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RECOMMENDATION SYSTEM FOR DAILY WATER INTAKE – BASED ON FUZZY SYSTEM

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Abstract. *Water is one of the most important constituents of our bodies. Our daily consumption of water of body needs to be properly supplemented in time to protect our health. Daily water consumption is related with several factors such as age, ambient temperature and degree of motion; these factors in actual discrimination are generally difficult to use the exact value to express. The main objective of this paper is to build a recommended daily water intake system using fuzzy methods. This system will use age, which is set to child, teenage, adult, old; and ambient temperature as the inputs; through constructing the corresponding rule base and fuzzy inference, the daily water intake will be treated as output. Through this reasoning mechanism of the fuzzy system, we can get the recommendation value of daily water intake. Finally, to compare with the actual recommended and the value of the recommendation system, we obtained relative satisfactory results to prove this recommendation system is effective in actual applications.*
Keywords: Recommendation system, Water intake, Fuzzy method, Fuzzy rules

1. **Introduction.** The human body is made up of many substances, of which the most important is water. It can be said that "Water is Life Source". Due to the activities of life, our bodies need to consume a large amount of water every day. At the same time, plus transpiration of the skin and sweat, the body must need to be supplemented enough water to protect our health. For an adult man, the water would account for 60% of his body weight; for adult women and elderly people, the water would account for 50% of their body weight [1]. The body's cells contain a lot of water, up to occupying two-thirds of the total weight. If the water of our body is lost but is not added, our health will be in danger. So, drinking enough and proper amount of water every day is essential for our health.

According to the recommendations from nutritionists that children and adults should supplement one and two liter water every day. This recommended value is first published by the Safe Drinking Water Committee of the National Academy of Sciences, and now appears routinely in guidance manuals published by the U.S. Environmental Protection Agency (EPA) [2]. However, the exact value of water for the human body needs is difficult to calculate and determine. The reason is obvious: water needs for our body associated with many factors. For example, with the increase of age, the water needs will change; temperature changes will lead to changes of the amount of sweat, and it also changes the needs for water supplement. Moreover, we are engaged in different work, it also will result in different daily water consumption, and the body needs will also change.

According to the above introduction, a daily drinking water recommendation system is extremely important for the guarantee of health. However, because it is difficult to measure the value of their uncertainty and there are so many factors involved, now fewer studies have focused on this topic.

The conventional methods require the explicit source data is crisp data [3] but the factors related to the amount of water are often difficult to describe with the exact values. For example, as one of the factors involved, age, we can only describe it with linguistic way, such as "middle-aged". Therefore, exact value cannot be provided. However, the traditional methods such as regression statistical method are unsuitable to complete this work. Compared with the traditional probability, statistical technique, the use of fuzzy method to solve similar problems is a good way because the fuzzy system does not require exact numeric data to recommend daily water intake [4].

The main purpose of this paper is to provide a daily recommendation system for water intake using fuzzy system. We construct a fuzzy modelling infrastructure based on vague data like age, temperature to deduce the amount water needs for human body. At the same time, we compare the fuzzy results with the recommendation value from nutritionists, and the value from our fuzzy system is satisfying.

2. Fuzzy Logic and Infrastructure.

In 1965, Zadeh, published his famous paper "Fuzzy sets" [5]. Zadeh extended the work on possibility theory into a formal system of mathematical logic, and introduced a new concept for applying natural language terms. This new logic for representing and manipulating fuzzy terms was called fuzzy logic. Fuzzy logic emphasized describing the different level of the things in real life, and it extended the range of truth values to all real numbers into the interval between 0 and 1. Unlike two-valued Boolean logic, fuzzy logic is multi-valued. It deals with degrees of membership and degree of truth. Fuzzy logic uses the continuous values between 0 and 1 to represent that things can be partly true and partly false.

The general fuzzy logic and infrastructure can be represented in Figure 1. Fuzzy logic can accept linguistic variables as input data. The input variables in a fuzzy system are in general mapped by sets of membership functions similar to this, known as "fuzzy sets". The process of converting a crisp input value to a fuzzy value is called "fuzzification" [6]. Inference engine is actually the processing stage that invokes each appropriate rule coming from rule base and knowledge base and generates a result for each, then combines the results of the rules. The system structure is showed in Figure 1 and the detailed explanation is as follows.

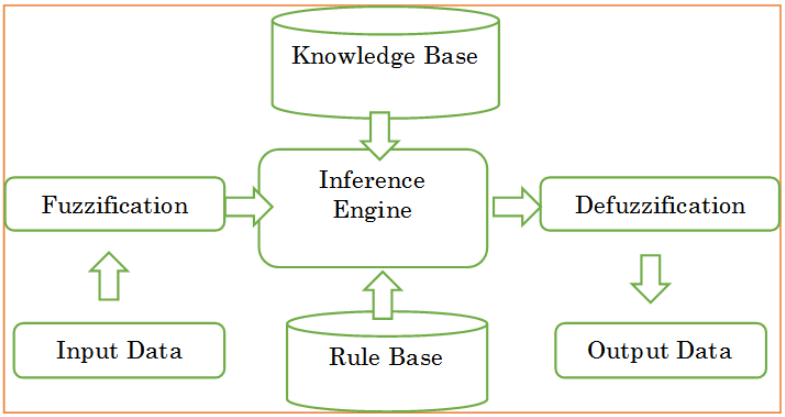


FIGURE 1. The infrastructure of the fuzzy system

(1) Fuzzification: this stage is to accept the input variables, maybe some linguistic words, and evaluate the degree to which fuzzy sets that these input variables should belong to.

(2) Knowledge base: fuzzy sets and membership functions stored in the knowledge base; it can be used as fuzzy rules to apply for input and output.

(3) Rules base: Stored in the rule base are fuzzy rules based on expert knowledge. The statement of [IF – THEN] is usually used to describe the fuzzy rules. If control system has multiple fuzzy variables, the [IF AND –THEN] statement is used to describe fuzzy rules [7].

For example: as to water intake recommendation, it can be described with the following statement:

R1: IF Age is Child and Temperature is Low THEN Water_Intake is low-low.

Here, R1 represents a rule, IF part is called [premise portion], and THEN part is called [inference result].

(4) Inference engine: Fuzzy reasoning is a process to find the fuzzy output through fuzzy logic operation, and followed the IF – THEN rules stored in rules base. There are many fuzzy reasoning methods, such as the max-min operation in Mamdani mode.

(5) Defuzzification: After the process of fuzzy reasoning, a fuzzy control value will be obtained, but it must go through the process of defuzzification to obtain a crisp output, and put it to the control system. There are many common defuzzification methods, such as the maximum home value method, the Centre of gravity method, and the weighted average method.

Mathematically the Centre of gravity (COG) [7] can be expressed as:

$$u^* = \frac{\int \mu_{B_i}(y)^* y dy}{\int \mu_{B_i}(y) dy} \tag{1}$$

3. **The Analysis of Fuzzy Logic and Infrastructure.** Several factors, like age, temperature and the level of body activity are directly proportional with the water consumption of our body. When the ambient temperature increases, we will lose much more water, so we need to supplement more water. Another factor, the age, with the different stage of our life, the water consumption of per weight of our body will vary. The relationship between age and water consumption is showed in Table 1.

For example, if we want calculate recommendation of water intake for a 14 years old teenage, assume his weight is 50kg, so we can get the recommended value maybe range from $50 * 50 = 2500$ ml to $80 * 50 = 4000$ ml. If we want give the exact value of water intake, we need think about other factors like temperature and level of body activity.

Ambient temperature is a remarkable factor that has great influence on the daily recommendation of water intake. Under normal temperature ($22 \sim 25°$), our body will consume $1500 \sim 2500$ ml water per day. However, when the temperature is higher, water losses

Table 1. Relationship between age and recommendation of water intake

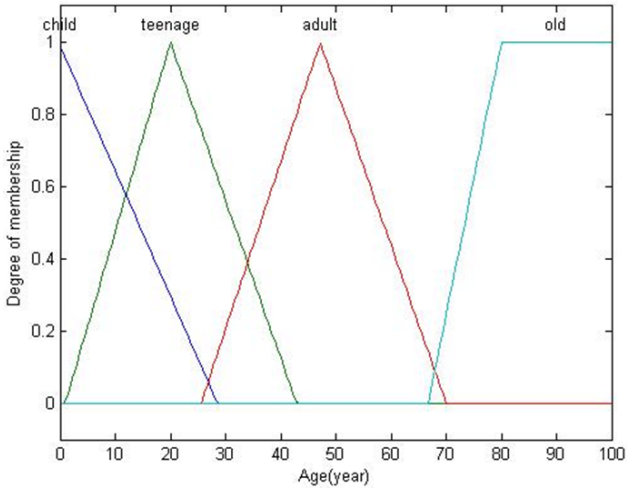
Age (year)	**Recommendation of water intake (ml/day)**
1 year infant	$120 \sim 160$ ml/kg
2 ∼ 3	$100 \sim 140$ ml/kg
4 ∼ 7	$90 \sim 100$ ml/kg
8 ∼ 9	$70 \sim 100$ ml/kg
10 ∼ 14	$50 \sim 80$ ml/kg
adult	40 ml/kg
Old people*	1500 ml/day

will increase. In the extremely hot environment, our body will lose 1.5 l/h water through the transpiration [10].

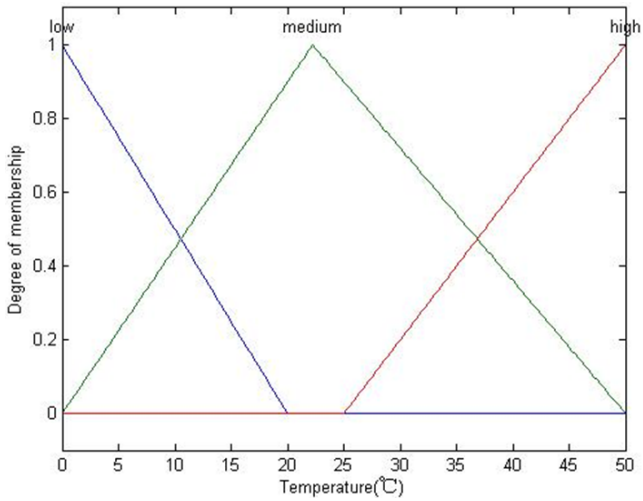
The degree of physical activity is another factor that will influence water consumption. However, it is hard to calculate and evaluate. The physical activity may be related to the jobs that we engaged in, and even under the condition of same job, it will vary with the different work content of every day. If we did exercise at the weekend, the water consumption also will change but we do not need to worry about it, and we can design a compensation mechanism of water intake by the selection of people's type of their activities.

Through the analysis about the factor of this recommendation of daily water intake, we may confirm what we need is a reasonable and trustworthy value about daily water intake. This recommended value may not to be very precise, but it should be close to median of recommendation range of water intake. In our fuzzy logic, we use age and temperature as the input factor, and water intake as the output factor, and we get satisfactory result with this fuzzy system.

The first input factor is age; by analyzing range of ages and recommendation of daily water intake, age variable is divided into following fuzzy sets: child, teenage, adult and old. The age membership function is shown in Figure 2(a). The range of age is between 0 and 70 years.



(a) Age



(b) Temperature

FIGURE 2. The membership function of age (year) and temperature

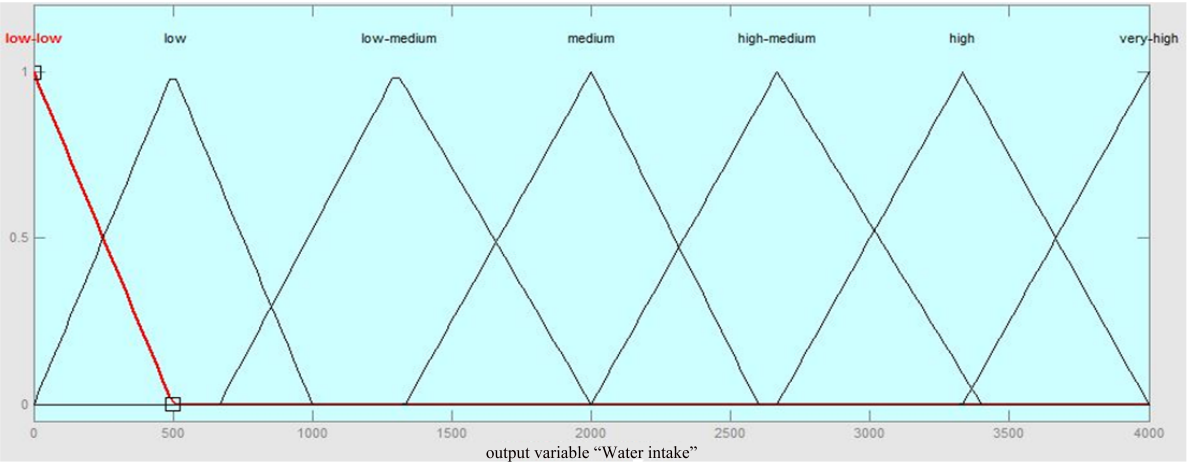


FIGURE 3. Membership function of daily water intake (ml/day)

The second input factor is ambient temperature, we set the vary range from 0 to 45, and the fuzzy set accordingly is divided into low, medium, high, which is shown in Figure 2(b).

As the output factor, we set the range value of recommendation of daily water intake from 0 to 4000 ml. The fuzzy sets are divided into following values: low-low, low, low-medium, medium, high medium, high and very high. The membership function is shown in Figure 3.

4. **Fuzzy Rules Design and Analysis.** In the process of construction of fuzzy logic of our daily drinking water recommendation systems, use two input factors, respectively, age and temperature. Age is subdivided into four fuzzy subsets, which are child, teenage, adult and old. Temperature are subdivided into low, medium and high. According to the theory of fuzzy logic, there will produce 12 fuzzy rules [11]. These fuzzy rules and the corresponding results are shown in Table 2.

TABLE 2. Fuzzy rules about recommendation of daily water intake

Rule No.	Age (year)	Temperature (μ)	Water intake (ml/day)
1	child	low	Low-low
2	child	medium	Low
3	child	high	Low-medium
4	teenage	low	Low-medium
5	teenage	medium	medium
6	teenage	high	high-medium
7	adult	low	high-medium
8	adult	medium	high-medium
9	adult	high	high
10	old	low	Low-medium
11	old	medium	Low-medium
12	old	high	medium

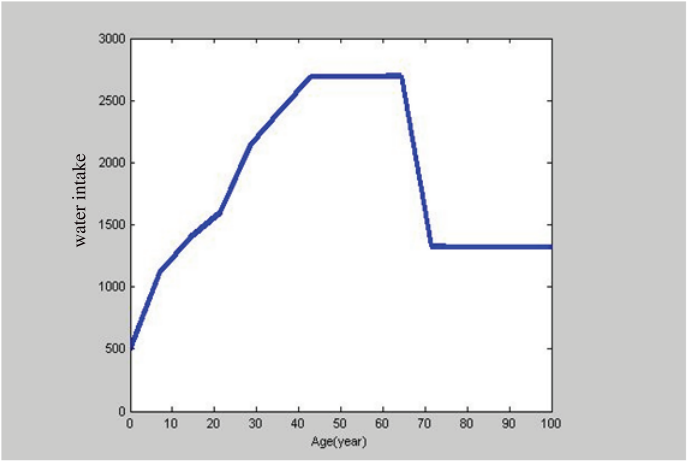
Especially, the design of column for water intake experienced adjustments repeatedly in the original system. The results generated by defuzzificaition phase have a large gap with the reasonable values. The problems are related to two aspects. The first aspect is that the design of output (water intake) membership function is not accurate for the definition of range and different level. The second aspect is that the generated values are related with the design of fuzzy. For example, the 10th rule, for the elderly people, the produced

value by the original system is relatively high; after the adjustment, the system generates a lower grade, and we can get satisfactory and reasonable recommendation value. Under the single factor condition, Figure 4 has shown the relationship between the age and water consumption, and the relationship between temperature and water consumption.

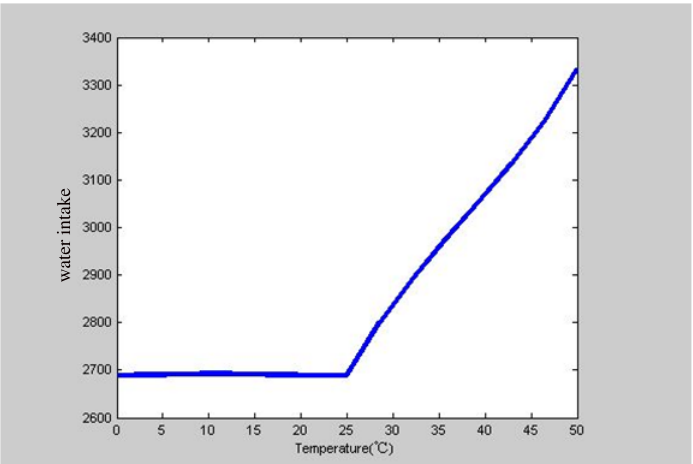
The 3-D relationship of age, temperature and water intake is shown in Figure 5. From Figure 6, we can get the recommendation value of daily water intake for a 30 years old person with temperature = 30.2°. The recommendation value is 2430 ml per day, and this value is relatively accurate.

Recommended daily water system for people's health is absolutely necessary. According to the recommendation values from nutritionists, different ages, different temperatures, and different levels of physical activity will lead to a different daily complement of water, so the recommended daily water intake is flexible value. We expected that the obtained results from our fuzzy system are reasonable within the range of recommendation. If the result values are very close to the median, we can say the system is valuable. Through continuous adjustment, now we can get a satisfactory result from the fuzzy system.

For example, a 25 years old adult, the temperature is 30 degrees Celsius, recommended value from the fuzzy inference system was 2820 ml per day, compared to the actual recommended value, assuming the body weight between 50 $\sim$ 80 kg, so the water intake per day should be 2000 $\sim$ 3200 ml, the median is 2600 ml, and this value is very close to our result value. At the same time, considering the influence of temperature of 30



(a) Age



(b) Temperature

FIGURE 4. The relationship of daily water consumption

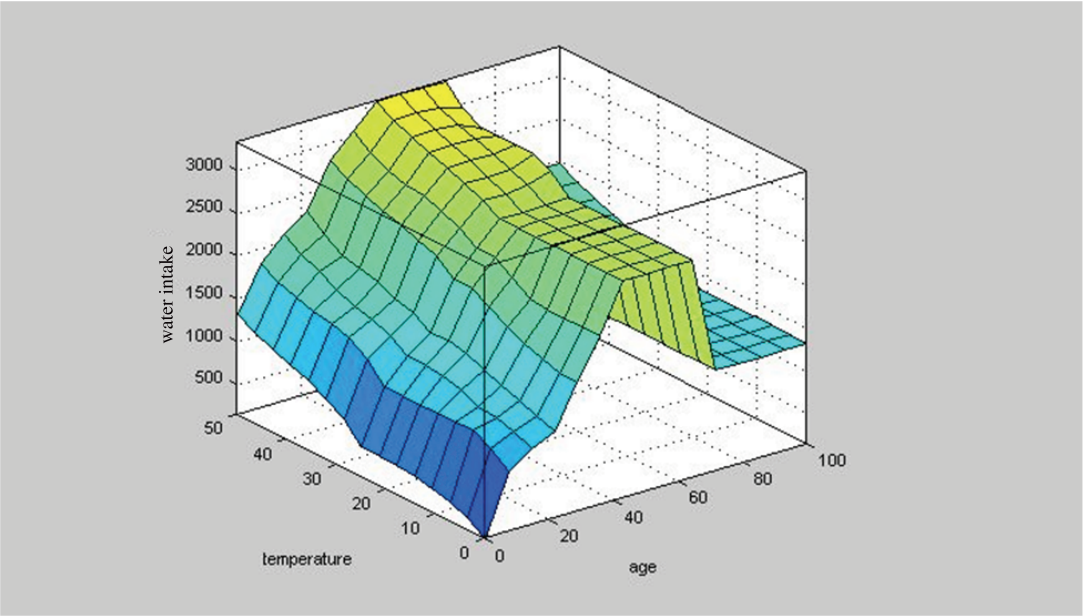


FIGURE 5. The relationship of age, temperature and water intake

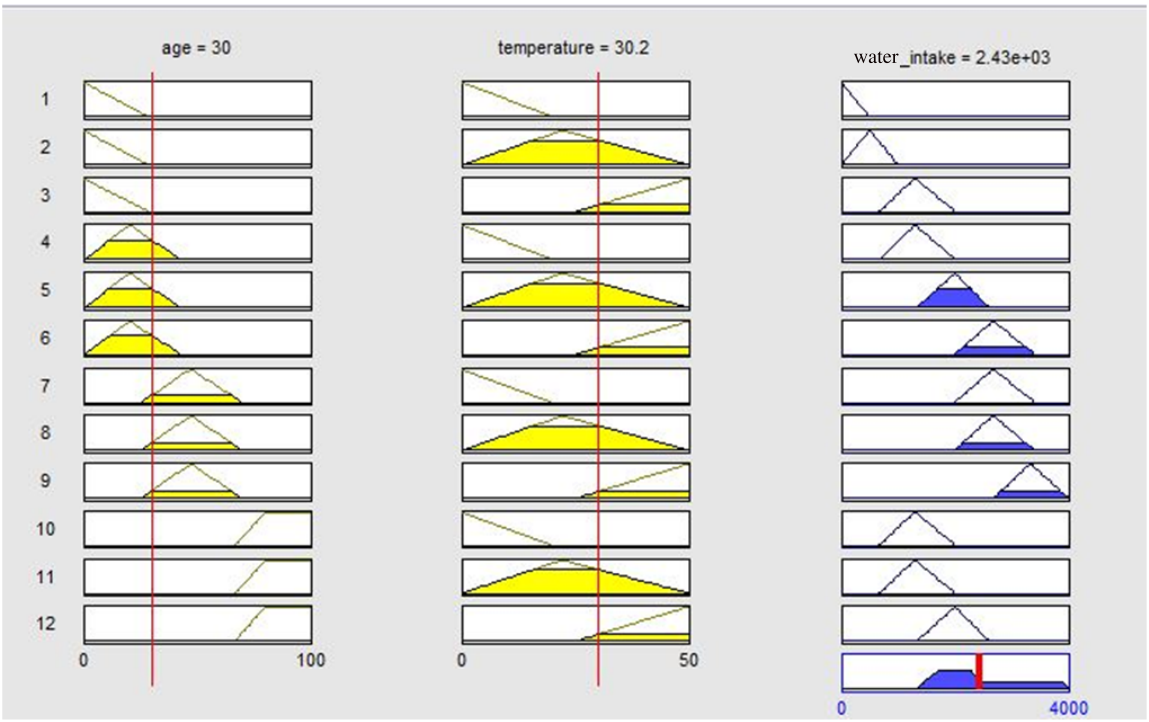


FIGURE 6. Recommendation value of daily water intake from fuzzy logic

degrees Celsius, people should drink more water, so the recommended value of 2820 ml is reasonable and accurate. In different age groups and different temperature conditions, we have done many tests, and the results were satisfactory.

5. **Conclusion and Future Work.** Since the fuzzy system can deal with uncertain and vaguest data, we use it on the recommendation of daily water intake, through careful design and adjustment of the rules to obtain more accurate data of recommendations. In our fuzzy logic system, using age and temperature as input, using the corresponding 12 rules as inference logical reasoning, the recommendation system can be used for future development of the actual products. In the future, we will add weight and exercise as input

factors to improve the accuracy of the recommended values. In subsequent work, we also will add more factors and design hardware to improve the accuracy of recommendation values and to implement a practical applications system based on fuzzy logic reasoning.

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REFERENCES

[1] M. N. Sawka, S. N. Cheuvront and R. Carter, Human water needs, *Nutrition Reviews*, vol.63, no.6, pp.30-36, 2005.
[2] A. Roseberry and D. Burmaster, Lognormal distributions for water intake by children adults, *Risk Analysis*, vol.12, no.1, pp.99-104, 1992.
[3] M. Russo and L. Jain, *Fuzzy Learning and Applications*, CRC Press, Boca Raton, 2001.
[4] S. Kalogirou, Artificial intelligence for the modeling and control of combustion processes: A review, *Progress in Energy and Combustion Science*, vol.29, no.6, pp.515-566, 2003.
[5] L. A. Zadeh, Fuzzy sets, *Information and Control*, vol.8, pp.338-353, 1965.
[6] G. Gerla, Food recommendation system using clustering analysis for diabetic patients, *Studia Logica*, vol.79, pp.231-254, 2005.
[7] A. Bastian, Identifying fuzzy models utilizing genetic programming, *Fuzzy Sets and Systems*, vol.113, no.3, pp.333-350,2000.
[8] C. Sangwin, Locating the centre of mass by mechanical means, *Journal of the Oughtred Society*, vol.15, no.2, pp.16-18, 2006.
[9] Z. Sen and A. Altunkaynak, Fuzzy system modelling of drinking water consumption prediction, *Expert Systems with Applications*, vol.36, no.9, pp.11745-11752, 2009.
[10] J. D. Wang, *The Neural Network and Fuzzy Control System*, Quanhua Science Book Company, 2006.
[11] *Fuzzy logic*, Http:// en.wikipedia.org/wiki/Fuzzy_logic, 2014.