Ministry of Education and Science of the Russian Federation
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Institute of Computer Sciences and Technologies
Graduate School of Cyber-Physical Systems and Control

Practice Task – Ch 9

Fuzzy Logic
Discipline: Intellectual Computing
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Student Group: 13541/8

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Contents

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Introduction

Chapter 9 of "AI Application Programming" by M. Tim Jones is about Fuzzy Logic. A fuzzy control is created to control the charger of a battery. The battery's state can be described by its voltage and temperature levels. Additionally, two different fuzzy methods are used, fuzzy sets and Mamdani. The battery's voltage is increased by a two-state charger for fuzzy sets and a variable charger for Mamdani. The voltage is reduced by a simple sinusoidal curve, to represent a connected device. The fuzzy controller is used to monitor the battery's voltage and temperature level and control which state the charge is in (trickle/fast, variable).

A sample C# program has been created to show the of fuzzy logic. The user may adjust the initial voltage, initial temperature, charging rates, and discharging rates. Additionally, the user may choose to simulate using fuzzy sets or using the Mamdani method.

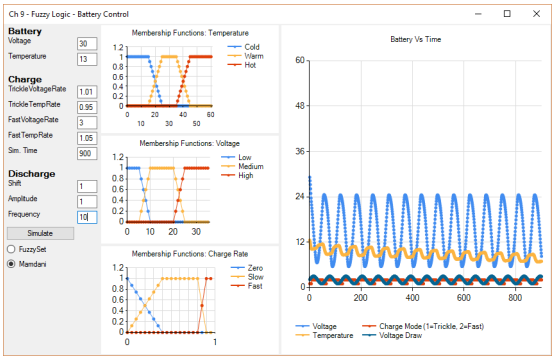

Figure 1: C# Sample Program

Background

Fuzzy logic is used to represent degrees of truth or membership to different possible states. In the situation of charging this battery, the charging rate is dependent on the battery voltage and temperature, which are converted to fuzzy values via two fuzzy membership functions and later processed through three fuzzy rules. These fuzzy values are then used with a defuzzification process to control the charger.

Membership functions

Membership functions are used for the voltage and temperature to convert crisp sensor data into linguistic data. Voltage is converted into degrees of low, medium, or high. Temperature is converted into degrees of cold, warm and hot. These are then used by the fuzzy rules.

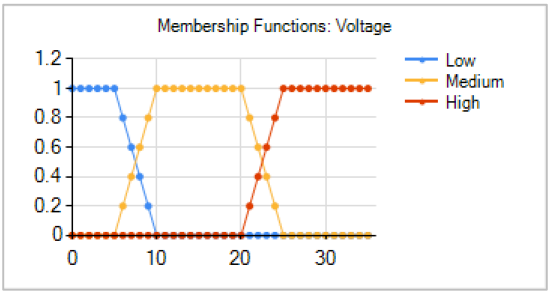

Figure 2: Membership Func. Voltage

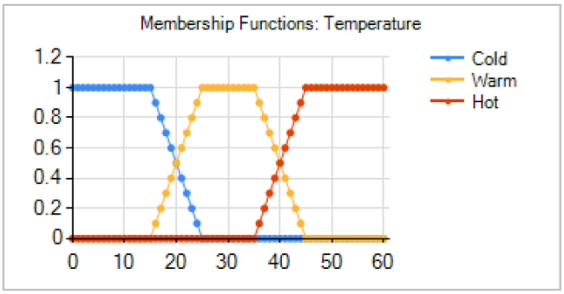

Figure 3: Membership Func. Temperature

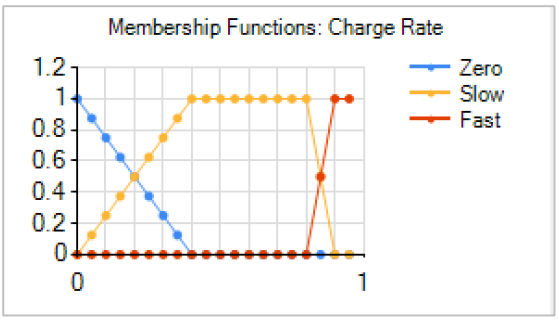

Figure 4: Membership Func. Charge Rate

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Fuzzy Set Rules

The rules and defined linguistically but are still related to mathematical operations of the values produced by the membership functions. The basic axioms are shown in figure 4. Below are the three linguistic rules that must be considered for controlling the charger state.

Truth(A OR B)	MAX(truth(A), truth(B))
Truth(A AND B)	MIN(truth(A), truth(B))
Truth(NOT A)	1.0 - truth(A)

Figure 5: Fuzzy Axioms

1. If the voltage is high, then the mode is trickle charge.
2. If the temperature is hot, then the mode is trickle charge.
3. If the voltage is not high and the temperature is not hot, then fast charge.

Mamdani Method Rules

The Mamdani method is significantly more complex, and requires more rules. It uses 5 rules instead of 3 rules. Additionally, it uses the centroid of the combined area of the rules, which requires significantly more calculation effort.

		Temperature		
		Cold	**Warm**	**Hot**
Voltage	**Low**	Fast	Slow	Zero
	Medium	Slow	Slow	Zero
	High	Zero	Zero	Zero

1.) Voltage high or Temperature high => Charge zero
2.) Voltage low and Temperature cold => Charge fast
3.) Voltage low and Temperature warm => Charge slow
4.) Voltage medium and Temperature cold => Charge slow
5.) Voltage medium and Temperature warm => Charge slow

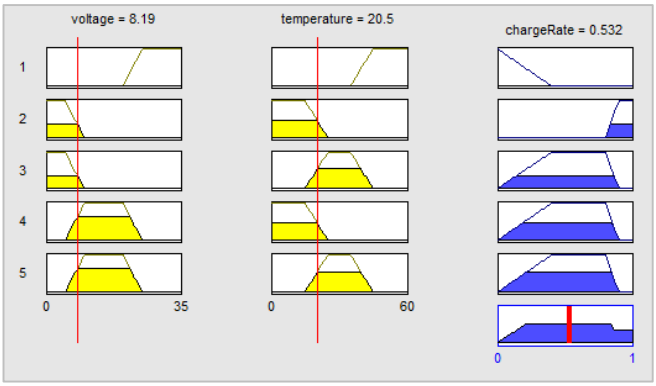

Figure 6: Mamdani Centroid Calculation

The clipped area is calculated for each rule above. These areas are then combined and the centroid is calculated, which is used as the final response of the fuzzy controller. (See figure 6).

When the different membership functions for input and output are combined, a grid of response possibilities can be produced. (See figure 7).

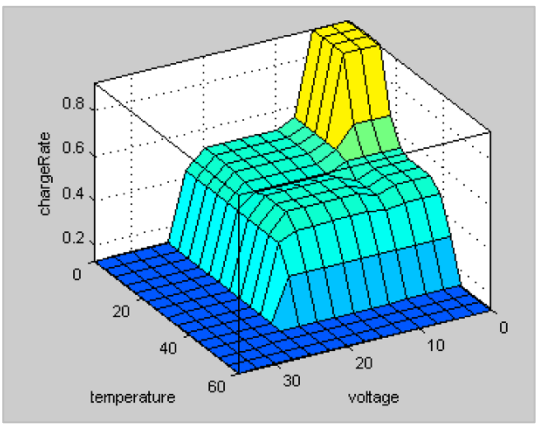

Figure 7: Combined Response (Mamdani)

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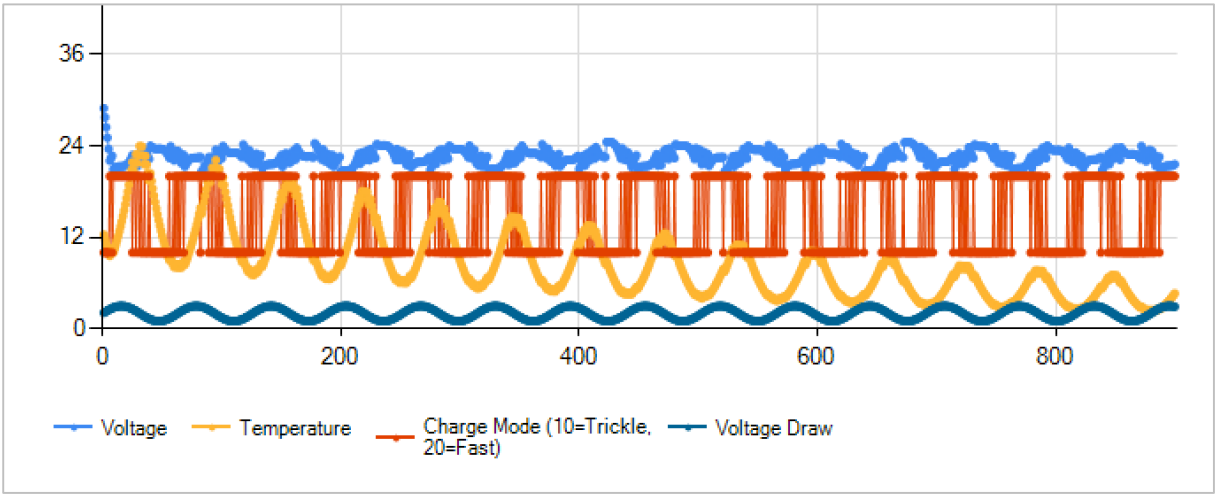
Results

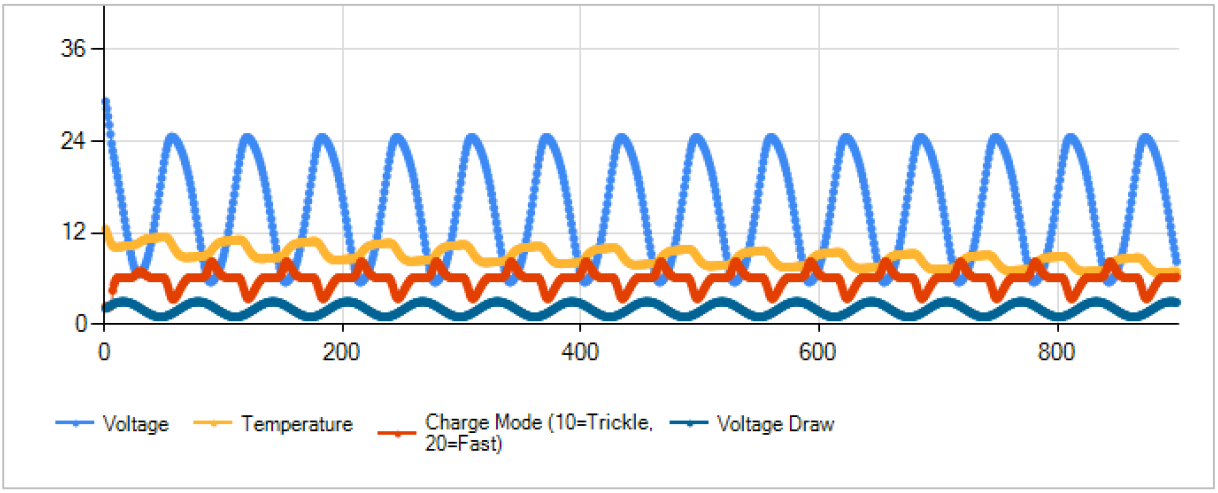
Two charts of battery vs time are produced which show the comparison of the fuzzy set method and the more complex Mamdani method. Both methods are fairly stable. Notes about each graph are below.

Fuzzy Set Method



1.) The charger switches charge states very often, because it oscillates around a voltage transition area from the membership function.
2.) The voltage is in a small window, but it is very erratic.

Mamdani Method



1.) The charging rate has a clear pattern as it shifts between different states.
2.) The voltage oscillates across a large range. However, this oscillation is smooth.

Conclusion

Control of a battery's voltage and temperature during charging is explored. Two methods of fuzzy control are explored, fuzzy sets and Mamdani. The fuzzy sets method is more erratic, but it is in a small windows. It is additionally fast to calculate. The Mamdani method produces a smoother curve, but it has a large oscillation amount. Additionally, the calculation efforts are significantly higher