



**Ahmedabad
University**

Report 4

CSE523 Machine Learning Section-1

Group members:

Kushalkumar Suthar (AU2140122)

Dhruvin Prajapati (AU2140064)

Rohit Rathi (AU2140023)

Krutarth Trivedi (AU2140141)

Problem Statement :

Fuzzy Logic for Vehicle Motion Direction Detection

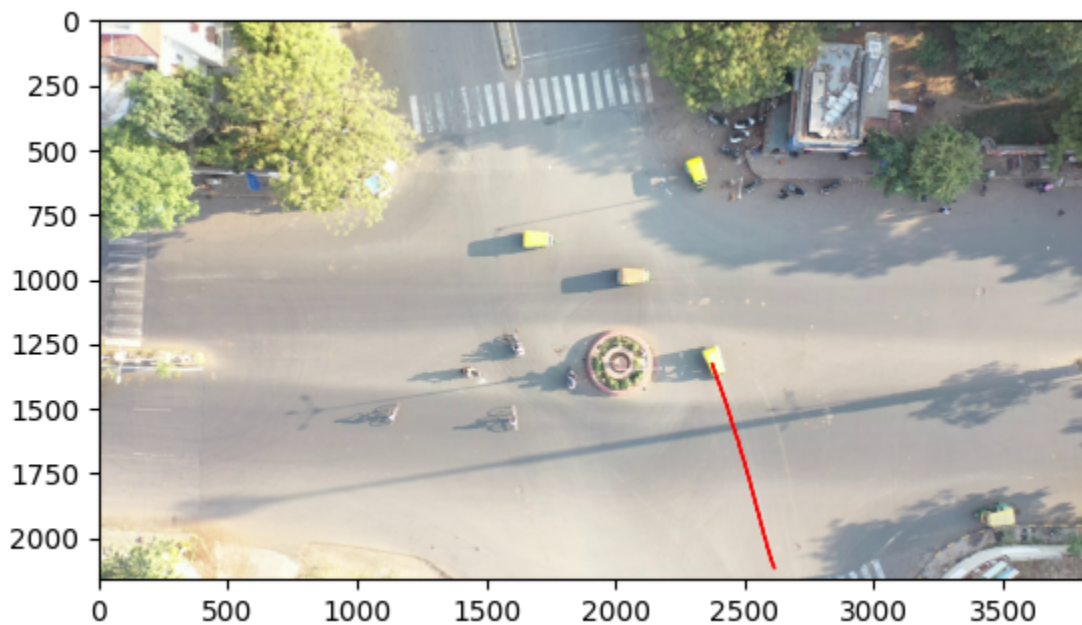
There are many different types of membership functions, used to represent the degree of membership of an element in a fuzzy set. The most commonly used membership functions are Triangular, Trapezoidal, Gaussian, Piecewise linear, Sigmoidal, and Bell-shaped.

- **Input data**

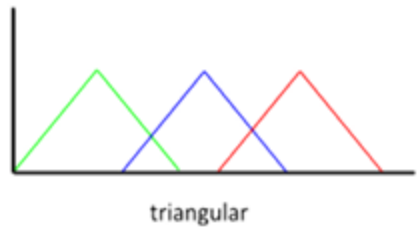
Frm	Track	xc	yc	w	h	Velocity(kmph)
1	1	2373	1324	95	128	0
2	1	2376	1331	94	128	22.12735165
3	1	2378	1338	96	127	21.32106834
4	1	2381	1347	96	129	26.45146189
5	1	2384	1356	97	129	28.12338374
6	1	2387	1363	96	128	25.49540046
7	1	2390	1371	95	130	25.49809004
8	1	2393	1379	94	130	25.47731044
9	1	2395	1387	94	128	25.08667118
10	1	2398	1395	94	128	25.14730526

>>> This is an example of input data of vehicle no. 1 in the first 10 frames.

- **The actual direction of the vehicle no.1**



1. Triangular



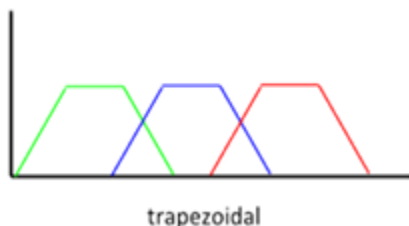
The triangular membership function involves three parameters: left edge, peak, and right edge. This resembles a triangle shape hence its name. Fuzzy systems commonly use these functions to represent qualitative linguistic variables where the maximum value represents the most typical or prototypical value. Membership degree increases linearly from the left edge up to the summit point and decreases linearly from the peak point down to the right edge.

- **Predicted direction**

angle	N	NE	E	SE	S	SW	W	NW	direction
1.165905		0	0	0	0	0.515524	0.484476	0	0 S
1.292497		0	0	0	0	0.354342	0.645658	0	0 SW
1.249046		0	0	0	0	0.409666	0.590334	0	0 SW
1.249046		0	0	0	0	0.409666	0.590334	0	0 SW
1.165905		0	0	0	0	0.515524	0.484476	0	0 S
1.212026		0	0	0	0	0.456801	0.543199	0	0 SW
1.212026		0	0	0	0	0.456801	0.543199	0	0 SW
1.325818		0	0	0	0	0.311917	0.688083	0	0 SW
1.212026		0	0	0	0	0.456801	0.543199	0	0 SW

>>> This is example data of the predicted direction of vehicle no. 1 in the first 10 frames, using a triangular approach.

2. Trapezoidal



Trapezoidal membership functions are generally extended for triangular functions with a flat top. They are specified by four parameters: the base's left and right edges as well as the peak's left and right edges. It is suitable for these functions to be used in situations where the fuzzy set has a defined range and not just a single peak since it allows for a wider range of uncertainty representation. Trapezoidal functions are often used in control systems and decision-making processes where multiple conditions need to be examined.

- **Predicted direction**

angle	N	NE	E	SE	S	SW	W	NW	direction
1.165905	0	0	0	0.515524	1	0.484476	0	0	S
1.292497	0	0	0	0.354342	1	0.645658	0	0	S
1.249046	0	0	0	0.409666	1	0.590334	0	0	S
1.249046	0	0	0	0.409666	1	0.590334	0	0	S
1.165905	0	0	0	0.515524	1	0.484476	0	0	S
1.212026	0	0	0	0.456801	1	0.543199	0	0	S
1.212026	0	0	0	0.456801	1	0.543199	0	0	S
1.325818	0	0	0	0.311917	1	0.688083	0	0	S
1.212026	0	0	0	0.456801	1	0.543199	0	0	S

>>> This is example data of the predicted direction of vehicle no. 1 in the first 10 frames, using a trapezoidal approach.

3. Gaussian



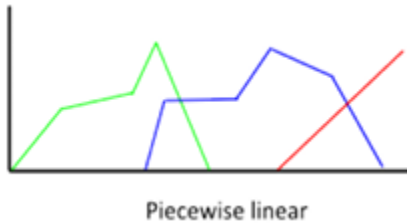
Continuous domain uncertainty is often represented using Gaussian membership functions. The former assumes a bell-shaped curve which has a central peak and tails that drop away gradually. The level of membership assigned to an element within the fuzzy set depends on how close it is to the center of the bell. These functions are especially useful when there is an expectation that the values will follow a normal distribution, as in statistical processes.

• Predicted direction

angle	N	NE	E	SE	S	SW	W	NW	direction
1.165905	2.94E-07	4.30E-05	0.002309	0.045671	0.332263	0.889264	0.875566	0.317143	SW
1.292497	1.20E-07	2.06E-05	0.0013	0.030205	0.258181	0.811852	0.939151	0.399668	W
1.249046	1.64E-07	2.66E-05	0.001588	0.034913	0.282359	0.840088	0.919509	0.37025	W
1.249046	1.64E-07	2.66E-05	0.001588	0.034913	0.282359	0.840088	0.919509	0.37025	W
1.165905	2.94E-07	4.30E-05	0.002309	0.045671	0.332263	0.889264	0.875566	0.317143	SW
1.212026	2.13E-07	3.30E-05	0.001879	0.039403	0.304001	0.862831	0.900921	0.346065	W
1.212026	2.13E-07	3.30E-05	0.001879	0.039403	0.304001	0.862831	0.900921	0.346065	W
1.325818	9.43E-08	1.69E-05	0.001113	0.026975	0.240556	0.789202	0.952513	0.422926	W
1.212026	2.13E-07	3.30E-05	0.001879	0.039403	0.304001	0.862831	0.900921	0.346065	W

>>> This is example data of the predicted direction of vehicle no. 1 in the first 10 frames, using the gaussian approach.

4. Piecewise linear



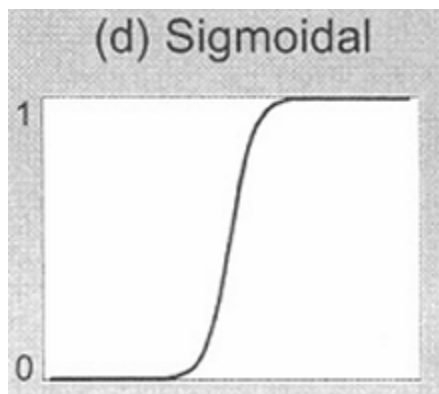
The piecewise linear membership function is created using linear segments, which can be formed from points where the slope of the function changes. They allow different shapes to be approximated by manipulating the number as well as the position of segments. When it needs to be exactly controlled or if complex patterns in underlying data cannot be properly mapped by other types of functions, a piecewise-linear function may come in handy.

- **Predicted direction**

angle	N	NE	E	SE	S	SW	W	NW	direction
1.165905	0	0	0	0.515524	1	0.484476	0	0	S
1.292497	0	0	0	0.354342	1	0.645658	0	0	S
1.249046	0	0	0	0.409666	1	0.590334	0	0	S
1.249046	0	0	0	0.409666	1	0.590334	0	0	S
1.165905	0	0	0	0.515524	1	0.484476	0	0	S
1.212026	0	0	0	0.456801	1	0.543199	0	0	S
1.212026	0	0	0	0.456801	1	0.543199	0	0	S
1.325818	0	0	0	0.311917	1	0.688083	0	0	S
1.212026	0	0	0	0.456801	1	0.543199	0	0	S

>>> This is example data of the predicted direction of vehicle no. 1 in the first 10 frames, using a piecewise linear approach.

5. Sigmoidal



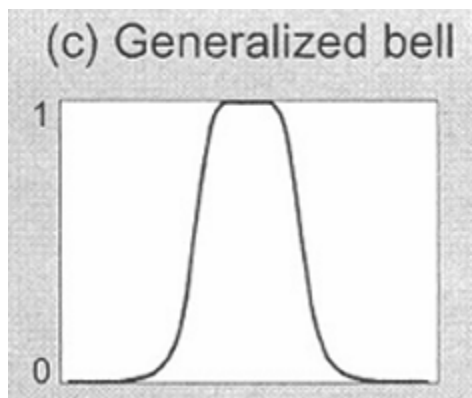
Sigmoidal membership functions look like an “S” curve that gradually changes its value from 0 to 1 or vice versa around some midpoint. They are widely applied for gradual or sigmoidal relationships between the variables such as logistic growth models or representing fuzzy linguistic terms with gradual transitions. Depending on the chosen parameters, sigmoidal functions can take both increasing and decreasing values of membership.

- **Predicted direction**

angle	N	NE	E	SE	S	SW	W	NW	direction
1.165905	0.986712	0.97131	0.939158	0.875588	0.762404	0.593995	0.400138	0.233207	N
1.292497	0.988273	0.974635	0.946002	0.888736	0.784569	0.624126	0.430871	0.256603	N
1.249046	0.987759	0.973538	0.943739	0.884366	0.777134	0.613879	0.420249	0.248403	N
1.249046	0.987759	0.973538	0.943739	0.884366	0.777134	0.613879	0.420249	0.248403	N
1.165905	0.986712	0.97131	0.939158	0.875588	0.762404	0.593995	0.400138	0.233207	N
1.212026	0.987303	0.972568	0.94174	0.880526	0.770657	0.605068	0.411257	0.241556	N
1.212026	0.987303	0.972568	0.94174	0.880526	0.770657	0.605068	0.411257	0.241556	N
1.325818	0.988653	0.975446	0.947679	0.891988	0.790148	0.63191	0.43906	0.263011	N
1.212026	0.987303	0.972568	0.94174	0.880526	0.770657	0.605068	0.411257	0.241556	N

>>> This is example data of the predicted direction of vehicle no. 1 in the first 10 frames, using a sigmoidal approach.

6. Bell-shaped



Bell-shaped membership functions, which resemble Gaussian functions, have central peaks and tails that taper off gently. However, they may differ in parameters allowing flexibility in modeling. They work best when the uncertainty or variability is focused around a central value but the distribution might not follow exactly normal distribution. For instance, bell-shaped functions find their applications in such areas as fuzzy control systems, pattern recognition, and decision support systems.

- **Predicted direction**

angle	N	NE	E	SE	S	SW	W	NW	direction
1.165905	0.000157	0.000524	0.002375	0.017794	0.284765	0.996973	0.995612	0.260158	SW
1.292497	0.000132	0.000424	0.001811	0.012271	0.176615	0.98328	0.999536	0.408418	W
1.249046	0.00014	0.000455	0.001985	0.013908	0.208457	0.990161	0.998891	0.351898	W
1.249046	0.00014	0.000455	0.001985	0.013908	0.208457	0.990161	0.998891	0.351898	W
1.165905	0.000157	0.000524	0.002375	0.017794	0.284765	0.996973	0.995612	0.260158	SW
1.212026	0.000147	0.000484	0.002149	0.015503	0.239813	0.994003	0.99787	0.308312	W
1.212026	0.000147	0.000484	0.002149	0.015503	0.239813	0.994003	0.99787	0.308312	W
1.325818	0.000126	0.000401	0.00169	0.011167	0.155499	0.975685	0.999783	0.455242	W
1.212026	0.000147	0.000484	0.002149	0.015503	0.239813	0.994003	0.99787	0.308312	W

>>> This is example data of the predicted direction of vehicle no. 1 in the first 10 frames, using a bell-shaped approach.

- **Comparison Table**

Method	Shape Flexibility	Computational Complexity	Interpretability	Applicability
Triangular	Limited flexibility, can represent simple shapes	Low complexity, uses simple mathematical functions	Easy to interpret, represents a symmetric triangular shape	Suitable for categorical variables or when only rough estimates are needed
Gaussian	Highly flexible, can represent a wide range of shapes	Moderate complexity due to the Gaussian function	Easy to interpret the center and spread of the curve	Suitable for continuous variables and when a smooth, bell-shaped curve is desired

Trapezoidal	Moderate flexibility can represent trapezoidal shapes	Low to moderate complexity, depending on the parameters	Fairly easy to interpret, it represents a trapezoidal shape with varying slopes	Suitable for variables with defined upper and lower bounds, such as thresholds
Bell-shaped	Highly flexible, can represent various shapes similar to the Gaussian	Moderate complexity due to the bell-shaped function	Easy to interpret, similar to Gaussian but with more parameters to adjust	Suitable for continuous variables and when a smooth, bell-shaped curve is desired
Sigmoidal	Moderate flexibility can represent S-shaped curves	Low complexity, often uses simple mathematical functions	Fairly easy to interpret, it represents an S-shaped curve	Suitable for variables with sigmoidal relationships, such as growth curves
Piecewise Linear	Limited flexibility, represents piecewise linear shapes	Low complexity, uses linear interpolation between points	Easy to interpret, represent straight line segments	Suitable for categorical or ordinal variables with discrete breakpoints

References:

<https://in.mathworks.com/help/fuzzy/foundations-of-fuzzy-logic.html>

https://www.philadelphia.edu.jo/academics/qhamarsheh/uploads/Lecture%2018_Different%20Types%20of%20Membership%20Functions%201.pdf

https://www.ripublication.com/gjpam16/gjpamv12n2_04.pdf

<https://cse.iitkgp.ac.in/~dsamanta/courses/archive/sca/Archives/Chapter%203%20Fuzzy%20Membership%20Functions.pdf>