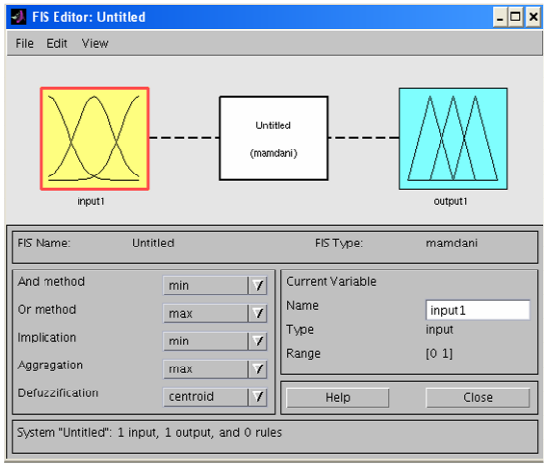
Fuzzy Logic Example

Exercise 1

- **Tipping example**

  You will be building the system using the graphical user interface (GUI) tools provided by Matlab's Fuzzy Logic Toolbox.

- Start Matlab and the Fuzzy Inference System (FIS) editor (see previous Lab how to launch Matlab).



NOTE: It is possible to use the Fuzzy Logic Toolbox by working strictly from the command line, but in general it is easier to build a system graphically.

Example taken from:

https://in.mathworks.com/help/fuzzy/an-introductory-example-fuzzy-versus-nonfuzzy-logic.html

https://in.mathworks.com/help/fuzzy/building-systems-with-fuzzy-logic-toolbox-software.html

https://in.mathworks.com/help/fuzzy/working-from-the-command-line.html

Exercise 1 – GUI tools

- The **FIS Editor** handles the high-level issues for the system:
  - How many input and output variables?
  - What are their names?

- The **Membership Function Editor** is used to define the shapes of all the membership functions associated with each variable.

- The **Rule Editor** is for editing the list of rules that defines the behaviour of the system.

- The **Rule Viewer** and the **Surface Viewer** are used for looking at, as opposed to editing, the FIS. They are strictly read-only tools.
  - The Rule Viewer is a MATLAB based display of the fuzzy inference diagram shown at the end of the last section. Used as a diagnostic, it can show (for example) which rules are active, or how individual membership function shapes are influencing the results.
  - The Surface Viewer is used to display the dependency of one of the outputs on any one or two of the inputs.

Example – Getting Started

- **The Basic Tipping Problem**

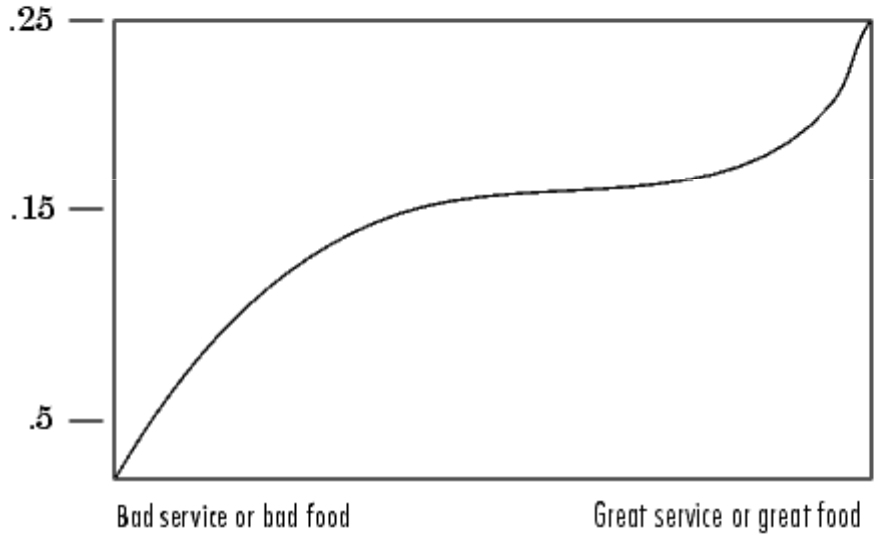
  Given a number between 0 and 10 that represents the quality of service at a restaurant (where 10 is excellent), and another number between 0 and 10 that represents the quality of the food at that restaurant (again, 10 is excellent), what should the tip be?

- The starting point is to write down the three golden rules of tipping, based on years of personal experience in restaurants:
  1. If the *service* is *poor* or the *food* is *rancid*, then *tip* is *cheap*.
  2. If the *service* is *good*, then *tip* is *average*.
  3. If the *service* is *excellent* or the *food* is *delicious*, then *tip* is *generous*.

- We'll assume that an average tip is 15%, a generous tip is 25%, and a cheap tip is 5%.

Example – Getting Started

- It is also useful to have a vague idea of what the tipping function should look like:



- Obviously the numbers and the shape of the curve are subject to local traditions, cultural bias, and so on, but the three rules are pretty universal.

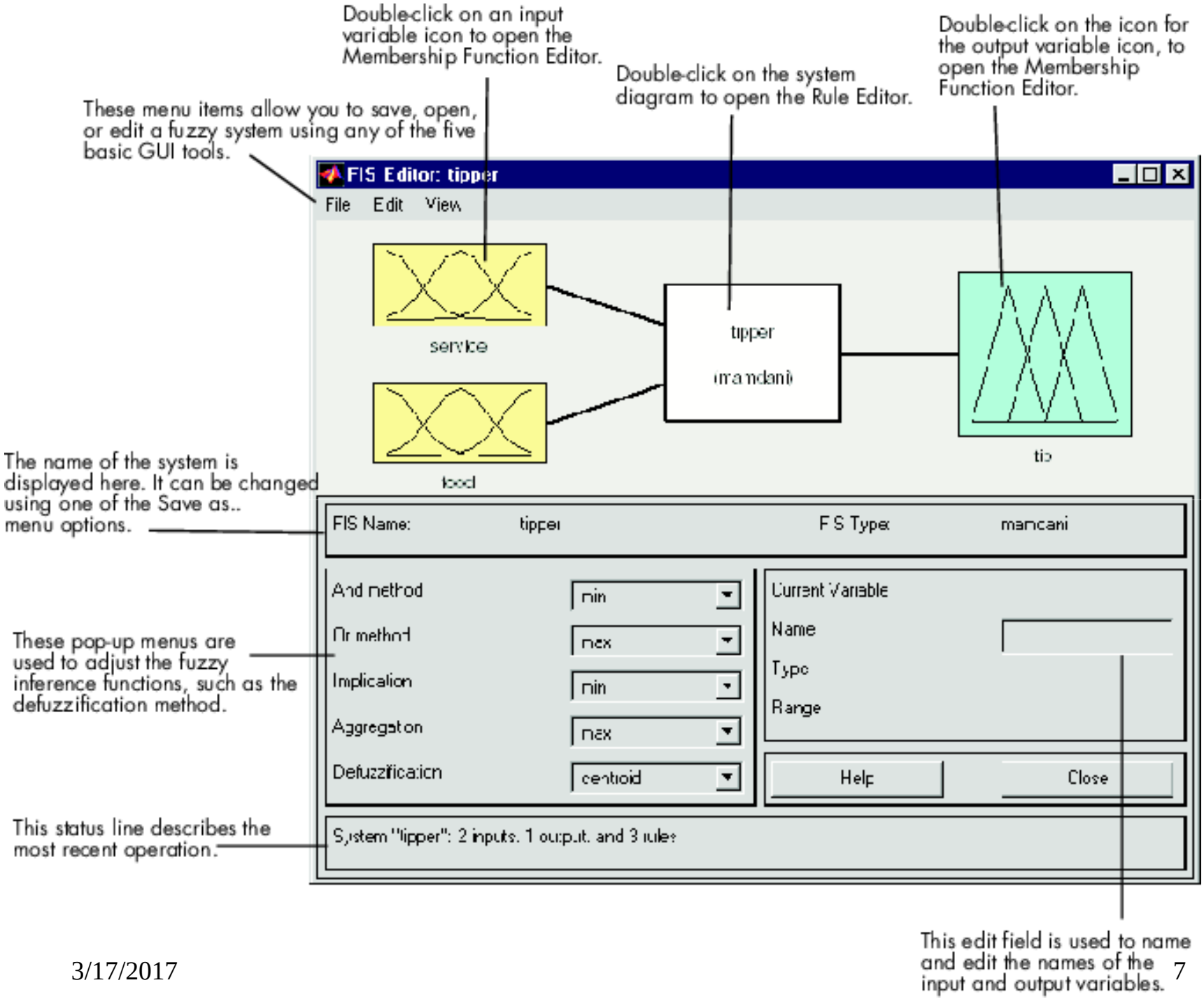
Example – The FIS Editor

- The FIS Editor displays general information about a fuzzy inference system. There is a simple diagram at the top that shows the names of each input variable on the left, and those of each output variable on the right.

- Below the diagram is the name of the system and the type of inference used. The default, Mamdani-type inference, is what we'll continue to use for this example.

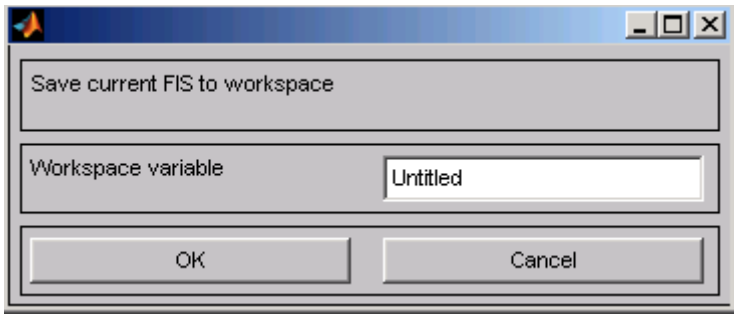
- Below the name of the fuzzy inference system, on the left side of the figure, are the pop-up menus that allow you to modify the various pieces of the inference process.

- On the right side at the bottom of the figure is the area that displays the name of either an input or output variable, its associated membership function type, and its range.


Double-click on an input variable icon to open the Membership Function Editor.
Double-click on the system diagram to open the Rule Editor.
Double-click on the icon for the output variable icon, to open the Membership Function Editor.
These menu items allow you to save, open, or edit a fuzzy system using any of the five basic GUI tools.
FIS Editor: tipper
File Edit View
service
food
tipper
mamdani
tip
The name of the system is displayed here. It can be changed using one of the Save as.. menu options.
FIS Name: tipper
FIS Type: mamdani
And method min
Or method max
Implication min
Aggregation max
Defuzzification centroid
These pop-up menus are used to adjust the fuzzy inference functions, such as the defuzzification method.
Current Variable
Name
Type
Range
Help
Close
This status line describes the most recent operation.
System "tipper": 2 inputs, 1 output, and 3 rules
This edit field is used to name and edit the names of the input and output variables.

Example – The FIS Editor

- The generic untitled FIS Editor opens, with one input, labelled input1, and one output, labelled output1. For this example, we will construct a two-input, one output system, so go to the Edit menu and select Add variable. A second yellow box labelled input2 will appear. The two inputs we will have in our example are service and food. Our one output is tip. We'd like to change the variable names to reflect that:
  1. Click once on the box (yellow) on the left marked input1 (the box will be highlighted in red).
  2. In the white edit field on the right, change input1 to service and press Return.
  3. Click once on the box (yellow) marked input2 (the box will be highlighted in red).
  4. In the white edit field on the right, change input2 to food and press Return.
  5. Click once on the box (blue) on the right marked output1.
  6. In the white edit field on the right, change output1 to tip.
  7. From the File menu, select Export and then To Workspace...
  8. Enter the variable name tipper and click OK.

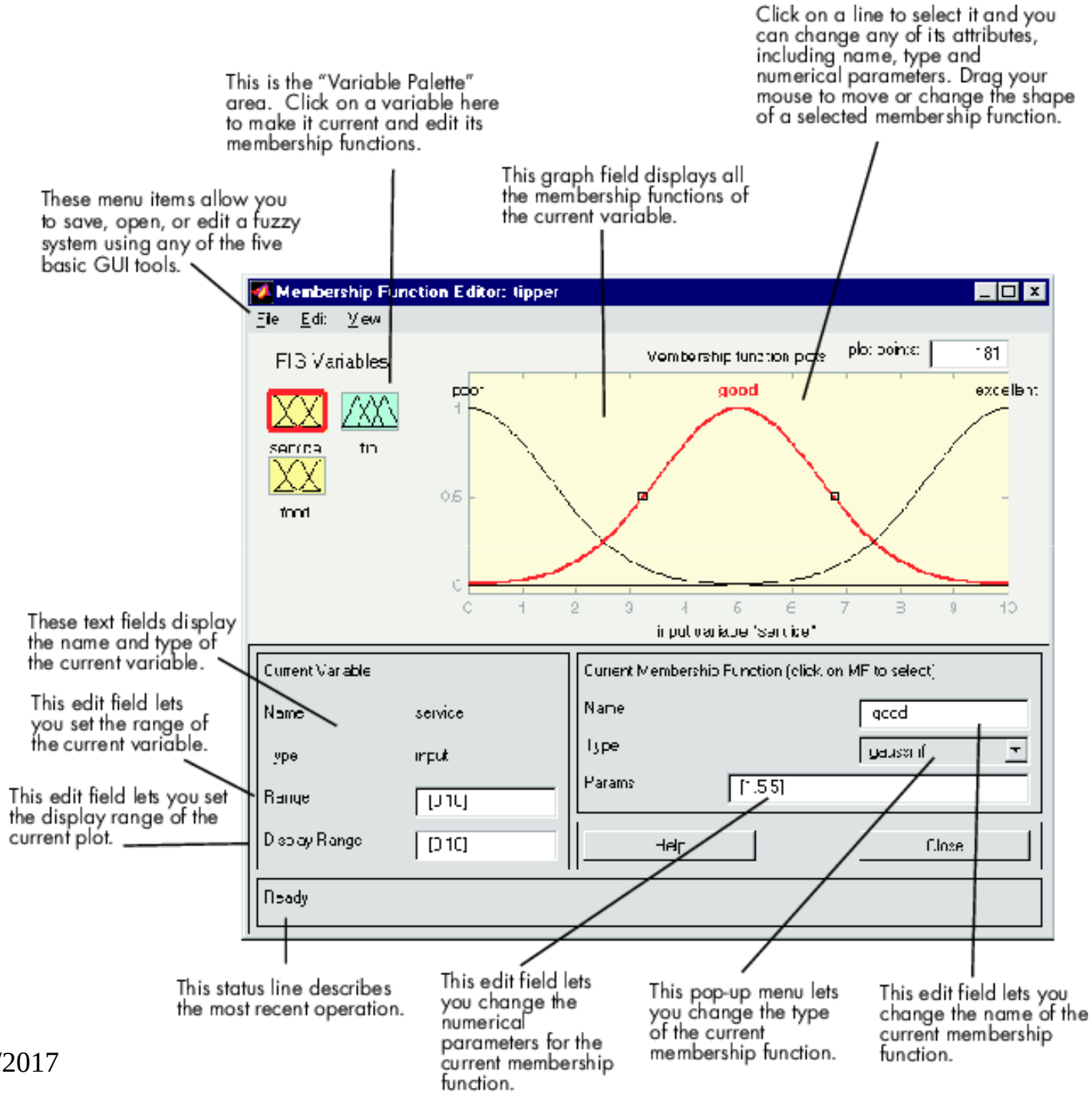


Example – Membership Function

- Next define the membership functions associated with each of the variables. To do this, open the Membership Function Editor:
  - Within the FIS Editor window, select Edit > Membership Functions.... (or double-click the icon for the output variable, tip)

- On the upper left side of the graph area in the Membership Function Editor is a "Variable Palette" that lets you set the membership functions for a given variable. To set up your membership functions associated with an input or an output variable for the FIS, select an FIS variable in this region by clicking on it.

- Next select the Edit pull-down menu, and choose Add MFs .... A new window will appear, which allows you to select both the membership function type and the number of membership functions associated with the selected variable. In the lower right corner of the window are the controls that let you change the name, type, and parameters (shape), of the membership function, once it has been selected.


Click on a line to select it and you can change any of its attributes, including name, type and numerical parameters. Drag your mouse to move or change the shape of a selected membership function.
This is the "Variable Palette" area. Click on a variable here to make it current and edit its membership functions.
This graph field displays all the membership functions of the current variable.
These menu items allow you to save, open, or edit a fuzzy system using any of the five basic GUI tools.
Membership Function Editor: tipper
File Edit View
FIS Variables
service
tip
food
Membership function plots
plot points:
poor
good
excellent
input variable "service"
These text fields display the name and type of the current variable.
This edit field lets you set the range of the current variable.
This edit field lets you set the display range of the current plot.
Current Variable
Name
service
Type
input
Range
[0 10]
Display Range
[0 10]
Current Membership Function (click on MF to select)
Name
good
Type
gaussmf
Params
[1.5 5]
Help
Close
Ready
This status line describes the most recent operation.
This edit field lets you change the numerical parameters for the current membership function.
This pop-up menu lets you change the type of the current membership function.
This edit field lets you change the name of the current membership function.

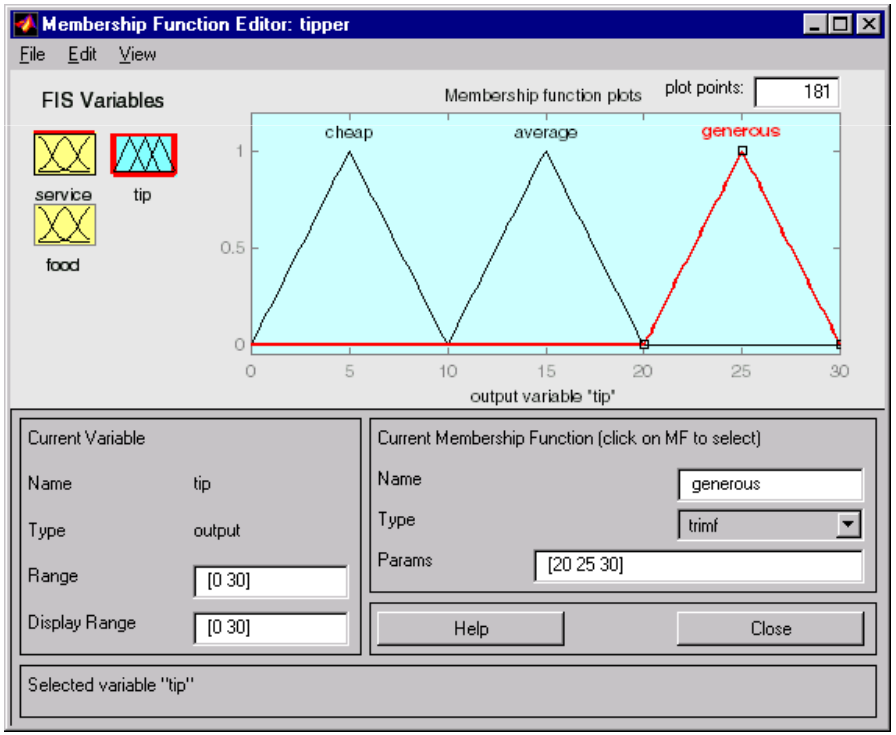
Example – Membership Function

- The process of specifying the input membership functions for this two input tipper problem is as follows:
  1. Select the input variable, service, by double-clicking on it. Set both the Range and the Display Range to the vector [0 10].
  2. Select Add MFs... from the Edit menu. Use the tab to choose *gaussmf* for MF Type and 3 for Number of MFs. This adds three Gaussian curves to the input variable service.
  3. Click once on the curve with the leftmost hump. Change the name of the curve to *poor*. To adjust the shape of the membership function, either use the mouse, as described above, or type in a desired parameter change, and then click on the membership function. The default parameter listing for this curve is [1.5 0].
  4. Name the curve with the middle hump, *good*, and the curve with the rightmost hump, *excellent*. Reset the associated parameters if desired.
  5. Select the input variable, *food*, by clicking on it. Set both the Range and the Display Range to the vector [0 10].
  6. Select Add MFs... from the Edit menu and add two *trapmf* curves to the input variable food.
  7. Click once directly on the curve with the leftmost trapezoid. Change the name of the curve to *rancid*. To adjust the shape of the membership function, either use the mouse, as described above, or type in a desired parameter change, and then click on the membership function. The default parameter listing for this curve is [0 0 1 3].
  8. Name the curve with the rightmost trapezoid, *delicious*, and reset the associated parameters if desired

Example – Membership Function

- Next you need to create the membership functions for the output variable, tip. To create the output variable membership functions, use the Variable Palette on the left, selecting the output variable, *tip*. The inputs ranged from 0 to 10, but the output scale is going to be a tip between 5 and 25 percent.

- Use triangular membership function types for the output. First, set the Range (and the Display Range) to [0 30], to cover the output range. Initially, the *cheap* membership function will have the parameters [0 5 10], the *average* membership function will be [10 15 20], and the *generous* membership function will be [20 25 30]. Your system should look something like this:



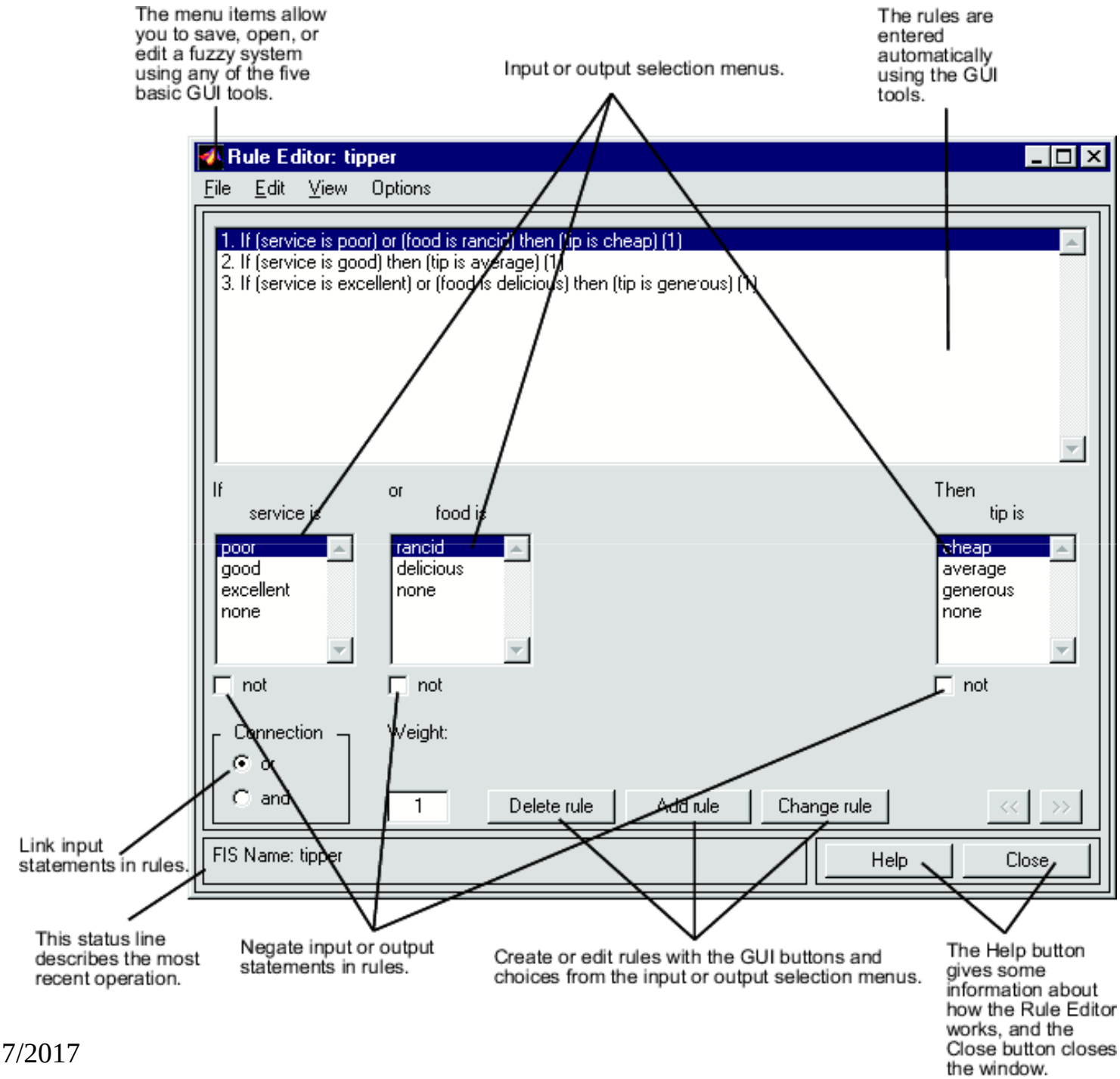
Example – Rule Editor

- Now that the variables have been named, and the membership functions have appropriate shapes and names, you're ready to write down the rules. To call up the Rule Editor, go to the View menu and select Rules.

- The Rule Editor allows you to construct the rule statements automatically, by clicking on and selecting one item in each input variable box, one item in each output box, and one connection item. Choosing none as one of the variable qualities will exclude that variable from a given rule. Choosing not under any variable name will negate the associated quality.

- To insert the first rule in the Rule Editor, select the following:
  1. *poor* under the variable *service*
  2. *rancid* under the variable *food*
  3. The *or* radio button, in the Connection block
  4. *cheap*, under the output variable, *tip*.

- The resulting rule is:
  1. If (*service* is *poor*) or (*food* is *rancid*) then (*tip* is *cheap*)


The menu items allow you to save, open, or edit a fuzzy system using any of the five basic GUI tools.
Input or output selection menus.
The rules are entered automatically using the GUI tools.
Rule Editor: tipper
File Edit View Options
1. If (service is poor) or (food is rancid) then (tip is cheap) (1)
2. If (service is good) then (tip is average) (1)
3. If (service is excellent) or (food is delicious) then (tip is generous) (1)
If
service is
poor
good
excellent
none
or
food is
rancid
delicious
none
Then
tip is
cheap
average
generous
none
not
not
not
Connection
or
and
Weight:
1
Delete rule
Add rule
Change rule
FIS Name: tipper
Help
Close
Link input statements in rules.
This status line describes the most recent operation.
Negate input or output statements in rules.
Create or edit rules with the GUI buttons and choices from the input or output selection menus.
The Help button gives some information about how the Rule Editor works, and the Close button closes the window.

Example – Rule Editor

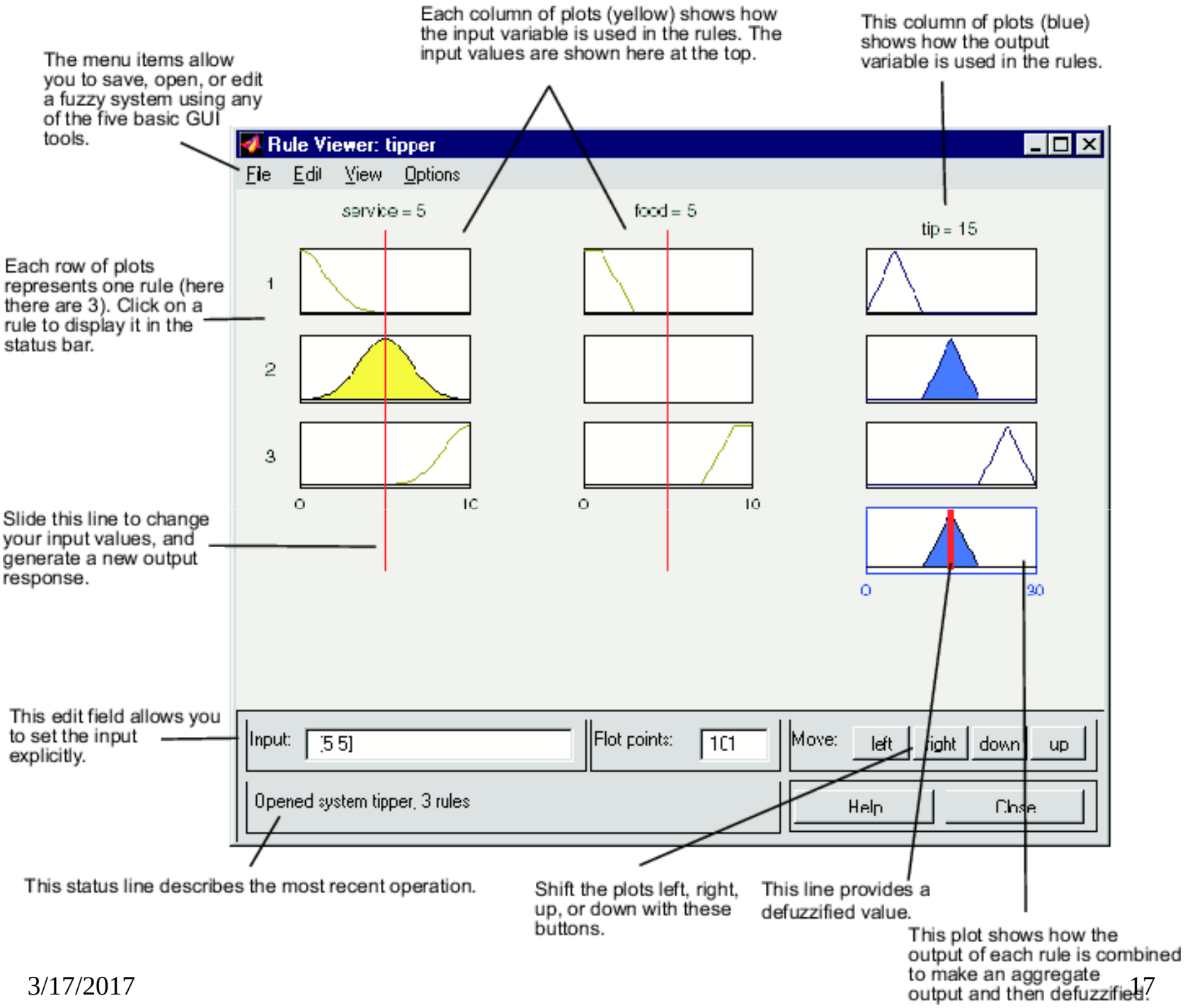
- Follow a similar procedure to insert the second and third rules in the Rule Editor to get:
  1. If (*service* is *poor*) or (*food* is *rancid*) then (*tip* is *cheap*)
  2. If (*service* is *good*) then (*tip* is *average*)
  3. If (*service* is *excellent*) or (*food* is *delicious*) then (*tip* is *generous*)

- At this point, the fuzzy inference system has been completely defined, in that the variables, membership functions, and the rules necessary to calculate tips are in place. Now look at the fuzzy inference diagram presented at the end of the previous section and verify that everything is behaving the way you think it should. This is exactly the purpose of the Rule Viewer.

Example – Rule Viewer

- From the View menu, select Rules.

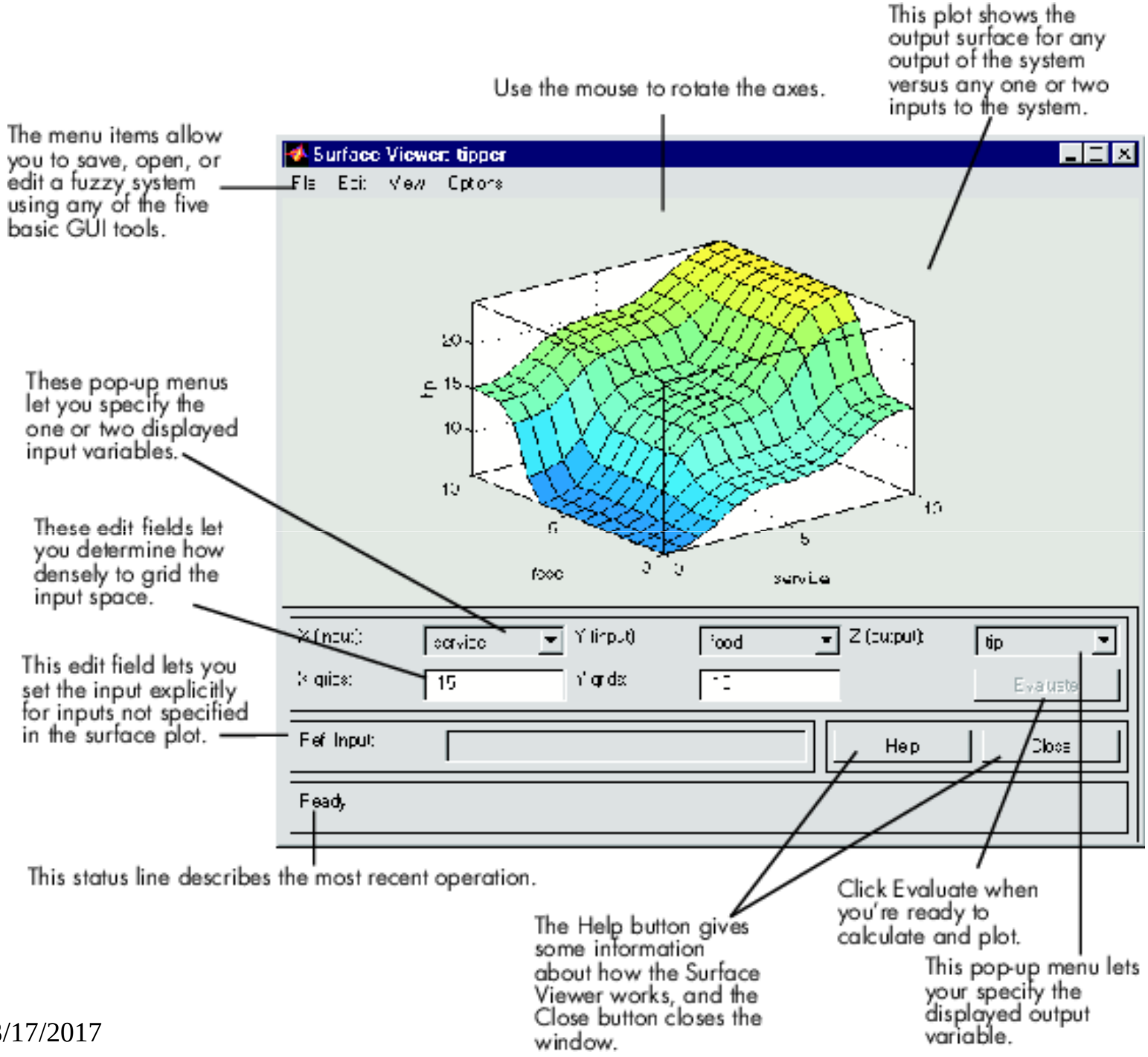
- The Rule Viewer displays a roadmap of the whole fuzzy inference process. it is based on the fuzzy inference diagram described in the previous section.
  - You see a single figure window with 10 small plots nested in it. The three small plots across the top of the figure represent the antecedent and consequent of the first rule. Each rule is a row of plots, and each column is a variable.
  - The first two columns of plots (the six yellow plots) show the membership functions referenced by the antecedent, or the if-part of each rule.
  - The third column of plots (the three blue plots) shows the membership functions referenced by the consequent, or the then-part of each rule.
  - If you click once on a rule number, the corresponding rule will be displayed at the bottom of the figure. Notice that under food, there is a plot which is blank. This corresponds to the characterization of none for the variable food in the second rule.
  - The fourth plot in the third column of plots represents the aggregate weighted decision for the given inference system. This decision will depend on the input values for the system.
  - The Rule Viewer allows you to interpret the entire fuzzy inference process at once, and also shows how the shape of certain membership functions influences the overall result


The menu items allow you to save, open, or edit a fuzzy system using any of the five basic GUI tools.
Each column of plots (yellow) shows how the input variable is used in the rules. The input values are shown here at the top.
This column of plots (blue) shows how the output variable is used in the rules.
Rule Viewer: tipper
File Edit View Options
service = 5
food = 5
tip = 15
Each row of plots represents one rule (here there are 3). Click on a rule to display it in the status bar.
1
2
3
0
10
0
10
0
30
Slide this line to change your input values, and generate a new output response.
This edit field allows you to set the input explicitly.
Input: [5 5]
Plot points: 101
Move: left right down up
Opened system tipper, 3 rules
Help Close
This status line describes the most recent operation.
Shift the plots left, right, up, or down with these buttons.
This line provides a defuzzified value.
This plot shows how the output of each rule is combined to make an aggregate output and then defuzzified.

Exercise – Surface Viewer

- If you want to see the entire output surface of your system, that is, the entire span of the output set based on the entire span of the input set, you need to open up the Surface Viewer. Open it by selecting Surface from the View menu.

- Upon opening the Surface Viewer, we are presented with a three-dimensional curve that represents the mapping from food and service quality to tip amount. Since this is a two-input one-output case, we can see the entire mapping in one plot. When we move beyond three dimensions overall, we start to encounter trouble displaying the results. Accordingly, the Surface Viewer is equipped with pop-up menus that let you select any two inputs and any one output for plotting.


This plot shows the output surface for any output of the system versus any one or two inputs to the system.
Use the mouse to rotate the axes.
The menu items allow you to save, open, or edit a fuzzy system using any of the five basic GUI tools.
Surface Viewer: tipper
File Edit View Options
These pop-up menus let you specify the one or two displayed input variables.
These edit fields let you determine how densely to grid the input space.
This edit field lets you set the input explicitly for inputs not specified in the surface plot.
Ref Input:
Help
Close
Ready
This status line describes the most recent operation.
The Help button gives some information about how the Surface Viewer works, and the Close button closes the window.
Click Evaluate when you're ready to calculate and plot.
This pop-up menu lets your specify the displayed output variable.

Exercise - Conclusions

- Your system is now “complete” and ready to be tested.

1. Try to save the system to your home directory. When you save a fuzzy system to disk, you're saving an ASCII text FIS file representation of that system with the file suffix *.fis*. If you do not save your FIS to your disk, but only save it to the MATLAB workspace, you will not be able to recover it for use in a new MATLAB session.
2. Use the Rule Viewer to test your system with different inputs.
3. Think again about the input and output fuzzy sets. Try to change the shapes and ranges of each (or some) of the sets to see how this will affect the output.
4. Try to add a new input *financial status* to the system, which describes the financial status of the customer: ranging from 0 for *poor*, to 10 for *rich*.
5. Think about the new rules you need to construct and add the new rules to the system (e.g. *poor financial status* → *cheap tip*, *rich financial status* → *generous tip*).
6. See how the output is now affected by the new input.