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CSE 454 Project 1
Fuzzy Robot Controller Report
Fall 2021

Description:

A rudimentary implementation of a fuzzy logic-based movement controller designed to relocate a robot from a starting position to a destination. The controller is only able to provide acceleration and angular acceleration to the robot as movement options..

Inputs:

- Initial coordinates of the robot
- Destination coordinates

Outputs:

- Weights of membership functions
- Current speed of the robot
- Current angular velocity of the robot
- Time stamp
- Current coordinates of the robot

Constraints:

- The movement and rotation of the robot must occur simultaneously.

Anything I defined:

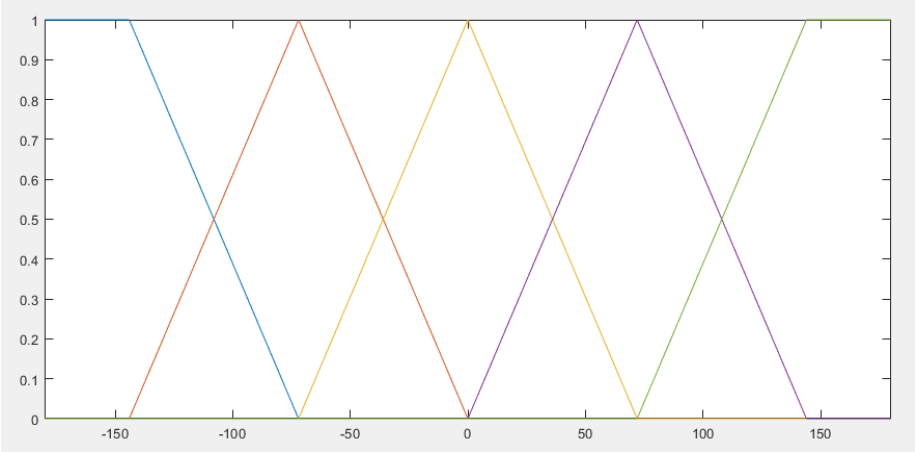
- When the x and y value of the current position of the robot is both within 0.25m from the destination, the program is completed. This is to limit infinite loops from circling the destination without fully reaching it.

Physics:

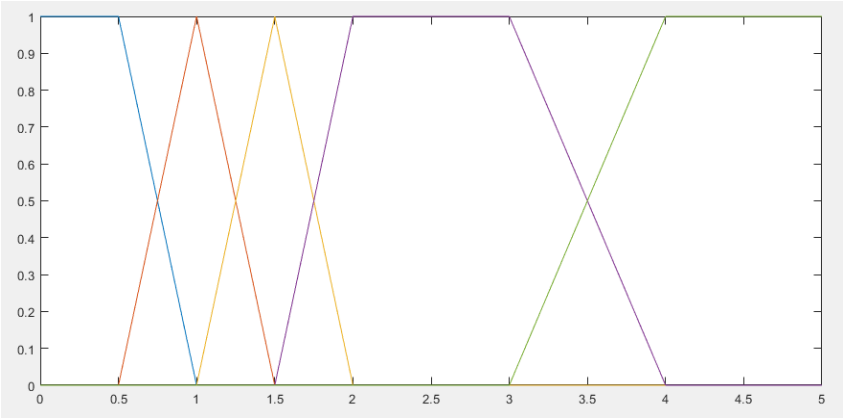
The main kinematics equations used were the standard acceleration formulas to determine final velocity: vf = vi+at. The formula for angular acceleration is essentially the same with the only difference being the variables are changed for angular motion: $\omega = \omega_0 + \alpha t$. The distance needed to stop at a specific velocity was retrieved by using $d=-(vi^2)/2a$ along with the corresponding formula for angular values.

Fuzzifier:

The angle was mapped to two fuzzifiers and the distance was mapped to one. For the angle, one fuzzifier showed directionality while the other was made to map the angle to acceleration. The acceleration fuzzifier was also used to map the distance in relation to the minimum distance needed to stop at the current speed.



Membership graph for angle directionality



Membership graph for angle/distance acceleration

Fuzzy Inference Engine:

The rules being implemented for the angle are:

1. If angle is to the left, turn left; if angle is far to the left, turn left faster; if angle is in front, don't turn;etc
2. If angular velocity is too fast, slow down; if angular velocity is too slow, speed up

The rules being implemented for the position are:

1. If the speed is too fast, slow down; if the speed is too slow, speed up

Defuzzifier:

For defuzzification, angle directionality was mapped to [-4,-1,0,1,4]. Angular acceleration was mapped to [-180,-90,0,90,180]. Linear acceleration was mapped to [-3,-1,0,1,3]. These values were chosen to allow the greatest range of turning for the robot without allowing the speed to limit the turning radius for a portion of time.

Results:

- 0,0 → 10,1

```
Input current location - X,Y
0,0
Input target destination - X,Y
10,1
0 - 0.03,3.7376e-05
   Angular Velocity: 0.71382degrees/s
   Forward Speed: 0.3m/s
   Angular Fuzz Weights: 0 0 0.92069 0.079314 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0 0 0 1
0.1 - 0.09,0.00026092
   Angular Velocity: 1.4208degrees/s
   Forward Speed: 0.6m/s
   Angular Fuzz Weights: 0 0 0.92144 0.078556 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0 0 0 1
1 - 1.8649,0.076579
   Angular Velocity: 6.3874degrees/s
   Forward Speed: 2.7231m/s
   Angular Fuzz Weights: 0 0 0.96097 0.039031 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0 0 1 0
1.1 - 2.1462,0.10069
   Angular Velocity: 6.6679degrees/s
   Forward Speed: 2.8231m/s
   Angular Fuzz Weights: 0 0 0.96884 0.031163 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0 0 1 0
1.2 - 2.4368,0.12908
   Angular Velocity: 6.8012degrees/s
   Forward Speed: 2.9199m/s
   Angular Fuzz Weights: 0 0 0.97732 0.022684 0
   Angular Distance Fuzz Weights: 0 0 0 0.69385 0.30615
   Distance Fuzz Weights: 0 0 0.032647 0.96735 0
2 - 4.7893,0.48318
   Angular Velocity: 5.2939degrees/s
   Forward Speed: 2.8889m/s
   Angular Fuzz Weights: 0 0.059026 0.94097 0 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0.42929 0.57071 0 0
2.1 - 5.0679,0.53821
   Angular Velocity: 4.6636degrees/s
   Forward Speed: 2.8398m/s
   Angular Fuzz Weights: 0 0.070036 0.92996 0 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0.49028 0.50972 0 0
2.2 - 5.3408,0.59406
   Angular Velocity: 3.9356degrees/s
   Forward Speed: 2.7855m/s
   Angular Fuzz Weights: 0 0.080893 0.91911 0 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0.54304 0.45696 0 0
4.6 - 9.6583,1.0962
   Angular Velocity: -18.9228degrees/s
   Forward Speed: 0.82379m/s
   Angular Fuzz Weights: 0 0.057528 0.94247 0 0
   Angular Distance Fuzz Weights: 0 0.97213 0.027866 0 0
   Distance Fuzz Weights: 0 0.9099 0.090103 0 0
4.7 - 9.7292,1.0774
   Angular Velocity: -18.6445degrees/s
   Forward Speed: 0.73301m/s
   Angular Fuzz Weights: 0 0.038496 0.9615 0 0
   Angular Distance Fuzz Weights: 0.60667 0.39333 0 0 0
   Distance Fuzz Weights: 0 0.90778 0.092217 0 0
4.8 - 9.7907,1.059
   Angular Velocity: -18.5016degrees/s
   Forward Speed: 0.6427m/s
   Angular Fuzz Weights: 0 0.015881 0.98412 0 0
   Angular Distance Fuzz Weights: 1 0 0 0 0
   Distance Fuzz Weights: 0 0.90309 0.09691 0 0
Completed - destination: 10,1
```

- -2,4 → 5,-3

```
Input current location - X,Y
-2,4
Input target destination - X,Y
5,-3
0 - -1.97,3.9997
   Angular Velocity: -5.625degrees/s
   Forward Speed: 0.3m/s
   Angular Fuzz Weights: 0 0.625 0.375 0 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0 0 0 1
0.1 - -1.91,3.9979
   Angular Velocity: -11.1949degrees/s
   Forward Speed: 0.6m/s
   Angular Fuzz Weights: 0 0.61888 0.38112 0 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0 0 0 1
1 - -0.2404,3.4441
   Angular Velocity: -38.7434degrees/s
   Forward Speed: 2.7269m/s
   Angular Fuzz Weights: 0 0.33264 0.66736 0 0
   Angular Distance Fuzz Weights: 0 0.16407 0.83593 0 0
   Distance Fuzz Weights: 0 0 0 1 0
1.1 - -0.005953,3.2861
   Angular Velocity: -38.0762degrees/s
   Forward Speed: 2.8269m/s
   Angular Fuzz Weights: 0 0.2878 0.7122 0 0
   Angular Distance Fuzz Weights: 0 0.51517 0.48483 0 0
   Distance Fuzz Weights: 0 0 0 1 0
1.2 - 0.22568,3.1072
   Angular Velocity: -37.1714degrees/s
   Forward Speed: 2.9269m/s
   Angular Fuzz Weights: 0 0.24306 0.75694 0 0
   Angular Distance Fuzz Weights: 0 0.82725 0.17275 0 0
   Distance Fuzz Weights: 0 0 0 1 0
4 - 2.4639,-3.3722
   Angular Velocity: 60.5278degrees/s
   Forward Speed: 1.963m/s
   Angular Fuzz Weights: 0 0 0.10839 0.89161 0
   Angular Distance Fuzz Weights: 0 0 0.72989 0.27011 0
   Distance Fuzz Weights: 0 0.32728 0.67272 0 0
4.1 - 2.5944,-3.5143
   Angular Velocity: 60.6822degrees/s
   Forward Speed: 1.9291m/s
   Angular Fuzz Weights: 0 0 0.14066 0.85934 0
   Angular Distance Fuzz Weights: 0 0 0.96008 0.039916 0
   Distance Fuzz Weights: 0 0.33933 0.66067 0 0
4.2 - 2.7364,-3.6396
   Angular Velocity: 60.346degrees/s
   Forward Speed: 1.8935m/s
   Angular Fuzz Weights: 0 0 0.17328 0.82672 0
   Angular Distance Fuzz Weights: 0 0.090367 0.90963 0 0
   Distance Fuzz Weights: 0 0.35587 0.64413 0 0
6.2 - 5.0905,-3.3161
   Angular Velocity: 48.1381degrees/s
   Forward Speed: 0.74767m/s
   Angular Fuzz Weights: 0 0 0.4373 0.5627 0
   Angular Distance Fuzz Weights: 0 0 0.77823 0.22177 0
   Distance Fuzz Weights: 0 0.67009 0.32991 0 0
6.3 - 5.1166,-3.253
   Angular Velocity: 49.1277degrees/s
   Forward Speed: 0.68293m/s
   Angular Fuzz Weights: 0 0 0.39825 0.60175 0
   Angular Distance Fuzz Weights: 0 0 0.63453 0.36547 0
   Distance Fuzz Weights: 0 0.6474 0.3526 0 0
6.4 - 5.1351,-3.1936
   Angular Velocity: 50.6562degrees/s
   Forward Speed: 0.6218m/s
   Angular Fuzz Weights: 0 0 0.34477 0.65523 0
   Angular Distance Fuzz Weights: 0 0 0.4816 0.5184 0
   Distance Fuzz Weights: 0 0.61127 0.38873 0 0
Completed - destination: 5,-3
```

- 2,3 → -5,-7

```
Input current location - X,Y
2,3
Input target destination - X,Y
-5,-7
0 - 2.03,2.9985
   Angular Velocity: -28.872degrees/s
   Forward Speed: 0.3m/s
   Angular Fuzz Weights: 0.736 0.264 0 0 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0 0 0 1
0.1 - 2.0893,2.9896
   Angular Velocity: -56.706degrees/s
   Forward Speed: 0.6m/s
   Angular Fuzz Weights: 0.69755 0.30245 0 0 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0 0 0 1
2 - 1.6478,1.2052
   Angular Velocity: -35.3545degrees/s
   Forward Speed: 2.9175m/s
   Angular Fuzz Weights: 0 0 0.86648 0.13352 0
   Angular Distance Fuzz Weights: 0.5402 0.4598 0 0 0
   Distance Fuzz Weights: 0 0.41322 0.58678 0 0
2.1 - 1.7511,0.93737
   Angular Velocity: -36.2245degrees/s
   Forward Speed: 2.8702m/s
   Angular Fuzz Weights: 0 0 0.80756 0.19244 0
   Angular Distance Fuzz Weights: 0.0046682 0.99533 0 0 0
   Distance Fuzz Weights: 0 0.47275 0.52725 0 0
2.2 - 1.8354,0.66847
   Angular Velocity: -36.7661degrees/s
   Forward Speed: 2.8181m/s
   Angular Fuzz Weights: 0 0 0.74381 0.25619 0
   Angular Distance Fuzz Weights: 0 0.46973 0.53027 0 0
   Distance Fuzz Weights: 0 0.52138 0.47862 0 0
5 - -5.7848,-3.0019
   Angular Velocity: 62.9468degrees/s
   Forward Speed: 2.4543m/s
   Angular Fuzz Weights: 0 0 0.16216 0.83784 0
   Angular Distance Fuzz Weights: 0 0.38026 0.61974 0 0
   Distance Fuzz Weights: 0 0.26041 0.73959 0 0
5.1 - -5.9393,-3.1888
   Angular Velocity: 61.4602degrees/s
   Forward Speed: 2.4249m/s
   Angular Fuzz Weights: 0 0 0.21077 0.78923 0
   Angular Distance Fuzz Weights: 0 0.41857 0.58143 0 0
   Distance Fuzz Weights: 0 0.29448 0.70552 0 0
5.2 - -6.0716,-3.3881
   Angular Velocity: 59.9428degrees/s
   Forward Speed: 2.3919m/s
   Angular Fuzz Weights: 0 0 0.25809 0.74191 0
   Angular Distance Fuzz Weights: 0 0.45453 0.54547 0 0
   Distance Fuzz Weights: 0 0.32984 0.67016 0 0
7.8 - -4.9515,-6.723
   Angular Velocity: 19.0582degrees/s
   Forward Speed: 0.62911m/s
   Angular Fuzz Weights: 0.006827 0.99317 0 0 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0.37866 0.62134 0 0
7.9 - -4.8916,-6.7364
   Angular Velocity: 4.493degrees/s
   Forward Speed: 0.61333m/s
   Angular Fuzz Weights: 0.20612 0.79388 0 0 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0.15786 0.84214 0 0
8 - -4.8319,-6.7515
   Angular Velocity: -14.8959degrees/s
   Forward Speed: 0.61636m/s
   Angular Fuzz Weights: 0.38477 0.61523 0 0 0
   Angular Distance Fuzz Weights: 0 0 0 0 1
   Distance Fuzz Weights: 0 0 0.96966 0.030338 0
Completed - destination: -5,-7
```

Ethical Issues:

There is an ethical issue due to the robot occasionally getting stuck orbiting the destination. Shipping this project as a complete product would be disingenuous and misleading. Future versions may have this issue fixed.