Fuzzy Logic for Robot Navigation

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Agenda

- Motivation
- Fuzzy logic introduction
- Fuzzy logic-based navigation
- Conclusion
- Discussion

Motivation

- Classical planning approaches are unable to cope with dynamic environment [1]
- Approach the problem of robot navigation in dynamic environment based on fuzzy logic
- Explore advantages and disadvantages of the given approach

Fuzzy logic introduction

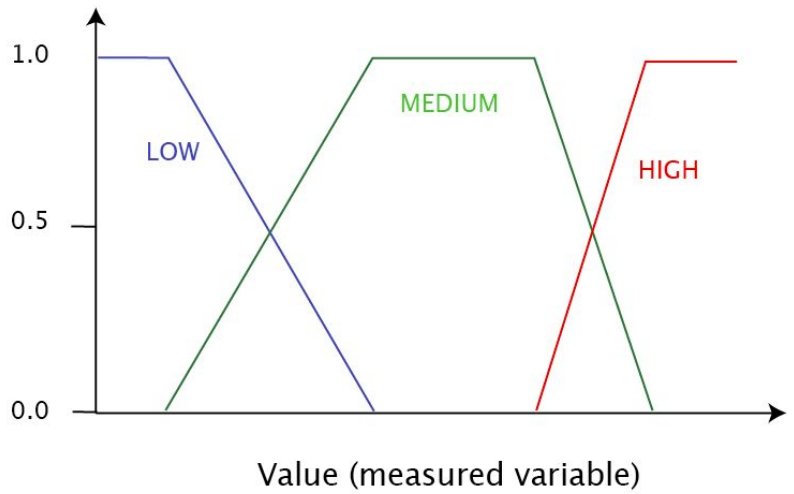
- Fuzzy logic
  - Fuzzy set
  - Membership function
  - ...
- Fuzzy system design
  - Fuzzification / Defuzzification
  - Inference engine
  - ...

Fuzzy sets

$$(U, m) \mid m: U \rightarrow [0, 1]$$

U - universe of discourse

m - membership function



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Fuzzy sets

$$(U, m) \mid m: U \rightarrow [0, 1]$$

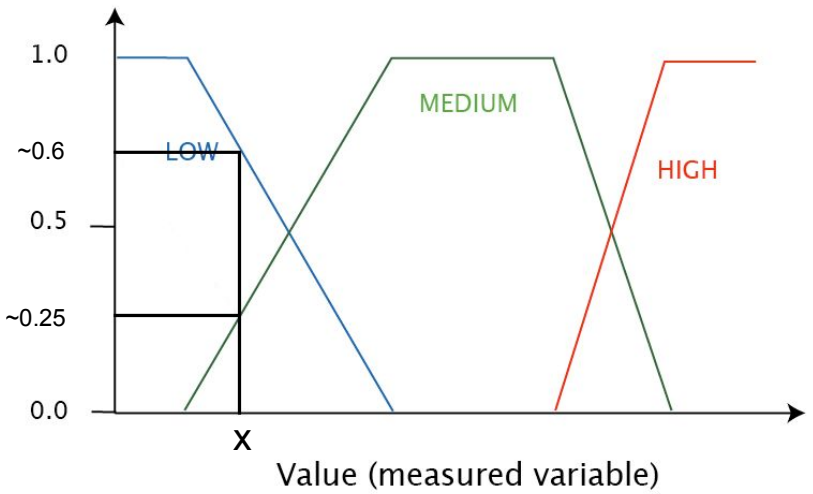
U - universe of discourse

m - membership function

$\mathrm{LOW}(x) \approx 0.6$

$\mathrm{MEDIUM}(x) \approx 0.25$

$\mathrm{HIGH}(x) = 0$



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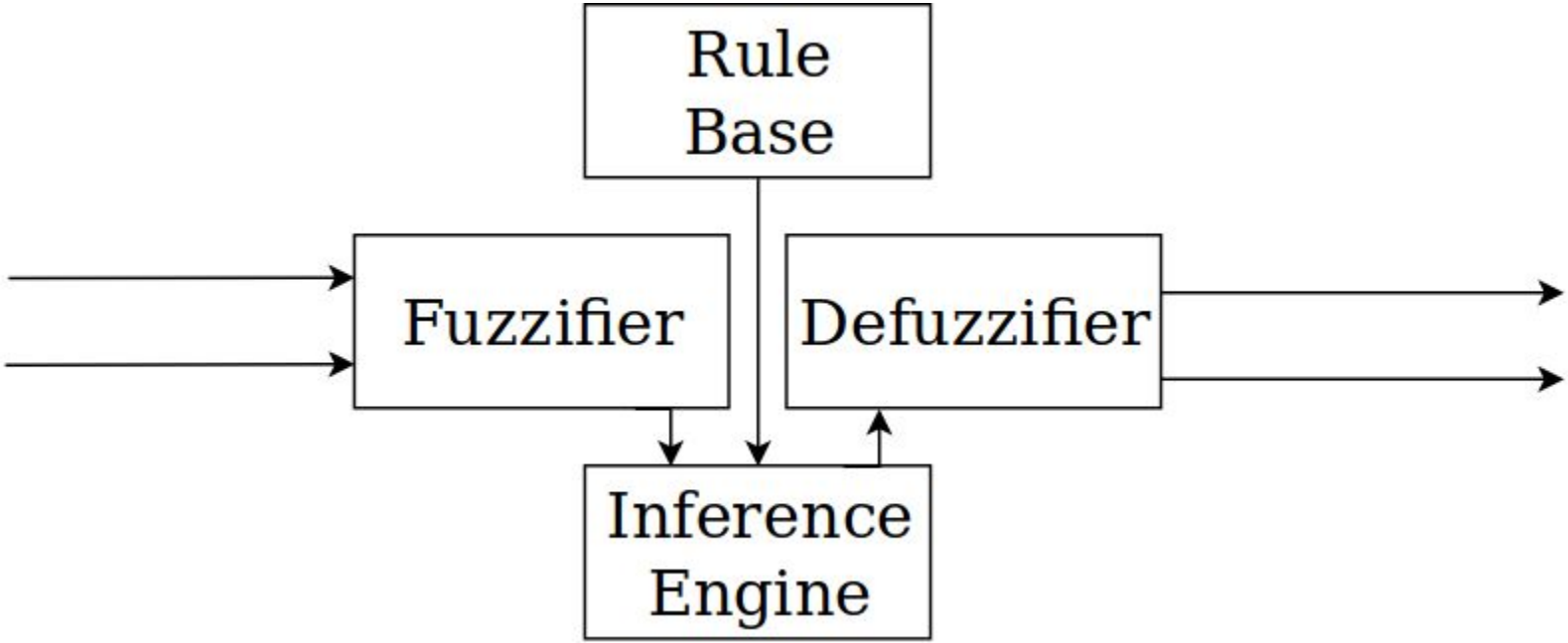
Fuzzy systems



Fuzzifier

real-value inputs	x
↓	↓
membership functions	$\mathrm{LOW}(x), \mathrm{MEDIUM}(x), \mathrm{HIGH}(x)$
↓	↓
truth values	$0.6, 0.25, 0$

Fuzzy Rule Base

Set of “if-then” rules that define system reaction to input

1. if x is LOW then y = 1
2. if x is MEDIUM then y = 2
3. if x is HIGH then y = 3

Fuzzy Inference Engine

- Contains rules to define “logic” in fuzzy logic
  - $m(x \vee y) = MAX(m(x), m(y))$
  - $m(x \wedge y) = MIN(m(x), m(y))$
  - $m(\neg x) = 1 - m(x)$

- Defines the relation between fuzzy input and fuzzy output

Defuzzifier

Produces the output based on the most suitable rule

1. if x is LOW then y = 1
2. if x is MEDIUM then y = 2
3. if x is HIGH then y = 3

$\mathrm{LOW}(x) = 0.6$

$\mathrm{MEDIUM}(x) = 0.25$

$\mathrm{HIGH}(x) = 0$

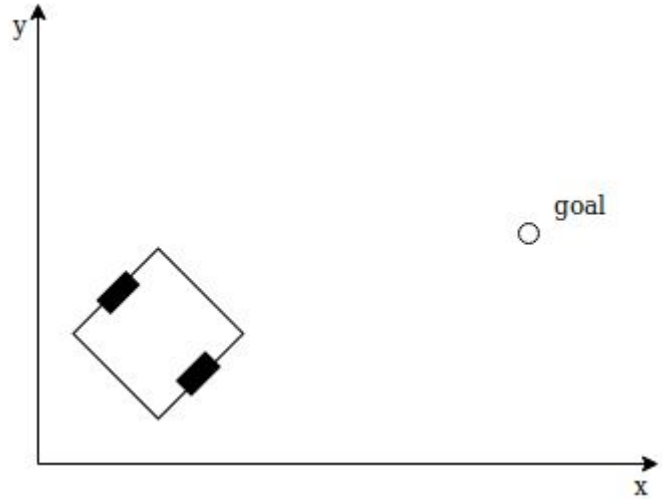
Fuzzy system design for robot navigation

Example fuzzy system - outline

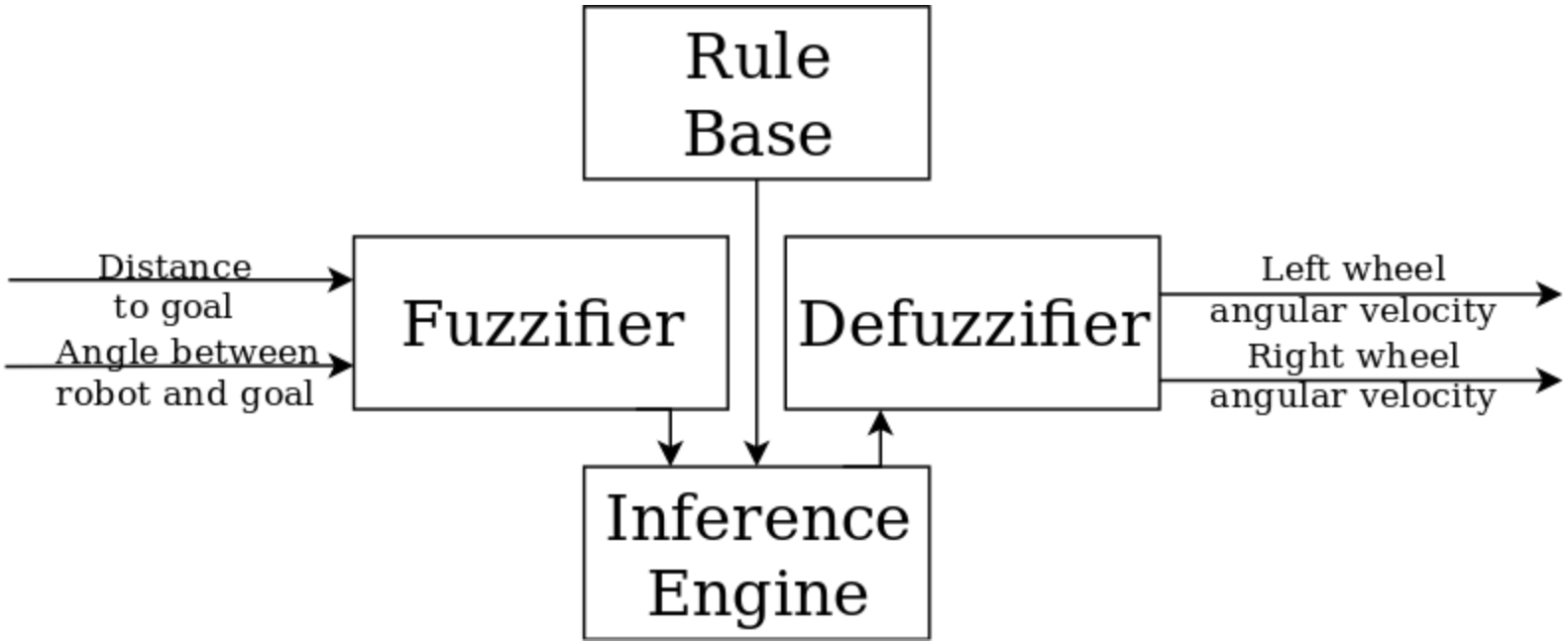
Navigation = goal tracking + obstacle avoidance

Assumptions:

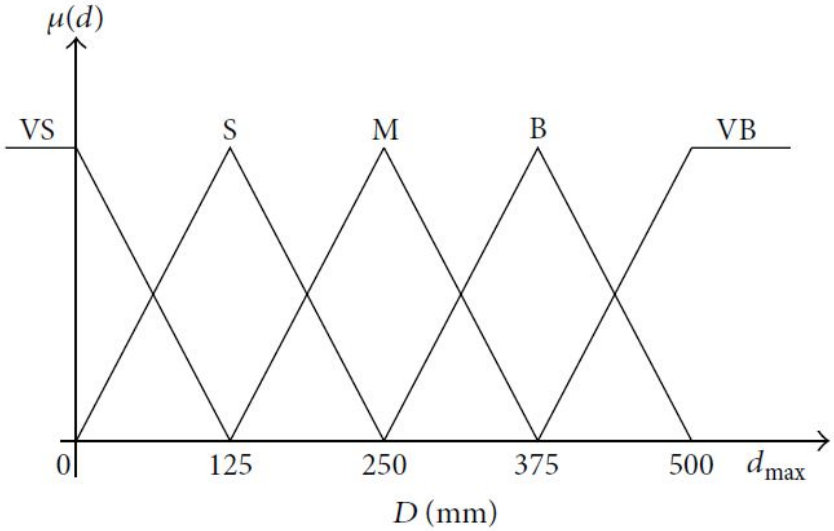
- 2 driving wheels on the same axis
- Goal position is known
- Obstacle positions are not known



Example fuzzy system - goal tracking



Example fuzzy system - goal tracking



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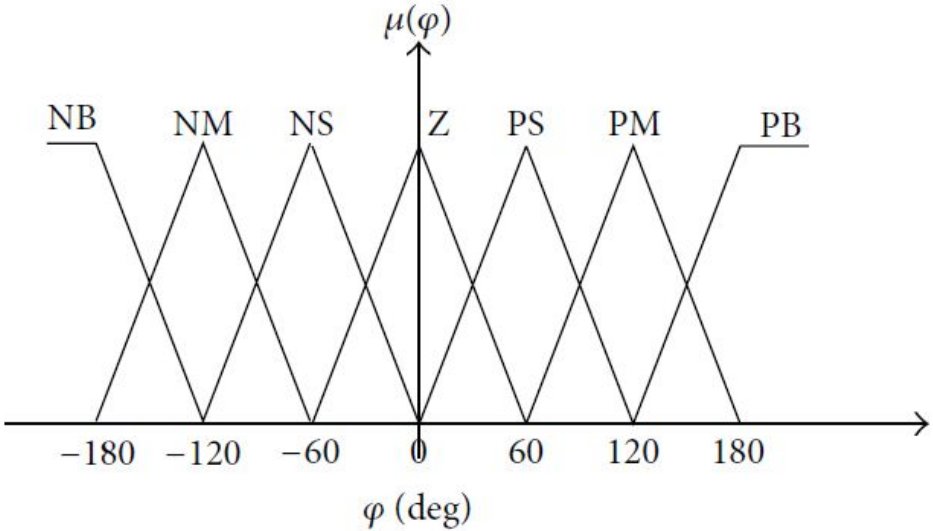


[2]

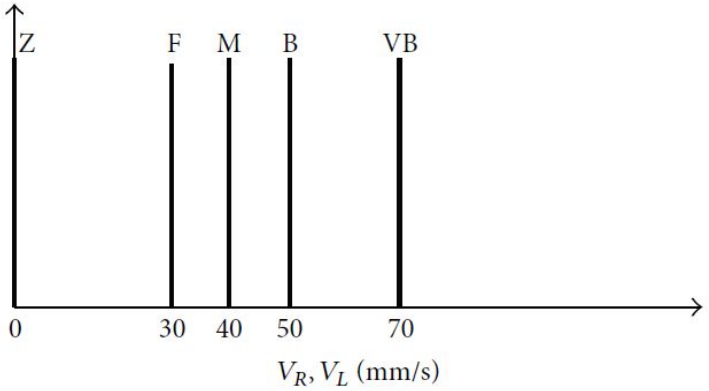
Example fuzzy system - goal tracking

$V_L, V_R = \{Z, F, M, B, VB\}$

		Angle (φ)													
		NB		NM		NS		Z		PS		PM		PB	
		V_R	V_L	V_R	V_L	V_R	V_L	V_R	V_L	V_R	V_L	V_R	V_L	V_R	V_L
Distance (D)	VS	B	Z	M	Z	F	Z	S	F	Z	F	Z	F	Z	M
	S	VB	Z	B	Z	M	Z	S	F	Z	M	Z	B	Z	VB
	M	VB	Z	VB	Z	B	Z	M	M	Z	B	Z	VB	Z	VB
	B	VB	Z	VB	Z	VB	Z	B	B	Z	VB	Z	VB	Z	VB
	VB	VB	Z	VB	Z	VB	Z	VB	VB	Z	VB	Z	VB	Z	VB

[2]

Example fuzzy system - goal tracking



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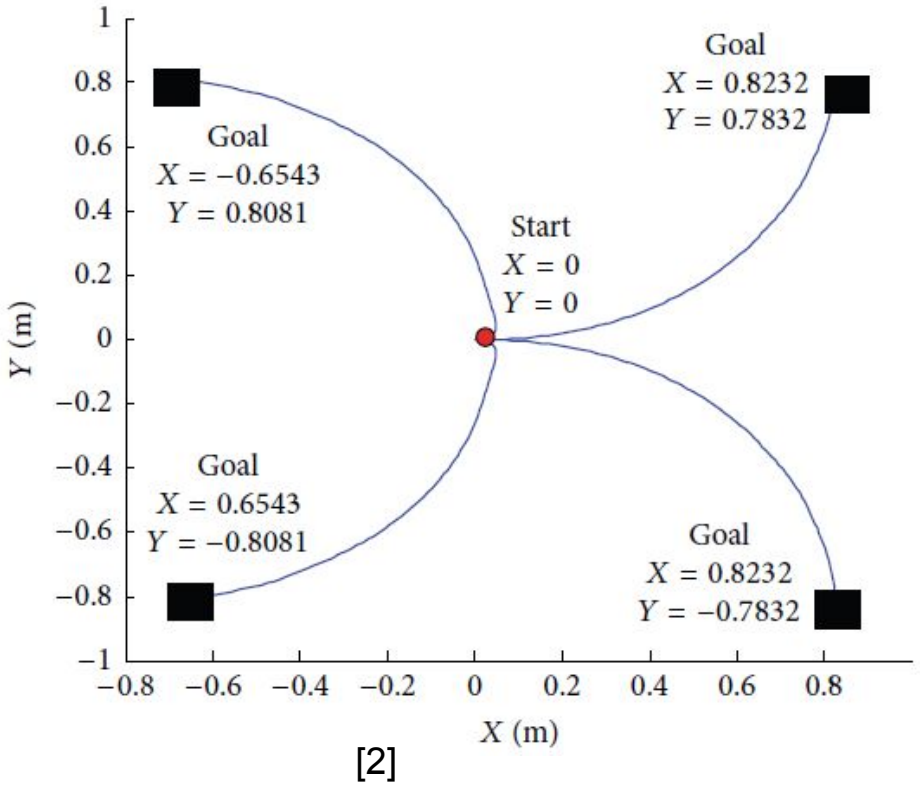

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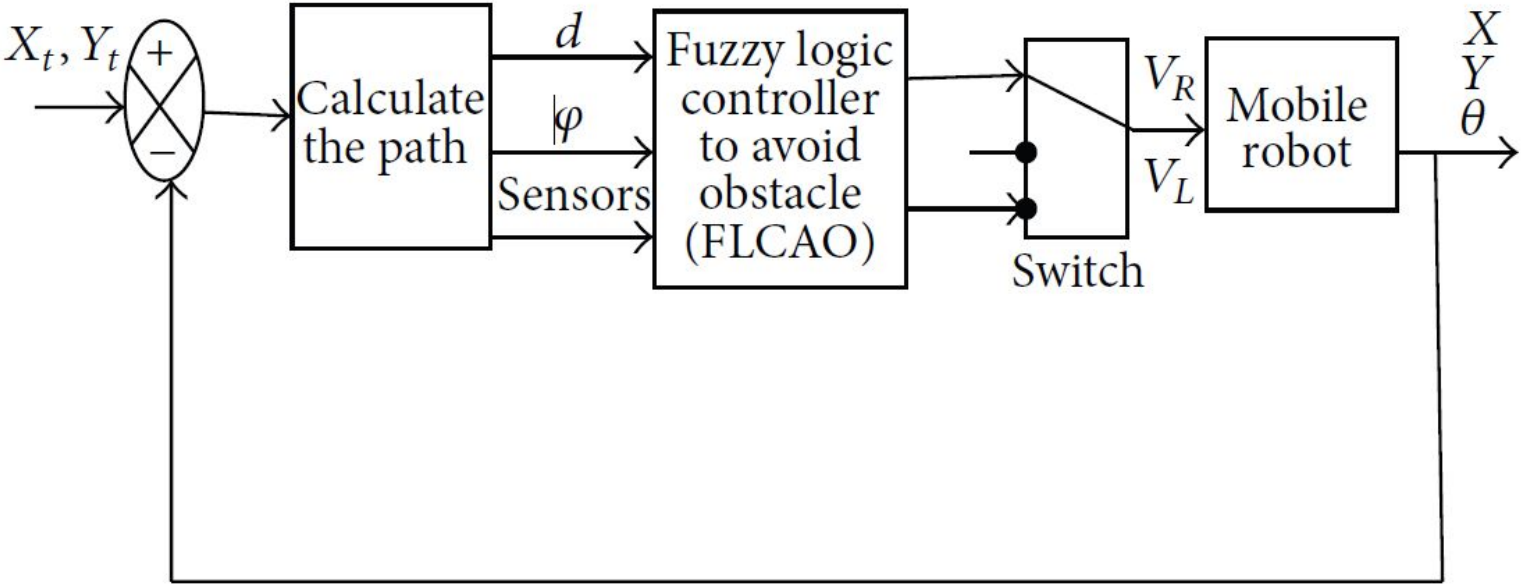
Notes:

- output is discrete
- path is not optimal

Example fuzzy system - obstacle avoidance



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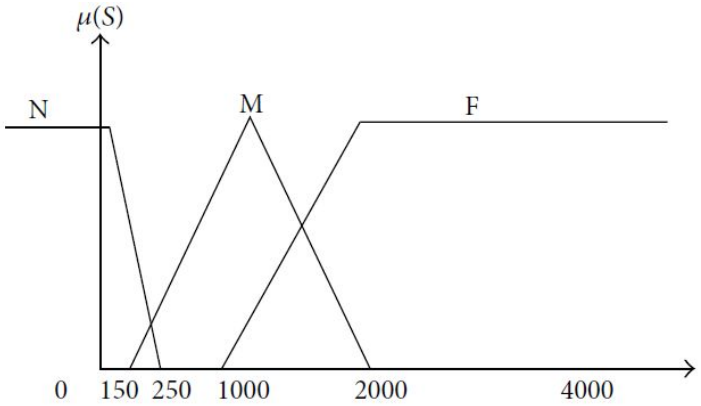
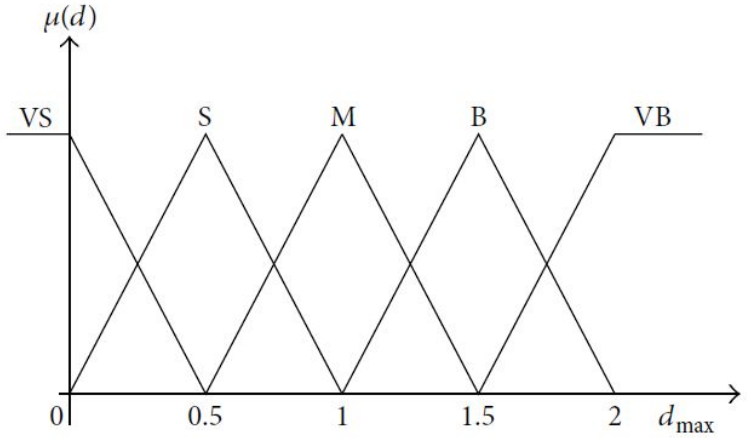
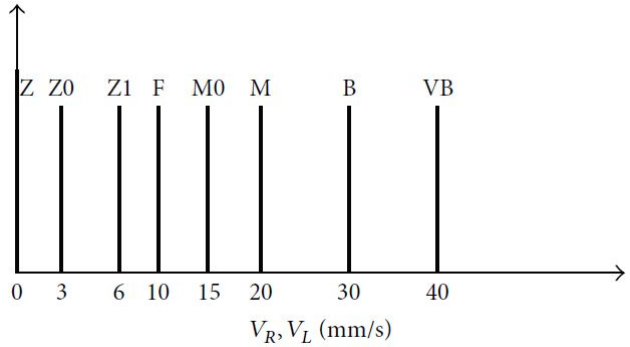
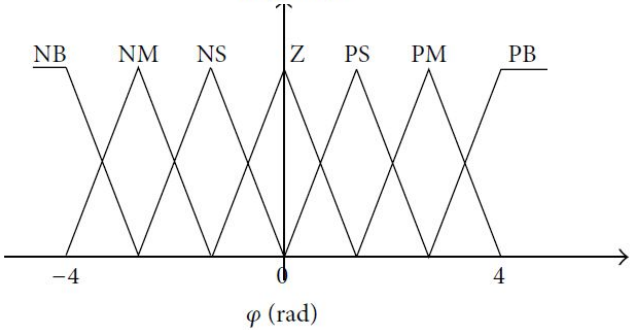
Example fuzzy system - obstacle avoidance







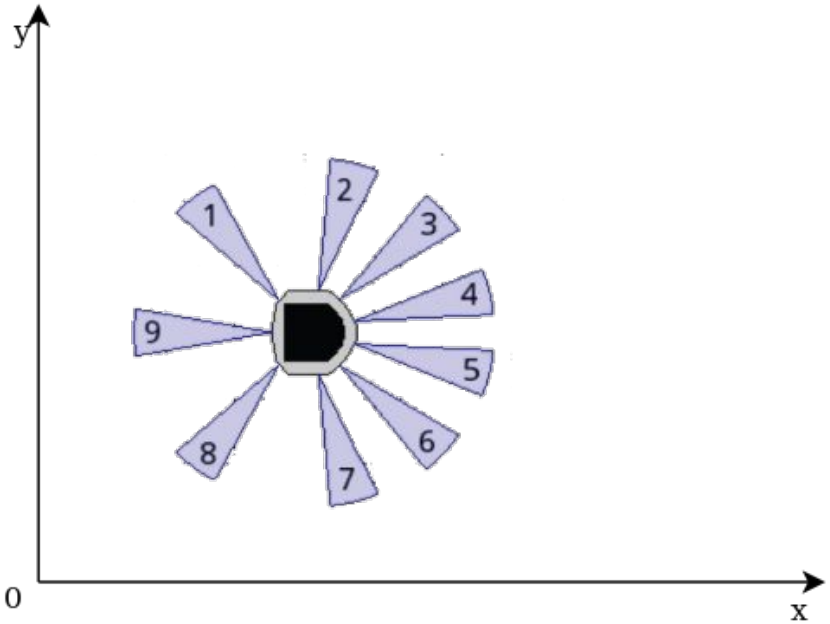


Example fuzzy system - obstacle avoidance

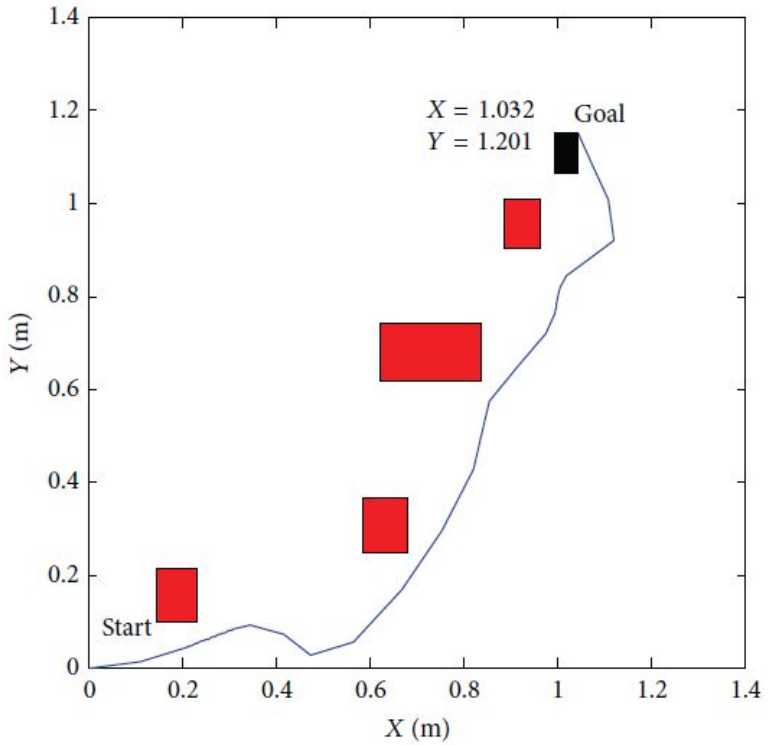
Rule base consists of 62 rules
(Takagi-Sugeno fuzzy inference [3])

Example:

- If (Distance is VS) and (Angle is NB) and (S_1 is F) and (S_2 is F) and (S_3 is F) and (S_4 is F) then (V_R is B) (V_L is Z)
- If (Distance is VS) and (Angle is NM) and (S_1 is F) and (S_2 is F) and (S_3 is F) and (S_4 is F) then (V_R is M) (V_L is Z)



Example fuzzy system - obstacle avoidance



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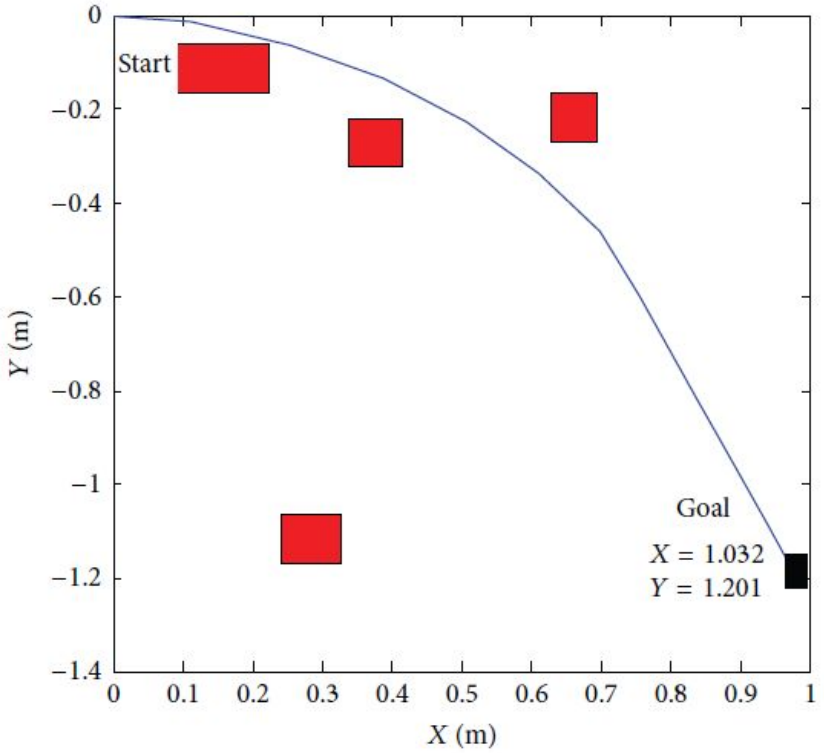

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Conclusion

- Pros
  - Applicable for navigating in dynamic environments
  - Computationally simple

- Cons
  - Outdated
  - Without obstacles path is not optimal
  - Relies on the set of predefined rules
  - ...

Reference

1. Ellips Masehian and Davoud Sedighizadeh, "Classic and Heuristic Approaches in Robot Motion Planning - A Chronological Review," Proceedings of World Academy of Science, Engineering and Technology, Vol. 23, pp. 101-106, August 2007
2. Hajer Omrane, Mohamed SlimMasmoudi, and Mohamed Masmoudi “Fuzzy Logic Based Control for Autonomous Mobile Robot Navigation”, Computational Intelligence and Neuroscience, Volume 2016, Article ID 9548482, August 2016
3. Michio Sugeno and Geuntaek Kang, “Structure identification of fuzzy model”, Fuzzy Sets and Systems, Vol. 28, Issue 1, pp. 15-33, October 1988