

Motion Planning Using Fuzzy Potentials

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Abstract

The aim of the project is to ensure the soft landing of the robot on the mobile target while avoiding nearby moving or stationary obstacles by using potential fields. Instead of using the traditional methods we model obstacles and targets using fuzzy inference systems. Attractive potential of the target is modeled using Mamdani Inference system. For obstacle(s) we use TSK inference system in which the parameters are learned through Adaptive Neuron Fuzzy Inference System (ANFIS).

Introduction

The field of motion planning is crucial to the evolution and integration of robots in the mainstream. Potential fields have been historically popular as means to modeling mobile or static obstacles and targets to a good accuracy. However caveats such as Local Minima Problem and high computation costs have hindered practical application. Most of the earlier work was based on static obstacles. In 2002, Ge and Cui [2] came up with a method to model mobile obstacles using relative position, relative velocity and region of influence as the three parameters. Lot of follow up research has been done on the paper.

Our project is inspired from a paper published by Jaradaat[1] which is a fuzzy logic based implementation of [2]. As suggested by [2] the attractive force between the robot and target is dependent only on the relative position and relative velocity. To model this situation we construct a Mamdani Inference system with 4 variables i.e Δx , Δy , Δvx , Δvz . For each variable 5 triangular membership functions each representing a certain range of values are constructed. The range of these functions is tuned manually for certain scenarios. The fuzzy If-Then rules are straightforward e.g. for large separation attractive force attains a large value so as for large relative velocity. For modeling obstacles we first consider the method implemented by [2]. It models obstacles as having a *sphere of influence*. Outside this sphere the robot isn't influenced by the obstacle. Once the robot enters the sphere the repulsive force due to the obstacle directly proportional to relative velocity and distance is calculated. Assuming Newtonian mechanics the resulting acceleration and trajectory of the robot is calculated and the process is repeated on until the robot escapes the *sphere of influence*.

ANFIS

The method presented by [2] can be computationally intensive when done repeatedly for similar scenarios as is the case in reality. To avoid this re-computation [1] proposed the use of ANFIS. A scenario is first modeled using [2] to get some input-output data pairs. The data is then modeled using TSK Inference system with Gaussian bell shaped membership functions. The membership functions are tuned by applying ANFIS[3] on the obtained data. Thus for planning similar other scenarios instead of performing the clumsy calculations of [2] we directly use the TSK Inference system with input only as Δx , Δy . This simplifies the calculations and lowers the processing time.

Implementation

The attractive force is implemented by using the Fuzzy Logic Toolbox[4] provided in Matlab [5]. The membership functions are to be auto-tuned for modeling different scenarios. The method prescribed by [2] is also implemented in Matlab and during simulations the refresh time is set to 0.3s although this could change depending on the range of velocity values. ANFIS is also implemented using the provided commands in [4].

Results

Two types of simulations were conducted. In the first type only the robot and mobile target were considered. It was observed that the robot was able to successfully chase and softly land on the target as shown in Fig1. The simulations for [2] are done assuming a static obstacle and a stationary or moving target. The results for both the cases are satisfactory. The local Minimum Problem is also avoided as shown in Fig2. A set of input-output tuples obtained from above is trained using ANFIS. For each input 11 Gaussian bell membership functions are considered the parameters of which are tuned by training on the earlier obtained data. A hybrid learning algorithm is used for ANFIS. An example of the tuned membership functions is shown in Fig3.

Conclusion

The new approach provided by [1] which introduced the use of fuzzy logic in motion planning was successful in planning paths in dynamic environments and ensuring soft landing of the robot. The problem of Local Minima is avoided in the case of dynamic as well as static environments. Also for the modeling of obstacles only the relative position is required, thereby simplifying the processing as there is no need for calculating velocities which is resource intensive. This makes this approach more desirable for real time application. The drawbacks of the approach include the manual tuning of the membership functions required in the step for calculating attractive forces. Another drawback is the inability to give good answers to untrained situations.

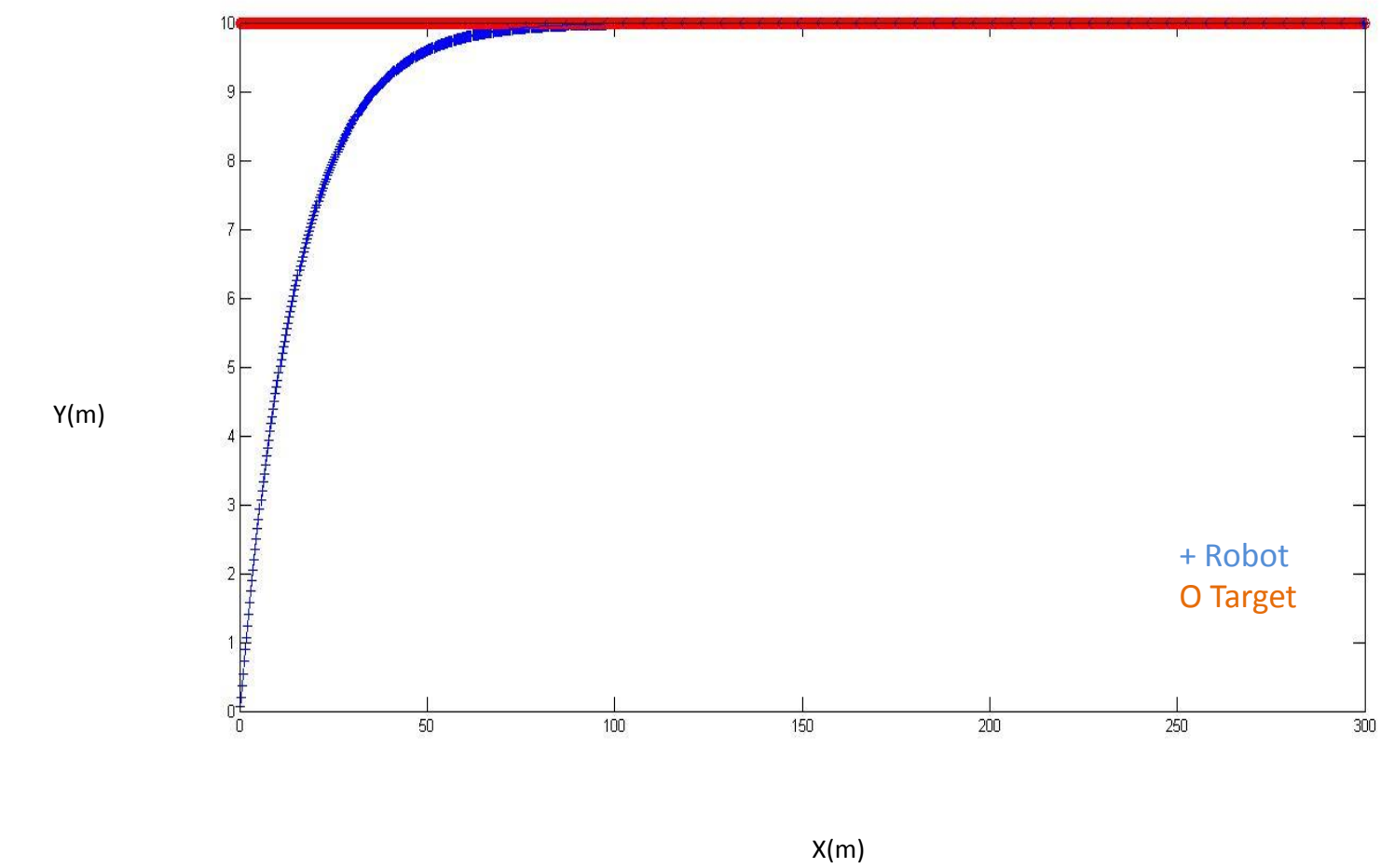


Figure 3. Soft Landing of robot at target.

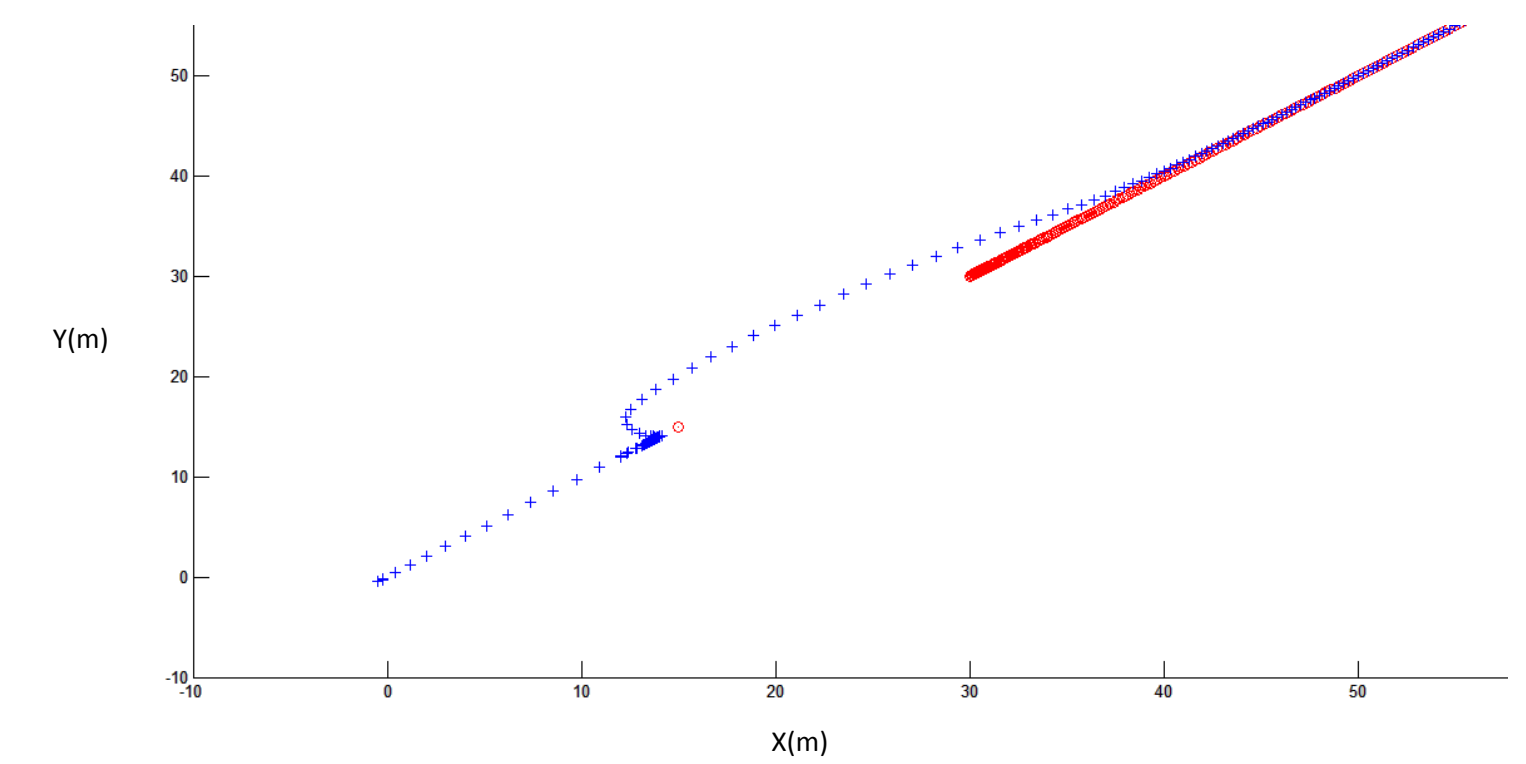
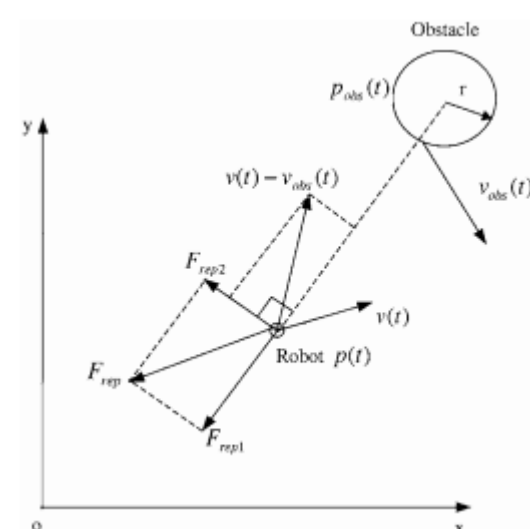
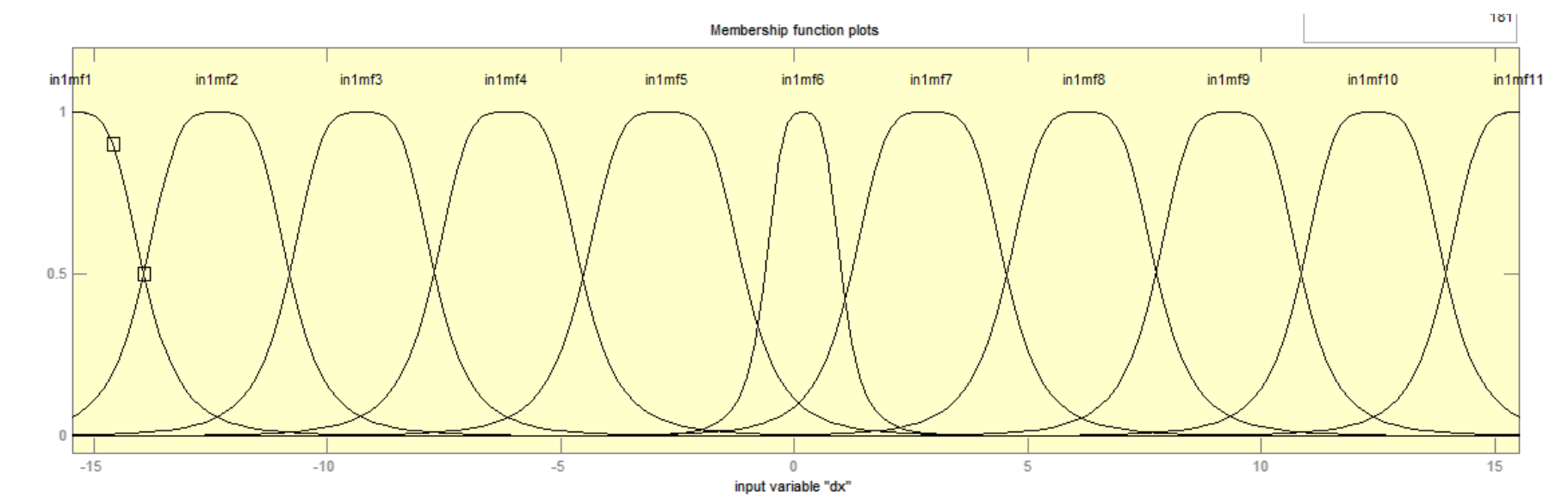


Figure 5. Local Minima problem avoidance.



$$F_{rep1} = \frac{-\eta}{(\rho_s(\mathbf{p}, \mathbf{p}_{obs}) - \rho_m(v_{RO}))^2} \left(1 + \frac{v_{RO}}{a_{max}}\right) \mathbf{n}_{RO}$$

$$F_{rep2} = \frac{\eta v_{RO} v_{RO \perp}}{\rho_s(\mathbf{p}, \mathbf{p}_{obs}) \rho_{max}(\rho_s(\mathbf{p}, \mathbf{p}_{obs}) - \rho_m(v_{RO}))^2} \mathbf{n}_{RO \perp}$$



References

1. 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.
2. <http://homepages.rpi.edu/~bonisp/fuzzy-course/Papers-pdf/anfis.rpi04.pdf>
3. http://www.4c.ucc.ie/~aholland/udg/Girona_Lec5.pdf