USERSMANUAL

DYNAMOD

Installing DynaMod

NOTE:
On Windows NT you may need to have administrator permission to install into the toolbox\local directory. Contact your system administrator, or alternatively install to a different directory.

1. Copy the 'DynaMod.exe' self extracting archive to your hard disk.
2. Double click on the 'DynaMod.exe' icon to start the installation process.
3. During installation, you will select the directories in which to install the toolbox. It is recommended that you install to the the subdirectory 'toolbox\local\DynaMod' in your Matlab© root directory. For example, if your Matlab© root directory is 'C:\Program Files\Matlab', the DynaMod installation path should be specified as:
   'C:\Program Files\Matlab\toolbox\local\DynaMod'.
   The default Matlab© root directory is:
   '<Windisk>:\Program Files\Matlab', where <Windisk> is your Windows installation drive. If the default path is not correct, use the 'Browse' button to set the path to the 'Matlab\toolbox\local' directory, then type in the subdirectory 'DynaMod'. You can find your Matlab© root directory by typing 'matlabroot' at the Matlab© command prompt. The installation program will also create a subdirectory for utility files, with the name 'fFiles'. This subdirectory will be placed at the same level as the DynaMod directory. In the above example, the utility file directory would be 'C:\Program Files\Matlab\toolbox\local\fFiles'.
4. After the installation has finished, add the toolbox to your Matlab© path as follows. Open a Matlab© command window. Use the 'File\Set Path.' menu to open the path browser. Select the 'Add path' menu item, and use the 'Browse' button to find the 'DynaMod' subdirectory. Click 'OK'. Select the 'Add path' menu item again, and use the 'Browse' button to add the 'fFiles' subdirectory. Click 'OK'. Select the 'Save path' menu item. Close the path browser.
5. Type 'help dynamod' to see an overview of the functions available in the toolbox.

ReferenceManual

The manual is arranged by command menu, depth first. For example, the 'Tune model' menu is a subsection of the 'Main menu' reference section. There are three sections; I). the introduction; II). the menu command reference, and III). a tutorial using the file 'sample.m' distributed with the DynaMod toolbox.

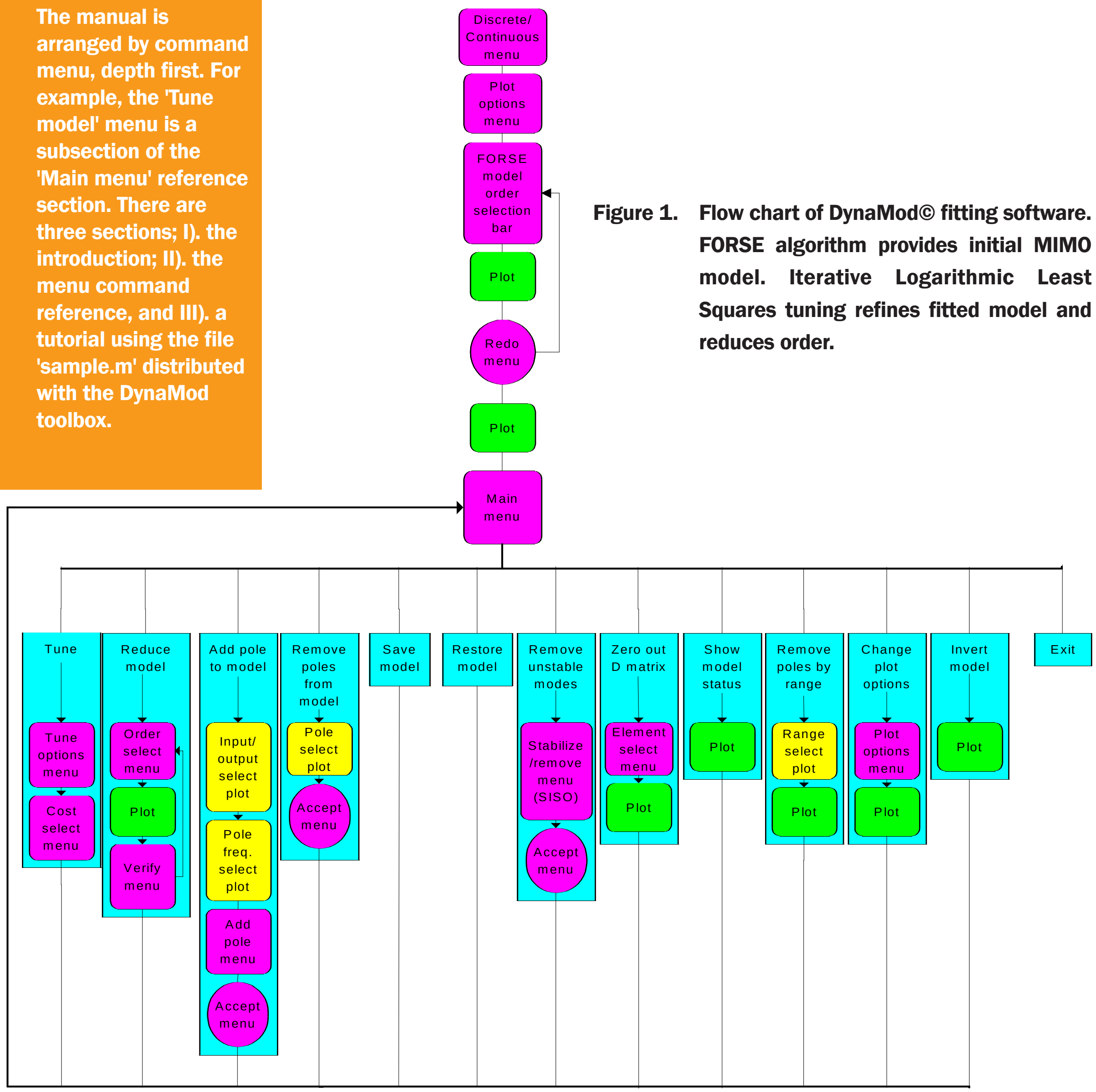

Figure 1. Flow chart of DynaMod© fitting software. FORSE algorithm provides initial MIMO model. Iterative Logarithmic Least Squares tuning refines fitted model and reduces order.

OVERVIEW

Figure 1 Flow chart of DynaMod© fitting software. FORSE algorithm provides initial MIMO model. Iterative Logarithmic Least Squares tuning refines fitted model and reduces order.

The information flow of the DynaMod© software is summarized in Figure 1. The first step requires the user to specify the number of modes in the initial model. The input data is used to synthesize an initial fit of the specified order using the FORSE algorithm. The fit is then displayed and the user prompted whether to accept the fit or change the model order and refit the data. Upon acceptance, the initial model is sent to the main Log Least Squares tuning algorithm which incorporates a set of subroutines to perform model tuning, model reduction, manual mode addition, and display of the current model fit to the data.

User data is entered via menu button selection, graphical input, and command window input, described in this manual. Menu buttons generally have keyboard shortcuts which are highlighted in parentheses. For example, the menu button '(D)one' can be selected from the keyboard by pressing the 'd' key. User information is displayed on the DynaMod© plot window and in the Matlab command window. The following conventions are used in the manual:

Menu windows will be boldfaced.

Individual menu buttons will be italicized.

The manual is arranged by command menu, depth first. For example, the 'Tune model' menu is a subsection of the 'Main menu' reference section. There are three sections; I). the introduction; II). the menu command reference, and III). a tutorial using the file 'sample.m' distributed with the DynaMod toolbox.

MenuCommandreference

1. Discrete/Continuous menu (Figure 2 Select whether the transfer function data represents a continuous time or discrete time plant. If 'Discrete' is chosen, you will be prompted for a sample time.

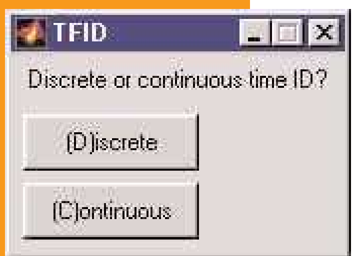

Figure 2. Discrete/continuous menu.

2. Plot options menu (Figure 3): Controls how the data and fitted model are displayed. Current plot options are displayed in the Matlab command window.

   2.1 Change x-axis: toggles linear/logarithmic scaling on the x-axis.

   2.2 Change plotting range: allows the user to enter minimum and maximum frequencies to be displayed on the plot.

   2.3 Change plotting mode: toggles between individual channels (input/output pairs) and singular values. If individual channels are chosen, the plot window will cycle through the channels.

   2.4 Toggle phase: if individual channels are chosen, either magnitude only, or magnitude and phase, can be displayed.

   2.5 Done: exits plot option setting routine.

Figure 3. Plot options menu.

3. FORSE order selection menu (Figure 4): determines the model order used by the FORSE routine to create the initial model. The current model order is displayed on the right. Grab and move the slider control to change the order. The left and right buttons can fine tune the value. Select the 'Done' button to begin the FORSE routine. Over-parameterization of the initial model will generally lead to the best results. The model reduction and tuning algorithms will reduce out spurious modes. Depending on noise, model order, and modal observability, over-parameterization by 10% to 100% model order may be appropriate.

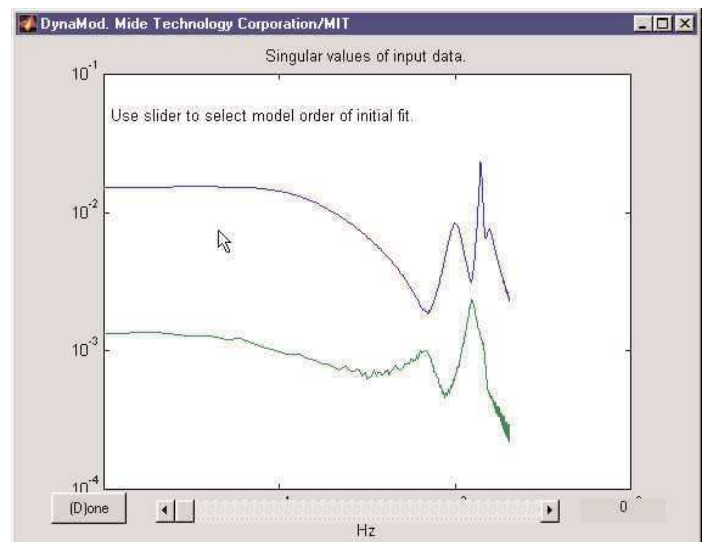

Figure 4. FORSE model order selection screen.

Menu Command reference

4. Plot window (Figure 5): displays the data and current model. If the 'Show individual channels' option is chosen, the display cycles from across the transfer functions by output. The current input and output are shown at the top of the window. The 'Continue' key cycles to the next channel. The 'Stop' button exits the plotting routine. If the plot option 'Display singular values' is chosen, the plot window shows a single plot of the model and data singular values, and the 'Continue' and 'Stop' buttons are not shown.

5. Redo menu: allows the FORSE routine to be re-run. If the fitted model is insufficiently accurate, select 'Yes' and increase the model order. If the fit is adequate, select 'No' to enter the Logarithmic Least Squares tuning loop.

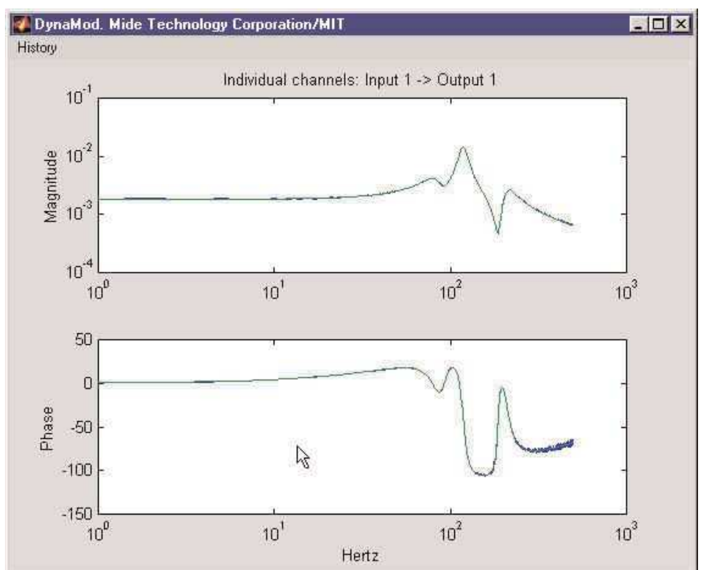

Figure 5. Plot window with the options 'Show individual channels' and 'Toggle phase' selected.

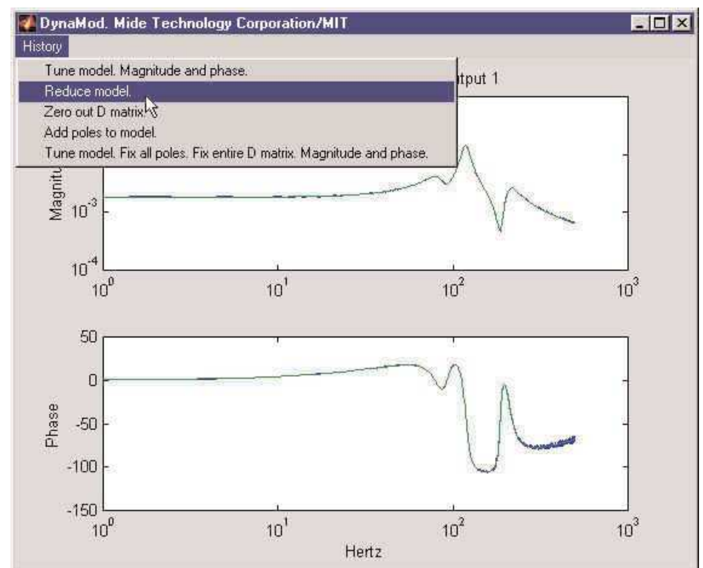

Figure 6. Example 'history' display.

MenuCommandreference.

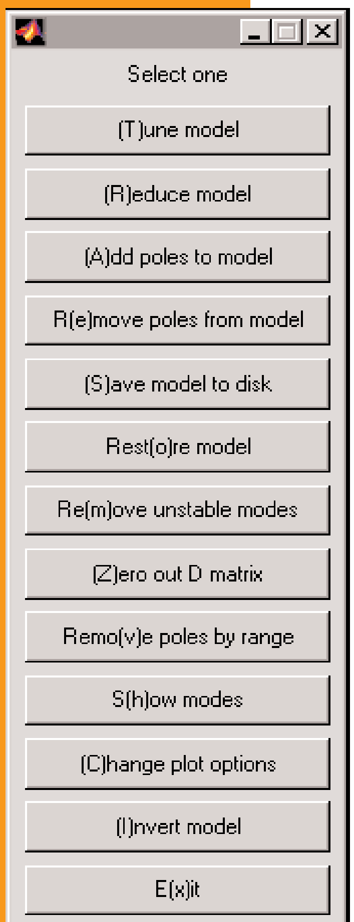

Figure 7.
Main menu for accessing model tuning, model reduction, pole addition, and fit display functions.

6. Main menu (Figure 7): user entry into the Logarithmic Least Squares model tuning and reduction functions.

6.6 Tune model: iteratively refine the fitted model. This will bring up the 'Tune options' menu.

6.6.1 Tune options menu (Figure 8): selects the model parameters to be tuned.

- Fix all poles: poles are not tuned. Useful as the first step in refining the FORSE initial fit, when errors in residue contribute to the cost, as well as for reducing the number of tuning parameters in a highly overparameterized model.
- Fix poles by range: user graphically selects a frequency range to hold fixed. Plot window will display singular values of the model and data, with poles overlaid as vertical bars. Real modes are displayed as solid bars, complex pairs as dashed bars. Stable poles are colored blue, unstable modes are colored red. Crosshairs are used to select minimum and maximum frequencies. The command window will prompt for minimum and maximum frequencies.
- Fix poles by index: user graphically selects individual modes to fix. Plot window will display singular values of the model and data, with modes overlaid as vertical bars. Real modes are displayed as solid bars, complex pairs as dashed bars. Stable poles are colored blue, unstable modes are colored red. Crosshairs are used to toggle modes between fixed and free states. Fixed modes will be highlighted in red.
- Fix B matrix: B matrix elements are not tuned. Useful when a physical model is used as an initial guess to the tuning algorithm, and the physical meaning of the influence matrix is to be retained.
- Fix C matrix: C matrix elements are not tuned. Useful when a physical model is used as an initial guess to the tuning algorithm, and the physical meaning of the sensor matrix is to be retained.
- Fix entire D matrix: D matrix elements are not tuned. Useful when the D matrix is zeroed out.
- Fix some of D matrix: brings up a selection menu matrix the size of D. Double click on elements which should be held fixed. Useful when only certain elements of the D matrix need be zeroed, for example D11 in an H2 control problem.
- Done: exits the tune options routine.

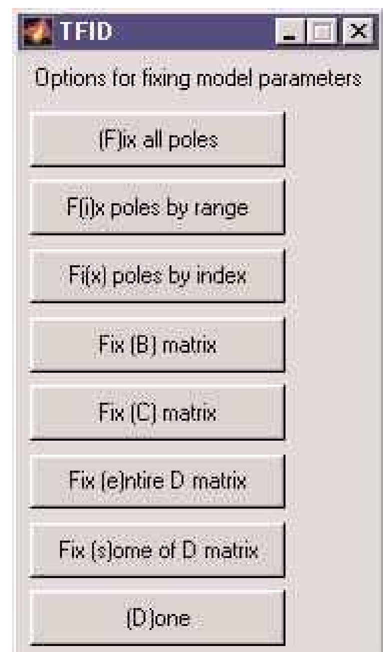

Figure 8
Log Least Squares tune options menu.

MenuCommandreference

Figure 9.
NLS Cost menu.

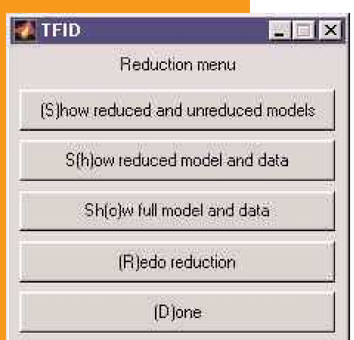

Figure 11.
Balanced reduction algorithm subroutine menu.

6.6.2 NLS Cost menu (Figure 9): selects the error cost used in the iterative tuning algorithm.

- Magnitude: only magnitude error between model and data is included in the cost. Phase error is ignored. Useful for reducing the number of tuning parameters needed to refine a highly over-parameterized initial model.
- Magnitude and phase: includes magnitude and phase error in the cost.

6.7 Reduce model: Use balanced reduction to remove low residue modes. The plot window will show the Hankel singular values (HSVs) of the current model, on a logarithmic axis, ranked from highest to lowest. The crosshairs are used to select the HSV of the highest mode to retain. The selected HSV will be highlighted in red. The 'Done' key will perform the reduction. If no HSV is selected, the reduction routine exits. Brings up the 'Reduction' menu.

6.7.1 Reduction menu (Figure 11): allows the reduced model to be evaluated against the data and unreduced model, to determine whether to re-do or accept the reduction.

- Show reduced and unreduced models: plot reduced and unreduced models.
- Show reduced model and data: plot reduced model and data.
- Show full model and data: plot unreduced model and data
- Redo reduction: loops back to HSV display.
- Done: exits the reduction routine.

6.8 Add pole to model: Interactively add a mode to the model. The model and data are plotted channel by channel; 'Stop' the plot at the desired channel. Use the crosshairs to click on the frequency to add the pole.

6.8.1 Add pole menu (Figure 12): allows the frequency, damping, and residue of the pole to be varied.

- Increase pole frequency: 10% increase.
- Decrease pole frequency: 10% decrease.
- Increase damping: factor of 2 increase.
- Decrease damping: factor of 2 decrease.
- Large increase in residue: factor of 10 increase.
- Large decrease in residue: factor of 10 decrease.

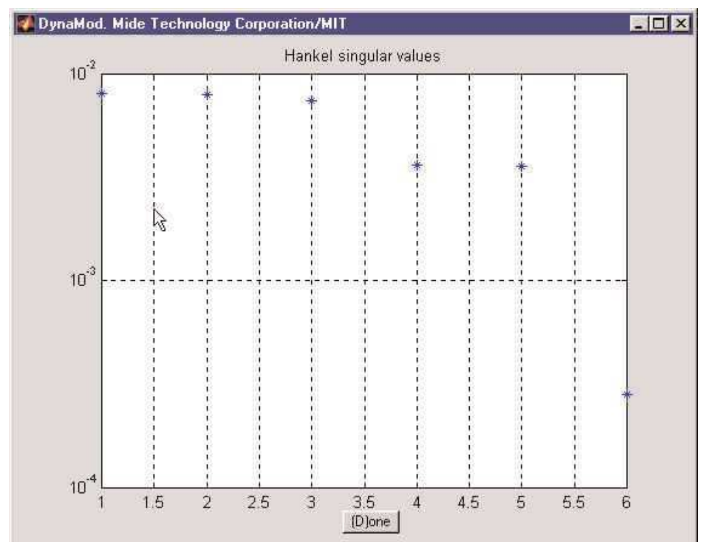

Figure 10. Balanced reduction algorithm plot showing Hankel Singular Values, organized by observability/controllability. Click on the last mode to retain (it will turn red) and select '(D)one'.

MenuCommandreference.

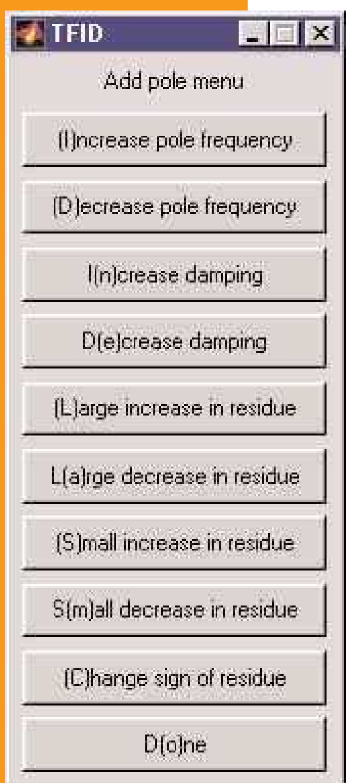

Figure 12.
Add pole menu.

- Small increase in residue: factor of 2 increase.
- Small decrease in residue: factor of 2 decrease.
- Change sign of residue: flips sign.
- Done: exits add pole routine.

6.8.2 Accept menu: select 'Yes' to incorporate the pole into the model. Select 'No' to revert to the previous model.

6.9 Remove poles from model: Interactively remove a mode from the model. The plot window will show the model and data singular values, with the model modes overlaid. Use the crosshairs to select the mode index to be removed. The selected mode will be highlighted in red. Click the 'Done' button to continue.

6.9.1 Accept menu: select 'Yes' to accept the truncated model. Select 'No' to revert to the previous model.

6.10 Save model to disk: saves the current model to the file 'tfiddat.mat'. This should be done before each tuning step, so that the tuning step can be undone if necessary.

6.11 Restore model: restores the last-saved model from disk.

6.12 Remove unstable modes: for MIMO systems, truncates unstable modes from the model. For SISO systems only, unstable modes can be stabilized or truncated. Unstable modes are stabilized by reflecting them across the imaginary axis.

6.13 Zero out D matrix: sets elements of the model D matrix to zero. Brings up a selection menu matrix the size of D. Double click on elements which should be zeroed.

6.14 Show modes: overplots the modal frequencies of the model over the frequency response data.

6.15 Remove poles by range: truncates out poles in a frequency range selected using crosshairs in the command window. The plot window will show the model and data singular values, with the model modes overlaid. Use the crosshairs to select the minimum and maximum frequencies of the range to be removed as prompted by the command window. Note there is no 'Accept' menu; save the model to disk prior to performing a remove poles by range.

6.16 Change plot options: enters the Plot options menu (See item 2).

6.17 Invert model: inverts the model and data frequency by frequency. Useful for refining the model around zeros. Requires a square system (equal number of inputs and outputs) and a nonzero D matrix. If either condition is not met, the routine will return the model unchanged.

6.18 Exit: exits to the Matlab workspace. The model is returned in DynaMod© 'SS' format; see 'help fpck' for information.

Tutorial DynaMod

1. Change to the DynaMod© installation directory. Run the script file 'sample.m'. The m-file will randomly generate an 8th order, 2 input, 3 output dynamic system, and generate transfer functions as pseudo-data. Then the DynaMod© software is called. The DynaMod© copyright screen will appear.

2. The Continuous/Discrete menu will appear. Select '(C)ontinuous' either by mouse-clicking on the button, or pressing 'c' on the keyboard (keyboard shortcuts are denoted by the presence of parentheses around the appropriate letter to select that menu function). Keyboard shortcuts are case-independent.

3. The Plot options menu will appear. Choose '(C)hange x-axis' to select logarithmic x-axis scaling, and '(T)oggle phase' to display the phase of each channel along with the magnitude. Note that the command window echos the current selection. Hit '(D)one'.

4. The DynaMod plotting window will appear with a '(D)one' button, a slider control, and a text box containing the numeral 0. This is the FORSE model order selection menu. Enter the value 15 by grabbing the slider. The text box will update when you let go of the slider. You can also change the model order by steps of 2 using the arrow keys at the ends of the slider. Hit '(D)one'.

5. The command window will echo the progress of the FORSE routine. When the routine terminates, the fit will be plotted against the data. Use the '(C)ontinue' button to cycle through the channels. Note the channel input/output pair is displayed at the top of the plot. Next the Redo menu will appear. Select '(n)' for no, to accept the initial fit. The fit and data will be re-plotted. Use the 'Stop' button to bypass the plotting routine.

6. The DynaMod© Main menu will appear. This is the entry point for the model tuning and reduction routines. Find the floating 'DynaMod Status' figure window and make it active by clicking on it. You will see that the current model has 15 states, 2 inputs, 3 outputs, no unstable modes, and a nonzero D matrix. Find the Main menu and select the 'S(h)ow modes' function. Look at the plotting window. You will see the model singular values plotted, against which are plotted eight vertical blue bars. Each dashed bar is a complex pole pair. The index number for each complex pair is shown at the base of the bar. The real pole is shown as a solid bar. Its index is plotted at the top. All bars are blue indicating all poles are stable. Unstable poles would be plotted in red.

7. Select '(S)ave model to disk'. This saves the current model to a file called 'tfiddat.mat', where it can be re-loaded if a model tuning step must be undone.

8. Select '(T)une model'. The Tune options menu will appear. Select '(F)ix all poles', then '(D)one'.

9. The NLS Cost menu will appear. Select 'M(a)gnitude and phase'. The tuning algorithm will begin to run. Intermediate cost results will be displayed in the command window. When the routine finishes, the fit will be plotted against the data. Cycle through the plots using the '(C)ontinue' button.

10. We will assume the model is to be used for an H2 control design. The current nonzero D matrix will result in an infinite H2 cost. We will correct this by enforcing a zero element in the D matrix of the fitted model. Select '(Z)ero out D matrix'.

11. Click on all elements. Element labels will turn from black to white as they are selected, indicating that they are zeroed in the model. Click on 'Done'. (Note that the 'Done' button does not appear with the keyboard shortcut indicator, showing that the keyboard shortcut is not available. You will only be able to select items using the mouse.)

12. Cycle through the plots. You will notice some error.

13. Select '(S)ave model to disk'.

14. Select '(T)une model'. This time, select 'Fix (e)ntire D matrix' to keep all D matrix elements zero. Hit '(D)one'.

TutorialDynaMod

15. Hit 'M(a)gnitude and phase'. The tuning function will run.

16. Cycle through the plots. The error should be reduced substantially.

17. Hit '(R)educe model'. A plot of the model Hankel Singular Values (HSVs) will appear. A larger HSV indicates a more important mode in the model. The HSVs are ranked by size, so that the dominant modes with high HSVs are on the left. The modes are decreasing in importance to the right. Note that the truth model from which the data is generated in sample.m is eighth order, but the HSVs do not necessarily exhibit a sharp break between 8 and 9 . Click on the 10th HSV marker to select a model order of 10. The HSV marker will turn red. Hit the '(D)one' key and cycle through the channels, examining the effect on the fit.

18. In turn, hit the '(S)how reduced and unreduced models', 'S(h)ow reduced model and data', and 'Sh(o)w full model and data' buttons, examining the differences in the models and the data. In this case the differences will not be significant, so hit '(D)one'.

19. Hit '(T)une model'. This time, do not save the model first, as the reduction may have been too drastic. Fix the entire D matrix, and fit the magnitude and phase cost. Cycle through the resulting fit. Since it is acceptable, save the model to disk.

20. Look at the 'DynaMod Status' window, which shows that the current model order is 10.

21. Select 'Remo(v)e poles by range'. Use the crosshairs to select all but the six lowest frequency poles of the model (deliberately introducing an error in the fit). Cycle through the plots to ensure that there is appreciable error.

22. Tune the model, holding D fixed, with the magnitude and phase cost.

23. Examine the transfer functions. Look for modes which appear in the data, but do not appear in the model. Mentally note which channels the discrepancies appear in.

24. Select '(A)dd poles to model'. Cycle through the channels until the missing mode appears. Press '(S)top' when that channel appears. Select '(y)' to confirm that you wish to use this channel.

25. Place the crosshairs at the missing mode frequency and mouse-click. Using the Add pole menu buttons, try to roughly match the model to the data. Increasing or decreasing the residue will change the height of the added mode in the channel. Changing the residue sign will change the phase excursion of the model near the added mode, either increasing around the mode or decreasing. Try to make the model phase excursion match the data, since sign flips are difficult for an automatic tuning algorithm to detect. Select 'D(o)ne' to finish. Click '(y)' to accept the mode.

26. Tune the model, fixing the D matrix, with the magnitude and phase cost.

27. Examine the resulting fit. There should be detectable errors, most noticable at the zeros, which arise from the lack of a D term in the model.

28. Save the model to disk. Use the 'Add pole' routine to add a highly damped, high frequency pole pair to the model. Tune the model, fixing the D matrix, using the magnitude and phase cost.

29. Examine the transfer functions. The resulting 10 pole fit to the 8 pole data should be fairly close. The 'S(h)ow modes' function should show a high frequency mode, which is the last pole pair added, whose residue at low frequency approximates the missing D term in the model.

30. Use the 'E(x)it' button to return to the Matlab workspace. Use the function 'finfo' to examine the output of the DynaMod© software: 'finfo(sys)'. The state space system can be extracted using the 'funpck' function: '[A,B,C,D] = funpck(sys)'.