithm

Fuzzy logic fits best in applications where the variables are continuous and/or mathematical models are difficult to define or they do not exist [4]. Fuzzy logic has rapidly become one of the most successful technologies for developing sophisticated control systems and decision support expert systems. Generally, fuzzy logic system consists of three steps. The first step is fuzzification that consists of giving membership degree or membership function to the input values. The second step is defined inference rules of the form “if … then”. The last step is defuzzification transforming the output into a crisp result. Fig. 1 shows the processing procedure of such intelligent fire detection algorithm for fire detection.

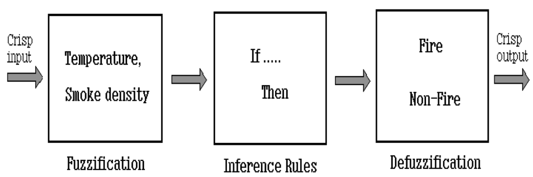


**Fig. 1.** Structure of Intelligent algorithm.

### 2.1 Input Variables and Fuzzification

Fuzzification is a mapping from the observed input to the fuzzy sets defined in the corresponding universes of discourse. It is the process of making a crisp quantity fuzzy. In this study, input variables for fuzzy logic algorithm are obtained by temperature and smoke density variations per sample time of temperature and smoke sensor, respectively. And fuzzy singleton is applied to input variables. So these signals are transformed into fuzzy singleton value.

### 2.2 Inference Rules and Method

Number of inference rules applied in this study are 25. The membership function are defined as VLOW, LOW, MED, HIGH, and VHIGH, corresponding to "very low", "low", "medium", "high", and "very high" linguistic terms, respectively. The types of rules used are constructed as follows:

**If** Temperature is low and Smoke density is low
**Then** Fire Probability is very low … etc.

| Smoke density \ Temperature | VLow | Low | Med | High | VHigh |
|---|---|---|---|---|---|
| VLow | VLow | VLow | Low | Med | Med |
| Low | VLow | Low | Low | Med | High |
| Med | Low | Low | Med | High | High |
| High | Low | Med | High | High | VHigh |
| VHigh | Med | Med | High | VHigh | VHigh |

**Fig. 2.** Inference rules base.

Triangular and trapezoidal shapes help simplify computations, therefore, are commonly used [5]. The triangular membership function is chosen for inference rules to simplify computation in this study. And inference method is applied to the Mamdani's implication method of inference [6].

In the Mamdani's method, fuzzy connective "And" corresponds to the "Min" of the fuzzy sets. For example, in the fuzzy rule

If $x_1$ is $A_1$ and $x_2$ is $A_2$ … $x_m$ is $A_m$ Then y is $B_1$

The membership function of the resulting Mamdani implication relation becomes

$$\mu_B(y) = \max[\min\{\mu_A(x_1) \wedge \mu_A(x_2) \ldots \wedge \mu_A(x_m)\}] \quad (1)$$

Fig. 3 and 4 show antecedent membership functions of temperature and smoke density, respectively. And Fig. 5 shows consequent membership functions.

### 2.3 Defuzzification

Defuzzification produces a crisp output value, using one of the three usual methods: center of area, max criteria, mean of maximum. The centroid [7] or center of area defuzzification method is used to compute the crisp output value in this study. In the centroid defuzzification, the crisp output value $\Re$ is the geometrical center

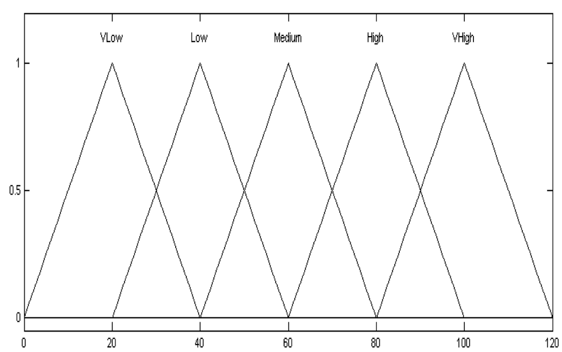


**Fig. 3.** Membership functions for temperature.

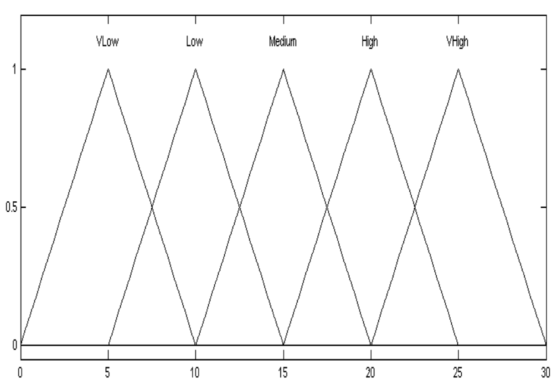


**Fig. 4.** Membership functions for smoke density.

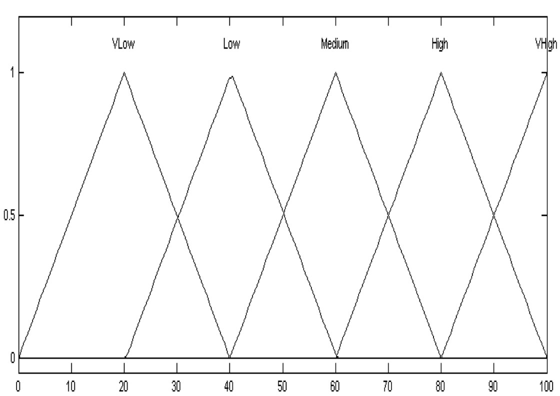


**Fig. 5.** Output fire probability membership functions.

of the output fuzzy value $\mu_{out}(d)$, where $\mu_{out}(d)$ is formed by taking the union of all the contributions of rules. The centroidof the aggregated output $\Re$ is defined as

$$\Re = \frac{\sum_{i=1}^{N} d_i^* \mu_{out}(d_i)}{\sum_{i=1}^{N} \mu_{out}(d_i)} \tag{2}$$

## 3. Simulation

A fire-experiment of small-scale is conducted to test that the fire detection algorithm suggested here effectively diagnoses whether fire or not. The experiment is conducted with combustibles to simulate fir and similar fire situation. Paper 500 g and 1,000 g are burned to simulate flame fire. And plastic 500 g is burned to simulate similar fir such as cigarette smoke, steam, and smoke produced by cooking and so on. Also, plastic 1,000 g is burned to simulate smoldering fire. N-heptane 300 mL and 500 mL are burned to simulate oil fire. The input variables for temperature and smoke density are obtained by temperature and smoke sensor. A smoke sensor of through-beam type photo sensor that is able to measure smoke opacity. And a temperature sensor of type K thermocouple is used. Fig. 6 shows schematic of experimental apparatus. The volume of combustion chamber is 2 cubic meter.

## 4. Results and Analysis

Results of flame fire simulated show figs. 7, 8, and 9. Figs. 7 and 8 is plotted with values of temperature and smoke density measured by temperature sensor and smoke density. The figures show temperature and smoke density for paper. In case of flame fire, it is measured relatively high temperature as shown in figure. The fire probability using these values is calculated by inference system in personal computer.

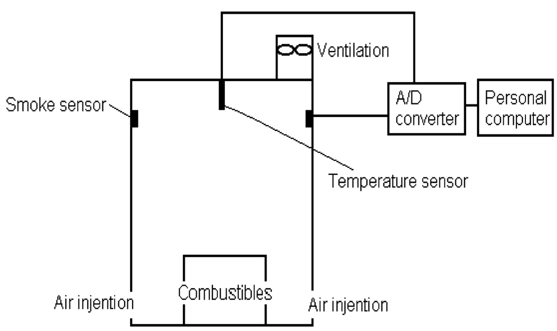


**Fig. 6.** Schematic of experimental setup.

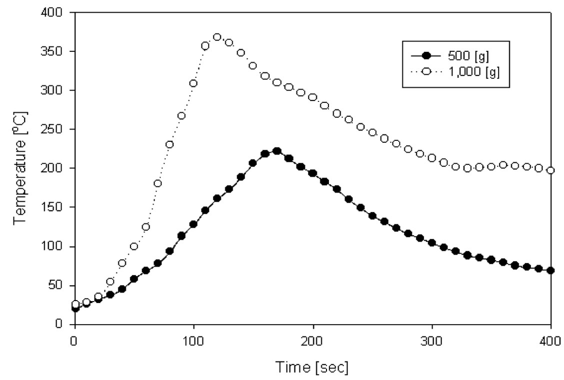


**Fig. 7.** Temperature vs. time for paper.

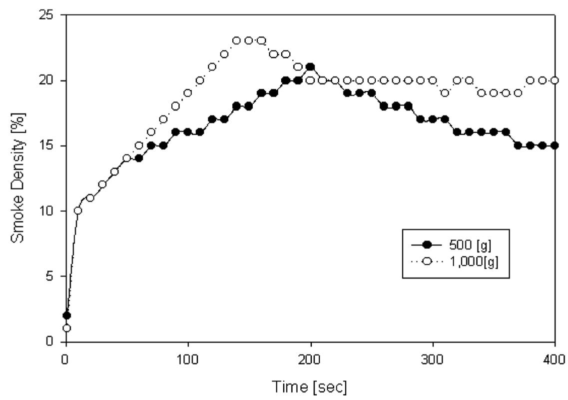


**Fig. 8.** Smoke density vs. time for paper.

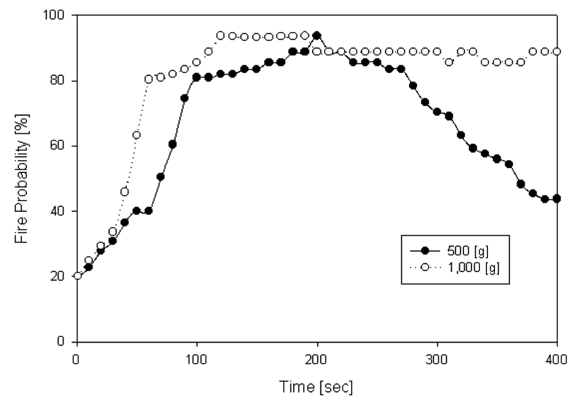


**Fig. 9.** Fire probability vs. time for paper.

Fig. 9 shows fire probability according to time in case of paper. The maximum of crisp output values that are fire probabilities using the fuzzy logic are calculated about 93.2% and 93.7% for paper 500 g and 1,000 g, respectively. Therefore, these values are interpreted as

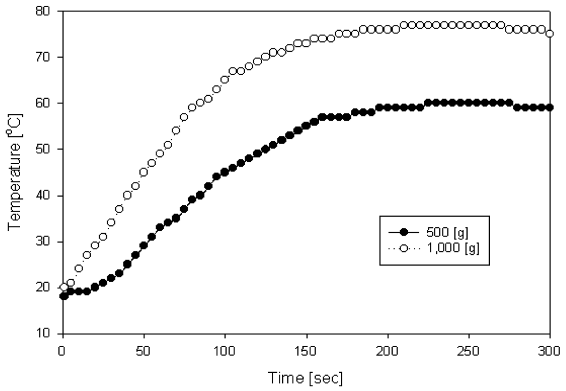


**Fig. 10.** Temperature vs. time for plastics.

more than 90% chance of a fire. If paper is burned in real fire environment, the flames spread to neighborhood. Then fire originates the place in which combustion of paper is produced. These experimental results concluded that fire detection algorithm presented here are able to diagnose fire very precisely.

Figs. 10 and 11 show temperature and smoke density for smoldering fire simulated by plastic. Contrary to flame fire, it is reported with high smoke density. The fire probability of 69.1% and 80.0% for 500 g and 1,000 g is calculated as shown in figure 12. Even though fire probability of plastic 500 g is lower than that of paper fire, as result of simulating similar fire condition it is high value.

However, it should be noticed that plastic fire slightly produces heat. Hence, fire probability may be calculated lower value for false alarm condition such as cigarette smoke, heat and smoke produced by cooking and so on. The calculated value of 69.1% is proper fire probability in this place. So fire probability of plastic 1,000 g is higher than that of 500 g.

Figs. 13 and 14 show temperature and smoke density

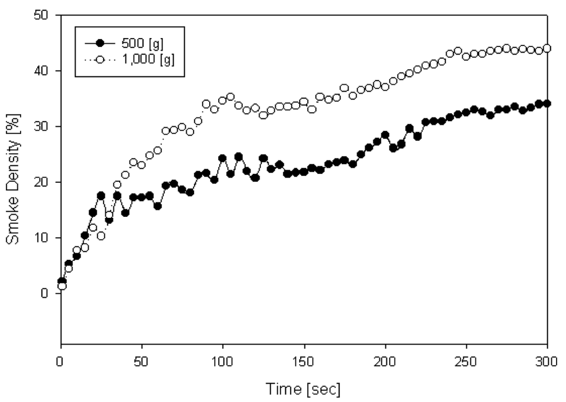


**Fig. 11.** Smoke density vs. time for plastics.

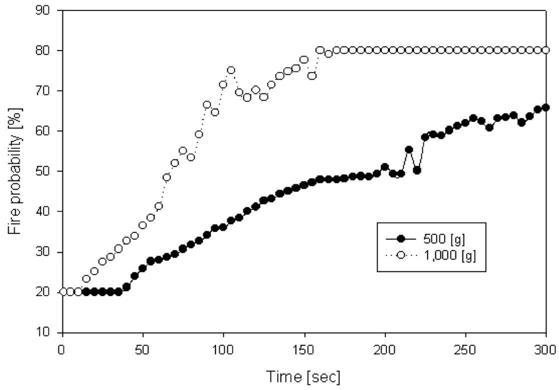


**Fig. 12.** Fire probability vs. time for plastics.

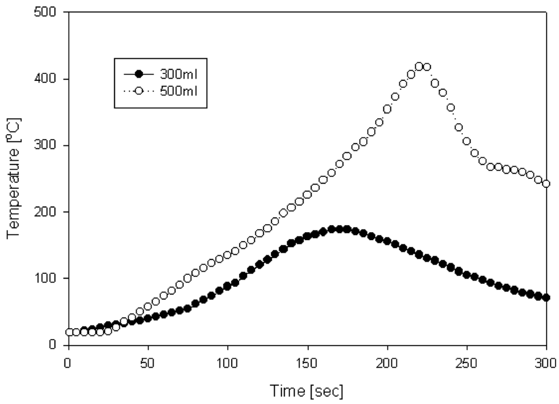


**Fig. 13.** Temperature vs. time for n-heptane.

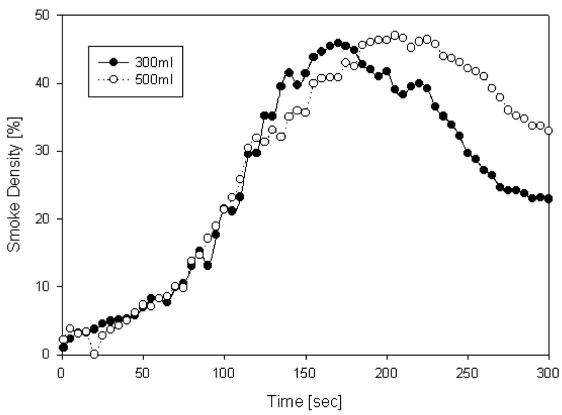


**Fig. 14.** Smoke density vs. time for n-heptane.

for smoldering fire simulated by n-heptane. As shown fig. 15 fire probability of n-heptane is calculated to 93.5% and 93.7% for 300 mL and 500 mL.

## 5. Conclusion and Further Research

In this study, intelligent fire detection algorithm with

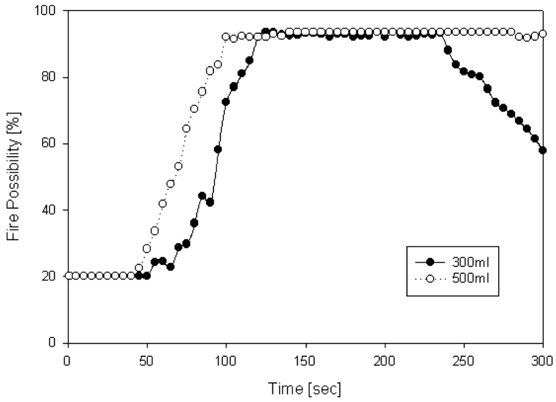


**Fig. 15.** Fire probability for n-heptane.

input variables by temperature and smoke sensor was suggested and studied. The Mamdani implication method of inference was applied to the fuzzy logic for fire detection. To verify fire detection algorithm small-scale, experiment was conducted for paper, plastic and n-heptane fire. It was shown that fire probabilities were 93.2% and 93.7% in case of paper fire, 69.1% and 88.1% in case of plastic fire, and 93.5% and 93.7% in case of n-heptane. These values mean that the algorithm suggested detects the fire situation very precisely. The algorithm presented here can be applied to reduce false alarm in harsh detection environment.

However, it is necessary to research fire detection algorithm applying with other algorithm and more fuzzy rules in combustion chamber simulating real fire of domestic premises. Also the experiments will be conducted with more various combustibles in the future studies.

## Refearence


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