Matlab: ANFIS Toolbox

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04/22/2003

What is ANFIS ?

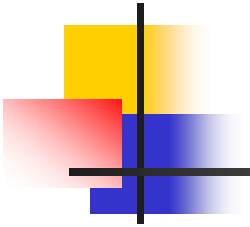
- ANFIS stands for Adaptive Neural Fuzzy Inference System.
- Using a given input/output data set, the toolbox function anfis constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using either a backpropagation algorithm alone, or in combination with a least squares type of method.
- This allows your fuzzy systems to learn from the data they are modeling.

ANFIS Background

- Algorithm defined by J.-S. Roger Jang in 1992
- Creates a fuzzy decision tree to classify the data into one of 2**n** (or p**n**) linear regression models to minimize the sum of squared errors (SSE):

$$SSE = \sum_{j} e_j^2$$

- where:
  - e_j is the error between the desired and the actual output
  - p is the number of fuzzy partitions of each variable
  - n is the number of input variables

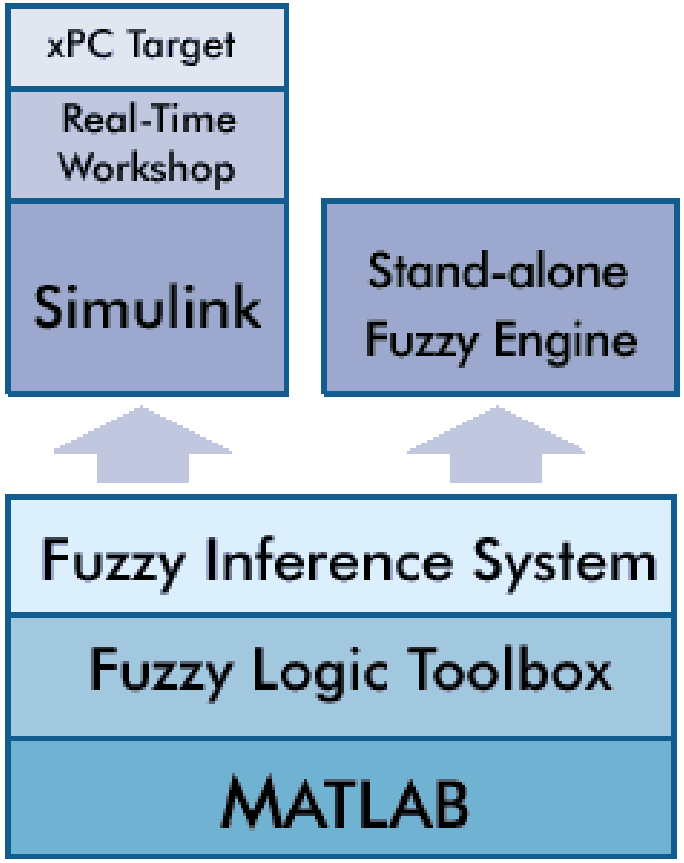


Model Learning

- The basic idea behind these neuro-adaptive learning techniques is very simple:
  - These techniques provide a method for the fuzzy modeling procedure to learn information about a data set, in order to compute the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data.
  - This learning method works similarly to that of neural networks.
- The Fuzzy Logic Toolbox function that accomplishes this membership function parameter adjustment is called anfis.
  - anfis can be accessed either from the command line, or through the ANFIS Editor GUI.

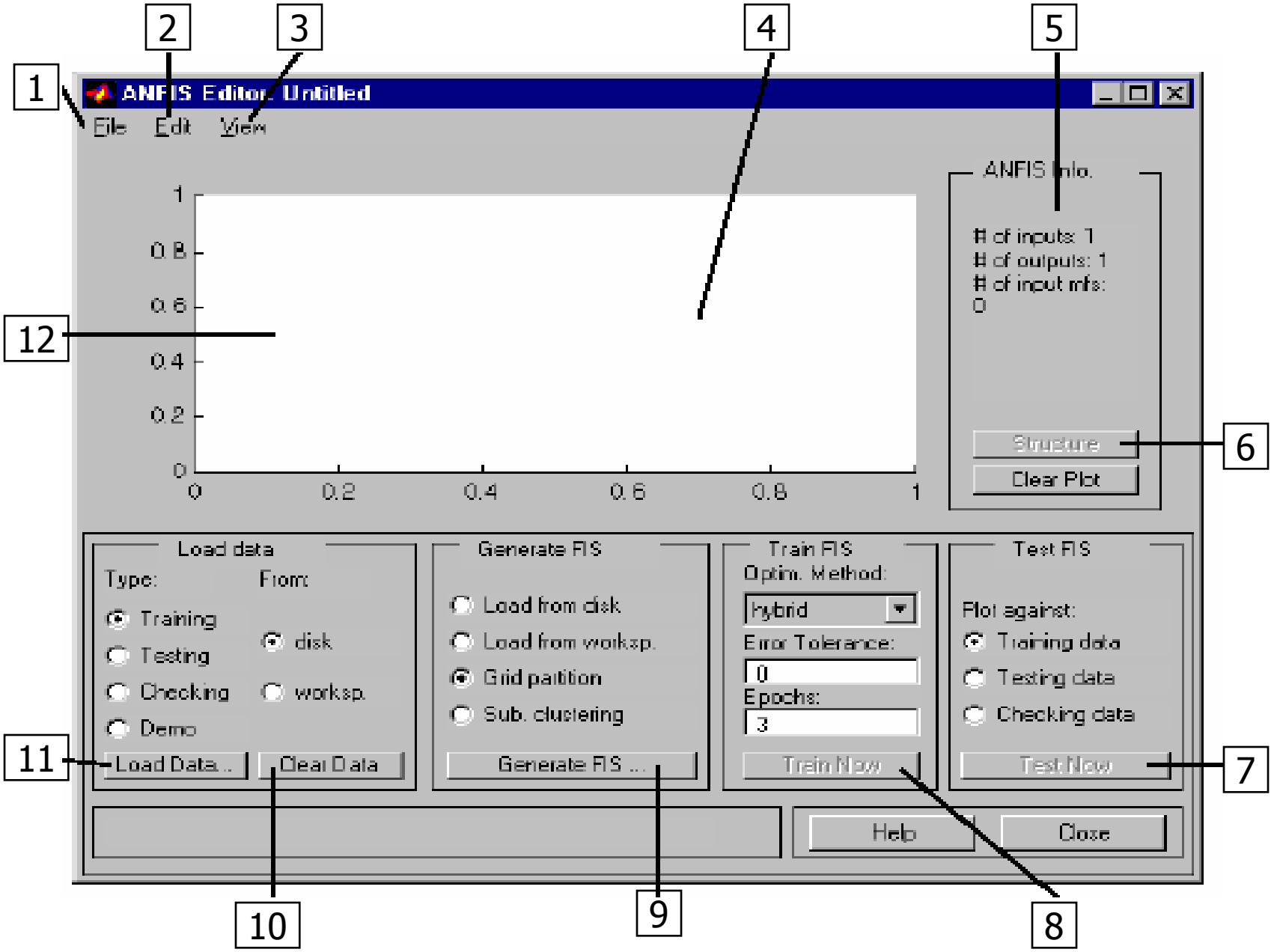
ANFIS Framework

- Like all MATLAB toolboxes, the Fuzzy Logic Toolbox can be customized. You can easily inspect algorithms, modify source code, and add your own membership functions or defuzzification techniques.



How to Start ANFIS

- Start Matlab
- For non-GUI anfis, just type *anfis* on the command line of Matlab.
- For ANFIS Editor GUI, just type *anfisedit* on the command line of Matlab.


1
2
3
4
5
6
7
8
9
10
11
12
ANFIS Editor: Untitled
File
Edit
View
ANFIS Info.
# of inputs: 1
# of outputs: 1
# of input mfs:
0
Structure
Clear Plot
Load data
Type:
Training
Testing
Checking
Demo
From:
disk
worksp.
Load Data...
Clear Data
Generate FIS
Load from disk
Load from worksp.
Grid partition
Sub. clustering
Generate FIS ...
Train FIS
Optim. Method:
hybrid
Error Tolerance:
0
Epochs:
3
Train Now
Test FIS
Plot against:
Training data
Testing data
Checking data
Test Now
Help
Close

GUI Screenshot

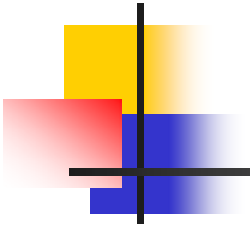
- 1 - Load or save a fuzzy Sugeno system, or open new Sugeno system.
- 2 - Undo.
- 3 - Open or edit a FIS with any of the other GUIs.
- 4 - Plot region.
- 5 - Status of the number of inputs, outputs, input membership functions, and output membership functions.
- 6 - After you generate or load a FIS, this button allows you to open a graphical representation of its input/output structure.
- 7 - Test data against the FIS model. The plot appears in the plot region.
- 8 -Train FIS after setting optimization method, error tolerance, and number of epochs. This generates error plots in the plot region.
- 9 - Load FIS or generate FIS from loaded data using your chosen number of MFs and rules or fuzzy.
- 10 - Clear Data unloads the data set selected under Type: and clears the plot region.
- 11 -Load either training, testing, or checking data from disk or workspace, or load demo data. Data appears in the plot region.
- 12 -Testing data appears on the plot in blue as **. .**; Training data appears on the plot in blue as **o o;** Checking data appears on the plot in blue as **++;** FIS output appears on the plot in red as **

From GUI you can:

- Load data (training, testing, and checking) by selecting appropriate radio buttons in the **Load data** portion of the GUI and then clicking Load Data... The loaded data is plotted on the plot region.
- Generate an initial FIS model or load an initial FIS model using the options in the **Generate FIS** portion of the GUI.
- View the FIS model structure once an initial FIS has been generated or
- loaded by clicking the **Structure** button.
- Choose the FIS model parameter optimization method: backpropagation or a mixture of backpropagation and least squares (hybrid method).
- Choose the number of training epochs and the training error tolerance.
- Train the FIS model by clicking the **Train** Now button.
  - This training adjusts the membership function parameters and plots the training (and/or checking data) error plot(s) in the plot region.
- View the FIS model output versus the training, checking, or testing data output by clicking the **Test Now** button.

Checking and Training

- To start training in ANFIS Editor GUI:
  - First, you need to have a training data set that contains desired input/output data pairs of the target system to be modeled.
  - Sometimes you also want to have the optional testing data set that can check the generalization capability of the resulting fuzzy inference system, and/or a checking data set that helps with model overfitting during the training.
  - Overfitting is accounted for by testing the FIS trained on the training data against the checking data, and choosing the membership function parameters to be those associated with the minimum checking error if these errors indicate model overfitting.
  - You will have to examine your training error plots fairly closely in order to determine this.
  - Usually these training and checking data sets are collected based on observations of the target system and are then stored in separate files.



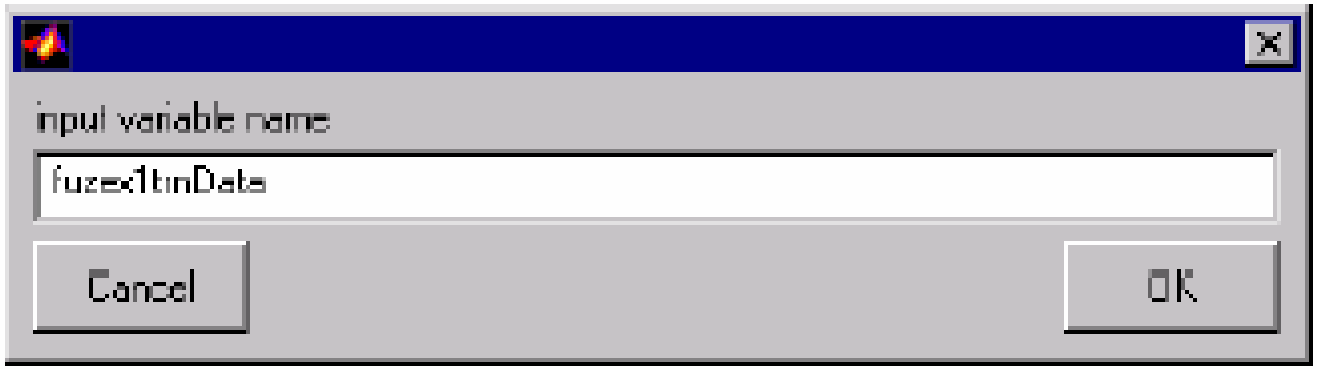
Example

Checking Data Helps Model Validation

- Loads similar training and checking data sets, only the checking data set is corrupted by noise.
- **Loading Data** into the ANFIS Editor GUI from the workspace:
  - Load the training data sets: fuzex1trnData and fuzex2trnData.
  - Load the checking data sets: fuzex1chkData and fuzex2chkData.
- **Loading Data** from command line (*load filename.dat*):
  - *load fuzex1trnData.dat*
  - Etc.

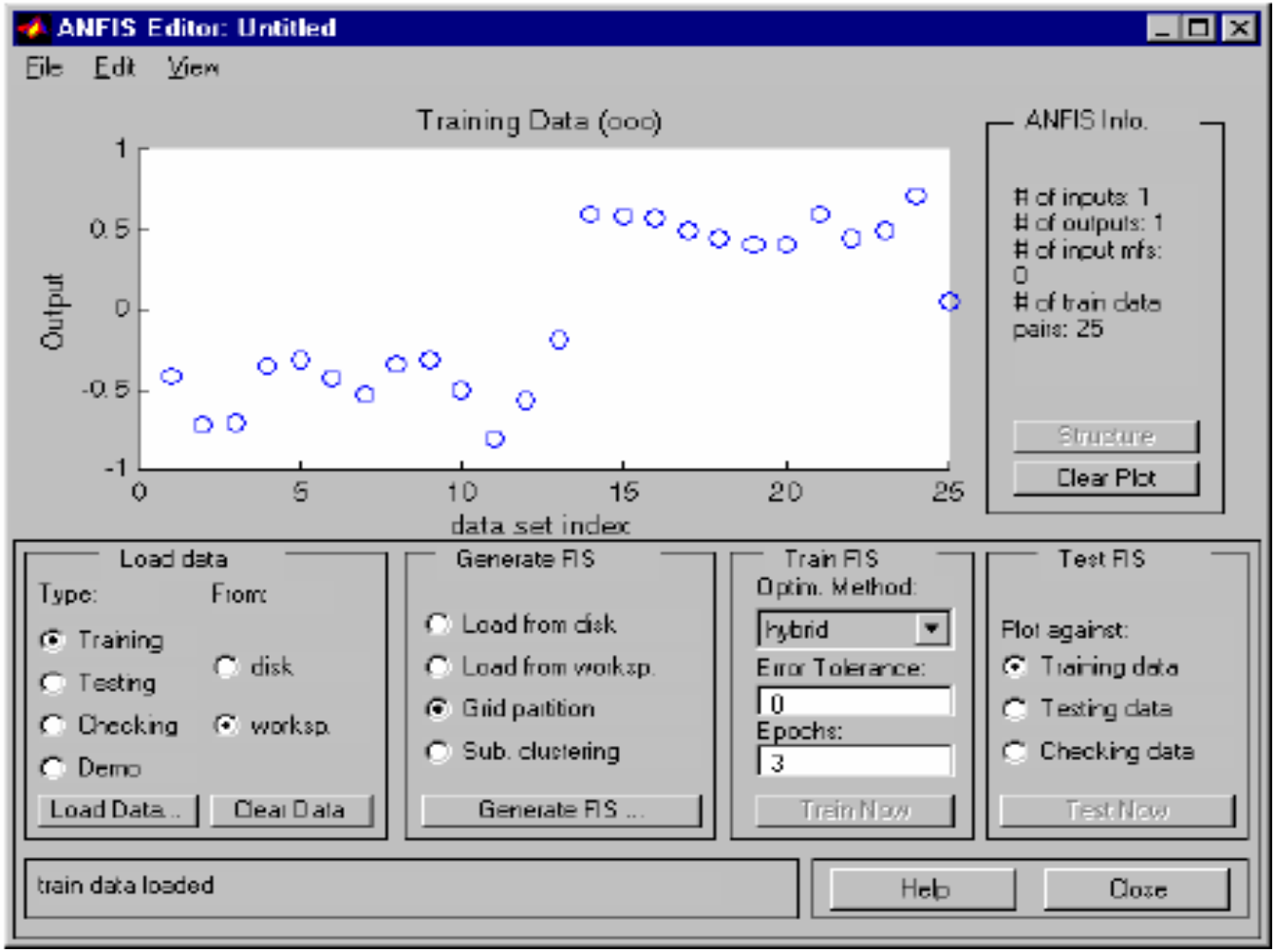
Example (cont)

- To load the training data set:
  - select Type: **Training**; From: **worksp.** ; click Load Data…



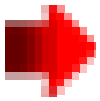
- The training data appears in the plot in the center of the GUI as a set of *circles*.

Example (cont)

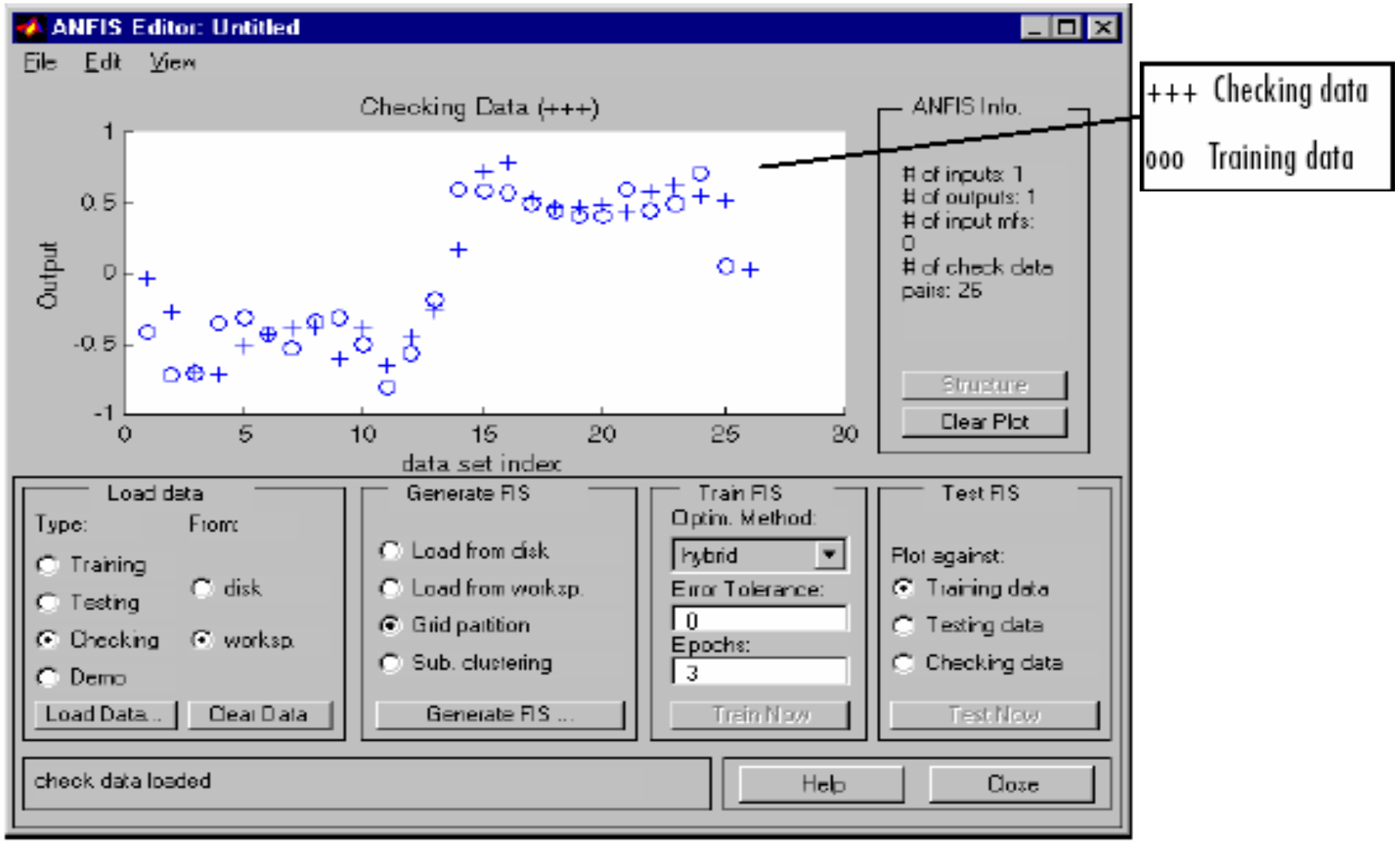


Example (cont)

- Next: click **Checking** in the **Type** column of the **Load data** portion of the GUI to load *fuzex1chkData* from the workspace.
- This data appears in the GUI plot as *plusses* superimposed on the training data.
- The data set will be used to train a fuzzy system by adjusting the membership function parameters that best model this data.
- The next step is to specify an initial fuzzy inference system for anfis to train.



Example (cont)



Example (cont)

Initializing and Generating FIS:

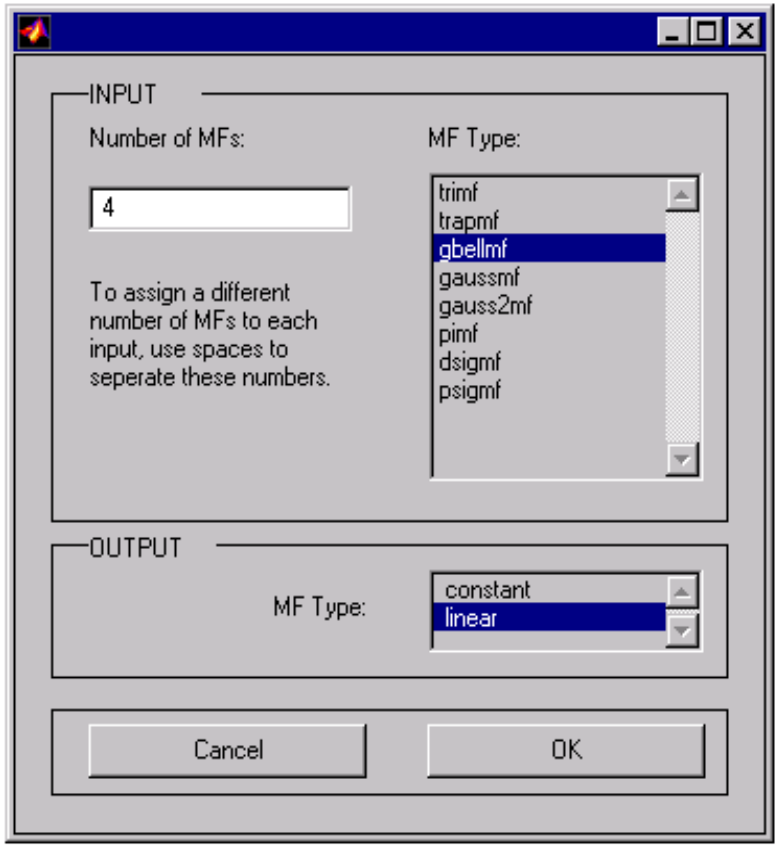
- You can either initialize the FIS parameters to your own preference, or if you do not have any preference for how you want the initial membership functions to be parameterized, you can let anfis do this for you.

Automatic FIS Structure Generation with ANFIS:

- To initialize your FIS using anfis Choose **Grid partition,** the default partitioning method. There are two partition methods: grid partitioning and subtractive clustering.
- Click on the **Generate FIS** button. This displays a menu from which you can choose the number of membership functions, **MFs**, and the type of input and output membership functions.
- Notice there are only two choices for the output membership function: constant and linear. This limitation of output membership function choices is because anfis only operates on Sugeno-type systems.

Example (cont)

- Fill in the entries as we've done below, and click **OK.**



Example (cont)

Specifying Your Own Membership Functions for ANFIS:

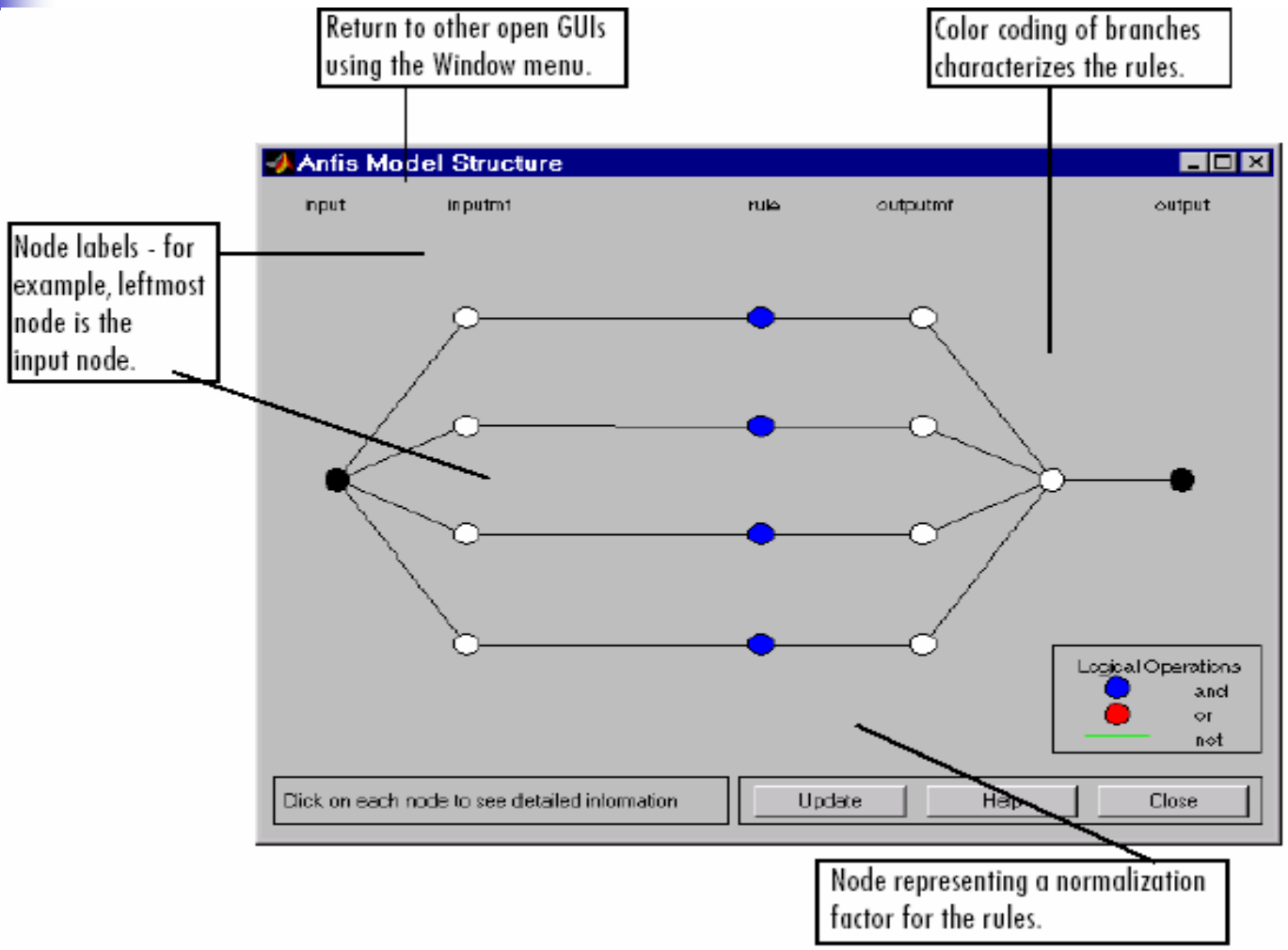
- Open the **Edit membership functions** menu item from the **View** menu.
- Add your desired membership functions (the custom membership option will be disabled for anfis). The output membership functions must either be all constant or all linear.
- Select the **Edit rules** menu item in the **View** menu. Use the Rule Editor to generate the rules.
- Select the **Edit FIS Properties** menu item from the **View** menu. Name your FIS, and save it to either the workspace or the disk.
- Use the **View** menu to return to the ANFIS Editor GUI to train the FIS.

Example (cont)

Viewing Your FIS Structure:

- After you generate the FIS, you can view the model structure by clicking the Structure button in the middle of the right side of the GUI.
- A new GUI appears, as follows

Example (cont)



Example (cont)

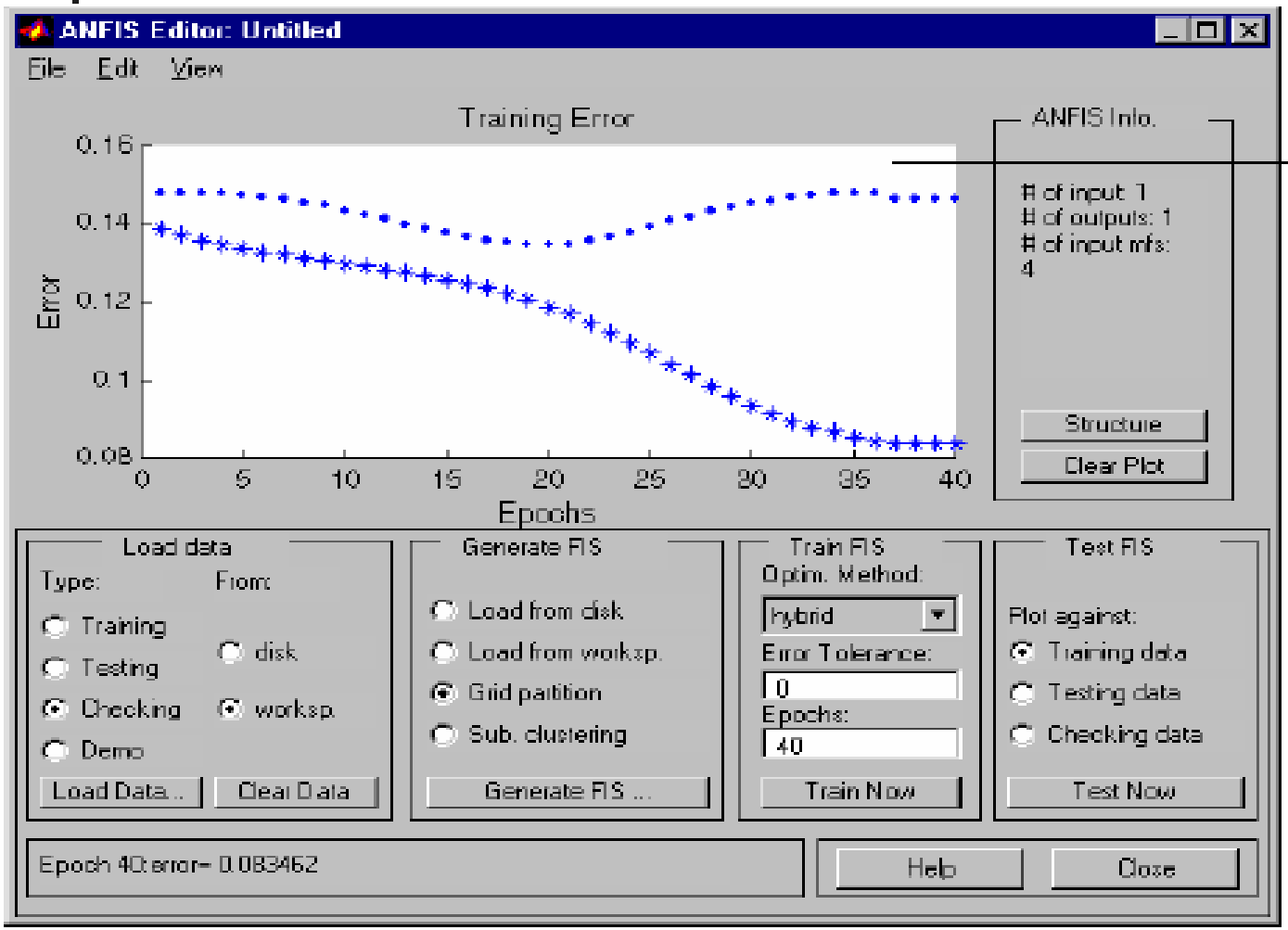
ANFIS Training

- The two anfis parameter optimization method options available for FIS training.
  - hybrid (the default, mixed least squares and backpropagation)
  - backpropa (backpropagation).
- The **Error Tolerance** is used to create a training stopping criterion, which is related to the error size. The training will stop after the training data error remains within this tolerance. This is best left set to 0 if you don't know how your training error is going to behave.

Example (cont)

- To start the training
  - Leave the optimization method at **hybrid**.
  - Set the number of training epochs to 40, under the **Epochs** listing on the GUI (the default value is 3).
  - Select **Train Now**.
- The following should appear on your screen.

Example (cont)



*** Training error

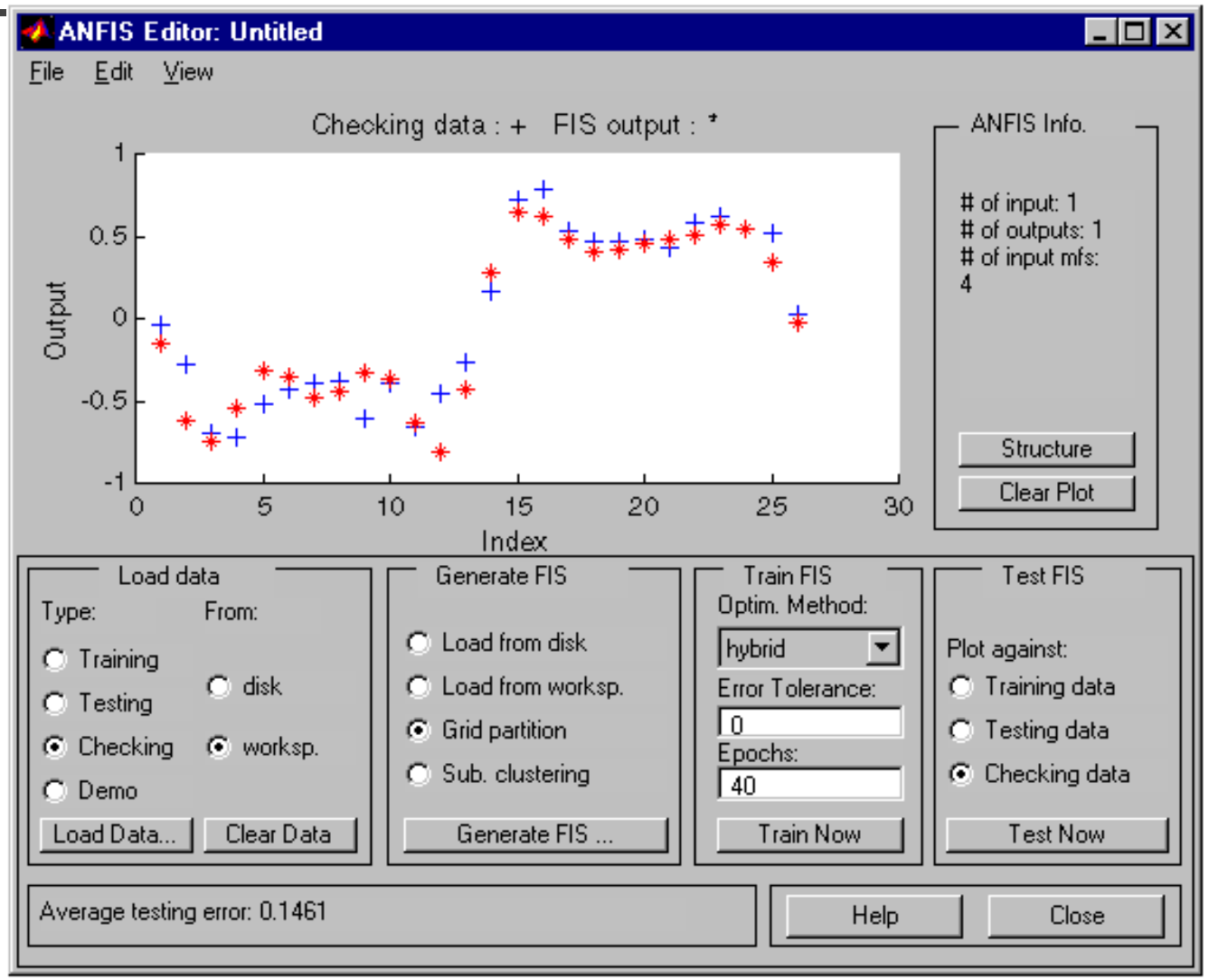
... Checking error

Example (cont)

Testing Your Data Against the Trained FIS.

- To test your FIS against the checking data, click **Checking data** in the **Test FIS** portion of the GUI, and click **Test Now**.
- Now when you test the checking data against the FIS it looks pretty good.

Example (cont)



Some ANFIS Tips

- **Tip 1** If you are ever loading data into anfis after clearing previously loaded data, you must make sure that the newly loaded data sets have the same number of inputs as the previously loaded ones did. Otherwise, you will have to start a new anfisedit session from the command line.
- **Tip 2** If you don't want to use the checking data option of anfis, don't load any checking data before you train the FIS. If you decide to retrain your FIS with no checking data, you can unload the checking data in one of two ways. One method is to click the **Checking** radio button in the **Load data** portion of the GUI and then click **Clear Data** to unload the checking data. The other method you can use is to close the GUI and go to the command line and retype anfisedit. In this case you will have to reload the training data. After clearing the data, you will need to regenerate your FIS. Once the FIS is generated, you can use your first training experience to decide on the number of training epochs you want for the second round of training.

The MathWorks store

- Matlab - $500.00
- Matlab Compiler - $500.00
- Simulink - $500.00
- Fuzzy Toolbox - $200.00

- Total: Just $1,700.00 for academic use only

References

- http://www.mathworks.com/access/helpdesk/help/toolbox/fuzzy/fuzzy.shtml
- http://www.rpi.edu/~bonisp/fuzzy-course/99/L9/ANFIS.pdf
- Alexander Valishevsky, Adaptive Learning Algorithm for Hybrid Fuzzy System, http://home.lanet.lv/~md80022/anfis.pdf