Analysis of Infrared Sensors As a Non Invasive Glucose Measuring By Applying Fuzzy Algorithm

G Gunawan¹*, Budi Harianto², Marina Elsera³, and Ferry Fachrizal¹

¹Department of Computer Engineering and Informatics, Politeknik Negeri Medan, Indonesia
²Department of Electrical Engineering, Politeknik Negeri Medan, Indonesia
³Department of Engineering and Computer, Universitas Harapan Medan, Indonesia

*gunawan@polmed.ac.id

Abstract. Medical equipment used to perform tests or test blood sugar levels in hospital laboratories generally applied using invasive methods namely by taking a patient's blood using a needle. This is a constraint and the price of equipment and kit stripnya still relatively expensive. Also feared needles used to injure the patient in taking a few drops of the patient's blood can lead to infection and other germs if needles used are not sterile. It is not rare some people are reluctant to test blood sugar levels. So that a person can not monitor the blood sugar levels in their bodies quickly and accurately. The measurement method of blood sugar levels in non-invasive rarely occurs because accuracy is questionable. Measuring tools, non-invasive blood sugar levels even yet widely used as medical devices. Of the problems that occurred the device technology development research of infrared sensors as a measure of non-invasive blood sugar levels in an attempt early detection and prevention of diabetes mellitus is necessary to get a tool kit prototype test blood sugar levels are cheap and easy to use in the community. Infrared is light waves that can be absorbed by a solution of glucose in the blood so that the method of technology development device's infrared sensor can easily measure blood sugar levels without injuring the body (non-invasive) for the extraction of blood. To obtain equal accuracy invasive methods will be tested on the finger sensor readings and also earlobe.

1. Introduction

World Health Organization (WHO) released the latest data on diabetes mellitus patients has increased to 422 million. As for Indonesia the number of people with diabetes mellitus based Data Basic Health Research (Risksesda) Ministry of Health in 2013 has reached 9.1 million and would have predicted in 2030 rose to 21.3 million [1]. The results showed that every 1 in 10 residents of diabetes mellitus. This causes costs to be high on the treatment process. National health insurance data from an unknown number of claims for diabetes mellitus almost 30%.

Diabetes mellitus is a hereditary disease that sometimes people do not realize that he suffered from the disease. This makes prevention difficult [2]. Moreover, to test blood sugar levels as an early detection of the disease is still using invasive methods or by piercing the patient with a needle to take a patient's blood. Patients often frightened and traumatized to test blood sugar levels. Another obstacle is the price of the strip test kits in blood sugar levels relatively expensive [3].
From the above background, this research will develop an infrared sensor device technology as a test kit, non-invasive blood sugar levels are without injuring the patient. The test kit uses infrared sensors that can be placed in the patient's earlobe or fingertip patient [4]. The technology is fairly still not been developed because there are still some weaknesses and a good level of accuracy less than test kits used today. Thus, in this study will be further developed this technology to obtain a test kit, non-invasive blood sugar levels are accurate and easy to use and the price can be suppressed so that the impact in the early detection and prevention of diabetes mellitus.

2. Literature Review

2.1. Definition of Fuzzy Logic

Fuzzy set theory developed by Prof. Dr. Lotfi Zadeh in the 1960s. Fuzzy logic is an appropriate way to map an input space into an output space. Zadeh found true and false logic of Boolean logic can not overcome the problem of gradations that are in the real world. To overcome the problem of the infinite gradations, Zadeh developed a fuzzy set. Unlike Boolean logic, fuzzy logic has a continuous value. Fuzzy expressed in degrees of a membership and degrees of truth. Therefore, something can be said to be partly correct and partly incorrect at the same time. The following example will explain how the concept of "age" classified "old" in the sense of fuzzy / vague and crisp (firm) [5] [6].

![Figure 1. Old Concept](image1)

Figure 1. Old Concept

In terms of crisp (firm), the boundaries between "old" and "old" is very clear, every person aged (40, ..., 55) is not "old" (Figure 1). There are no degrees of aging, while the fuzzy each member has a value based on the degree of membership, while the concept of "age" classified "old" in the sense of fuzzy:

![Figure 2. Old Concept in Fuzzy](image2)

Figure 2. Old Concept in Fuzzy

Figure 2 shows that members aged 55 years, the degree of membership is worth 0.7, while the 60-year-old member of the membership degree is 1. To represent accurately the old concept of "old" that has a degree of membership 1, while members aged less than 60 years has a different degree. This membership degree indicates how closely the value of each member of the set's age within the concept of the "old". It can be said that members aged 55 years was 70% (0.7) closer to the "old", or with natural language "almost or close to the old".

2.2 The set of fuzzy
In the decisive set (Crisp), the value of membership of an item \( x \) in a set \( A \), which is often written with \( u_{A}[x] \), has two possibilities, namely:
- One (1), which means that an item be a member in a set or
- Zero (0), which means that an item is not a member in a set.

**Example:**
Suppose the age variable is divided into three categories, namely:
- MUDA: \( \text{umur} < 35 \) years
- PAROBAYA: \( 35 \leq \text{age} \leq 55 \) years
- TUA: \( \text{umur} > 55 \) years

Membership value graphically, set YOUNG, OLD middle-aged and this can be seen in Figure 2.3.

![Figure 3. Member of Age](image)

In Figure 3, it can be explained that:
- If someone is 34 years old, he said MUDA (\( \mu_{\text{MUDA}}[34] = 1 \))
- If a person aged 35 years, he said NO YOUNG (\( \mu_{\text{MUDA}}[35] = 0 \))
- If a person aged 35 years less one day, he said NO YOUNG (\( \mu_{\text{MUDA}}[35-1 \text{ days}] = 0 \))
- If a person aged 35 years, he said a middle-aged (\( \mu_{\text{PAROBAYA}}[35] = 1 \))
- If someone is 34 years old, he said NO middle-aged (\( \mu_{\text{PAROBAYA}}[34] = 0 \))
- If someone is 55 years old, he is said to be a middle-aged (\( \mu_{\text{PAROBAYA}}[55] = 1 \))
- If a person aged 35 years less one day, he said NO middle-aged (\( \mu_{\text{PAROBAYA}}[35-1 \text{ days}] = 0 \))

**2.3 Fuzzy Inference System**

**2.3.1 Methods Tsukamoto**

In Tsukamoto method, each consequent upon the rules in the form of IF-THEN shall be represented by a fuzzy set with membership function monotonous. As a result, output inference result of each rule is given explicitly (crisp) by \( \alpha \)-predicate (fire strength). The end result is obtained by using a weighted average (Weight Average).

Suppose there are two input variables, \( \text{Var}_1(x) \) and \( \text{Var}_2(y) \) and 1 output variables, \( \text{Var}_3(z) \). \( \text{Var}_1 \) is divided into two sets, namely \( A_1 \) and \( A_2 \). \( \text{Var}_2 \) is divided into two sets \( B_1 \) and \( B_2 \). \( \text{Var}_3 \) is divided into two sets, namely \( C_1 \) and \( C_2 \) (\( C_1 \) and \( C_2 \) MUST monotonous). There are two rules are used, namely:

[R1] IF (\( x \) is \( A_1 \)) AND (\( y \) is \( B_2 \)) THEN (\( z \) is \( C_1 \))
[R2] IF (\( x \) is \( A_2 \)) AND (\( y \) is \( B_1 \)) THEN (\( z \) is \( C_2 \))

Flow inference to obtain a crisp value \( z \) as shown in Figure 4.
2.4. Infrared Sensor

Infrared (Infrared) is an electromagnetic wave with a wavelength range between 750nm up 10000nm wave with wave number between 14000 cm \(^{-1}\) to 20 cm [4]. Wave infrared rays can be grouped into three parts:

a. Near infrared (NIR) is a group of infrared wavelengths 750-2500nm. IR group is typically used to make the measurements -pengukuran for NIR is able to penetrate tissue with 1mm thick - can penetrate 100mm including bone.

b. Mid Infrared (MIR) has a wavelength between 2500- 5000nm. In the infrared group is often used for chemical purposes. That is because the MIR is very easily absorbed by the molecules.

c. Far Infrared (FIR) is the infrared spectrum is closest to the microwaves is between 5000 - 10000nm. FIR is very sensitive to the vibrations of molecules - molecules. So that the FIR is usually used for the identification of the material that can not be done with MIR. FIR is also used to identify the color.
2.5. microcontroller
Microcontroller is a component of an integrated circuit that can be programmed and process data input in the form of digital data. Microprocessor in this study is useful as a data-processing brain blood glucose test results using the algorithm will fuzzy obtained more accurate results [7].

2.6. Diabetes mellitus
Diabetes mellitus is a hereditary disease or difficult to detect because the patient will feel pain after complications occur with other diseases. Diabetes mellitus can lead to complications of a stroke, neuropathy and peripheral vascular [8]. Diabetes mellitus is a syndrome of chronic hyperglycemia impaired metabolism of carbohydrates, fats and proteins due to lack of insulin secretion [9].

3. Result And Discussion
From the research results of checking blood sugar levels then the tool will display a high condition of the blood sugar level exceeds the threshold set by the fuzzy algorithm, namely the sensor output voltage of above 4 volts. As for the normal condition of the sensor output voltage range from 2 volts 3-9 volts, whereas for low conditions below 2 volts.

Table 1. Testing Sensor

| condition | gluco Level | Voltage (V) |
|-----------|-------------|-------------|
| High      | > 23        | 4.2         |
| Normal    | 20-14       | 3.9         |
| Low       | <14         | 3.1         |

Display the measurement results shown in Figure 7.
4. Conclusion

The detector's blood sugar levels just as the early detection of diabetes mellitus. This tool can only be detected three conditions, namely patients with Dula levels low, normal and high. The tool does not display the value of sugar by using figures such as invasive test tool because prinsif works using fuzzy algorithms only determine the threshold levels of blood sugar with a scale not with numbers.

References

[1] 6(1). http://doi.org/10.1186/s13613-015-0104-6 Deye, N., Vincent, F., Michel, P., Ehrmann, S., Da Silva, D., Piagnerelli, M., … Laterre, P.-F. (2016). Changes in cardiac arrest patients’ temperature management after the 2013 “TTM” trial: Results from an international survey. Annals of Intensive Care et al., “Global and national burden of diseases and injuries among children and adolescents between 1990 and 2013 findings from the global burden of disease 2013 study,” JAMA Pediatr., 2016.

[2] A. Tuchman, “Diabetes and the public’s health,” Lancet. 2009.

[3] R. Rahim et al., “Pest plant disease prevention and identification system using certainty factor method,” Int. J. Eng. Technol., vol. 7, no. 3.2 Special Issue 2, 2018.

[4] P. Norton, “HgCdTe infrared detectors,” Opto-Electronic Rev., 2002.

[5] L. A. Zadeh, “Fuzzy logic,” in Computational Complexity: Theory, Techniques, and Applications, 2013.

[6] S. N. Sivanandam, S. Sumathi, and S. N. Deepa, Introduction to fuzzy logic using MATLAB. 2007.

[7] Digi Inc, “Arduino UNO Reference Design,” Arduino, 2013.

[8] M. R. and C. S., “Elderly onset of diabetes mellitus type 1,” J. Gen. Intern. Med., 2016.

[9] N. Schaper, “How to assess diabetic foot problems clinically,” Cardiovasc. Intervent. Radiol., 2012.