Development of Fuzzy Logic Based Odor Detection

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***Abstract*— The development of electronic nose technologies has come through advances in sensor design, material improvements and software innovations. The integration of fuzzy logic technique in the electronic nose gives a new perspective way on the development of electronic nose. Fuzzy logic is one of the techniques in Artificial Intelligent that widely used to control environmental factors. The effectiveness of fuzzy logic has been proven through a lot of creations of intelligent System using fuzzy logic approach such rice cooker, washing machine etc. The purpose of this project is to develop a fuzzy logic based electronic nose able to detect the different odor produced by different chemical vapor. Three gas sensors are used in this project. This study focused on evaluating the possibility of using different gas sensors to detect odor produced by three different materials which are gasoline, perfume and coke. The inputs value from these sensors will then fused using fuzzy logic controller. The fuzzification process will be performed using Mamdani style. The result of this project will be display in form of percentage value at LCD display and will be compared to the result of simulation by Matlab.**

Keywords— Fuzzy Logic, Odor Detection, Gas Sensors

I. INTRODUCTION

Development of electronic olfactory devices is an emergent technology in chemical sensors. Categorically, sensing in liquid phase is carried out by electronic tongues (e-tongues), e.g. taste sensing [1]. On the other hand, electronic noses (e-nose) are responsible for sensing of gases, e.g. odor, aroma etc. These devices in reality mimic the living olfaction system when used with multivariate data analysis tools.

A successful model of e-nose was presented by Persaud and Dodd in 1982 [2]. Their idea was detection of volatile compounds produced by microbial species. They followed different steps in human olfaction system and used biochemical sensors for measuring volatile compounds. Signal monitoring, amplification were recorded by instruments whereas patterns recognition in the data was done by neural networks which on the other hand in humans is performed by brain. In fact e-noses, in chemical sensor technology really helped mankind in several fields: from early diagnosis of diseases to quality control in food products and so on. Gardner and Bartlett in 1994 defined e-nose as: an electronic device comprised of multi-channels or an array of non-specific chemical sensors with partial specificity and an efficient model for pattern recognition, for detecting simple or complex mixtures of analyses [3].

In this project, the odor detection system is consisted of mainly by odor sensors and an Arduino Duemilanove, a microcontroller board based on ATmega328 used to acquire and analyze data from the sensors. The objectives of the study were to evaluate the possibility of using gas sensors to identify different type of odors and to develop odor detection prototype system based on Fuzzy logic algorithm and technique.

II. SYSTEM ARCHITECTURE

The project consists of hardware and software parts. From a hardware point of view for developing an electronic nose, an electronic nose that has been developed in order to study mechanical olfaction uses a sensor array containing multiple sensors which can sense odorant molecules. An electronic nose is an instrument which comprises of an array of electronic chemical sensors with partial specificity and an appropriate pattern recognition system, capable of recognize simple or complex odors [4]. It comprises of hardware and software to monitor and analyze the data received. As an analytic system, electronic nose must be designed with high ability of obtaining the same pattern of the same sample over short interval time. Briefly, it is an artificial technology of mimicking human or animal olfaction system by analyze the chemical (odorant molecule) belongs to each odor.

Figure 1 illustrate the overall function of the system. The system architecture consists of an Arduino board controller which based on 8-bits microcontroller (ATmega328), odor sensors, LCD display and a computer.

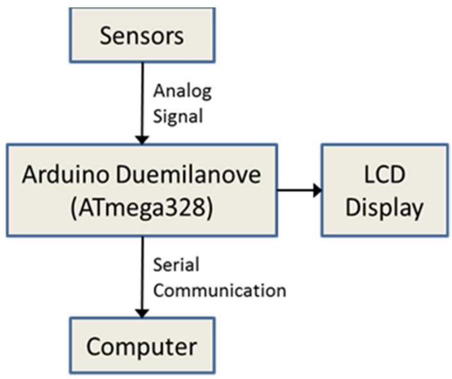

Fig. 1. Odor detection prototyping system

In this proposed system, the gas sensors detect the concentrations of the intended gases if they are present and generate a proportional continuous voltage signal. Then this voltage is fed to the microcontroller (Arduino Duemilanove) in which the voltage signal is converted to a digital values. The Arduino Duemilanove is a microcontroller board based on the ATmega328. It has fourteen (14) digital inputs/outputs (of which six (6) can be used as PWM outputs) and six (6) analogue inputs. In this study, all Arduino programs are written in C language using Arduino IDE software.

III. Methodology and System Development

The system consists of two main part; hardware and software. The hardware part of the system mainly comprises of an Arduino board controller which based on 8-bits microcontroller (ATmega328), odor sensors, display module and a computer. While the software part of the system comprises of programming Arduino using Arduino IDE.

A. Hardware

The following hardware is used in the project which is explained as follows:-

1. *Odor Sensor:* Three sensor are used for detect the different gas odor from the different chemical. Three sensors are MQ 3, TGS2611 and TGS 800. MQ3 is used to detect ethanol gas, TGS2611 for detect methane gases and TGS 800 for detect various types of gases.

2. *Arduino Duemilanove controller board:* Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It is an open-source circuit board with a microprocessor and input/output (I/O) pins for communication and controlling physical objects (LED, servos, buttons, etc.). The board will typically be powered via USB or an external power supply which in turn allows it to power other hardware and sensors. In this project, we are using Arduino Deumilanove. The Arduino Duemilanove is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. Figure 2 shows the Arduino Duemilanove Board with pins connection.

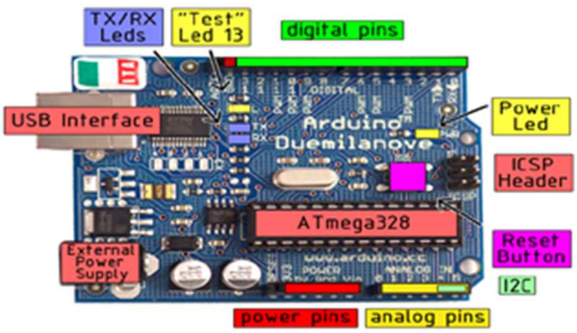

Fig. 2. Arduino Duemilanove board

B. Software

The Arduino integrated development environment (IDE) is a cross-platform application written in Java, and derives from the IDE for the Processing programming language and the Wiring projects. It is designed to introduce programming to artists and other newcomers unfamiliar with software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the board with a single click. Arduino programs are written in C or C++. The Arduino IDE comes with a software library called "Wiring" from the original Wiring project, which makes many common input/output operations much easier. In this project, Arduino programs are written in C language, and figure 3 shows the overall process flow of the system.

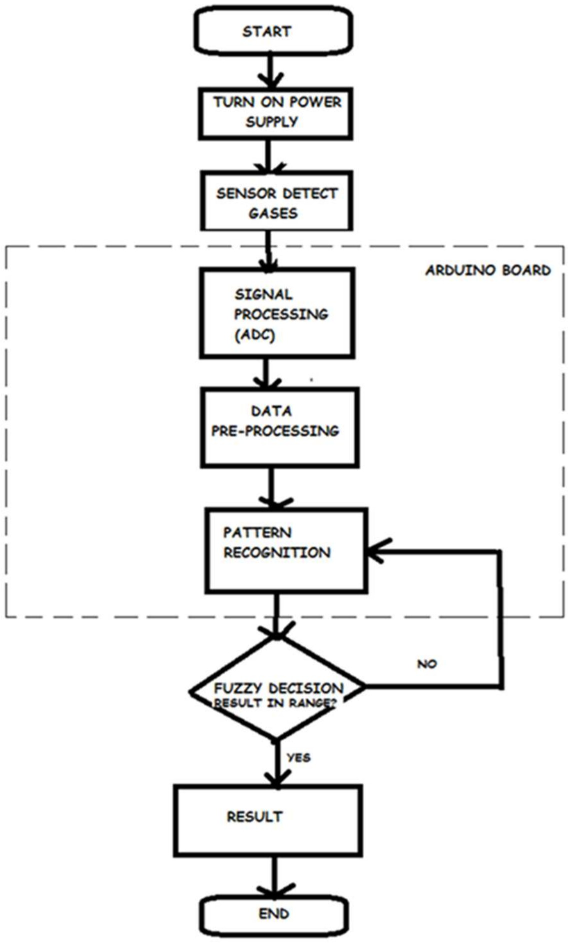

Fig. 3. System overall process

IV. Result

A. Analysis of Coke

The coke has been testing using three types of sensor (MQ3, TGS2611 and TGS 800) by measuring the reading simultaneously. The reading is taken through the program that is uploaded to Arduino and the reading is displayed in serial monitoring for 30 seconds. Figure 4-6 shows the result for each sensor.

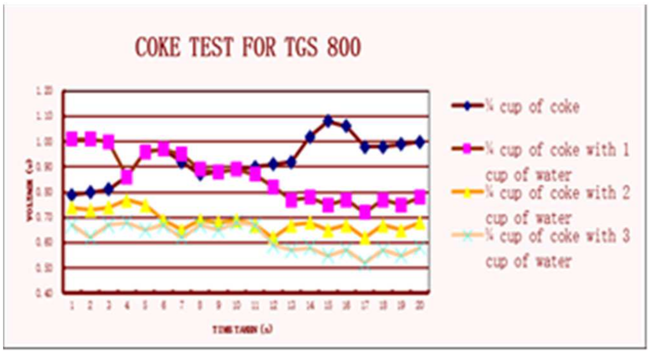

Fig. 4. Graph of coke analysis for TGS800

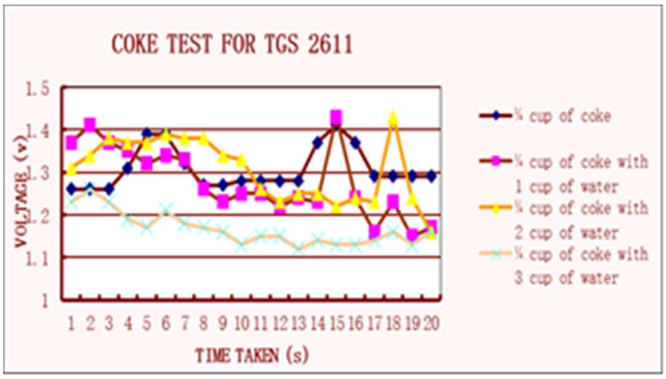

Fig. 5. Graph of coke analysis for TGS2611

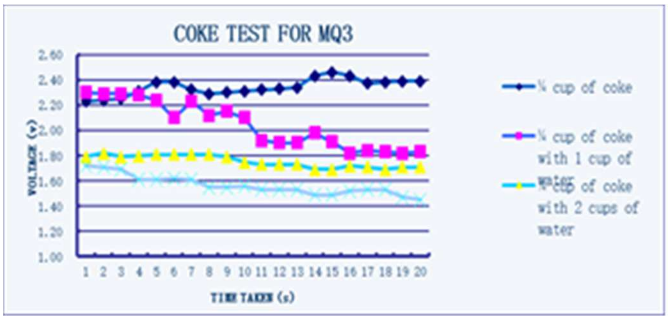

Fig. 6. Graph of coke analysis for MQ3

B. Analysis of Apple Cider

The apple cider has been testing using three types of sensor (MQ3, TGS2611 and TGS 800) by measuring the reading simultaneously. The reading is taken through the program that is uploaded to Arduino and the reading is displayed in serial monitoring for 30 seconds. Figure 7-9 shows the result for each sensor.

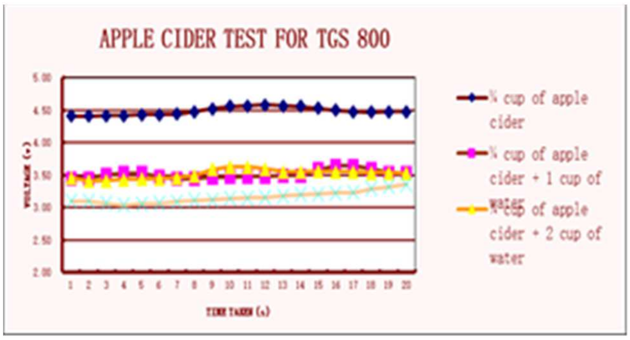

Fig. 7. Graph of apple cider analysis for TGS800

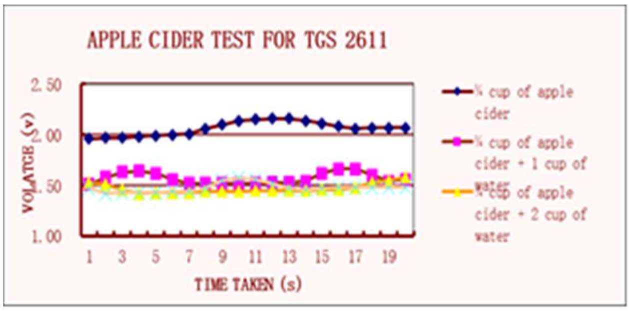

Fig. 8. Graph analysis of apple cider for TGS2611

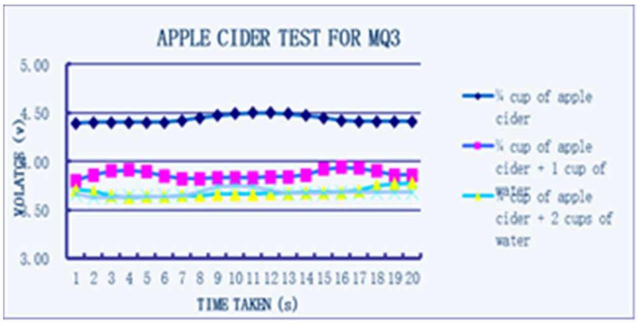

Fig. 9. Graph analysis of cider apple for MQ3

C. Analysis of Perfume

The perfume has been testing using three types of sensor (MQ3, TGS2611 and TGS 800) by measuring the reading simultaneously. The reading is taken through the program that is uploaded to Arduino and the reading is displayed in serial monitoring for 30 seconds. Figure 10-12 shows the result for each sensor.

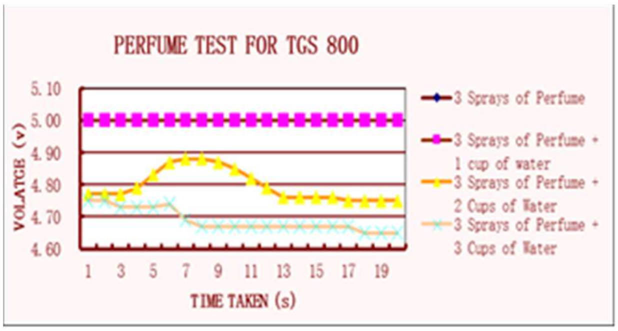

Fig. 10. Graph analysis of perfume for TGS800

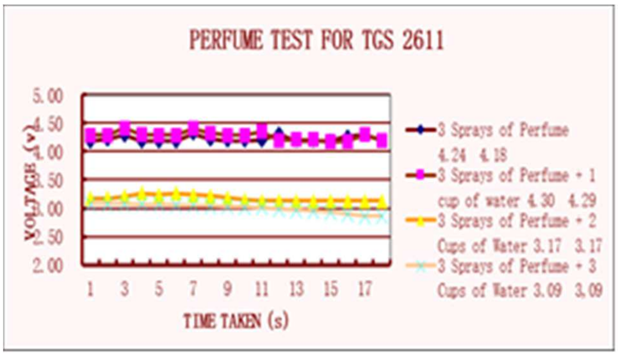

Fig. 11. Graph analysis of perfume for TGS2611

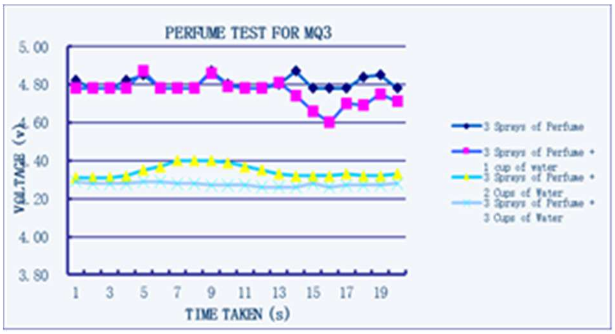

Fig. 12. Graph analysis of perfume for MQ3

D. Classification

The classification of the gases is done using fuzzy logic based approach. The member functions and rules of the fuzzy inference system are defined. The inputs applied to the five sensors are combined by AND operations. By applying the rules to the FIS, the outputs are obtained. A fixed parameter is assumed for a particular gas sample. The output obtained from the system is verified based on the closeness of the obtained output to the assumed fixed value. The steps involved in the fuzzy logic classifier are described below:

1. *Fuzzification:* The first step in applying Sugeno based fuzzy logic algorithm is to fuzzify the inputs using membership functions. A membership function (MF) is a curve that defines how each input is mapped to a membership value (or degree of membership) between 0 and 1 [5]. The input values refer to the voltage levels given by the sensors. The inputs are fuzzified using nine triangular shaped member functions. The fuzzification of the input voltage levels is shown in figure 13.

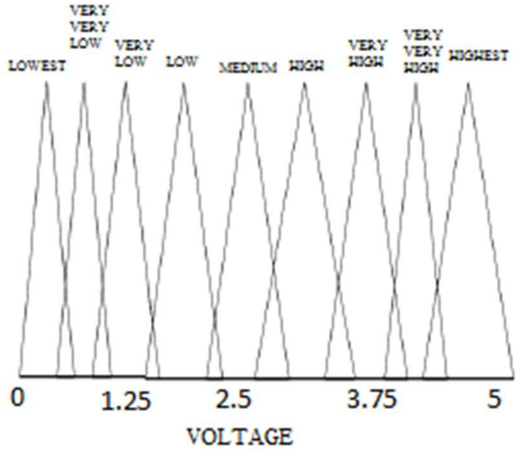

Fig. 13. Fuzzification process

2. *Fuzzy Inference System:* The relationship between the input of the three sensors and the output gas samples is determined by the fuzzy rules in the inference system. A fuzzy control rule refers to a fuzzy conditional statement in which the antecedent is a condition in the application domain and the consequent is a control action for the system [6].

Twenty-seven rules are developed for the controller; these rules are based on the different scenarios for the linguistic input variables states as shown in Table 1.

Table 1: Fuzzy Inference Rules

IF (MQ-3 is Low) AND (TGS-2611 is Low) AND (TGS-800 is Low) THEN (Result is Coke)
IF (MQ-3 is Low) AND (TGS-2611 is Low) AND (TGS-800 is Medium) THEN (Result is Coke)
IF (MQ-3 is Low) AND (TGS-2611 is Low) AND (TGS-800 is High) THEN (Result is Coke)
IF (MQ-3 is Low) AND (TGS-2611 is Medium) AND (TGS-800 is Low) THEN (Result is Coke)
IF (MQ-3 is Low) AND (TGS-2611 is Medium) AND (TGS-800 is Medium) THEN (Result is Apple Cider)
IF (MQ-3 is Low) AND (TGS-2611 is Medium) AND (TGS-800 is High) THEN (Result is Apple Cider)
IF (MQ-3 is Low) AND (TGS-2611 is High) AND (TGS-800 is Low) THEN (Result is Coke)
IF (MQ-3 is Low) AND (TGS-2611 is High) AND (TGS-800 is Medium) THEN (Result is Coke)
IF (MQ-3 is Low) AND (TGS-2611 is High) AND (TGS-800 is High) THEN (Result is Perfume)
IF (MQ-3 is Medium) AND (TGS-2611 is Low) AND (TGS-800 is Low) THEN (Result is Coke)
IF (MQ-3 is Medium) AND (TGS-2611 is Low) AND (TGS-800 is Medium) THEN (Result is Apple Cider)
IF (MQ-3 is Medium) AND (TGS-2611 is Low) AND (TGS-800 is High) then (Result is Apple Cider)

IF (MQ-3 is Medium) AND (TGS-2611 is Medium) AND (TGS-800 is Low) THEN (Result is Apple Cider)
IF (MQ-3 is Medium) AND (TGS-2611 is Medium) AND (TGS-800 is Medium) THEN (Result is Apple Cider)
IF (MQ-3 is Medium) AND (TGS-2611 is Medium) AND (TGS-800 is High) THEN (Result is Apple Cider)
IF (MQ-3 is Medium) AND (TGS-2611 is High) AND (TGS-800 is Low) THEN (Result is Apple Cider)
IF (MQ-3 is Medium) AND (TGS-2611 is High) AND (TGS-800 is Medium) THEN (Result is Apple Cider)
IF (MQ-3 is Medium) AND (TGS-2611 is High) AND (TGS-800 is High) THEN (Result is Perfume)
IF (MQ-3 is High) AND (TGS-2611 is Low) AND (TGS-800 is Low) THEN (Result is Perfume)
IF (MQ-3 is High) AND (TGS-2611 is Low) AND (TGS-800 is Medium) THEN (Result is Perfume)
IF (MQ-3 is High) AND (TGS-2611 is Low) AND (TGS-800 is High) THEN (Result is Perfume)
IF (MQ-3 is High) AND (TGS-2611 is Medium) AND (TGS-800 is Low) THEN (Result is Apple Cider)
IF (MQ-3 is High) AND (TGS-2611 is Medium) AND (TGS-800 is Medium) THEN (Result is Apple Cider)
IF (MQ-3 is High) AND (TGS-2611 is Medium) AND (TGS-800 is High) THEN (Result is Perfume)
IF (MQ-3 is High) AND (TGS-2611 is High) AND (TGS-800 is Low) THEN (Result is Perfume)
IF (MQ-3 is High) AND (TGS-2611 is High) AND (TGS-800 is Medium) THEN (Result is Perfume)
IF (MQ-3 is High) AND (TGS-2611 is High) AND (TGS-800 is High) THEN (Result is Perfume)

3. Defuzzification:

Defuzzification was carried out using centroid method and this defuzzified value will then be utilized to determine the intensity level of the odor produced by Coke, Apple Cider and Perfume. The process is illustrated as in figure 14.

Once inputs from gas sensors are detected, the system will automatically map the defuzzified value to the specified lookup table, and it will also determine the intensity level of Coke, Apple Cider and Perfume in form of percentage value.

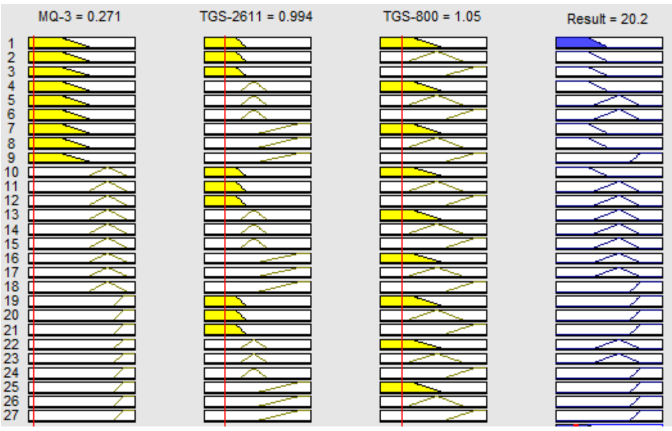

Fig. 14. Fuzzification process

V. Conclusion

The objectives of the project to develop a prototype of fuzzy logic based electronic nose and to evaluate the possibility of using gases sensor to detect odor is attained. It is important to design a device including hardware and software that able to help human to detect a very low levels of smells, which can help keep people safe and healthy.

This paper presented the development of an electronic nose system using three (3) gas sensors. The fuzzy logic based electronic nose has been tested to confirm its repeatability, reproducibility and discriminative ability which are important characteristics of an analytical instrument. Measurements on three liquids: coke, apple cider and perfume repeatedly produced similar patterns with high correlation for the same liquids and produced different patterns with lower correlation for different liquids, consequently confirming its repeatability characteristics by using fuzzy logic. Fuzzy Logic allows the system to get optimum result. The developed electronic nose also produces repeatable responses in the measurement of three liquids using different sensor batches, hence confirm its reproducibility characteristics. The developed electronic nose is also able to produce different patterns for different samples. Based on the results we concluded that the developed electronic nose is a reliable analytical instrument.

The objectives had been accomplished when the goal has been archived. This prototype is able to analyze the gases from three different liquids and state the type of liquid. The future work is necessary for the project improvements.

Acknowledgment

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