Lab 6

Aim: Explainable Fuzzy Support System for Black-Box Model of Robot Obstacle Avoidance

Theorem:

The environment describes a navigation task to reach a specified target while avoiding obstacles. The direction to the target is represented as a unit force vector ($\rightarrow F_t$) directed from the robot to a target location. The obstacle avoidance direction is represented by a unit force vector ($\rightarrow F_O$) directed towards the robot from the closest obstacle location. The robot, target, and obstacle are shown as circles with 0.5 m radius in the 25 m x 25 m simulation environment. The navigation task is to combine the force vectors such that the direction ϑ of the resultant force vector $\rightarrow F$ provides a collision-free direction for the robot.

$\rightarrow F = w \rightarrow F_O + (1-w) \rightarrow F_t$, where $0 \leq w \leq 1$

$$\vartheta = \angle \rightarrow F$$

The weight w of the force vector $\rightarrow F_O$ is calculated using function f_W.

$$w = f_W(\alpha, \vartheta_{t,o})$$

Here:

- $\alpha = \frac{d_o}{d_t}$ is the ratio of the robot-to-obstacle distance (d_O) and the robot-to-target-distance (d_t)
- $\vartheta_{t,o}$ is the absolute difference between the target and obstacle directions with respect to the robot

The RL agent learns a policy to model f_W for collision-free robot navigation in the environment using $(\alpha, \vartheta_{t,o})$ as the observation and w as the action.

Code:

```
numMFs = 2;
% Input 1
fisin = addInput(fisin,[0 2],"Name","alpha","NumMFs",numMFs);
fisin.Inputs(1).MembershipFunctions(1).Type = "linzmf";
fisin.Inputs(1).MembershipFunctions(end).Type = "linsmf";

% Input 2
fisin = addInput(fisin,[0 pi/2],"Name","theta_t_o","NumMFs",numMFs);
fisin.Inputs(2).MembershipFunctions(1).Type = "linzmf";
fisin.Inputs(2).MembershipFunctions(end).Type = "linsmf";

numOutMFs = numMFs^2;
fisin = addOutput(fisin,[0 1],"Name","w","NumMFs",numOutMFs);
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```
[in1,in2] = ndgrid(1:numMFs,1:numMFs);
rules = [in1(:) in2(:) ones(numOutMFs,3)];
fisin = addRule(fisin,rules);
figure
plotfis(fisin)
for ct = 1:length(rule)
    rule(ct).Antecedent.Free = 0;
end
options = tunefisOptions("Method","particleswarm");
options.MethodOptions.MaxIterations = 50;
runtunefis = false;
if runtunefis
    rng("default")
    fisR = tunefis(fisin,rule,X,Y,options);
else
    data = load("flNavModel.mat");
    fisR = data.fisR;
end
disp([fisR.Rules.Description]')
fisR.Outputs(1).MembershipFunctions(3:4) = [];
[in,out] = getTunableSettings(fisR);
if runtunefis
    rng("default")
    fisMF = tunefis(fisR,[in;out],X,Y,options);
else
    fisMF = data.fisMF;
end
fisout = fisMF;
figure
plotfis(fisout)
simTestCasesWithFIS(env,fisout,testCases)
fisout.Inputs(1).MembershipFunctions(1).Name = "low";
fisout.Inputs(1).MembershipFunctions(2).Name = "high";
fisout.Inputs(2).MembershipFunctions(1).Name = "low";
fisout.Inputs(2).MembershipFunctions(2).Name = "high";
fisout.Outputs(1).MembershipFunctions(1).Name = "low";
fisout.Outputs(1).MembershipFunctions(2).Name = "high";
figure
plot(agentActions)
hold on
plot(fisActions)
hold off
xlabel("Decision cycle")
ylabel("Weight for obstacle avoidance")
legend(["Agent actions" "FIS actions"])


setDefaultPositions(env);
[agentActions,fisActions] = compareAgentWithFIS(env,trainedAgent,fisout);



========== Control cycle: 1 ==========
Observations = [0.8 0], agent output (weight) = 0.000371873, FIS output (weight) =
0.0097047
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 2 ==========
Observations = [0.794872 0], agent output (weight) = 0.000371873, FIS output
(weight) = 0.00974128
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Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 3 ==========
Observations = [0.789474 0], agent output (weight) = 0.000409514, FIS output
(weight) = 0.0097804
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 4 ==========
Observations = [0.783784 0], agent output (weight) = 0.000453234, FIS output
(weight) = 0.00982234
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 5 ==========
Observations = [0.777778 0], agent output (weight) = 0.000504375, FIS output
(weight) = 0.00986741
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 6 ==========
Observations = [0.771429 0], agent output (weight) = 0.000564635, FIS output
(weight) = 0.00991599
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 7 ==========
Observations = [0.764706 0], agent output (weight) = 0.00063616, FIS output
(weight) = 0.0099685
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 8 ==========
Observations = [0.757576 0], agent output (weight) = 0.000721812, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 9 ==========
Observations = [0.75 0], agent output (weight) = 0.000842512, FIS output (weight)
= 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 10 ==========
Observations = [0.741935 0], agent output (weight) = 0.000993103, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 11 ==========
Observations = [0.733333 0], agent output (weight) = 0.00118306, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 12 ==========
Observations = [0.724138 0], agent output (weight) = 0.00142586, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 13 ==========
Observations = [0.714286 0], agent output (weight) = 0.00174063, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 14 ==========
Observations = [0.703704 0], agent output (weight) = 0.00215521, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 15 ==========
Observations = [0.692308 0], agent output (weight) = 0.00271079, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 16 ==========
Observations = [0.68 0], agent output (weight) = 0.00346974, FIS output (weight) =
0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 17 ==========
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Observations = [0.666667 0], agent output (weight) = 0.00452864, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 18 ==========
Observations = [0.652174 0], agent output (weight) = 0.00657335, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 19 ==========
Observations = [0.636364 0], agent output (weight) = 0.00989613, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 20 ==========
Observations = [0.619048 0], agent output (weight) = 0.0154329, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 21 ==========
Observations = [0.6 0], agent output (weight) = 0.0238907, FIS output (weight) =
0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 22 ==========
Observations = [0.578947 0], agent output (weight) = 0.0415951, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 23 ==========
Observations = [0.555556 0], agent output (weight) = 0.0757059, FIS output
(weight) = 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 24 ==========
Observations = [0.529412 0], agent output (weight) = 0.158672, FIS output (weight)
= 0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 25 ==========
Observations = [0.5 0], agent output (weight) = 0.325787, FIS output (weight) =
0.01
Max strength rule: alpha==high & theta_t_o==low => w=low (1)
========== Control cycle: 26 ==========
Observations = [0.466667 0], agent output (weight) = 0.582038, FIS output (weight)
= 0.545197
Max strength rule: alpha==low & theta_t_o==low => w=high (1)
========== Control cycle: 27 ==========
Observations = [0.428571 0], agent output (weight) = 0.770591, FIS output (weight)
= 0.703252
Max strength rule: alpha==low & theta_t_o==low => w=high (1)
========== Control cycle: 28 ==========
Observations = [0.401145 0.0796649], agent output (weight) = 0.81328, FIS output
(weight) = 0.760163
Max strength rule: alpha==low & theta_t_o==low => w=high (1)
========== Control cycle: 29 ==========
Observations = [0.414964 0.184271], agent output (weight) = 0.729063, FIS output
(weight) = 0.734112
Max strength rule: alpha==low & theta_t_o==low => w=high (1)
========== Control cycle: 30 ==========
Observations = [0.447487 0.249775], agent output (weight) = 0.381589, FIS output
(weight) = 0.5
Max strength rule: alpha==low & theta_t_o==low => w=high (1)
========== Control cycle: 31 ==========
Observations = [0.459347 0.339489], agent output (weight) = 0.0742273, FIS output
(weight) = 0.01
Max strength rule: alpha==low & theta_t_o==high => w=low (1)
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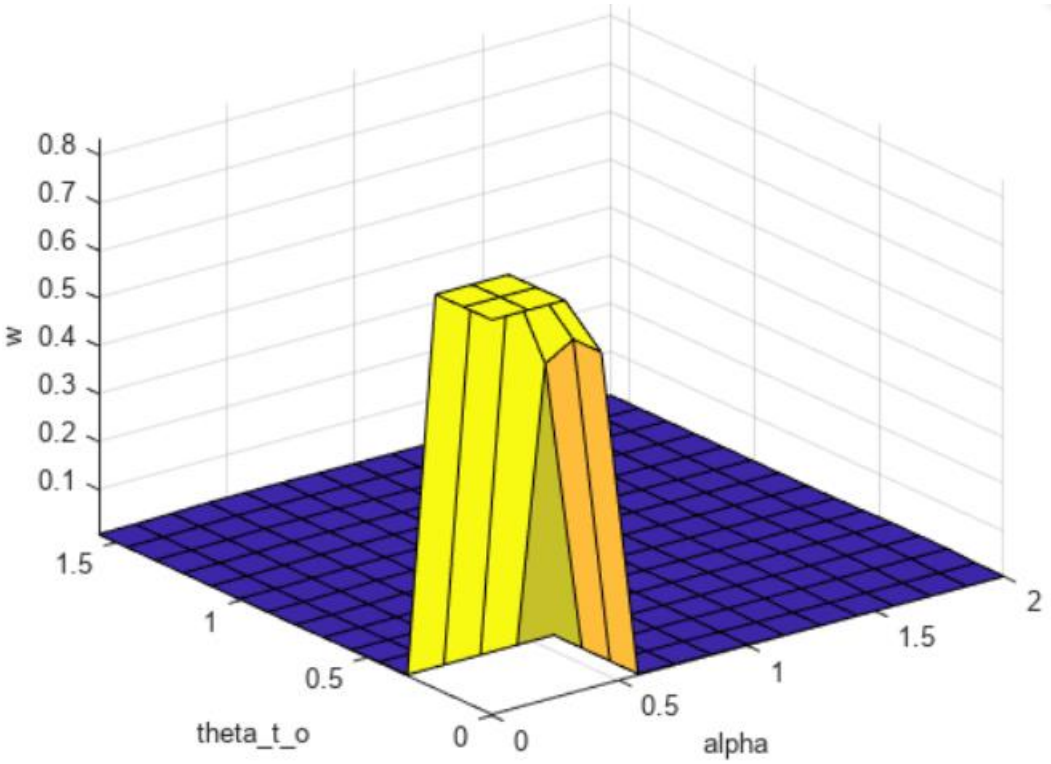
========== Control cycle: 32 ==========
Observations = [0.446 0.436475], agent output (weight) = 0.00935188, FIS output
(weight) = 0.01
Max strength rule: alpha==low & theta_t_o==high => w=low (1)
========== Control cycle: 33 ==========
Observations = [0.40865 0.524433], agent output (weight) = 0.00226036, FIS output
(weight) = 0.01
Max strength rule: alpha==low & theta_t_o==high => w=low (1)
========== Control cycle: 34 ==========
Observations = [0.369292 0.650354], agent output (weight) = 0.00163391, FIS output
(weight) = 0.00946582
Max strength rule: alpha==low & theta_t_o==high => w=low (1)
========== Control cycle: 35 ==========
Observations = [0.331602 0.837792], agent output (weight) = 0.000674069, FIS
output (weight) = 0.00871378
Max strength rule: alpha==low & theta_t_o==high => w=low (1)
========== Control cycle: 36 ==========
Observations = [0.305187 1.11815], agent output (weight) = 0.00017646, FIS output
(weight) = 0.00832172
Max strength rule: alpha==low & theta_t_o==high => w=low (1)
========== Control cycle: 37 ==========
Observations = [0.310447 1.49858], agent output (weight) = 3.00407e-05, FIS output
(weight) = 0.00839306
Max strength rule: alpha==low & theta_t_o==high => w=low (1)
========== Control cycle: 38 ==========
Observations = [0.37532 1.9], agent output (weight) = 8.04663e-07, FIS output
(weight) = 0.00961531
Max strength rule: alpha==low & theta_t_o==high => w=low (1)
========== Control cycle: 39 ==========
Observations = [0.521888 2.21788], agent output (weight) = 0, FIS output (weight)
= 0.01
Max strength rule: alpha==high & theta_t_o==high => w=low (1)
========== Control cycle: 40 ==========
Observations = [0.774188 2.4342], agent output (weight) = 0, FIS output (weight) =
0.00989476
Max strength rule: alpha==high & theta_t_o==high => w=low (1)
========== Control cycle: 41 ==========
Observations = [1.19014 2.57834], agent output (weight) = 0, FIS output (weight) =
0.00796472
Max strength rule: alpha==high & theta_t_o==high => w=low (1)
========== Control cycle: 42 ==========
Observations = [1.92626 2.67745], agent output (weight) = 0, FIS output (weight) =
0.00625
Max strength rule: alpha==high & theta_t_o==high => w=low (1)
========== Control cycle: 43 ==========
Observations = [3.50085 2.7485], agent output (weight) = 0, FIS output (weight) =
0.00625
Max strength rule: alpha==high & theta_t_o==high => w=low (1)
```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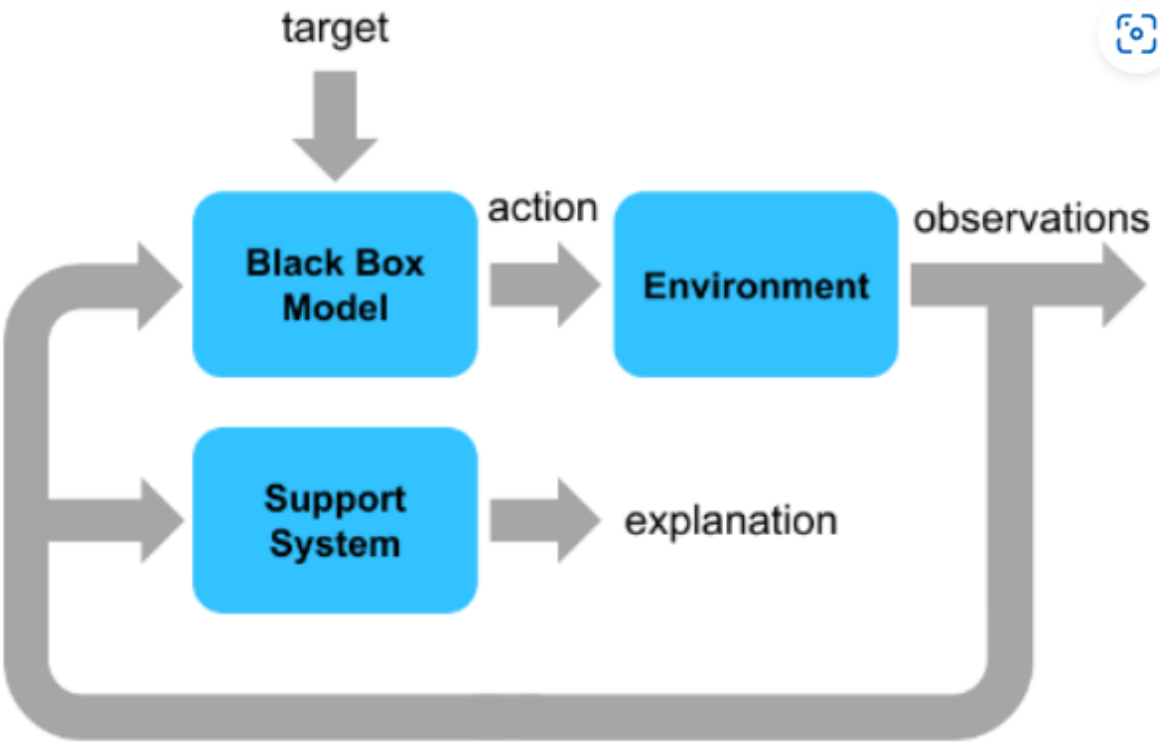
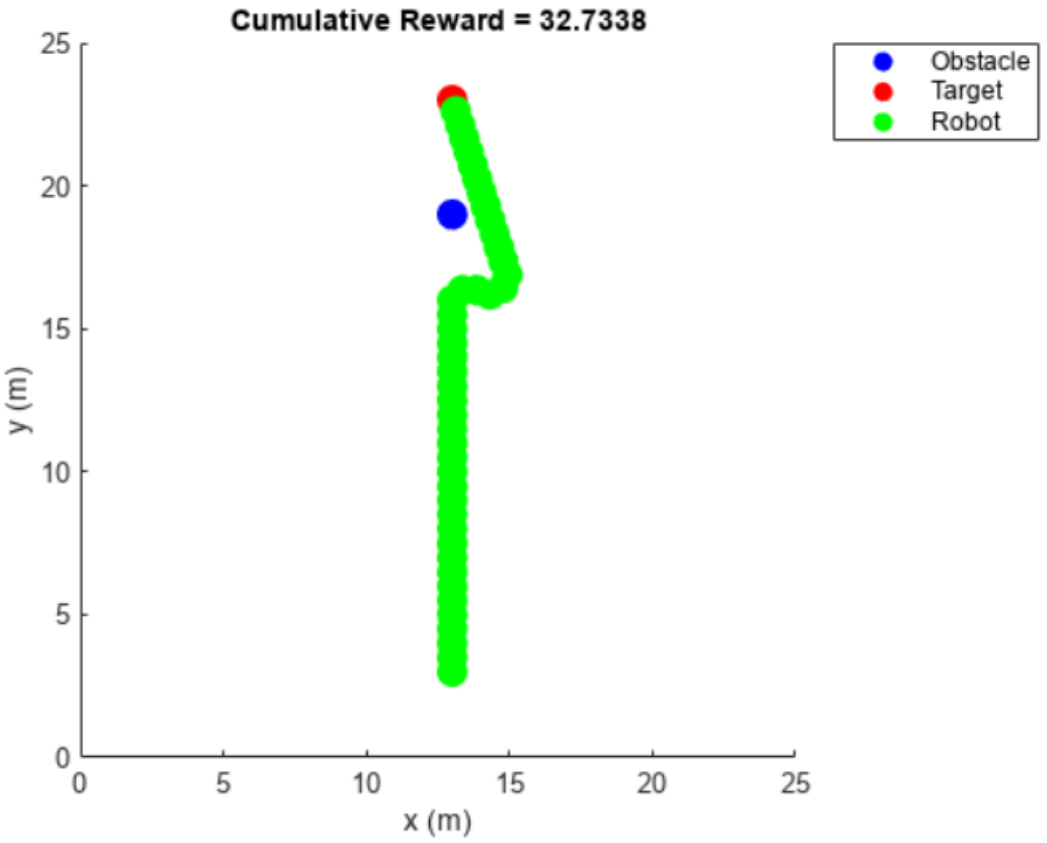
0.7
0.6
0.5
0.4
0.3
0.2
0.1
w
1.5
1
0.5
0
theta_t_o
0
0.5
1
1.5
2
alpha


target
Black Box Model
action
Environment
observations
Support System
explanation

OUTPUT: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Obstacle
Target
Robot
y (m)
x (m)
0
5
10
15
20
25