Project 4: Use fuzzy logic to find the direction of motion of a vehicle.

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***Abstract*—Our proposal in this paper is a novel method to determine the direction of motion of vehicles. In other words, we apply "fuzzy logic," which is essentially a clever strategy for decision-making in uncertain situations. Fuzzy logic and time-series analysis of vehicle movement allow us to more accurately determine whether a vehicle is traveling in the Northeast, Southeast, Southwest, North, East, or Northwest directions. We walk through our systematic methodology and demonstrate how fuzzy logic can contribute to more intelligent transportation systems. Traffic management and self-driving cars could be improved by this research. Additionally, we tried to determine which approach from the various fuzzy logic approaches is more accurate and efficient in terms of results.**

***Index Terms*—Fuzzy logic, vehicle motion, direction estimation, trajectory analysis, intelligent transportation systems.**

I. Introduction

UNDERSTANDING which way vehicles are moving is really important for things like traffic control and self-driving cars. But figuring out direction can be tricky, especially when cars are moving in crowded or confusing environments. Traditional methods for doing this can sometimes struggle when things get complicated. So, we suggest using something called "fuzzy logic," which is like a smart way of making decisions based on uncertain information. It helps us make better decisions when things aren't clear. We're looking at how vehicles move over time and then using fuzzy logic to say if they're going North, East, West, South, Northeast, Southeast, Southwest, or Northwest.unlike other methods which says its is yes or no. fuzzy logic tries to make decision in the ranges like it is kind of true or sort of false.. So it tend to make flexible decisions.

II. Methodology

Data Preprocessing: Load trajectory data from a CSV file containing frame number, track ID, x and y coordinates, width, and height. Filter data is used to select trajectories for analysis based on user-defined track ID.

Calculate Motion Vectors: Compute the difference in centroids (dx and dy) between consecutive frames to determine the direction of motion.

Angle Calculation: We find out which way the vehicle is moving by looking at how much it moves left or right (x) and up or down (y). We use a special math trick called "arctan2" to help us do this.

Using Fuzzy Logic in Practice: We make up fuzzy rules for the eight main directions (like North, Northeast, East, and so on). These rules are like guides that tell us which way the vehicle might be going. Then, we use fuzzy math to figure out how much the vehicle fits into each direction based on its angle.

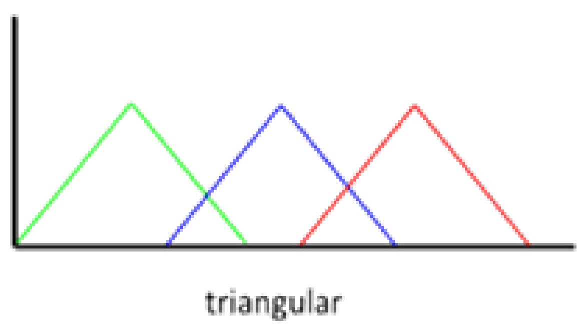
Direction Categorization: Assign the direction with the highest membership value to each data point using the argmax function.

Visualization: Plot the predicted direction on an image overlay with arrows representing vehicle motion between consecutive frames. Add direction annotations around the image to indicate the eight cardinal directions.

III. Different Approaches: Comparision

There are many different membership functions to find fuzzy logic. Here are some of the approaches to identifying the motion of the vehicle using fuzzy logic, and their advantages and disadvantages.

A. Triangular

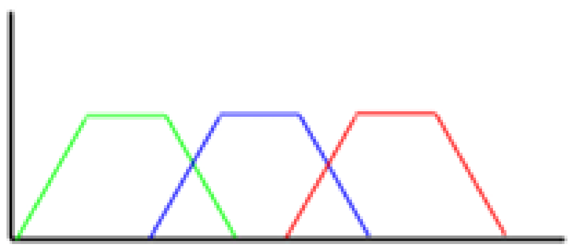


$$\mu_{\text{tri}}(x) = \begin{cases} 0 & \text{if } x \leq a \\ \frac{x-a}{b-a} & \text{if } a \leq x \leq b \\ \frac{c-x}{c-b} & \text{if } b \leq x \leq c \\ 0 & \text{if } x \geq c \end{cases}$$

Define 8 triangular membership features, one for every

route. Each triangle covers a number of stages across the corresponding cardinal or intermediate direction price. The the base of every triangle overlaps slightly with its associates, creating a fuzzy place wherein a heading could belong to a couple of directions with various stages of the club (e.g., a heading of forty levels could have a few memberships in each North and Northeast).
Advantages: Simple to put in force and apprehend.
Disadvantages: Abrupt transitions among directions can cause less accurate predictions, mainly for headings close to boundaries.

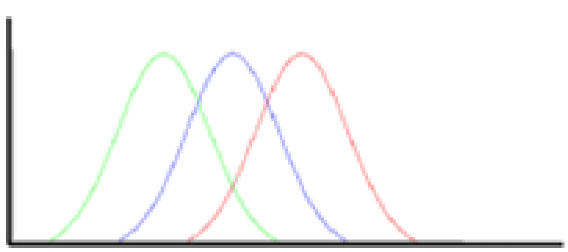
B. Trapezoidal



trapezoidal

Similar to triangular, however, use trapezoids instead. This permits smoother transitions among instructions. The width of the pinnacle and backside of the trapezoid determines the fuzziness of the route barriers. A wider top or backside creates a more sluggish exchange in the club between directions.
Advantages: Offers smoother transitions compared to triangular features, enhancing prediction accuracy close to path limitations.
Disadvantages: Slightly more complex to define and visualize as compared to triangular capabilities.

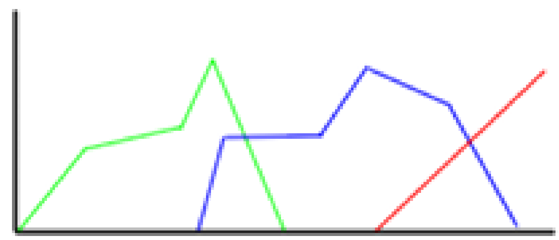
C. Gaussian



Gaussian

Gaussian functions (bell-formed curves) focused on each cardinal and intermediate course cost (0 for North, ninety for East, and many others.). The fashionable deviation of the Gaussian function controls the "unfold" of the curve. A smaller trendy deviation creates a narrower curve, making the course prediction extra specific. Conversely, a larger general deviation creates a much broader curve, main to fuzzier obstacles and ability membership in a couple of directions for certain headings.
Advantages: Provides a clean and herbal illustration of route uncertainty.
Disadvantages: Tuning the usual deviation for each feature requires cautious attention to stability precision and fuzziness.

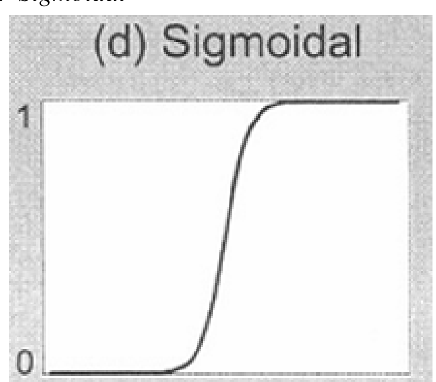
D. Piecewise Linear



Piecewise linear

Divide the 360-degree range into eight segments (one for every course). Within every phase, define a linear membership feature that increases towards 1 as the car heading studying gets towards the middle value of the section (e.G., forty five degrees for Northeast). This creates a "stair-step" sample of membership values for specific guidelines.
Advantages: Computationally efficient and smooth to put in force.
Disadvantages: The linear nature can result in less accurate predictions for headings close to phase obstacles compared to smoother functions like Gaussian or Sigmoid.

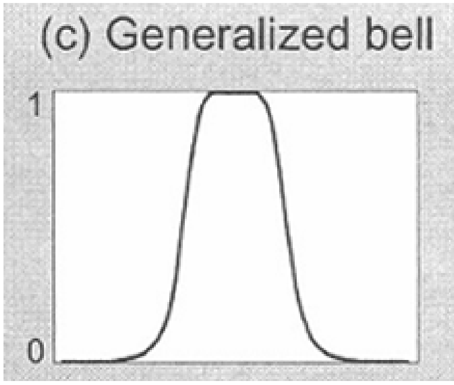
E. Sigmoidal



Use S-fashioned curves, also referred to as sigmoid capabilities, for each path. These curves regularly transition from low club (no longer that path) to high club (that route) because the car heading receives toward the corresponding value. This is especially useful for taking pictures of intermediate instructions like Northeast, where both North and East have some effect on.
Advantages: Excellent for modeling slow transitions between directions, main to greater correct predictions for headings near intermediate directions.
Disadvantages: Sigmoid capabilities may be barely greater complex to outline mathematically compared to less difficult

functions.

F. Generalized bell



These capabilities provide the most flexibility in shape compared to traditional Gaussian capabilities. Imagine bell-shaped curves with adjustable parameters that manipulate the steepness of the curve's aspects and the width of the base. This allows for fine-tuning the fuzziness and impact of different automobile heading readings on the output direction.
Advantages: Most versatile technique, taking into consideration precise control over membership feature form and fuzziness.
Advantages: Requires extra complicated mathematical definitions and careful parameter tuning for gold standard performance.

IV. Results

Fuzzy logic is a mathematical model used to predict the direction of motion of a vehicle from initial frames. The eight directions are assigned angles. Membership functions are also assigned for the directions. The direction having maximum membership function will be the predicted direction in which the vehicle will move. Model also predicts the output of the vehicles from the dataset.

The Gaussian method holds a awesome gain over the triangular approach in fuzzy good judgment structures because of its potential to provide a more correct and practical representation of uncertainty. Unlike triangular club features, that are limited to linear transitions between linguistic phrases, Gaussian capabilities intently replicate the herbal distributions generally located in real-world phenomena. This resemblance to natural distributions permits the Gaussian method to seize the inherent complexity and variability found in many systems with extra fidelity. Moreover, Gaussian features facilitate smoother transitions between linguistic terms, contributing to a greater nuanced and precise illustration of fuzzy sets. By presenting a non-stop and sluggish transition between linguistic phrases, the Gaussian approach minimizes the hazard of abrupt adjustments in output values. Such abrupt adjustments can result in erratic behavior on top of things structures, probably compromising their balance and reliability. Furthermore, Gaussian features offer advanced flexibility in parameter tuning, empowering system designers to great-song the shapes of the club abilities to align more carefully with the particular trends and necessities of the machine being modeled. This flexibility permits the Gaussian technique to comply more efficaciously to numerous conditions and optimize the general overall performance of the fuzzy not unusual experience tool. In essence, the Gaussian method's advanced capability to capture practical uncertainty, facilitate clean transitions, and provide greater flexibility in parameter tuning positions it because the popular choice over the triangular method in lots of applications of fuzzy not unusual sense.

Frm	Track	xc	yc	w	h	Velocity(kmph)
1	1	2373	1324	95	128	0
2	1	2376	1331	94	128	22.12735165
3	1	2378	1338	96	127	21.32106834
4	1	2381	1347	96	129	26.45146189
5	1	2384	1356	97	129	28.12338374
6	1	2387	1363	96	128	25.49540046
7	1	2390	1371	95	130	25.49809004
8	1	2393	1379	94	130	25.47731044
9	1	2395	1387	94	128	25.08667118
10	1	2398	1395	94	128	25.14730526
11	1	2402	1403	94	130	25.58595195
12	1	2405	1412	96	130	26.39773612
13	1	2408	1420	97	130	26.16989314
14	1	2411	1428	94	130	25.98810281
15	1	2413	1437	94	130	26.35463835
16	1	2416	1445	94	130	26.15008535
17	1	2419	1453	94	130	25.97926713
18	1	2422	1462	95	129	26.44989327
19	1	2425	1469	95	130	25.66228096
20	1	2427	1477	95	130	25.37886817

Table 1: Given dataset

Table 1 contains the first 20 frames of vehicle no.1 from the given dataset. It has frame numbers, the track ID of the vehicle, x-coordinate(xc) and y-coordinate(yc), the width and height of the boundary box, and its velocity.

Frm	angle	S	SW	direction
1				
2	1.1659045	0.5155242	0.4844757	S
3	1.2924966	0.3543421	0.6456578	SW
4	1.2490457	0.4096655	0.5903344	SW
5	1.2490457	0.4096655	0.5903344	SW
6	1.1659045	0.5155242	0.4844757	S
7	1.2120256	0.4568010	0.5431989	SW
8	1.2120256	0.4568010	0.5431989	SW
9	1.3258176	0.3119165	0.6880834	SW
10	1.2120256	0.4568010	0.5431989	SW
11	1.1071487	0.5903344	0.4096655	S
12	1.2490457	0.4096655	0.5903344	SW
13	1.2120256	0.4568010	0.5431989	SW
14	1.2120256	0.4568010	0.5431989	SW
15	1.3521273	0.2784179	0.7215820	SW
16	1.2120256	0.4568010	0.5431989	SW
17	1.2120256	0.4568010	0.5431989	SW
18	1.2490457	0.4096655	0.5903344	SW
19	1.1659045	0.5155242	0.4844757	S
20	1.3258176	0.3119165	0.6880834	SW

Table 2: Results

Table 2 contains the output predicted by the fuzzy logic. Here, the angle is the angle between two consecutive frames, and S (south) and SW (southwest) indicate the membership value in that direction. For this example, the vehicle has no membership value in N, NW, NE, W, E, or SE directions. From the two membership values model predicts the direction in which the value is higher, which is shown in the direction column in table 2.

V. Discussion

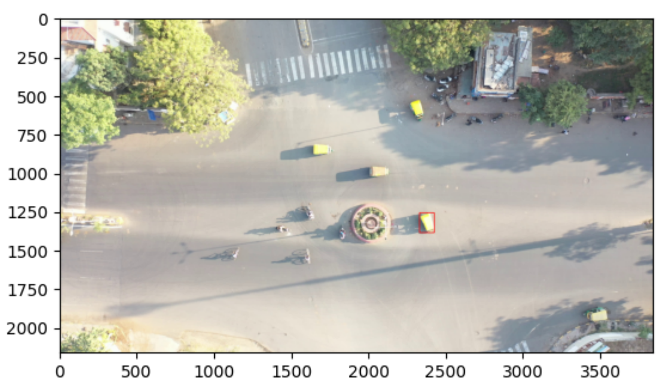


Image 1
In image 1, it detects vehicle 1 and creates the boundary box around it with the given data shown in Table 1.

Image 2
Image 2 shows the direction in which vehicle 1 is going in the given dataset, which is the same as the direction predicted by the fuzzy logic which are S and SW, given in table 2.

Image 3
Image 3 shows the example of object 13's trajectory direction.

VI. Summary

In summary, our study shows that using fuzzy logic can help us figure out which way vehicles are moving more accurately. This could make traffic control and self-driving cars better. While fuzzy logic is flexible, we still need to make it work in real-time better. In the future, we can improve fuzzy logic and use it with other technologies like machine learning to make direction estimation even better. This would help transportation systems become more efficient and safer.

VII. References

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