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DETECTING THE PEOPLE ATTENTION FOR EXHIBITS IN EXHIBITION USING FUZZY METHOD

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Abstract. *There are many exhibitions in daily life. The exhibition staff usually hope to know the popularity degree of each exhibit to display exhibits suitable. However, the information is difficult to gain. In this paper, we try to combine fuzzy method and the IoT (Internet of Things) technology to design and implement an application system which can serve for the exhibitions to evaluate the popularity degree of each exhibit. We have implemented a system to understand how many people are attentive to the exhibits in an exhibition. The system can help the exhibition staff display exhibits more reasonably.*
Keywords: IoT, Shiny, Fuzzy method

1. **Introduction.** The era of mobile Internet and intelligent terminals has changed the traditional exhibition design. How to provide visitors with a better experience within the limited space of the exhibition hall is a problem considered by the exhibition staff [1-3]. The modern intelligence exhibition service platform is based on the mobile communication technology, the Internet technology, the Internet of things and the cloud platform technology, which can expand the exhibition space and greatly improve the quality of service for visitors. The exhibition staff are also needed to achieve some information such as the degree of the popularity of the exhibits to serve the visitors. How to evaluate the degree of demand is a problem, because no one has given the definition and the quantitative rule about the popularity degree of the exhibits. In our study, we try to provide the quantitative method, and we also design and implement a system which can detect the popularity degree of each exhibit using a fuzzy method.

In [1], authors proposed combination of virtual reality (VR) and augmented reality (AR) to effectively present museum exhibition to visitors. The drawback of this method is that visitor needs to bring gadget like cellphones whole time. In [2], authors proposed a module algorithm to recommend users how effectively to join the exhibition by clustering user preferences. The algorithm works by combining user preferences and ranking of user preferences. The problems are hard to collect user preferences and rank their choices. In [3], authors proposed a virtual device for exhibition platform for the museum. They also utilize AR and VR to present museum exhibition to visitors.

In this paper, we cite a painting exhibition as an example to introduce our system. The ultrasonic sensor is set before a painting, which aims to collect the valid data. The valid data includes the viewing distance, the visitor's residence time before this painting. And then the data is transmitted to the back-end system, where the data will be processed

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by the fuzzy method to count the popularity degree of this painting, and we call it the attention rate of each exhibit.

Different from another system, this system aims not to count the amount of visitor before each exhibit, it concerns the visitors' interest for the exhibits, and we describe the interest as the attention rate of each exhibit. We also develop a system convenient for the user.

We will introduce our system in the following parts of this paper in detail. Section 2 is the introduction of the system architecture. Section 3 is the fuzzy method, Section 4 is the experiment results. The last section is the conclusion and future work.

2. **The System Structure.** The system overall architecture is shown in Figure 1. The system mainly consists of three parts: data collecting part, data processed part, and data presentation part. The ultrasonic module is responsible for collecting data. The data is processed in Arduino development board. The user can see the final result on the website.

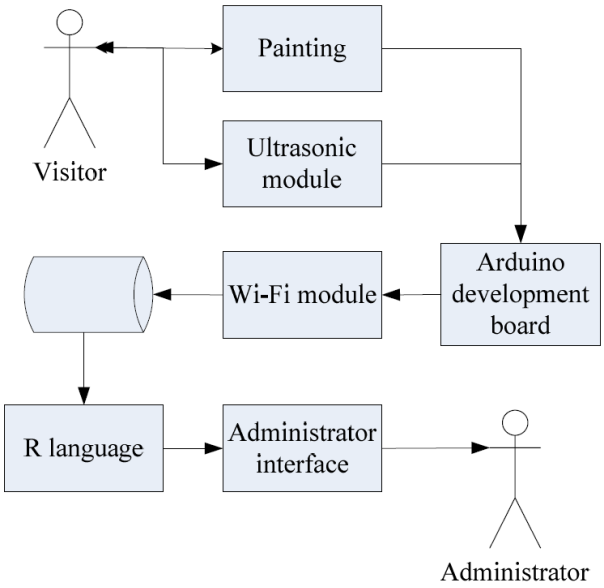

FIGURE 1. The system overall architecture

The hardware part includes Arduino development platform [4], ultrasonic sensors, Chip HC-SR04 and Wi-Fi sensor, Chip ESP8266-ESP01. Chip HC-SR04's measured distance between 2 and 400cm, and the effective angle is less than 15-degree angle. Its fade zone is 2cm [5]. The default distance is within the range of 110cm. So it can collect the data effectively. Chip ESP8266 has been widely used in different domains such as smart grid, smart transportation, smart furniture, handheld devices and industrial control [6]. In this system, Chip ESP8266 is in charge of transmitting data to the back-end system.

The ultrasonic sensor is placed in front of a painting, which detects the viewing distance and the residence time of a visitor. More than 7 seconds residence time is considered valid. The data is processed by a fuzzy method which is presented in a visual chart at the back-end system.

The website provides friendly interface to show the data to the user as shown in Figure 2. In the main page, the user can see the location of the exhibits, the introduction information for each exhibit, and the viewing rate of each exhibit.

We use RStudio as the development platform. A new team of RStudio develops shiny for data analysis [7,8]. Shiny is easy to use for the R language engineer who is unskilled for website design [9]. The engineer, who just needs to know R syntax, can complete website development in the shortest possible time [10].

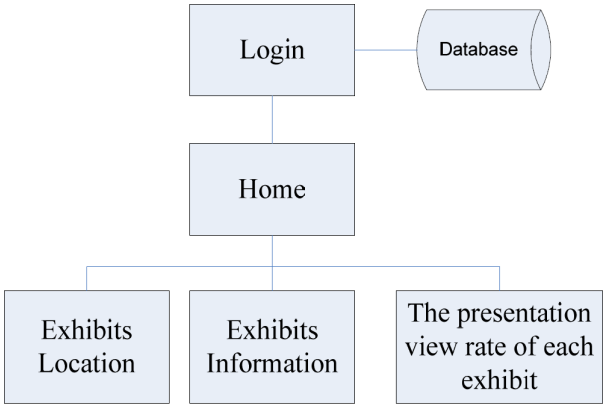

FIGURE 2. The website main page

3. **Fuzzy Method.** The term "fuzzy logic" was introduced in 1965 by L. A. Zadeh [11]. Fuzzy logic is a form of many-valued logic or probabilistic logic; fuzzy logic variables may have a truth value that ranges in degree between 0 and 1.

A type-1 fuzzy set denoted A is characterized by a type-1 membership function $\mu_A(X)$, where $x \in X$, and x is the domain of definition of the variable. If x is a continuum, we represent A as

$$A = \int_{x \in X} \mu_A(x)/x \tag{1}$$

If x is discrete, we replace the integral in Formula (1) by a summation. The type-1 membership function [12] maps each element of x to a membership grade between 0 and 1. A type-1 fuzzy inference system process is performed in three steps as shown in Figure 3:

1) Fuzzification of the input variables;
2) Inference based on the fuzzy rule;
3) Aggregation of the rule outputs, and finally defuzzifier.

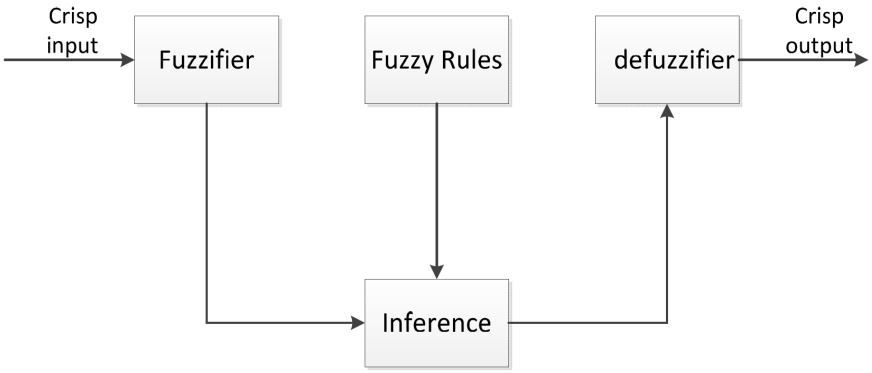

FIGURE 3. Fuzzy logic system

Fuzzification comprises the process of transforming crisp values into grades of membership or linguistic terms of fuzzy sets. The membership function is used to associate a grade with each scientific term.

The most commonly used fuzzy inference technique is the Mamdani method. In 1975, Professor Ebrahim Mamdani of London University built one of the first fuzzy systems to control a steam engine and boiler combination [13]. He applied a set of fuzzy rules supplied by experienced human operators. For the type-1 case, we generally have "IF-THEN" rules, and the jth rule has the form:

$$R^{(j)}: \quad \text{if } x_1 \text{ is } A_1^j \text{ and } \ldots \text{and } x_n \text{ is } A_n^j \text{ Then } y \text{ is } B^j$$

where x_is are input; A_i^js are antecedent sets ($i = 1, 2, \ldots, n$); y is the output and B^js are consequent sets.

The inference engine combines rules and gives a mapping from input type-1 fuzzy sets to output type-1 fuzzy sets. Multiple antecedents in rules are connected by the t-norm (corresponding to the intersection of sets).

$$\mu_{A_x}(X) = \mu_{x_1}(X_1) * \cdots * \mu_{x_p}(X_p) \tag{2}$$

The membership grades in the input sets are combined with those in the output sets using the up-star composition.

$$\mu_{B'}(y) = \sup_{x \in X} \left[\mu_{x_1}(X_1) * \cdots * \mu_{x_p}(X) * \mu^l_{A_1}(X_1) * \cdots * \mu^l_{A_2}(X_p)\right] * \mu^l_{G^1} \tag{3}$$

Multiple rules may be combined using the t-conorm operation (corresponding to the union of sets) or during defuzzification by weighted summation.

The output corresponding to each fired rule is a type-1 set in the output space. The de-fuzzifier combines the output sets corresponding to all the fired rules in some way to obtain a single output set and then finds a crisp number that is representative of this combined output set. Five commonly used de-fuzzifying methods include centroid of the area (COA), bisector of the area (BOA), mean of maximum (MOM), smallest of maximum (SOM), and largest of maximum (LOM), which are depicted in Figure 4.

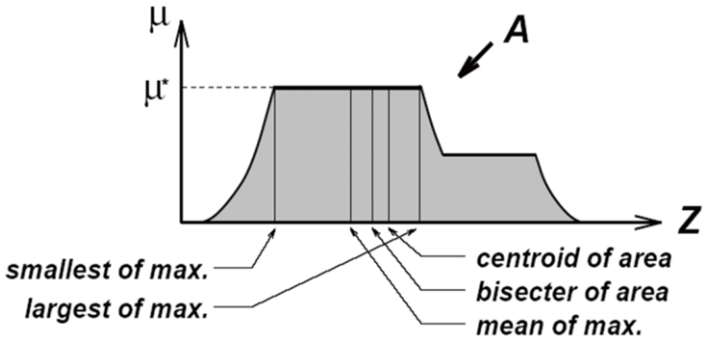

FIGURE 4. Defuzzifying methods

In our study, we need to define the degree of the visitor's favorite to the painting, which is fuzzy and inaccurate. A fuzzy method is used to reflect the counting visitors more accurately here. If the user likes the painting, the user will stand in front of the painting and enjoy it for a long time. So the degree of the visitor's favorite to the painting is highly relevant to the duration of standing before the painting and the viewing distance.

For the different size of the painting, the best viewing distance is different. We must consider the effect of the size of a painting to view. The picture is large, and the detection distance will increase; the art is moderate, and the detection distance will be the same; the picture is small, and the detection distance will be shortened.

According to the size of most of the paintings, we divide the size of the painting into three intervals as shown in the formula

$$\begin{cases} d_1, d_2 \to \{110, 150+\}, \text{ width (large)} \\ d_1, d_2 \to \{70, 110\}, \text{ width (middle)} \\ d_1, d_2 \to \{60-, 100\}, \text{ width (small)} \end{cases} \tag{4}$$

where $\{110, 150+\}$ indicates that the detected distance is a reasonable value, and if it exceeds this value, it means an unreasonable detection distance. So our system chooses the residence time, the viewing distance, and the size of the painting as three input parameters. We firstly give the membership functions of these three parameters. The

membership function of time and distance is shown in Figure 5 and Figure 6. The corresponding formula is shown in Formula (5) and Formula (6) respectively.

$$\text{time} \begin{cases} y = 0, & t < 0 \\ y = \dfrac{ty_1}{t_1}, & t < t_1 \\ y = 1, & t_1 \le t \le t_2 \\ y = \dfrac{(t - t_3)}{t_2 - t_3}, & t \ge t_2 \\ y = 0, & t > t_3 \end{cases} \tag{5}$$

$$\text{distance} \begin{cases} y = 0, & d < 0 \\ y = \dfrac{dy_1}{d_1}, & d < d_1 \\ y = 1, & d_1 \le d \le d_2 \\ y = \dfrac{(d - d_3)}{d_2 - d_3}, & d \ge d_2 \\ y = 0, & d > d_3 \end{cases} \tag{6}$$

The membership function of the size of the painting is shown in Figure 7.

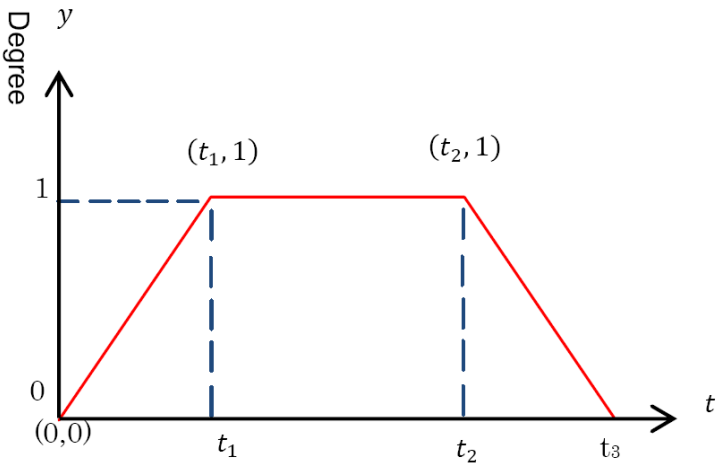

FIGURE 5. Time membership function

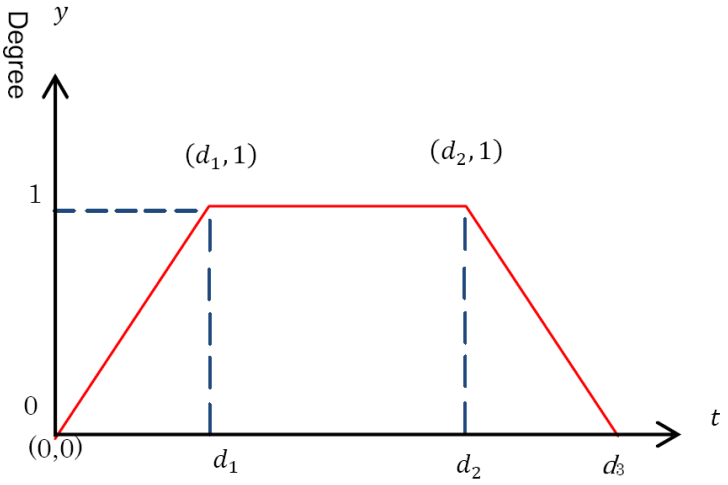

FIGURE 6. Distance membership functions

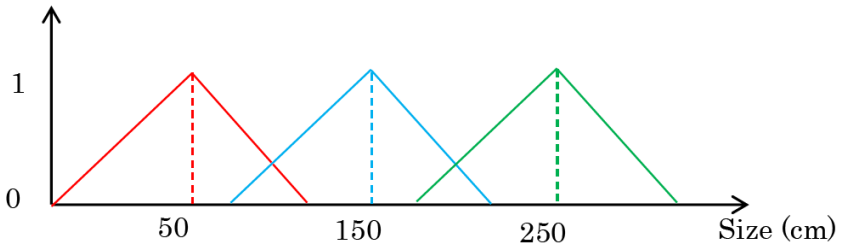

FIGURE 7. The membership function of the size of the painting

4. **Experimental Results.** The sensor is set before the exhibits. Every ten minutes a group of data will be sent to the back-end system. The user can directly see the processed data through the backend website. HTML, CSS, JavaScript, PHP, and R are used for website development. The pages include the main web page, the exhibits map page, data visualization page.

Figure 8 shows the location of each exhibit. The users can choose the data they want to view. We found that in several places, such as A1 has two clusters of high attention for each position is mapping in the figure. In this research, we extracted two concentration clusters for each section of location. The concentration clusters for each section are as shown in Figure 8.

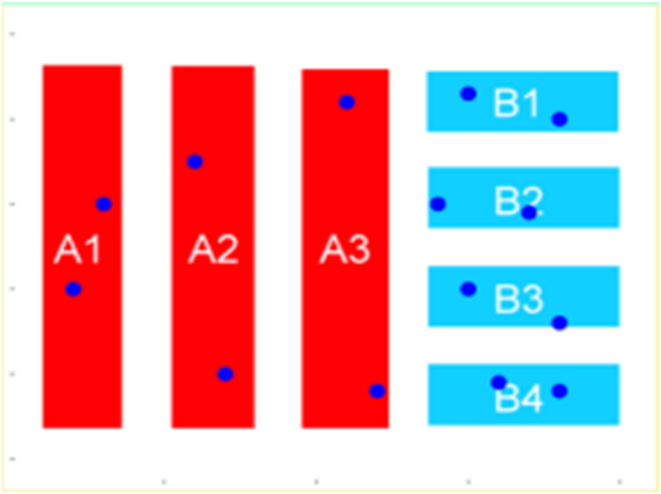

FIGURE 8. Exhibitor high attention's location

The website page shows the daily, weekly, monthly data according to the user's attention as shown in Figures 9(a)-9(d). The data is presented as a line chart or a bar chart, and so on. In Figure 9(a), we can find exhibition in week 40 to get high attention level from visitors compared with other exhibition. The average attention level for exhibitions is 0.5. We find that the trends in the exhibition are 3-5 days averagely. In Figures 9(b), 9(c), and 9(d), we can find the rush hour to view exhibits is from 9 am to 11 am.

5. **Conclusions and Future Works.** In this paper, we design a system which can detective view exhibits attention rate using a fuzzy method. It can be used not only for the exhibitions also on any trade show. Visitors use the system to record the degree of the concern for each exhibit. We found that exhibition's trends will likely increase 3 to 5 days after it started, and the busy time of the visitors within 9 to 11 am.

In the future, we will apply other parameters, such as national holidays, weekend, and peek days and hours to predicting the novelty of our proposed method.

(a) 50 weeks line chart

(b) Specific date bar chart

(c) Specific date dot chart

(d) The range of hours bar chart

FIGURE 9. Different data visualization, (a) 50 weeks line chart, (b) specific date bar chart, (c) specific date dot chart, (d) the range of hour's bar chart

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