Blood Glucose Analysis Utilizing Artificial Raindrop Algorithm and Capacitance Method

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Abstract — **Controlling blood glucose is a way to avoid complications of diabetes. Blood glucose monitoring is a way to test the concentration of glucose in the blood. This study aims to determine the suitability of Artificial Raindrop Algorithm (ARA) and capacitance method in measuring the blood glucose. ARA is a new search algorithm that produces very promising results on the nonlinear function approximation. Blood samples were obtained from 65 different individuals. The sample was placed in a glass slide and the blood glucose is measured using the developed prototype. The results were compared to the laborotary result. The developed device showed 96.92% accuracy.**

Index Terms — **Capacitance Method, Artificial Raindrop Algorithm, Diabetes, Blood Glucose, Glucometer.**

I. INTRODUCTION

One of the most popular disease in the world is diabetes. A person may get this disease if his/her blood glucose level in the body is too high. The highness and lowness of the blood glucose level can be obtained from the food that a person takes. Insulin is a hormone secreted by the pancreas which allows the body the usage of sugar or glucose from carbohydrates. This hormone keeps the level of the blood sugar from getting too high (hyperglycemia) or too low (hypoglycemia) [1]. There are two types of pre-diabetes. The first is the Type 1 wherein the body does not secrete insulin. The second is the Type 2 wherein the body does not respond well or is resistant to insulin. Pre-diabetes simply means that the blood sugar level is not normal but it is not high enough to be considered as diabetes. People who are in range of this pre-diabetes are usually the ones who is triggered with Type 2 [2, 3, 4]. Table 1 shows the blood glucose measurement.

There are ways on measuring glucose level. One of the commonly used device is the glucometer. It used to measure the glucose level but the results are not 100% accurate. It is said to have a 10% - 15% error because of the meter calibration, coding, enzymes and test strips. This uses a test strip. Another method use for medical laboratory is medical hematology blood testing analyzer. Laboratory tests eliminate virtually all variation except for manufacturing variation from their testing. Laboratory testing is more accurate than glucometer. It gives 90% to 95% accuracy. The problem with this is the responsible for taking of the blood sample to the laboratory. The blood should be tested within 30 minutes because the glucose of the blood sample will breakdown and the measurement will not be accurate [5, 6]. All these methods are much expensive. Calibration of the meter also affects the result of the blood glucose. This is the same as testing blood sample twice which gives a different result. Many blood samples for the laboratory testing must first be collected before it can be tested. In laboratory, blood samples are collected first before the glucose measurement. This method gives the blood samples a time lapse of 2 to 4 hours before testing [7, 8]. Also, medical experts strictly follow the tight glycemic protocol for patients that are in close-fitting glycemic control therapy [5, 9].

TABLE I. Blood Glucose Measurements

Target Level by Type	Upon Waking mmol/L	Before Meal (Pre Prandial) mmol/L	90 mins. After Meal (Post Prandial) mmol/L
Non Diabetic		4 – 5.9	below 7.8
Type 2 Diabetes		4 - 7	below 8.5
Type 1 Diabetes	5 -7	4 -7	5 -9
Type 1 (for children)	4 - 7	4 - 7	5 -9

This study aims to determine the suitability of ARA and capacitance method in measuring the blood glucose. It can be used to determine the blood sugar level of normal, diabetic and pre-diabetic persons. The study will benefit all the individuals to warn them on balancing their eating habit and regulate the sugar intake. It will provide also a low-cost blood glucose measuring device.

The paper is organized as follows: Section II discusses on how the ARA works and Section III explains the materials and methods. In Section IV, the data obtained from the simulation and testing are discussed. Finally, Section V gives conclusions.

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II. ARTIFICIAL RAINDROP ALGORITHM

ARA is a global numerical optimization that has delivered several applications in the area of engineering and science. It is also similar to Genetic algorithm and Binary search algorithm. This algorithm works with a surface pool that eliminates all the values outside the area and for those values inside the surface pool will be analyzed to obtain the best value. Some of its uses are classification of unbalanced data, sensor scheduling in wireless sensor networks, and data clustering. According to the No Free Lunch theorem, however, there is no obvious approach to be optimized for all optimization problems. As a result, how to strategize efficient optimization techniques to explain them has become a hot and inspiring research topic whether in the mathematical programming or evolutionary computation area [6, 7, 8]

ARA is a brand new search algorithm that produces very promising results on the nonlinear function approximation [10]. The concept of this algorithm is from the phenomenon of natural drops of rainfall and focuses its attention only on the changing process of a raindrop as shown in Figure 1. The flow of the algorithm follows a distinct closed-loop journey of a finite number of raindrops. The main idea is by tracking the raindrops to where they are found occupying the lowest energy state with the largest number - the Raindrop Pool (RP). These raindrops are considered the subjects. The performance of these raindrops is assessed by corresponding altitude. The place of the lowest elevation corresponds to the optimal solution.

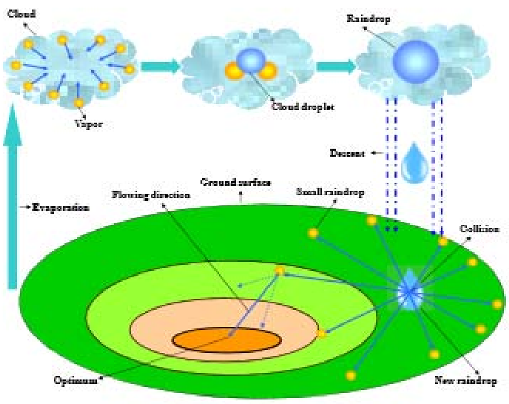

Fig. 1. Representation of Artificial Raindrop Algorithm

Figure 2 shows the whole cyclical process of this algorithm. It is incorporated into six stages: raindrop generation, raindrop descent, raindrop collision, raindrop flowing, RP updating, and vapor updating [11]. It does not involve the operation of having the first or second order derivatives of the object function. Hence, ARA is a method that is direct. Lastly, this algorithm is applied to explain a non-linear optimization problem wherein the object function is highly irregular (neither convex nor concave). And the global optimal solution can be found with limited stages of iterations but still having a high success probability [12].

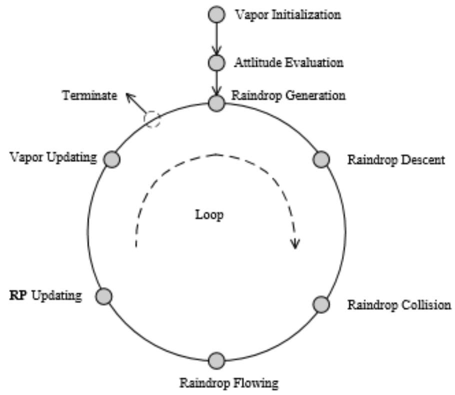

Fig. 2. The scene graph of Artificial Raindrop Algorithm [16]

Several studies are conducted to see the effectivity of ARA as a search algorithm and optimization technique. Promising results are obtained in using multi-objective ARA on dynamic optimization problems in chemical processes [13]. In one study, ARA with simulated binary crossover (SBX) operator are used in solving multi-objective test problems [14]. It shows that it has an advantage compared to other optimization tools. An extension of ARA is proposed in the study of [11]. All vapors are dynamically divided into several small-sized groups according to the relative distance of vapors in each generation. It has been compared and tested using CEC2005 contest benchmark and showed a better performance. Jiang et al. also conducted a numerical experiment on the optimal approximations of a typical stable linear system in two fixed intervals using ARA [10]. Based on the previous studies, ARA has not been used in the optimization problem of blood glucose measurement.

III. METHODOLOGY

The block diagram of the system is shown in Figure 3. The blood sample will be the input of the system. It will then be measured through the capacitance method. The blood sample will become the dielectric between the parallel plates. The capacitance difference will be the input to the ARA. And the ARA will be the search algorithm to give the equivalent measurement in terms of blood glucose level. The blood glucose level will be displayed through an LCD.

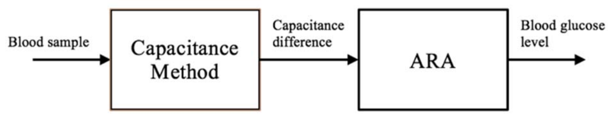

Fig. 3. Block Diagram of the System

A. Capacitance Method

The capacitance method shown in Figure 4 is used for determining the equivalent capacitance difference of the blood sample. The formula for the capacitance method shown in Equation 1.

$$C = \frac{Q}{V} \quad \text{(Eq. 1)}$$

where Q = the charge on the conductor, V = is the potential applied across the conductor, and C = is proportionality constant called as capacitance.

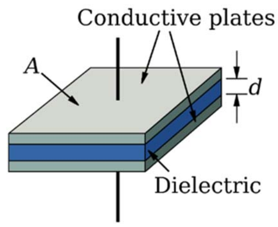

Fig. 4. Capacitance Method

Capacitance method as applied in this study works by placing the blood sample between parallel plates. It will give the dielectric value of the blood sample. Figure 5 shows the parallel plates of conductor used for getting the capacitance difference. The output value of the capacitance method will be input of the microcontroller and will display glucose level and identify the type of diabetes.

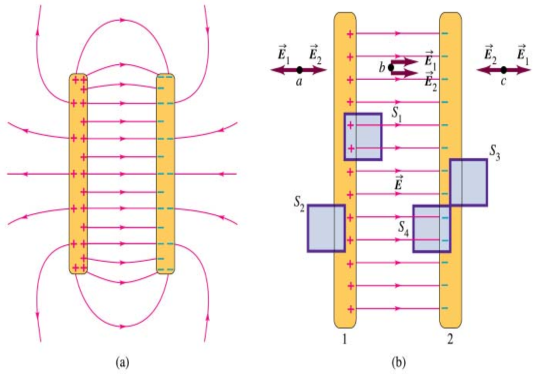

Fig. 5. Parallel Plates

Capacitive sensors have been extensively applied in sensing pressure, acceleration, deformation, displacement, and position. In recent decades, capacitance methods have found new applications in biomedical analysis. By monitoring the cellular membrane capacitance, one can assay cell cycle progression. With the latest development of microfluidics, capacitance sensors have been successfully integrated in lab-on-a-chip devices. Capacitance method renders an attractive option for detection because they are nonintrusive, highly sensitive, and compatible with electrically conducting or insulating liquids.

Figure 6 shows the actual prototype. The distance between the plates are designed experimentally to obtain the nearest value of the equivalent capacitance difference. The case of the device has a dimension of 3.5” in width, 6.2” in length and 2” in height.

Fig. 6. Actual prototype

B. Architecture of ARA

The programming language used is C# since it is compatible for ARA implementation. The program flowchart is shown in Figure 6.

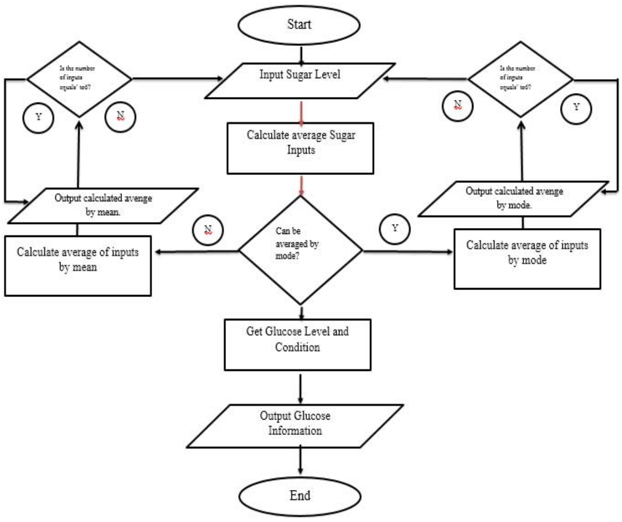

Fig. 6. Program Flow Chart

It starts with the input of blood then calculate the capacitance difference of the sample and will be determined if the input sample can be calculated by mode. The process will repeat itself until it reaches six measured values. And will pick the value that is repeated. If the measured value does not have a repeating value, the measured capacitance difference will be average to present as a result. After the result of the capacitance difference it will be converted into the glucose level and displayed as the final result.

C. Experimental Setup

Blood samples are obtained from 65 patients in the presence of 2 medical technologists and 1 doctor of Pilar Health Center. Each blood samples were measured simultaneously with the device and the FBS laboratory procedure.

In using the prototype, a drop of blood is to be placed in the glass slide which is positioned between two parallel copper plates. The glucose level will be determined through the capacitance difference measured using a capacitance meter attached to the plates. The result will be forwarded to the database created to compare the results of the glucometer and capacitance difference and an algorithm is used to pick out the best outcome which will be the determining factor for the accuracy of the said device.

IV. RESULTS AND DISCUSSION

The parallel copper plates were placed on top and bottom of the glass slide. The positions were known through some experiments which lead to this decision. With the plates placed on those positions, the distance of the sample from the parallel plates will always be equal regardless of its position on the glass slide.

Table 2 shows the experiment result conducted to obtain the correct distance of two parallel plates. It shows that the smaller the distance between the plates the more significant the difference of the capacitance. For this experiment it is decided that the plates are in horizontal position.

TABLE II. Plate Distance Approximation Data

Sample	Expected Value (pF)	Capacitance Difference (pF) Distance 0.5 in.	1.0 in.	1.5 in.
Patient 1	33	33.3	27	26
Patient 2	33	35.4	27.5	26.6
Patient 3	33	33.6	28.0	25.0
Patient 4	36	36.2	30.7	27.9
Patient 5	35	35.5	27.6	26.6

Based on the experiments conducted shown in Figure 7, using the laboratory testing and device, the device can reach the 96.92% accuracy which is the same as the laboratory testing. The said result came from the factor called time lapse which lessens the problem of the laboratory testing because after pricking, the blood can instantly be inserted to the device. The said laboratory testing's accuracy depends on the time duration that the blood will be inserted to the blood analyzer or machine because it is said that the glucose in the blood can break down rapidly. According to experts, the time frame that the glucose will breakdown is around 30 minutes after extraction to the body. But, the standard time that the blood will be placed in the machine has a minimum of 2 – 4 hours, and will still depends on the clinic.

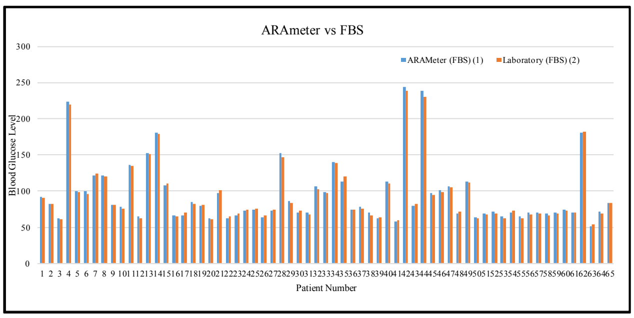

Fig. 7. Accuracy of the Device

V. CONCLUSION

Based on the findings and results of the study, the glucose level of the blood was successfully measured using capacitance method. Thus, glucose level and capacitance value has an inverse linear relationship. The ARA was successfully used as a new system or algorithm to internally find the best value from the data gathered through repetitively monitoring of the capacitance value. But, with the device, the ARA records the variation of capacitance values and then will repeatedly look and record for the data which has the same values and then converts it to glucose level reading. The device successfully performed its function by proving that the data produced an accuracy of 96.92% as compared to the laboratory testing results. A range of +5 and -5 is used to compare the result, concluding that these methods are close but not identical.

However, it is recommended to use other clustering methods to utilize more the capability of ARA as an optimizing and searching technique.

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