**Table of Contents**

Table of Figures 3

Introduction to Fuzzy Logic 4

Brainstorming

References

**Table of Figures**

Figure 1. Example Membership Functions

Figure 2. Brainstorming

**Introduction to Fuzzy Logic**

Fuzzy logic systems, along with genetic algorithms and neural networks, are an important facet of advanced computational techniques. Sometimes, it is difficult to know the exact parameters and data points of a system. In these cases, programmers use what is known as “fuzzy” logic to simulate the system. For example, rather than knowing that an air conditioning system should turn on the heat when the temperature drops below 70 degrees Fahrenheit, we tell the system to turn on the heat when the temperature is “low.” These “fuzzy rules,” as they are called, define the behavior of the system. This approach to simulating behavior “mimics how a person would make decisions, only much faster” (Kaehler).

Fuzzy logic follows three basic steps: creating the rules, determining membership, and defuzzification. The team’s project will walk through these three steps in greater detail; however, a description of each step is as follows:

1. Creating the rules: First, the parameters of the system are defined. In the case of an air conditioning system, these would be the change in temperature and the rate of change in temperature. Fuzzy rules are then created for every combination of parameters in the form of an antecedent block (If x and y) followed by a consequent block (Then z). For example, one rule for the previously-mentioned air conditioning system would be, “If the temperature has decreased and the temperature is still decreasing, then turn on the heat.” Large systems, such as the one the team will create in this project, could require a plethora of rules.
2. Determining membership: The next step is to construct membership functions for each of the parameters in the system. Example membership functions for the air conditioning system are as shown below in Figure 1(Kaehler).

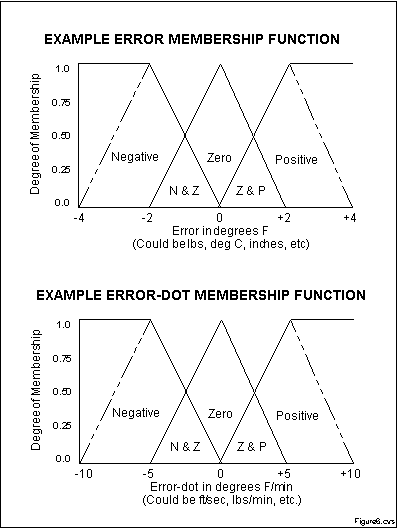


Figure 1. Example Membership Functions

Given that these membership functions provide a range of possible values for each parameter, it is now possible to match up the given values into the system with a value on this function. For example, an error in degrees of -1 degrees Fahrenheit would give a membership of 0.50 for Negative and 0.50 for Zero. The same process is applied for every membership function to give a membership for every possible linguistic variable.

1. Defuzzification: Using the calculated membership values, the rules are followed using logical AND procedures. For example, in the rule, “If the temperature has decreased and the temperature is still decreasing, then turn on the heat,” if the membership of decreased temperature is 0.5, and the membership of decreasing temperature is 0.25, turn on heat would result in 0.25. This procedure is followed for every rule. The rules are then grouped by output and one of several defuzzification methods can be used to determine a crisp numerical output. The team’s chosen defuzzification method will be addressed in greater detail later in the report.

Upon following these three steps, the program should produce one crisp output for each set of input values to the system. In much the same way that human behavior works, this crisp output will determine the actions needed to put the system at an ideal state. In this way, fuzzy logic can be applied to many control systems from HVAC to fuel injection.

**Brainstorming**

To begin, the team spent an afternoon researching and brainstorming possible ideas for a fuzzy logic system. The team eventually decided on modeling a glucose monitoring system for diabetic patients. Given the prevalence of diabetes in the general population and the serious ramifications of not properly modulating glucose levels, the team believes this system has significant real-world applications.

Given the inexperience of the team members with glucose levels and rates, the team spent time researching ideal levels of glucose and rate of change of glucose in diabetes patients. These data points will allow us to estimate which levels and rates are too low, ideal, or too high and will serve as the range of acceptable results for the various parameters. According to Spero, an ideal glucose level for those with diabetes is about 100 mg/dL (2016). A low glucose level is about 50 mg/dL, and a high glucose level is about 150 mg/dL. According to the scholarly article written by Dunn, Eastman, and Tamada, glucose typically decreases at a rate of about -1 mg/dL/min, whereas glucose typically increases at a rate of about +1 mg/dL/min (2004).

To modulate the glucose level in the team’s fictional patients, three parameters were analyzed: the current glucose level, the rate of change in glucose level, and the activity level. These three parameters are the three factors that play the largest role in regulating the glucose level of a diabetic patient. The team set three linguistic variables for the current glucose level: low, ideal, and high, three variables for the rate of change in glucose level: decreasing, constant, and increasing, and four variables for activity level: resting, minimal, intermediate, and rigorous. The team then created one-parameter fuzzy rules for each of these parameters, as shown in Figure 2, below.

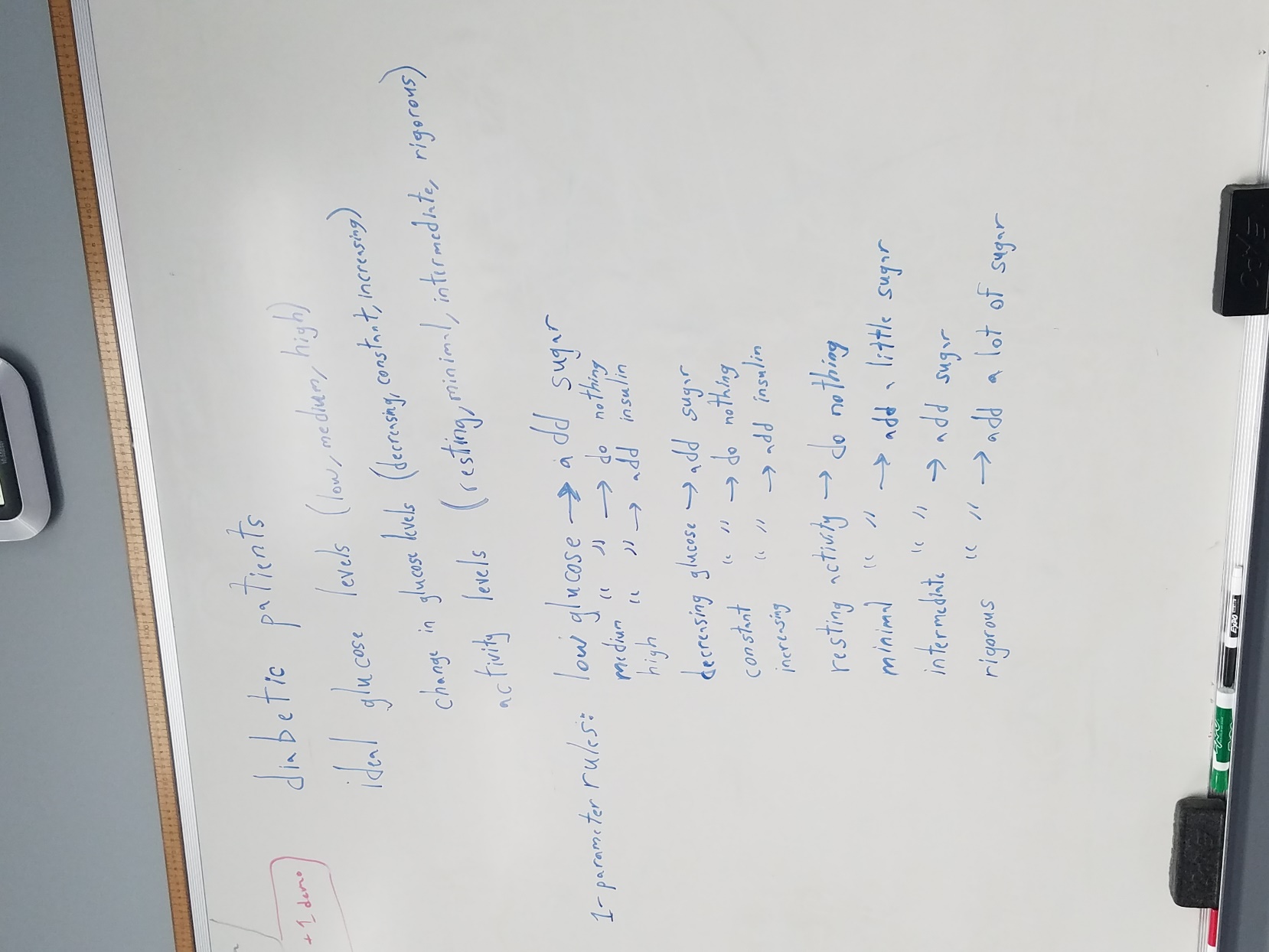


Figure 2. Brainstorming

Between this initial brainstorming session and the final project, only the number of activity levels was changed. Rather than using four activity levels, the team decided to use two activity levels, thus eliminating the need for qualifiers in the output (i.e. “add a lot of sugar”). After this brainstorming session, the team still needed to accomplish three critical tasks: finishing writing the multi-parameter rules, creating the membership functions, and determining the defuzzification method. The team split up these tasks accordingly and proceeded to code the program.

**References**

Dunn, T. C., Eastman, R. C., & Tamada, J. A. (Sep. 2004). Rates of Glucose Change Measured by Blood Glucose Meter and the GlucoWatch Biographer During Day, Night, and Around Mealtimes. *Diabetes Care*, 27(9), 2161-2165. Retrieved from http://care.diabetesjournals.org/content/27/9/2161

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