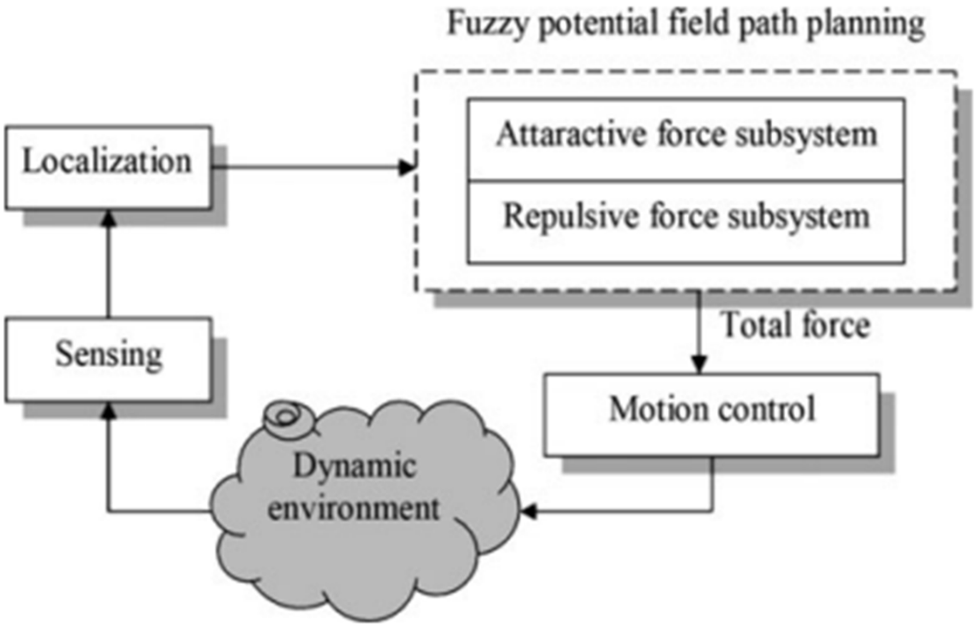
AUTONOMOUS MOBILE ROBOT DYNAMIC MOTION PLANNING USING HYBRID FUZZY POTENTIAL FIELD

Shujaat Ishaq shujaat@iitk.ac.in
Satyam Kumar Shivam satyams@iitk.ac.in

Description

- Problem
  - Autonomous Robot Motion Planning
  - Moving target and Obstacles
  - Soft Landing
- Assumptions
  - Fully Observable
  - Single Agent

Model



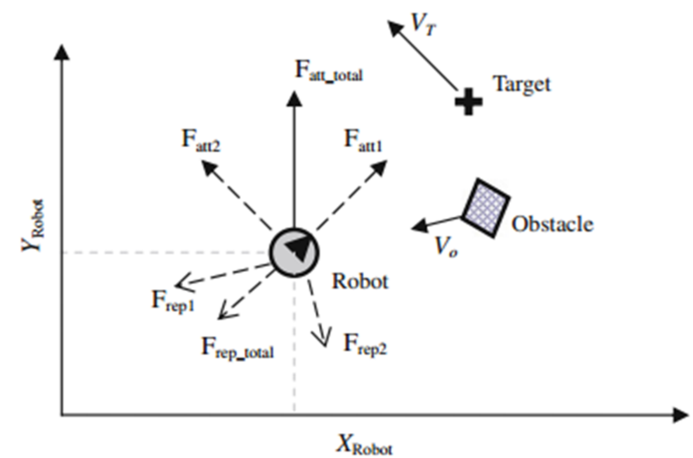
Fuzzy potential field path planning
Localization
Attaractive force subsystem
Repulsive force subsystem
Sensing
Total force
Motion control
Dynamic
environment

[5]

Model

- Attractive force due to a target depends on
  - Relative position
  - Relative velocity

$$Fattx = m \times \alpha_p \times \Delta x + n \times \alpha_v \times \Delta v_x$$
$$Fatty = m \times \alpha_p \times \Delta y + n \times \alpha_v \times \Delta v_y$$

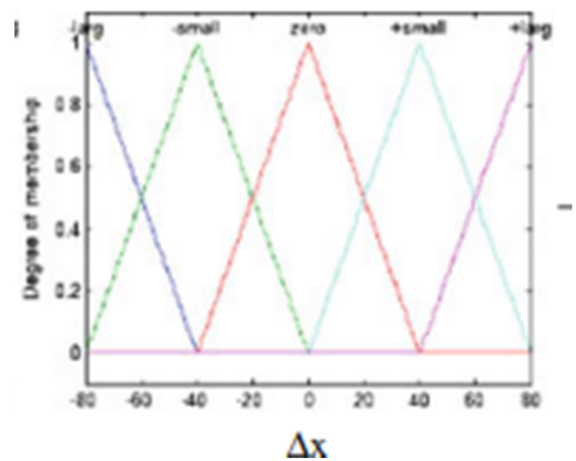


[5]

- Computationally expensive
- Modeled using Mamdani fuzzy Inference System
  - Fuzzy input variables { Δx , Δy , v_x , v_y }
  - Triangular Membership function

Mamdani Fuzzy Inference

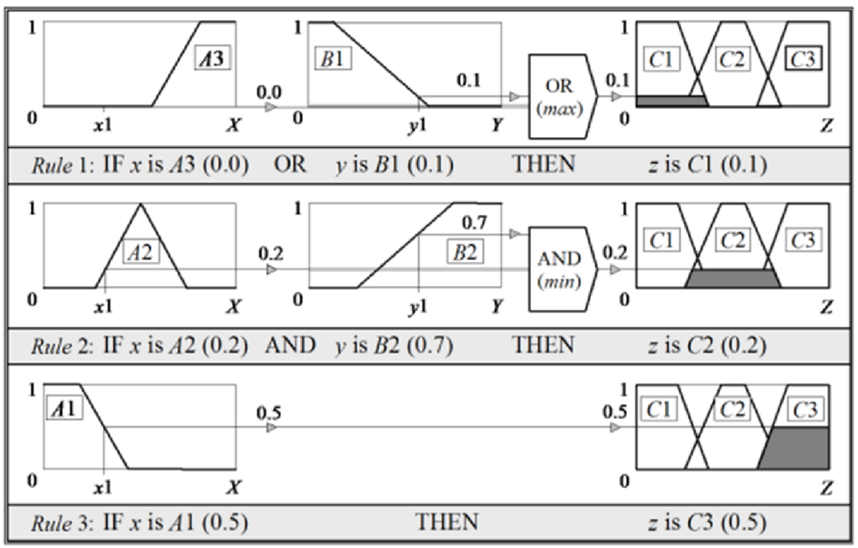
- 4 step method
  - Fuzzification of input variables
    - { -large, -small, zero, +small, +large}
  - Rule evaluation
    - 4 set of rules
      - R1: IF Δx is _ THEN Fatt_x is _
      - R2: IF v_x is _ THEN Fatt_v_x is _
      - R3: IF Δy is _ THEN Fatt_y is _
      - R4: IF v_y is _ THEN Fatt_v_y is _
  - Aggregation of rule outputs



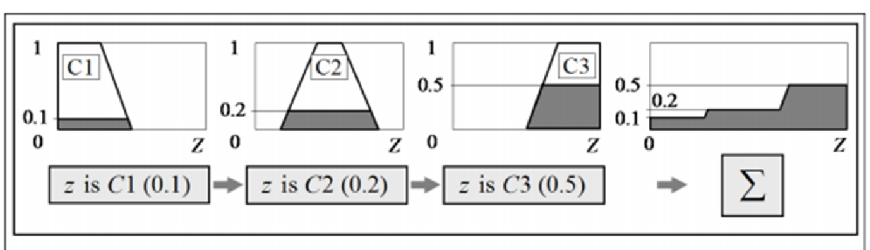
[5]

Mamdani Fuzzy Inference

Step 2: Mamdami Rule Evaluation



Step 3: Aggregation of Rule Outputs



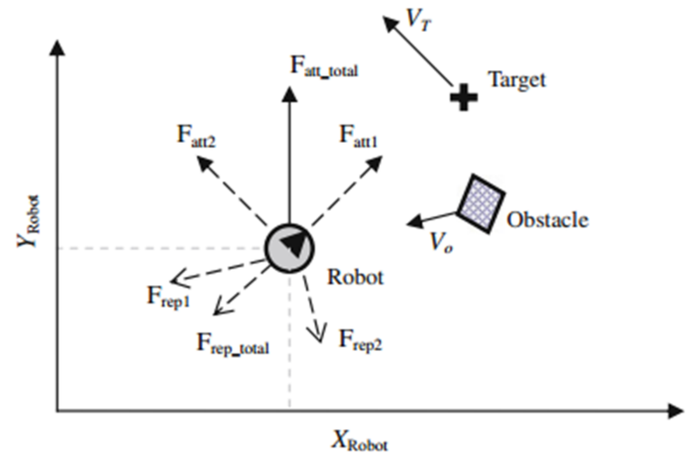
[6]

Mamdani Fuzzy Inference

- Defuzzification
  - Final output of a fuzzy system has to be a crisp number
  - **Centroid**
    - Locate the point where a vertical line would divide the aggregate set into two parts of equal areas.

Model

- Repulsive force due to an obstacle depends on
  - Relative position
  - Relative velocity



[5]

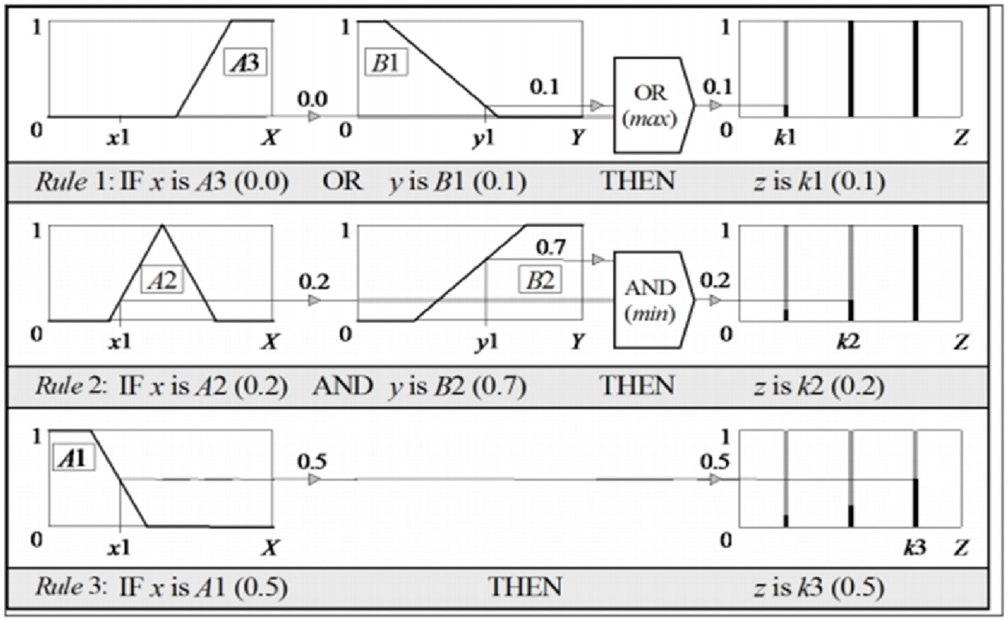
- Modeled using TSK fuzzy Inference System
  - Fuzzy input variables { Δx , Δy }
  - Gaussian Bell Membership function

TSK Inference

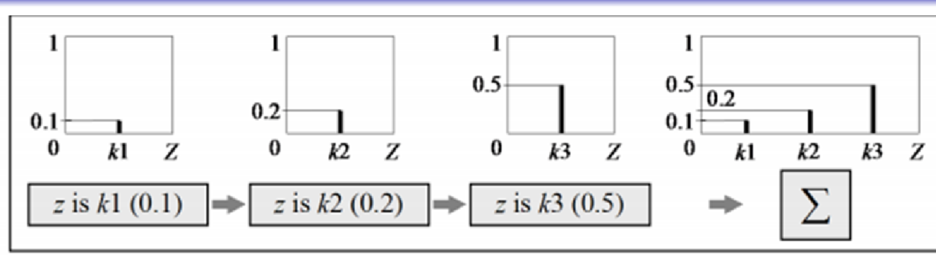
- Similar to Mamdani except for the rule evaluation part.
- Michio Sugeno suggested to use a single value as the membership function instead of a slice as used in Mamdani.
- IF Δx is _ and Δ y is _ THEN
  $f_{repulsive} = a_i \, \Delta x + b_i \, \Delta y + c_i$
- How to determine a_i , b_i and c_i ?
  - ANFIS

TSK Inference

Sugeno-style rule evaluation



Sugeno-style aggregation

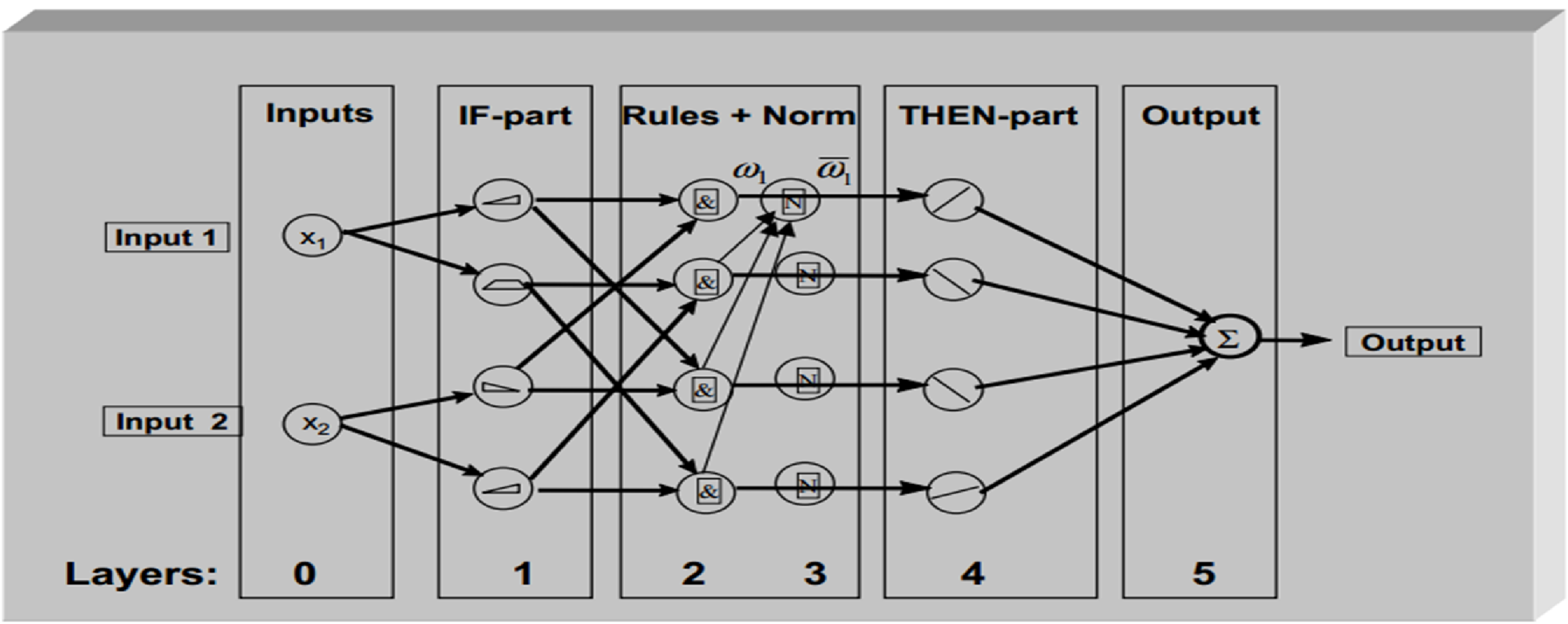


[5]

ANFIS

- Adaptive Neuron Fuzzy Interference System

ANFIS Network



[4]

Adaptive Neuron Fuzzy Inference System (ANFIS)

- Layer 1: Each node is an adaptive fuzzification node.
- Gaussian bell membership functions

$$\mu_i(x) = \left(1 + \left|\frac{x - m_i}{\alpha_i}\right|^{2\beta_i}\right)^{-1}$$

- α_i , β_i & m_i are the modifiable parameters to be tuned by the network.
- 11 membership functions for each input.

Adaptive Neuron Fuzzy Inference System (ANFIS)

- Layer 2: Firing strength of each rule is determined using the T norm Operator.
- Product T norm Operator

$$w_i = \prod \mu_j.$$

- Layer 3 normalizes the fired strength calculated from layer 2 over all nodes within this layer.

.

Adaptive Neuron Fuzzy Inference System (ANFIS)

- Layer 4 is also an adaptive layer.
- Each node output is obtained using normalized weighted output of the linear fuzzy TSK IF-THEN rule of the following form.

$$\overline{w_i} f_i = \overline{w_i}(a_i \Delta x + b_i \Delta y + c_i).$$

- The parameters (a_i, b_i, c_i) are tuned during the training phase.
- Layer 5 sums all the normalized weighted outputs from the previous layer. Thus a final crisp value is obtained at layer 5.

DATASET

- The training data set is gathered by simulating the repulsive force model presented in [1](Ge and Cui 2002).
- Difficult to generate a dataset that completely represents the dynamic system.
- Quantization of the work space of the mobile robot is done to limit the size of training set. Uniformity along all directions is ensured to prevent bias.

ANFIS Learning Algorithm

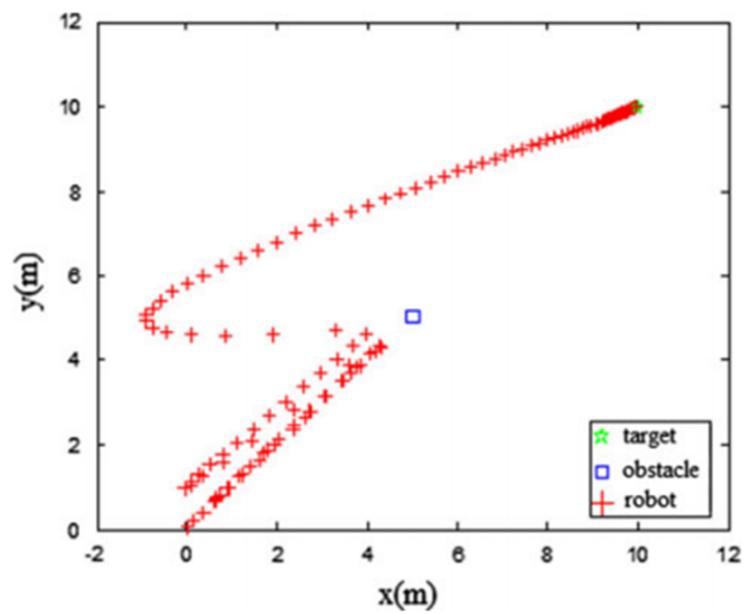
- ANFIS uses two sets of modifiable parameters say A1 and A2.
  - A1 represents the parameters of Gaussian bell membership functions used in Layer 1.
  - A2 represents the coefficients of the linear functions as in Layer 4.

ANFIS Learning Algorithm

- ANFIS uses a two pass learning cycle.
- Forward pass
  - A1 is fixed and A2 is computed using a Least Squared Error algorithm
- Backward pass
  - A2 is fixed and A1 is computed using a gradient descent algorithm.

Local Minima Problem (LMP)

- Many ANFIS model has been chosen for optimal number of input membership functions so as to solve LMP.
- Finally, the ANFIS model with 15 membership functions solves the local minima problem.



[5]

References

1. Ge SE, Cui YJ (2002) Dynamic motion planning for mobile robots using potential field method. Autonomous Robots 13:207–222.

2. Jang J-SR (1993) ANFIS: adaptive-network-based fuzzy inference system. IEEE Trans Syst Man Cybern 23:665–685

4. http://homepages.rpi.edu/~bonisp/fuzzy-course/Papers-pdf/anfis.rpi04.pdf

3. Matlab Inc. (2008) Matlab fuzzy logic toolbox.http://www.Mathwork.com

5. Jaradat, Mohammad Abdel Kareem, Mohammad H. Garibeh, and Eyad A. Feilat. "Autonomous mobile robot dynamic motion planning using hybrid fuzzy potential field." *Soft Computing* 16.1 (2012): 153-164.

6. http://www.4c.ucc.ie/~aholland/udg/Girona_Lec5.pdf

Any Questions ??