# Fuzzy Logic Introduction

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This lab is part of the project ADlabs.

See https://github.com/augustodamasceno/adlabs/



## Contents



## Clean

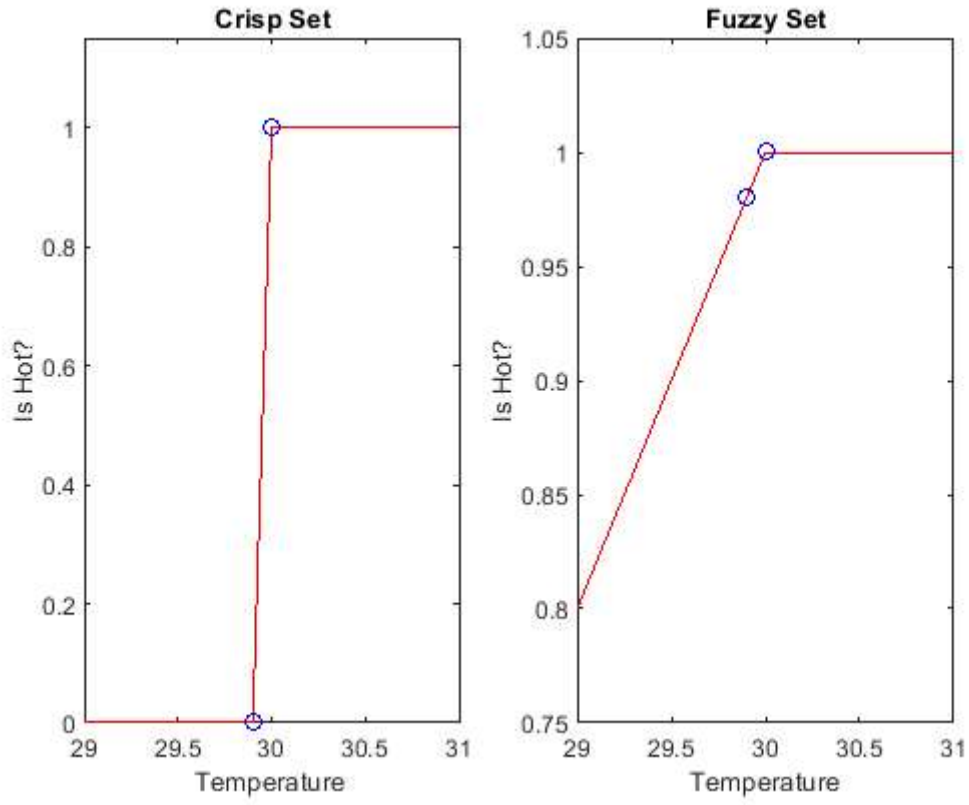
```
% Removes all variables from the workspace.
clear;
% Close all figures and
close all;
% Clear Command Window
```

## Configuration

```
figureIdx = 1;
if ~exist('img', 'dir')
   mkdir('img')
end
```

## Crisp and Fuzzy Sets for a temperature range.

```
figs(figureIdx) = figure(figureIdx);
figureIdx = figureIdx + 1;
t = 29:0.1:31;
half = floor(length(t)/2);

% Classical Logic - Crisp Sets
subplot(1, 2, 1);
HC = hotCrisp(t);
plot(t, HC, 'r');
hold on;
plot(t(half), HC(half), 'bo');
plot(t(half+1), HC(half+1), 'bo');
xlim([29 31]);
ylim([0 1.15]);
title('Crisp Set');
xlabel('Temperature');
ylabel('Is Hot?');

% Fuzzy Logic - Fuzzy Sets
subplot(1, 2, 2);
HF = hotFuzzy(t);
plot(t, HF, 'r');
hold on;
plot(t(half), HF(half), 'bo');
plot(t(half+1), HF(half+1), 'bo');
xlim([29 31]);
ylim([0.75 1.05]);
title('Fuzzy Set');
xlabel('Temperature');
ylabel('Is Hot?');
% Save Figure Image File
saveas(figs(figureIdx-1), 'img/IsHot-Crisp-and-Fuzzy-sets.png');
```

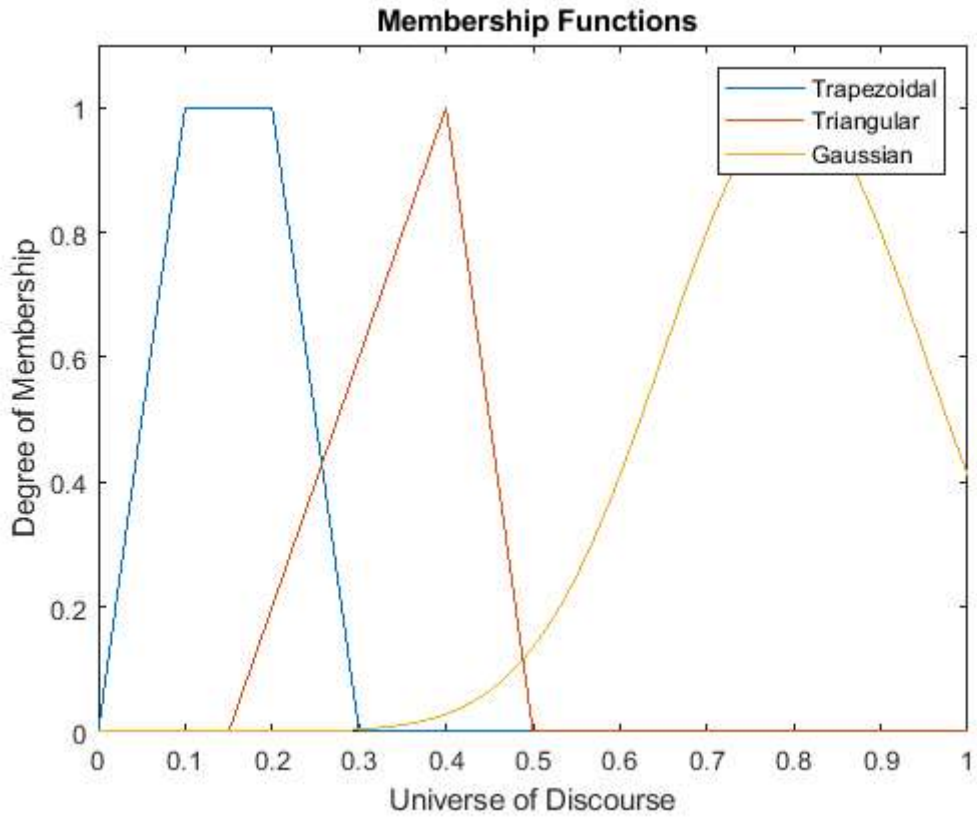



## Russell's Paradox

```
% Call the set of all sets that are not members of themselves R
% If R is a member of itself, then by definition it must not be a member
% of itself. Similarly, if R is not a member of itself, then by definition
% it must be a member of itself.
```

### Membership Functions

```
figs(figureIdx) = figure(figureIdx);
figureIdx = figureIdx + 1;
x = 0:0.01:1;

plot(x, trapmf(x, [0, 0.1, 0.2, 0.3]),'DisplayName', 'Trapezoidal');
hold on;
plot(x, trimf(x, [0.15, 0.4, 0.5]), 'DisplayName', 'Triangular ');
plot(x, gaussmf(x, [0.15, 0.8]),'DisplayName', 'Gaussian');
xlim([0 1]);
ylim([0 1.1]);
title(' Membership Functions');
xlabel('Universe of Discourse');
ylabel('Degree of Membership');
legend;
% Save Figure Image File
saveas(figs(figureIdx-1), 'img/Membership-Functions.png');
```




### Definitions

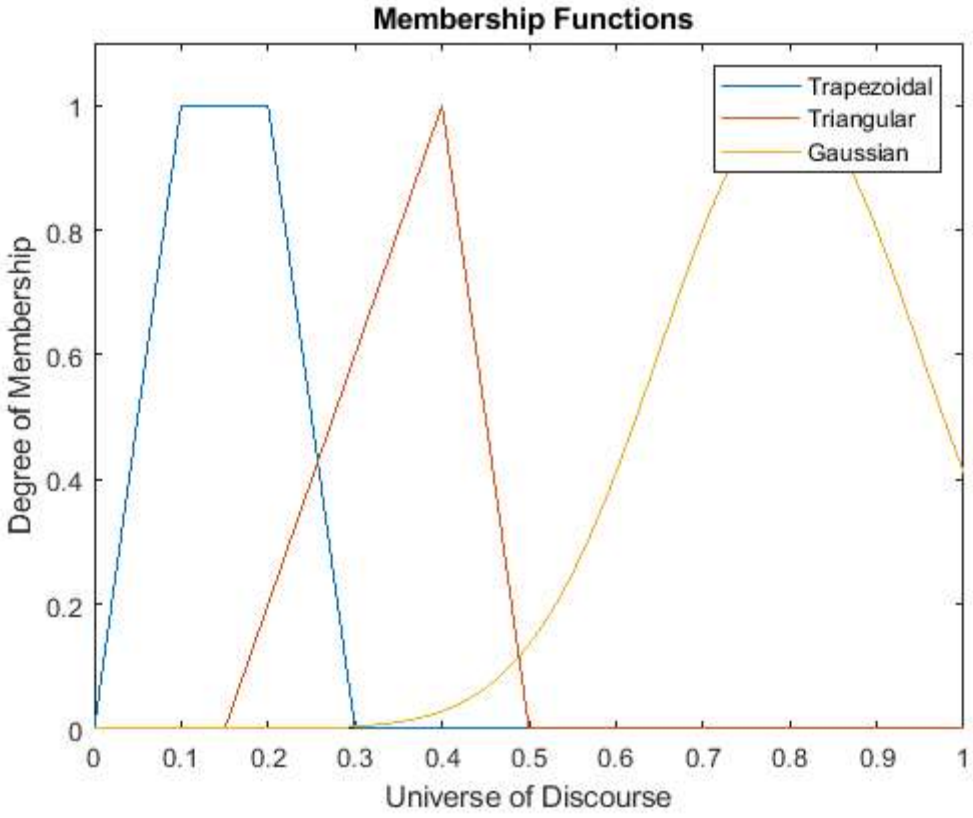
```
% Support
% Crisp subset where the membership function is larger than zero.

% Core
% Crisp subset where the membership function is 1.

% Height
% The supremum the membership function.
```

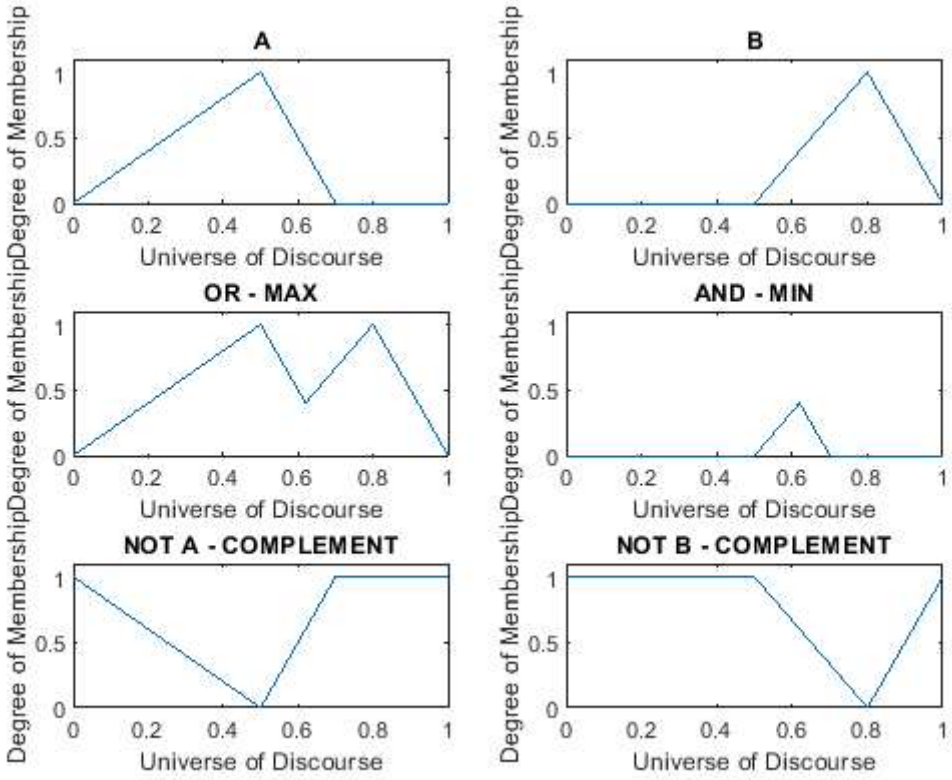
```
% Normal Fuzzy Set
% At least one value where the membership function is 1;

% Alpha-cut
% The crisp subset where the  membership function is equal or less than alpha.

% Strict-cut
% The crisp subset where the  membership function is less than alpha.

% Convexity
% If all alpha-cuts are convex.
```

## Fuzzy Operators

```
figs(figureIdx) = figure(figureIdx);
figureIdx = figureIdx + 1;
x = 0:0.01:1;
A = trimf(x, [0, 0.5, 0.7]);
B = trimf(x, [0.5, 0.8, 1]);

subplot(3, 2, 1);
plot(x, A,'DisplayName', 'A');
title('A');
xlabel('Universe of Discourse');
ylabel('Degree of Membership');
xlim([0 1]);
ylim([0 1.1]);
subplot(3, 2, 2);
plot(x, B, 'DisplayName', 'B');
title('B');
xlabel('Universe of Discourse');
ylabel('Degree of Membership');
xlim([0 1]);
ylim([0 1.1]);
subplot(3, 2, 3);
plot(x, max([A; B]),'DisplayName', 'OR - MAX');
title('OR - MAX');
xlabel('Universe of Discourse');
ylabel('Degree of Membership');
xlim([0 1]);
ylim([0 1.1]);
subplot(3, 2, 4);
plot(x, min([A; B]),'DisplayName', 'AND - MIN');
title('AND - MIN');
xlabel('Universe of Discourse');
ylabel('Degree of Membership');
xlim([0 1]);
ylim([0 1.1]);
subplot(3, 2, 5);
plot(x, 1-A,'DisplayName', 'NOT A - COMPLEMENT');
title('NOT A - COMPLEMENT');
xlabel('Universe of Discourse');
ylabel('Degree of Membership');
xlim([0 1]);
ylim([0 1.1]);
subplot(3, 2, 6);
plot(x, 1-B,'DisplayName', 'NOT B - COMPLEMENT');
title('NOT B - COMPLEMENT');
xlabel('Universe of Discourse');
ylabel('Degree of Membership');
xlim([0 1]);
ylim([0 1.1]);
```

```
% Save Figure Image File
saveas(figs(figureIdx-1), 'img/fuzzy-operators.png');
```




### Defuzzification - Center of Area or Center of Gravity

$$x^* = \frac{\sum_{i=1}^{n} x_i \mu U(x_i)}{\sum_{i=1}^{n} \mu U(x_i)}$$

### Defuzzification - Center of Sums

$$x^* = \frac{\sum_{i=1}^{n} x_i \sum_{k=1}^{l} \mu k(x_i)}{\sum_{i=1}^{n} \sum_{k=1}^{l} \mu k(x_i)}$$

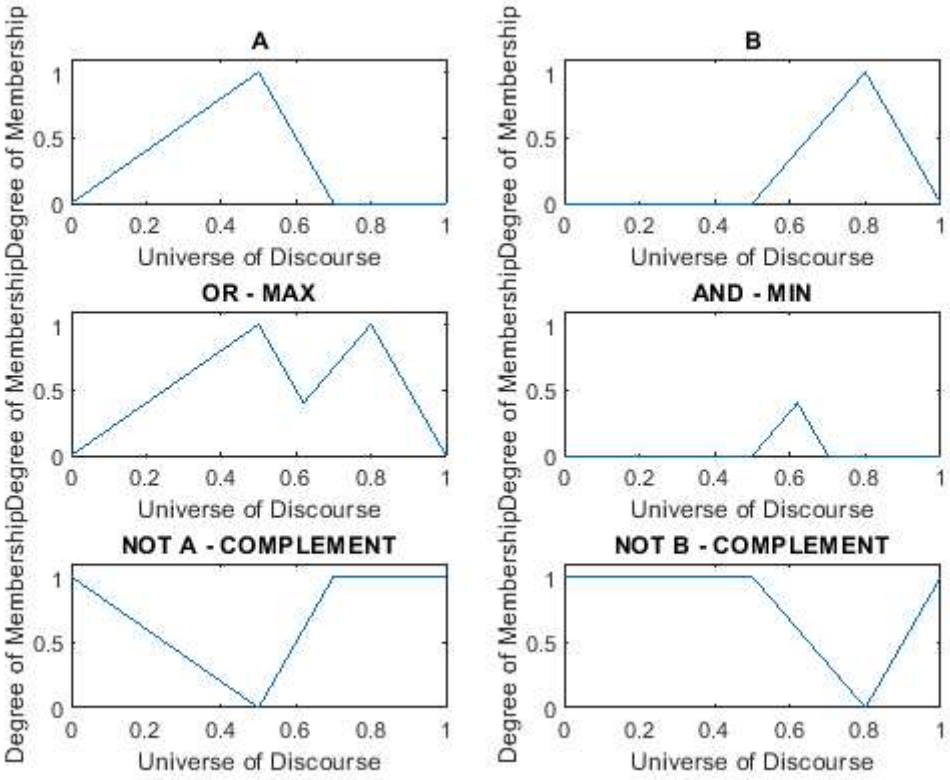
### Defuzzification - Heigth

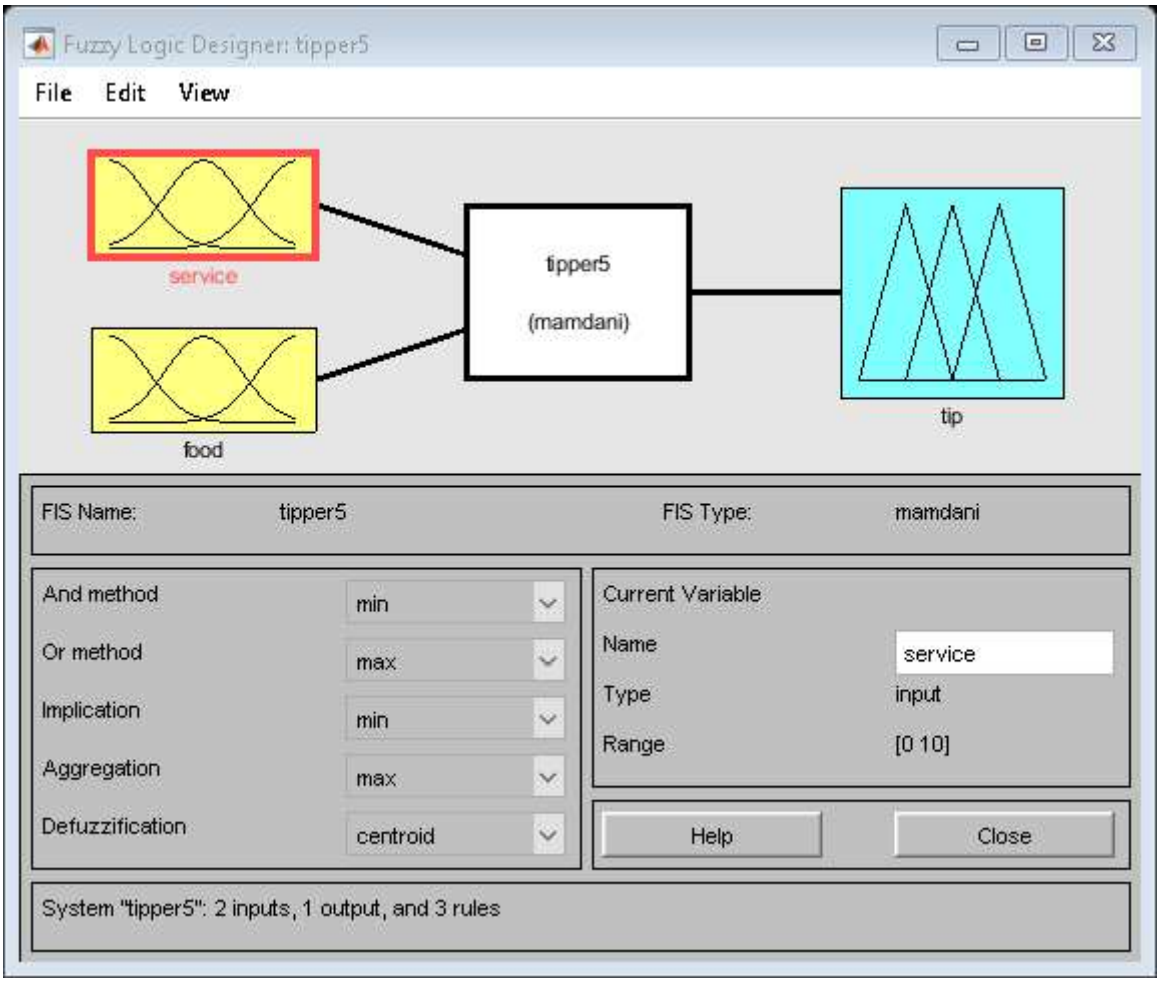
$$x^* = \frac{\sum_{i=1}^{L} x_i \mu_i(x)}{\sum_{i=1}^{L} \mu(x_i)}$$

### The Basic Tipping Problem

```
fuzzyLogicDesigner('tipper.fis');
fis = readfis('tipper');

service = 7;
food = 5;
fprintf('Service = %d, Food = %d, Then Tip = %.2d\n', ...
    service, food, evalfis(fis,[service, food]));
```

```
Service = 7, Food = 5, Then Tip = 1.78e+01
```




## Functions

```
function H = hotCrisp(x)
   H = x;
   H(H<30) = 0;
```

```
   H(H>=30) = 1;
end

function H = hotFuzzy(x)
    H = trapmf(x, [25, 30, 1000, 1000]);
end
```

## References


1. MATLAB DOC - https://www.mathworks.com/help/

2. Coppin, B. (2004). Artificial intelligence illuminated. Jones & Bartlett Learning.

3. Oviedo, J., Vandewalle, J., Wertz, V.: Fuzzy Logic, Identification and Predictive Control. Advances in Industrial Control. Springer London (2004)

4. Stanford Encyclopedia of Philosophy. Russell's Paradox. https://plato.stanford.edu/entries/russell-paradox/

5. Build Fuzzy Systems Using Fuzzy Logic Designer - https://www.mathworks.com/help/fuzzy/building-systems-with-fuzzy-logic-toolbox-software.html#brzqs45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