2019

Fuzzy inference system for classification of fruit

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Introduction

The fuzzy inference system described in this report attempts to classify fruit in to one of six categories:

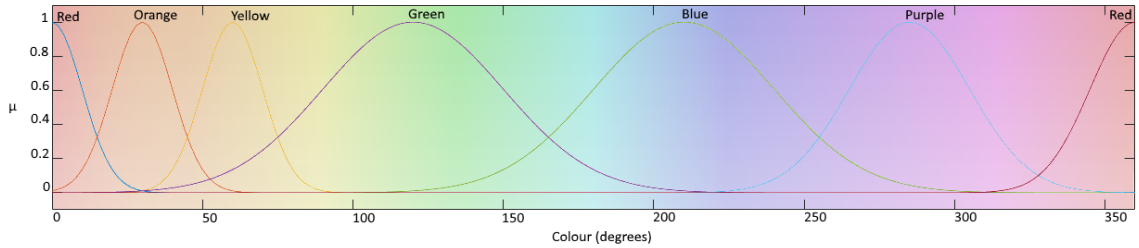
- Mango
- Orange
- Apple
- Kiwi
- Plum
- Apricot
- Grape
- Blueberry
- Physalis

In order to accurately assign the correct fruit three inputs were chosen: Colour, Size, and Hardness. The system a comprehensive rule set to define each fruit by the three qualities. The raw output of the fuzzy system gives 9 x % certainties relating to how likely the inputs describe a fruit, the highest of the values is chosen and used as the output to give a more usable output. This could be described as a limitation because only one fruit type can be output; therefore, if two certainties are equal (or close) only one can be output which can cause inaccuracy or confusion.

Inputs

There are three inputs to this fuzzy inference system: Colour, Size, and Hardness. These inputs were chosen because of their ability to separate fruits into different categories easily.

Figure 1

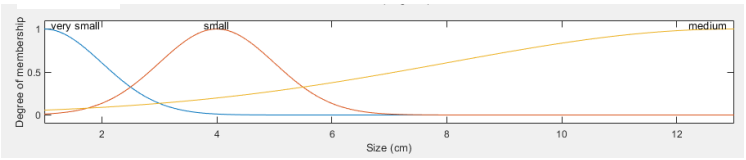


Colour

The obvious input where classifying fruit is colour. When describing colour, the input used is hue, hue is described on a continuous circle with 0° and 360° both being red, in order to input this to a fuzzy system the scale needs to become linear; therefore, a red membership function appears at both ends of the spectrum. Figure 1 shows membership functions created to split colour in to natural sections.

The colour membership functions are gaussian because it's describes the colour membership most naturally; for example: kiwi fruit are usually green, however between different kiwis the colour may vary slightly some being a darker green and perhaps some more yellow. A gaussian function best describes the colour of kiwis: most will be green (100 – 140), however occasionally a kiwi may be yellow (70).

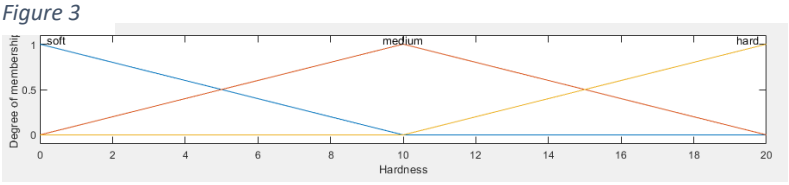
Figure 2



Size

The second input, size, is input on a scale from 1cm to 13cm. These limits were chosen because most fruit that can be determined by the system will fall between these two boundaries. Figure 2 shows the membership functions for size. Gaussian functions were used again because of their ability to describe real life distributions: most grapes will be less than 2cm, however it is not impossible for a 5cm grape to exist.

Figure 3



Hardness

The final input, hardness, is described on a scale from 0 to 20. Figure 3 shows the membership functions used, each of them is a triangle with a very large base. A single type of fruit can vary how hard it is: some apples are hard some apples are soft; therefore, the triangle functions have a wide base to represent this variety.

Rules

The rules define the fuzzy system, when creating the rules they were split up by fruit and in to a few sections. For each fruit there are multiple rules to describe a perfect example of the fruit for example grapes can be green or yellow, small and mediumly hard. There are also rules to describe unripe or overripe fruit, this tends to be softer / harder than the ideal and occasionally more yellow / green. The rules describe different types of each fruit: apples can be red, yellow, or green. This is discussed in the output section in greater detail.

The next pages contain a table of all the rules included in the system, they have been ordered by fruit type, the colours column has been conditionally formatted to allow for easier reading of the table.

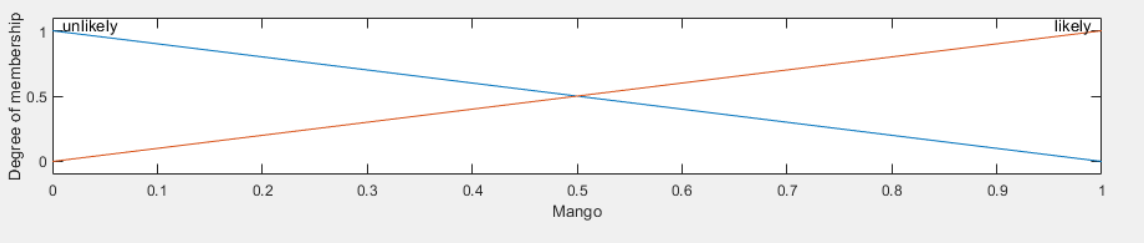
Fruit	Description	Colour	Size	Hardness	μ(Mango)	μ(Orange)	μ(Apple)	μ(Kiwi)	μ(Plum)	μ(Apricot)	μ(Grape)	μ(Blueberry)	μ(Physalis)	Strength
Apple	A Small Apple	1	2	3	0	0	2	0	0	0	0	0	0	0.5
		2	2	3	0	0	2	0	0	0	0	0	0	0.5
		3	2	3	0	0	2	0	0	0	0	0	0	0.5
		4	2	3	0	0	2	0	0	0	0	0	0	0.5
		7	2	3	0	0	2	0	0	0	0	0	0	0.5
	A Medium Apple	1	3	3	0	0	2	0	0	0	0	0	0	1
		2	3	3	0	0	2	0	0	0	0	0	0	1
		3	3	3	0	0	2	0	0	0	0	0	0	1
		4	3	3	0	0	2	0	0	0	0	0	0	1
		7	3	3	0	0	2	0	0	0	0	0	0	1
	A Soft Small Apple	1	2	2	0	0	2	0	0	0	0	0	0	0.25
		2	2	2	0	0	2	0	0	0	0	0	0	0.25
		3	2	2	0	0	2	0	0	0	0	0	0	0.25
		4	2	2	0	0	2	0	0	0	0	0	0	0.25
		7	2	2	0	0	2	0	0	0	0	0	0	0.25
	A Soft Medium Apple	1	3	2	0	0	2	0	0	0	0	0	0	0.5
		2	3	2	0	0	2	0	0	0	0	0	0	0.5
		3	3	2	0	0	2	0	0	0	0	0	0	0.5
		4	2	2	0	0	2	0	0	0	0	0	0	0.5
		7	3	2	0	0	2	0	0	0	0	0	0	0.5
	Not An Apple	5	0	0	0	0	1	0	0	0	0	0	0	1
		6	0	0	0	0	1	0	0	0	0	0	0	1
		0	1	0	0	0	1	0	0	0	0	0	0	1
		0	0	1	0	0	1	0	0	0	0	0	0	1

		3	2	1	0	0	0	0	0	2	0	0	0	1
	An Apricot	2	2	1	0	0	0	0	0	2	0	0	0	1
		3	2	2	0	0	0	0	0	2	0	0	0	0.5
		2	2	2	0	0	0	0	0	2	0	0	0	0.5
		3	2	3	0	0	0	0	0	2	0	0	0	0.25
	An Unripe Apricot	2	2	3	0	0	0	0	0	2	0	0	0	0.25
		1	0	0	0	0	0	0	0	1	0	0	0	0.5
		4	0	0	0	0	0	0	0	1	0	0	0	1
		5	0	0	0	0	0	0	0	1	0	0	0	1
		6	0	0	0	0	0	0	0	1	0	0	0	1
		7	0	0	0	0	0	0	0	1	0	0	0	0.5
		0	1	0	0	0	0	0	0	1	0	0	0	1
Apricot	Not An Apricot	0	3	0	0	0	0	0	0	1	0	0	0	1
		5	1	1	0	0	0	0	0	0	0	2	0	1
	A Blueberry	6	1	1	0	0	0	0	0	0	0	2	0	1
		1	0	0	0	0	0	0	0	0	0	1	0	1
		2	0	0	0	0	0	0	0	0	0	1	0	1
		3	0	0	0	0	0	0	0	0	0	1	0	1
		4	0	0	0	0	0	0	0	0	0	1	0	1
		7	0	0	0	0	0	0	0	0	0	1	0	1
		0	2	0	0	0	0	0	0	0	0	1	0	1
		0	3	0	0	0	0	0	0	0	0	1	0	1
		0	0	2	0	0	0	0	0	0	0	1	0	1
Blueberry	Not A Blueberry	0	0	3	0	0	0	0	0	0	0	1	0	1
		3	1	2	0	0	0	0	0	0	2	0	0	0.5
	A Grape	4	1	2	0	0	0	0	0	0	2	0	0	1
		1	0	0	0	0	0	0	0	0	1	0	0	1
		2	0	0	0	0	0	0	0	0	1	0	0	1
Grape	Not A Grape	5	0	0	0	0	0	0	0	0	1	0	0	1

		6	0	0	0	0	0	0	0	0	1	0	0	1
		7	0	0	0	0	0	0	0	0	1	0	0	1
		0	2	0	0	0	0	0	0	0	1	0	0	1
		0	3	0	0	0	0	0	0	0	1	0	0	1
		0	0	1	0	0	0	0	0	0	1	0	0	0.5
		0	0	3	0	0	0	0	0	0	1	0	0	0.5
		4	2	2	0	0	0	2	0	0	0	0	0	1
		4	2	3	0	0	0	2	0	0	0	0	0	0.5
	A Kiwi	4	2	1	0	0	0	2	0	0	0	0	0	0.5
		1	0	0	0	0	0	1	0	0	0	0	0	1
		2	0	0	0	0	0	1	0	0	0	0	0	1
		3	0	0	0	0	0	1	0	0	0	0	0	1
		5	0	0	0	0	0	1	0	0	0	0	0	1
		6	0	0	0	0	0	1	0	0	0	0	0	1
		7	0	0	0	0	0	1	0	0	0	0	0	1
		0	1	0	0	0	0	1	0	0	0	0	0	1
Kiwi	Not A Kiwi	0	3	0	0	0	0	1	0	0	0	0	0	1
		2	3	2	2	0	0	0	0	0	0	0	0	1
	A Mango	3	3	2	2	0	0	0	0	0	0	0	0	1
	An Unripe Mango	3	3	3	2	0	0	0	0	0	0	0	0	0.5
		4	3	3	2	0	0	0	0	0	0	0	0	0.5
		1	0	0	1	0	0	0	0	0	0	0	0	1
		5	0	0	1	0	0	0	0	0	0	0	0	1
		6	0	0	1	0	0	0	0	0	0	0	0	1
		0	2	0	1	0	0	0	0	0	0	0	0	1
		0	1	0	1	0	0	0	0	0	0	0	0	1
Mango	Not A Mango	0	0	1	1	0	0	0	0	0	0	0	0	1
	An Orange	2	3	1	0	2	0	0	0	0	0	0	0	1
Orange	An Unripe Orange	3	3	1	0	2	0	0	0	0	0	0	0	0.75

		4	3	2	0	2	0	0	0	0	0	0	0	0.75
		1	0	0	0	1	0	0	0	0	0	0	0	1
		5	0	0	0	1	0	0	0	0	0	0	0	1
		6	0	0	0	1	0	0	0	0	0	0	0	1
		7	0	0	0	1	0	0	0	0	0	0	0	1
		0	1	0	0	1	0	0	0	0	0	0	0	1
		0	0	2	0	1	0	0	0	0	0	0	0	1
	Not An Orange	0	0	3	0	1	0	0	0	0	0	0	0	1
	A Physalis	2	1	2	0	0	0	0	0	0	0	0	2	1
		3	1	2	0	0	0	0	0	0	0	0	2	0.5
	An Unripe Physalis	4	1	3	0	0	0	0	0	0	0	0	2	0.5
		1	0	0	0	0	0	0	0	0	0	0	1	1
		5	0	0	0	0	0	0	0	0	0	0	1	1
		6	0	0	0	0	0	0	0	0	0	0	1	1
		7	0	0	0	0	0	0	0	0	0	0	1	1
		0	2	0	0	0	0	0	0	0	0	0	1	1
		0	3	0	0	0	0	0	0	0	0	0	1	1
Physalis	Not A Physalis	0	0	1	0	0	0	0	0	0	0	0	1	1
		1	2	1	0	0	0	0	2	0	0	0	0	1
		6	2	1	0	0	0	0	2	0	0	0	0	1
	A Soft Plum	7	2	1	0	0	0	0	2	0	0	0	0	1
		1	2	2	0	0	0	0	2	0	0	0	0	1
	A Medium Hard	6	2	2	0	0	0	0	2	0	0	0	0	1
	Plum	7	2	2	0	0	0	0	2	0	0	0	0	1
		1	2	3	0	0	0	0	2	0	0	0	0	0.5
		6	2	3	0	0	0	0	2	0	0	0	0	0.5
		7	2	3	0	0	0	0	2	0	0	0	0	0.5
		1	1	3	0	0	0	0	2	0	0	0	0	0.5
Plum	An Unripe Plum	6	1	3	0	0	0	0	2	0	0	0	0	0.5

		7	1	3	0	0	0	0	2	0	0	0	0	0.5
		2	0	0	0	0	0	0	1	0	0	0	0	1
		3	0	0	0	0	0	0	1	0	0	0	0	1
		4	0	0	0	0	0	0	1	0	0	0	0	1
		5	0	0	0	0	0	0	1	0	0	0	0	1
	Not A Plum	0	3	0	0	0	0	0	1	0	0	0	0	1



Outputs

Each of the outputs is described by two membership functions, likely and unlikely, the rules define a high membership to likely if the inputs display ALL the qualities of that type of fruit, and a high membership to unlikely if the inputs display ANY of the qualities not common among that type of fruit.

Mango

Mangoes are medium size, medium hardness, yellow or orange fruit. Unripe mangoes are defined as yellow and harder, green mangoes were not included due to their similarity to green apples (green, medium size, hard).

Orange

Oranges are specifically defined as orange, medium size and soft. Unripe oranges are similar however yellow or green. Unlike mangoes an unripe orange is dissimilar enough from a green apple (oranges are softer).

Apple

There are many types of apples, and this is reflected in the rule base: apples can be red, orange, yellow, or green; hard or medium hardness; and medium or small size. Therefore, there is a rule to describe each of these scenarios.

Kiwi

Kiwis are small green fruits with a medium hardness. Unripe kiwis are harder and overripe kiwis are softer. These rules define anything that is green and small as a kiwi; therefore, the unripe and overripe rules have a lower weighting to stop the system from classifying too many fruits as kiwis.

Plum

Plums are small purple or red fruits they are soft or medium hardness. Unripe plums are harder and smaller.

Apricot

Apricots are small, yellow or orange, soft fruits. Unripe apricots are more hard than ripe ones; therefore, there are rules that add both hard and medium hardness into the apricot definition.

Grape

Grapes can also exist in a variety of colours; however, this system only recognises them as green or yellow. They are also small and medium hard.

Blueberry

Blueberries were added for their colour, there are not many fruits that are blue / purple. They are defined as blue/ purple, small and soft.

Physalis

Physalis were also added for their colour, it is a small orange fruit that are medium hard. A full range of colours were added to ensure there was an output for any combination of inputs.

Testing

Multiple tests have been defined and entered into an excel file, the code is designed to iterate through each row of the excel file and apply the inputs to the fuzzy inference system. Below is a table of each of the tests, their inputs, description and outputs.

Most of the tests pass as expected; however, attention should be given to test 3, where a

hard green mango is described, the system outputs apple as the expected fruit. The output for apple (0.65) only slightly beats the output for mango (0.58). This is because both an unripe mango and a green apple are defined as green, hard and medium size. This is a problem caused by the inputs: there are simply not enough to define this many fruit types, to correct this a new input could be added for example: seed size. Fruit can be separated by how large the seed is, logical membership functions include: tiny (blueberries, physalis), pips (apples, oranges), stones(apricots, mangoes).

ID	Colour	Size	Hardness	Description	Output
1	60	13	8	a perfect yellow mango	1: Colour: 60, Size: 13, Hardness: 8, Fruit: Mango 0.6800 0.3100 0.5800 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900
2	30	12	10	a perfect orange mango	2: Colour: 30, Size: 12, Hardness: 10, Fruit: Mango 0.7100 0.2900 0.6300 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900
3	90	13	18	an unripe mango (green and hard)	3: Colour: 90, Size: 13, Hardness: 18, Fruit: Apple 0.5800 0.3100 0.6500 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900
4	90	11	10	an unripe mango (green)	4: Colour: 90, Size: 11, Hardness: 10, Fruit: Mango 0.5100 0.3700 0.5000 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900
5	30	10	2	a perfect orange	5: Colour: 30, Size: 10, Hardness: 2, Fruit: Orange 0.3700 0.6800 0.3100 0.2900 0.2900 0.3000 0.2900 0.2900 0.3000
6	60	11	1	an unripe orange (yellow)	6: Colour: 60, Size: 11, Hardness: 1, Fruit: Orange 0.3700 0.6700 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900
7	100	12	2	a very unripe orange (green)	7: Colour: 100, Size: 12, Hardness: 2, Fruit: Orange 0.3000 0.4800 0.3000 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900
8	35	6	3	a tangerine	8: Colour: 35, Size: 6, Hardness: 3, Fruit: Orange 0.3600 0.5300 0.3300 0.2900 0.2900 0.4200 0.2900 0.2900 0.3200
9	15	10	15	a red apple	9: Colour: 15, Size: 10, Hardness: 15, Fruit: Apple 0.5000 0.3700 0.5800 0.3000 0.3000 0.3000 0.3000 0.3000 0.3000
10	100	8	17	a green apple	10: Colour: 100, Size: 8, Hardness: 17, Fruit: Apple 0.5800 0.3400 0.6500 0.3500 0.3000 0.3000 0.3500 0.3000 0.3500
11	45	9	20	an overripe yellow apple	11: Colour: 45, Size: 9, Hardness: 20, Fruit: Apple 0.5400 0.2900 0.5800 0.3200 0.3200 0.3200 0.3200 0.2900 0.3200
12	100	5	2	a perfect kiwi	12: Colour: 100, Size: 5, Hardness: 2, Fruit: Kiwi 0.3000 0.3600 0.3100 0.5100 0.3000 0.3000 0.3500 0.3000 0.3000
13	120	4	7	an unripe kiwi (hard)	13: Colour: 120, Size: 4, Hardness: 7, Fruit: Kiwi 0.2900 0.3000 0.5200 0.6600 0.2900 0.2900 0.2900 0.2900 0.2900
14	290	5	1	a perfect purple plum	14: Colour: 290, Size: 5, Hardness: 1, Fruit: Plum 0.2900 0.2900 0.2900 0.2900 0.6200 0.2900 0.2900 0.3500 0.2900
15	350	3	11	a perfect red plum	15: Colour: 350, Size: 3, Hardness: 11, Fruit: Plum 0.3500 0.2900 0.5100 0.3000 0.6500 0.4000 0.3000 0.2900 0.3000

16	320	4	20	an unripe plum (hard)	16: Colour: 320, Size: 4, Hardness: 20, Fruit: Plum 0.2900 0.2900 0.4400 0.4400 0.4600 0.4400 0.2900 0.2900 0.2900
17	30	3	2	a perfect yellow apricot	17: Colour: 30, Size: 3, Hardness: 2, Fruit: Apricot 0.3100 0.3500 0.3100 0.2900 0.2900 0.6500 0.2900 0.2900 0.3100
18	60	5	1	a perfect orange apricot	18: Colour: 60, Size: 5, Hardness: 1, Fruit: Apricot 0.3000 0.3600 0.2900 0.2900 0.2900 0.6200 0.3500 0.2900 0.2900
19	45	4	7	an unripe apricot (hard)	19: Colour: 45, Size: 4, Hardness: 7, Fruit: Apricot 0.3000 0.3000 0.4300 0.4200 0.4200 0.5400 0.2900 0.2900 0.2900
20	105	2	8	a perfect grape	20: Colour: 105, Size: 2, Hardness: 8, Fruit: Grape 0.3500 0.3100 0.3500 0.3500 0.2900 0.2900 0.6500 0.2900 0.4500
21	150	1	13	a perfect grape	21: Colour: 150, Size: 1, Hardness: 13, Fruit: Grape 0.2900 0.2900 0.2900 0.2900 0.3500 0.2900 0.6400 0.3200 0.5100
22	200	1	3	a perfect blue blueberry	22: Colour: 200, Size: 1, Hardness: 3, Fruit: Blueberry 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900 0.6400 0.2900
23	300	2	1	a perfect purple blueberry	23: Colour: 300, Size: 2, Hardness: 1, Fruit: Blueberry 0.2900 0.3100 0.2900 0.3100 0.5200 0.3100 0.3100 0.6500 0.2900
24	250	1	6	an unripe blueberry (hard and small)	24: Colour: 250, Size: 1, Hardness: 6, Fruit: Blueberry 0.2900 0.2900 0.2900 0.2900 0.3900 0.2900 0.3900 0.4200 0.3900
25	30	1	10	a perfect orange physalis	25: Colour: 30, Size: 1, Hardness: 10, Fruit: Physalis 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900 0.7100
26	105	1	20	unripe physalis (green)	26: Colour: 105, Size: 1, Hardness: 20, Fruit: Physalis 0.2900 0.2900 0.2900 0.2900 0.2900 0.2900 0.3700 0.2900 0.6100

Appendicies

Fruit.m

```
%the fuzzy inference system
FruitFIS = newfis('Fruit');



%INPUTS

%input 1
%Colour input, on a scale of 0-360, red being 0 and 360 progressing through
%red -> orange -> yellow -> green -> blue -> purple -> red
FruitFIS = addvar(FruitFIS, 'input', 'Colour (Degrees)', [0 360]);

%membership functions
FruitFIS = addmf(FruitFIS, 'input', 1, 'red 1', 'gaussmf', [10 0]);
FruitFIS = addmf(FruitFIS, 'input', 1, 'orange', 'gaussmf', [10 30]);
FruitFIS = addmf(FruitFIS, 'input', 1, 'yellow', 'gaussmf', [10 60]);
FruitFIS = addmf(FruitFIS, 'input', 1, 'green', 'gaussmf', [30 120]);
FruitFIS = addmf(FruitFIS, 'input', 1, 'blue', 'gaussmf', [30 210]);
FruitFIS = addmf(FruitFIS, 'input', 1, 'purple', 'gaussmf', [20 285]);
FruitFIS = addmf(FruitFIS, 'input', 1, 'red 2', 'gaussmf', [15 360]);

%input 2
%Size input, only accepting fruits between 1 and 20 cm
%very small -> small -> medium -> large
FruitFIS = addvar(FruitFIS, 'input', 'Size (cm)', [1 13]);

%membership functions
FruitFIS = addmf(FruitFIS, 'input', 2, 'very small', 'gaussmf', [1 1]);
FruitFIS = addmf(FruitFIS, 'input', 2, 'small', 'gaussmf', [1 4]);
FruitFIS = addmf(FruitFIS, 'input', 2, 'medium', 'gaussmf', [5 13]);

%input 3
%Hardness input, no unit, simply on a scale of 0 to 30
%very soft -> soft -> medium -> hard
FruitFIS = addvar(FruitFIS, 'input', 'Hardness', [0 20]);

%membership functions
FruitFIS = addmf(FruitFIS, 'input', 3, 'soft', 'trimf', [0 0 10]);
FruitFIS = addmf(FruitFIS, 'input', 3, 'medium', 'trimf', [0 10 20]);
FruitFIS = addmf(FruitFIS, 'input', 3, 'hard', 'trimf', [10 20 20]);

figure(1)
subplot(4,1,1), plotmf(FruitFIS,'input',1);
subplot(4,1,2), plotmf(FruitFIS,'input',2);
subplot(4,1,3), plotmf(FruitFIS,'input',3);



%OUTPUTS

FruitFIS = newOutput(FruitFIS, 1, 'Mango');
FruitFIS = newOutput(FruitFIS, 2, 'Orange');
FruitFIS = newOutput(FruitFIS, 3, 'Apple');
```

```
FruitFIS = newOutput(FruitFIS, 4, 'Kiwi');
FruitFIS = newOutput(FruitFIS, 5, 'Plum');
FruitFIS = newOutput(FruitFIS, 6, 'Apricot');

FruitFIS = newOutput(FruitFIS, 7, 'Grape');
FruitFIS = newOutput(FruitFIS, 8, 'Blueberry');
FruitFIS = newOutput(FruitFIS, 9, 'Physalis');

subplot(4,1,4), plotmf(FruitFIS, 'output',1);

%RULES

%Mango rules
%Ripe
Mango01 = [2 3 2   2 0 0  0 0 0  0 0 0   1 1];
Mango02 = [3 3 2   2 0 0  0 0 0  0 0 0   1 1];

%Unripe
Mango03 = [3 3 3   2 0 0  0 0 0  0 0 0   0.5 1];
Mango04 = [4 3 3   2 0 0  0 0 0  0 0 0   0.5 1];

%Not
%Colour
Mango07 = [1 0 0   1 0 0  0 0 0  0 0 0   1 1];
Mango08 = [5 0 0   1 0 0  0 0 0  0 0 0   1 1];
Mango09 = [6 0 0   1 0 0  0 0 0  0 0 0   1 1];

%Size
Mango10 = [0 2 0   1 0 0  0 0 0  0 0 0   1 1];
Mango11 = [0 1 0   1 0 0  0 0 0  0 0 0   1 1];

%Hardness
Mango12 = [0 0 1   1 0 0  0 0 0  0 0 0   1 1];


%Orange Rules
%Ripe
Orange01 = [2 3 1   0 2 0  0 0 0  0 0 0   1 1];

%Unripe
Orange02 = [3 3 1   0 2 0  0 0 0  0 0 0   0.75 1];
Orange03 = [4 3 2   0 2 0  0 0 0  0 0 0   0.75 1];

%Not
%Colour
Orange04 = [1 0 0   0 1 0  0 0 0  0 0 0   1 1];
Orange06 = [5 0 0   0 1 0  0 0 0  0 0 0   1 1];
Orange07 = [6 0 0   0 1 0  0 0 0  0 0 0   1 1];
Orange08 = [7 0 0   0 1 0  0 0 0  0 0 0   1 1];

%Size
Orange09 = [0 1 0   0 1 0  0 0 0  0 0 0   1 1];

%Hardness
Orange11 = [0 0 2   0 1 0  0 0 0  0 0 0   1 1];
Orange12 = [0 0 3   0 1 0  0 0 0  0 0 0   1 1];
```

```
%Apple Rules
%Ripe
Apple01 = [1 2 3   0 0 2  0 0 0  0 0 0   0.5 1];
Apple02 = [2 2 3   0 0 2  0 0 0  0 0 0   0.5 1];
Apple03 = [3 2 3   0 0 2  0 0 0  0 0 0   0.5 1];
Apple04 = [4 2 3   0 0 2  0 0 0  0 0 0   0.5 1];
Apple05 = [7 2 3   0 0 2  0 0 0  0 0 0   0.5 1];

Apple06 = [1 3 3   0 0 2  0 0 0  0 0 0   1 1];
Apple07 = [2 3 3   0 0 2  0 0 0  0 0 0   1 1];
Apple08 = [3 3 3   0 0 2  0 0 0  0 0 0   1 1];
Apple09 = [4 3 3   0 0 2  0 0 0  0 0 0   1 1];
Apple10 = [7 3 3   0 0 2  0 0 0  0 0 0   1 1];

%Overripe
Apple11 = [1 2 2   0 0 2  0 0 0  0 0 0   0.25 1];
Apple12 = [2 2 2   0 0 2  0 0 0  0 0 0   0.25 1];
Apple13 = [3 2 2   0 0 2  0 0 0  0 0 0   0.25 1];
Apple14 = [4 2 2   0 0 2  0 0 0  0 0 0   0.25 1];
Apple15 = [7 2 2   0 0 2  0 0 0  0 0 0   0.25 1];

Apple16 = [1 3 2   0 0 2  0 0 0  0 0 0   0.5 1];
Apple17 = [2 3 2   0 0 2  0 0 0  0 0 0   0.5 1];
Apple18 = [3 3 2   0 0 2  0 0 0  0 0 0   0.5 1];
Apple19 = [4 2 2   0 0 2  0 0 0  0 0 0   0.5 1];
Apple20 = [7 3 2   0 0 2  0 0 0  0 0 0   0.5 1];

%Not
%Colour
Apple21 = [5 0 0   0 0 1  0 0 0  0 0 0   1 1];
Apple22 = [6 0 0   0 0 1  0 0 0  0 0 0   1 1];

%Size
Apple23 = [0 1 0   0 0 1  0 0 0  0 0 0   1 1];

%Hardness
Apple24 = [0 0 1   0 0 1  0 0 0  0 0 0   1 1];



%Kiwi Rules
%Ripe
Kiwi01 = [4 2 2   0 0 0  2 0 0  0 0 0   1 1];

%Unripe
Kiwi02 = [4 2 3   0 0 0  2 0 0  0 0 0   0.5 1];

%Overripe
Kiwi03 = [4 2 1   0 0 0  2 0 0  0 0 0   0.5 1];

%Not
%Colour
Kiwi04 = [1 0 0   0 0 0  1 0 0  0 0 0   1 1];
Kiwi05 = [2 0 0   0 0 0  1 0 0  0 0 0   1 1];
Kiwi06 = [3 0 0   0 0 0  1 0 0  0 0 0   1 1];
Kiwi07 = [5 0 0   0 0 0  1 0 0  0 0 0   1 1];
Kiwi08 = [6 0 0   0 0 0  1 0 0  0 0 0   1 1];
Kiwi09 = [7 0 0   0 0 0  1 0 0  0 0 0   1 1];
```

```
%Size
Kiwi10 = [0 1 0   0 0 0  1 0 0  0 0 0   1 1];
Kiwi11 = [0 3 0   0 0 0  1 0 0  0 0 0   1 1];



%Plum Rules
%Ripe
Plum01  = [1 2 1   0 0 0  0 2 0  0 0 0   1 1];
Plum02  = [6 2 1   0 0 0  0 2 0  0 0 0   1 1];
Plum03  = [7 2 1   0 0 0  0 2 0  0 0 0   1 1];

Plum04  = [1 2 2   0 0 0  0 2 0  0 0 0   1 1];
Plum05  = [6 2 2   0 0 0  0 2 0  0 0 0   1 1];
Plum06  = [7 2 2   0 0 0  0 2 0  0 0 0   1 1];

%Unripe
Plum07  = [1 2 3   0 0 0  0 2 0  0 0 0   0.5 1];
Plum08  = [6 2 3   0 0 0  0 2 0  0 0 0   0.5 1];
Plum09  = [7 2 3   0 0 0  0 2 0  0 0 0   0.5 1];

Plum10  = [1 1 3   0 0 0  0 2 0  0 0 0   0.5 1];
Plum11  = [6 1 3   0 0 0  0 2 0  0 0 0   0.5 1];
Plum12  = [7 1 3   0 0 0  0 2 0  0 0 0   0.5 1];

%Not
%Colour
Plum13  = [2 0 0   0 0 0  0 1 0  0 0 0   1 1];
Plum14  = [3 0 0   0 0 0  0 1 0  0 0 0   1 1];
Plum15  = [4 0 0   0 0 0  0 1 0  0 0 0   1 1];
Plum16  = [5 0 0   0 0 0  0 1 0  0 0 0   1 1];

%Size
Plum17  = [0 3 0   0 0 0  0 1 0  0 0 0   1 1];



%Apricot Rules
%Ripe
Apricot01  = [3 2 1   0 0 0  0 0 2  0 0 0   1 1];
Apricot02  = [2 2 1   0 0 0  0 0 2  0 0 0   1 1];

%Unripe
Apricot03  = [3 2 2   0 0 0  0 0 2  0 0 0   0.5 1];
Apricot04  = [2 2 2   0 0 0  0 0 2  0 0 0   0.5 1];

Apricot05  = [3 2 3   0 0 0  0 0 2  0 0 0   0.25 1];
Apricot06  = [2 2 3   0 0 0  0 0 2  0 0 0   0.25 1];

%Not
%Colour
Apricot07  = [1 0 0   0 0 0  0 0 1  0 0 0   0.5 1];
Apricot08  = [4 0 0   0 0 0  0 0 1  0 0 0   1 1];
Apricot09  = [5 0 0   0 0 0  0 0 1  0 0 0   1 1];
Apricot10  = [6 0 0   0 0 0  0 0 1  0 0 0   1 1];
Apricot11  = [7 0 0   0 0 0  0 0 1  0 0 0   0.5 1];
```

```
%Size
Apricot12  = [0 1 0   0 0 0  0 0 1  0 0 0   1 1];
Apricot13  = [0 3 0   0 0 0  0 0 1  0 0 0   1 1];



%Grape Rules
%Ripe
Grape01 = [3 1 2   0 0 0  0 0 0  2 0 0   0.5 1];
Grape02 = [4 1 2   0 0 0  0 0 0  2 0 0   1 1];

%Not
%Colour
Grape03 = [1 0 0   0 0 0  0 0 0  1 0 0   1 1];
Grape04 = [2 0 0   0 0 0  0 0 0  1 0 0   1 1];
Grape05 = [5 0 0   0 0 0  0 0 0  1 0 0   1 1];
Grape06 = [6 0 0   0 0 0  0 0 0  1 0 0   1 1];
Grape07 = [7 0 0   0 0 0  0 0 0  1 0 0   1 1];

%Size
Grape08 = [0 2 0   0 0 0  0 0 0  1 0 0   1 1];
Grape09 = [0 3 0   0 0 0  0 0 0  1 0 0   1 1];

%Hardness
Grape10 = [0 0 1   0 0 0  0 0 0  1 0 0   0.5 1];
Grape11 = [0 0 3   0 0 0  0 0 0  1 0 0   0.5 1];



%Blueberry Rules
%Ripe
Blueberry01 = [5 1 1   0 0 0  0 0 0  0 2 0   1 1];
Blueberry02 = [6 1 1   0 0 0  0 0 0  0 2 0   1 1];

%Not
%Colour
Blueberry03 = [1 0 0   0 0 0  0 0 0  0 1 0   1 1];
Blueberry04 = [2 0 0   0 0 0  0 0 0  0 1 0   1 1];
Blueberry05 = [3 0 0   0 0 0  0 0 0  0 1 0   1 1];
Blueberry06 = [4 0 0   0 0 0  0 0 0  0 1 0   1 1];
Blueberry07 = [7 0 0   0 0 0  0 0 0  0 1 0   1 1];

%Size
Blueberry08 = [0 2 0   0 0 0  0 0 0  0 1 0   1 1];
Blueberry09 = [0 3 0   0 0 0  0 0 0  0 1 0   1 1];

%Hardness
Blueberry10 = [0 0 2   0 0 0  0 0 0  0 1 0   1 1];
Blueberry11 = [0 0 3   0 0 0  0 0 0  0 1 0   1 1];



%Physalis Rules
%Ripe
Physalis01 = [2 1 2   0 0 0  0 0 0  0 0 2   1 1];

%Unripe
```

```
Physalis02 = [3 1 2   0 0 0  0 0 0  0 0 2   0.5 1];
Physalis03 = [4 1 3   0 0 0  0 0 0  0 0 2   0.5 1];


%Not
%Colour
Physalis04 = [1 0 0   0 0 0  0 0 0  0 0 1   1 1];
Physalis05 = [5 0 0   0 0 0  0 0 0  0 0 1   1 1];
Physalis06 = [6 0 0   0 0 0  0 0 0  0 0 1   1 1];
Physalis07 = [7 0 0   0 0 0  0 0 0  0 0 1   1 1];

%Size
Physalis08 = [0 2 0   0 0 0  0 0 0  0 0 1   1 1];
Physalis09 = [0 3 0   0 0 0  0 0 0  0 0 1   1 1];

%Hardness
Physalis10 = [0 0 1   0 0 0  0 0 0  0 0 1   1 1];



RuleList = [Apple01; Apple02; Apple03; Apple04; Apple05; Apple06; Apple07;
Apple08; Apple09; Apple10; Apple11; Apple12; Apple13; Apple14; Apple15;
Apple16; Apple17; Apple18; Apple19; Apple20; Apple21; Apple22; Apple23;
Apple24; Apricot01; Apricot02; Apricot03; Apricot04; Apricot05; Apricot06;
Apricot07; Apricot08; Apricot09; Apricot10; Apricot11; Apricot12;
Apricot13; Blueberry01; Blueberry02; Blueberry03; Blueberry04; Blueberry05;
Blueberry06; Blueberry07; Blueberry08; Blueberry09; Blueberry10;
Blueberry11; Grape01; Grape02; Grape03; Grape04; Grape05; Grape06; Grape07;
Grape08; Grape09; Grape10; Grape11; Kiwi01; Kiwi02; Kiwi03; Kiwi04; Kiwi05;
Kiwi06; Kiwi07; Kiwi08; Kiwi09; Kiwi10; Kiwi11; Mango01; Mango02; Mango03;
Mango04; Mango07; Mango08; Mango09; Mango10; Mango11; Mango12; Orange01;
Orange02; Orange03; Orange04; Orange06; Orange07; Orange08; Orange09;
Orange11; Orange12; Physalis01; Physalis02; Physalis03; Physalis04;
Physalis05; Physalis06; Physalis07; Physalis08; Physalis09; Physalis10;
Plum01; Plum02; Plum03; Plum04; Plum05; Plum06; Plum07; Plum08; Plum09;
Plum10; Plum11; Plum12; Plum13; Plum14; Plum15; Plum16; Plum17];
FruitFIS = addrule(FruitFIS, RuleList);
%showrule(FruitFIS)
FruitFIS.defuzzMethod = 'bisector';
names = ["Mango"; "Orange"; "Apple"; "Kiwi"; "Plum"; "Apricot"; "Grape";
"Blueberry"; "Physalis"];



Inputs = xlsread('Inputs.xlsx');

i=1;
while (i <= size(Inputs,1))
    out = evalfis([Inputs(i, 1), Inputs(i, 2), Inputs(i, 3)], FruitFIS);
    [a,pos] = max(out);
    output = names(pos);
    fprintf('%i: Colour: %i, Size: %i, Hardness: %i, Fruit: %s\n', i,
Inputs(i, 1), Inputs(i, 2), Inputs(i, 3), output);
    disp(out);
    %printf('   %i, %i, %i,  %i, %i, %i,  %i, %i, %i',

    i = i + 1;
end
```

NewOutput.m

```
function newFIS = newOutput(oldFIS, num, name)
%adds a variable and its membership functions to the FIS for an input
newFIS = oldFIS;

newFIS = addvar(newFIS, 'output', name, [0, 1]);
newFIS = addmf(newFIS, 'output', num, 'unlikely', 'trimf', [0 0 1]);
newFIS = addmf(newFIS, 'output', num, 'likely', 'trimf', [0 1 1]);
```

Inputs.xslx

60	13	8	a perfect yellow mango
30	12	10	a perfect orange mango
90	13	18	an unripe mango (green and hard)
90	11	10	an unripe mango (green)
30	10	2	a perfect orange
60	11	1	an unripe orange (yellow)
100	12	2	a very unripe orange (green)
35	6	3	a tangerine
15	10	15	a red apple
100	8	17	a green apple
45	9	20	an overripe yellow apple
100	5	2	a perfect kiwi
120	4	7	an unripe kiwi (hard)
290	5	1	a perfect purple plum
350	3	11	a perfect red plum
320	4	20	an unripe plum (hard)
30	3	2	a perfect yellow apricot
60	5	1	a perfect orange apricot
45	4	7	an unripe apricot (hard)
105	2	8	a perfect grape
150	1	13	a perfect grape
200	1	3	a perfect blue blueberry
300	2	1	a perfect purple blueberry
250	1	6	an unripe blueberry (hard and small)
30	1	10	a perfect orange physalis
105	1	20	unripe physalis (green)