Systems and Control Theory

Master Degree in ELECTRONICS ENGINEERING

(http://www.dii.unimore.it/~lbiagiotti/SystemsControlTheory.html)

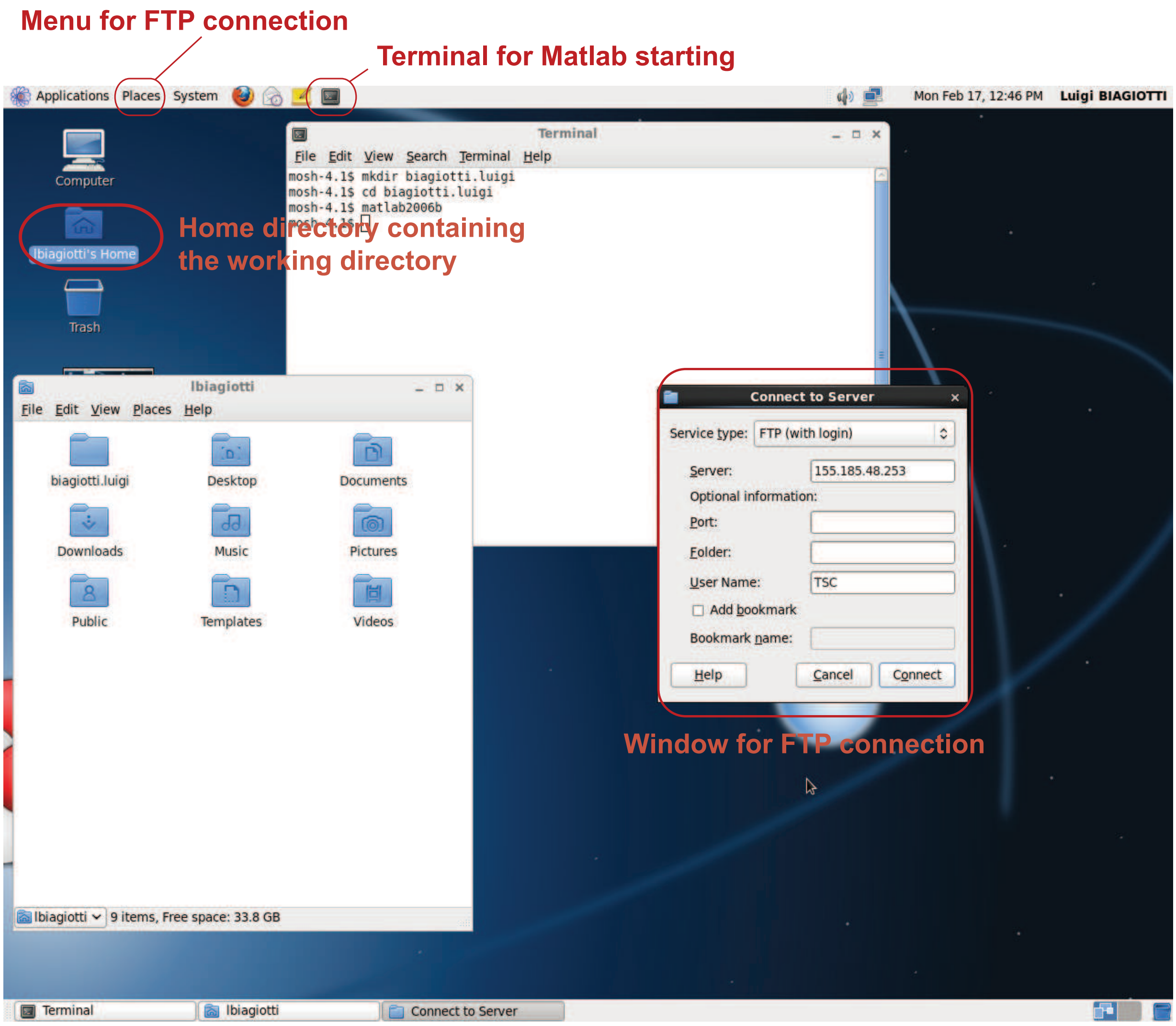
Practical test - April 12, 2017

Instructions

The exercises are carried out under Linux operating system. In order to start the MATLAB program and create the working directory `surname.name`, where all the MATLAB and SIMULINK files must be included, follow the procedure here reported:

1. Login with username and password used for the Unimore e-mail.
2. Open a `Terminal`.
3. Create the working directory and enter it with the commands
   `mkdir surname.name`
   `cd surname.name`
4. Open MATLAB with the command `matlab_R2006b`
5. Carry out the practical test, by using M-file, M-functions and Simulink schemes. Remember that the main file must be named `exercise.m` (in the first line of this file specify your first name and surname, properly commented).

Conclusion of the examination. At the end of the exam, it is necessary to save the directory (`surname.name`) on a FTP server located at the address 155.185.48.253, which can be reached with the option `Connect to server` of the dropdown menu `Places`. The options of the command `Connect to server` are reported in the figure (username: `TSC`, password: `TSC`). **It is necessary to save the solution of the test no later than 5 minutes after the end of the exam**. Late solutions will not be taken into account.



Text of the exercises

Design an M-file (exercise.m) that, with the help of other M-files and SIMULINK schemes if necessary, solves the following problems. [Duration 90 min.]

1. Define the Matlab function

   `[A,B,C,D] = ControllableCanonicalForm(Num,Den)`

   that, starting from the transfer function of a SISO system (whose numerator and denominator polynomials are the vectors `Num` and `Den`, respectively), provides the value of the matrices of the corresponding state space model in the so-called controllable canonical form. *Remember the relationship between the n-th order transfer function*

$$G(s) = \frac{c_{n-1}s^{n-1} + c_{n-2}s^{n-2} + \ldots + c_1 s + c_0}{s^n + a_{n-1}s^{n-1} + a_{n-2}s^{n-2} + \ldots + a_1 s + a_0}$$

   and the matrices of the of the state space model in the controllable canonical form:

$$\mathbf{A} = \begin{bmatrix} 0 & 1 & 0 & \ldots & 0 \\ 0 & 0 & 1 & \ldots & 0 \\ 0 & 0 & 0 & \ldots & 0 \\ \vdots & \vdots & \vdots & \ldots & \vdots \\ 0 & 0 & 0 & \ldots & 1 \\ -a_0 & -a_1 & -a_2 & \ldots & -a_{n-1} \end{bmatrix}, \qquad \mathbf{B} = \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \\ 1 \end{bmatrix}, \qquad \mathbf{C} = [c_0,\ c_1,\ \ldots,\ c_{n-2},\ c_{n-1}].$$

2. By using the function defined in the previous point, find the state space model[1] of the system defined by

$$G(s) = \frac{10s + 10}{s^3 - 1.6s^2 - 15.4s + 6.1}. \tag{1}$$

3. Design an LQ regulator, which weights the output and the control variables according to $\mathbf{Q}_y = 1$ and $\mathbf{R} = 5$. Build the simulink scheme by considering also a reference input.

4. Simulate the evolution of the controlled system from zero initial conditions when the reference signal $y_d(t) = 5u(t) + 20u(t-10)$, being $u(t)$ the unit step function, is applied (duration of the simulation 30 s). Plot in a unique figure the output of the system (`'b'`), superimposed to the reference signal (`'r:'`), and the error $e(t) = y_d(t) - y(t)$ (2 different subplots).

5. After having analyzed the observability of the system, design an asymptotic state estimator and insert it in the Simulink scheme. Simulate the evolution of the system under the same conditions of the previous point. Plot in a unique figure the output of the system (`'b'`), superimposed to the reference signal (`'r:'`), and the error $e(t) = y_d(t) - y(t)$ (2 different subplots). In a new figure compare the components of the actual state and those of the estimated state.

6. Insert in the Simulink scheme the system model defined in the transfer function form and compare the response of the nominal system $G(s)$ in (1) with the one of the perturbed system defined by

$$G_p(s) = \frac{10s + 11}{s^3 - 1.6s^2 - 15.4s + 6.1}$$

   under the same conditions of previous points. Plot in the same figure the output of $G(s)$ (`'b'`) and $G_p(s)$ (`'g--'`), superimposed to the reference signal (`'r:'`), and the error $e(t) = y_d(t) - y(t)$ obtained in the 2 cases.

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[1] The model should be

$$\begin{aligned} \dot{\mathbf{x}}(t) &= \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6.1 & 15.4 & 1.6 \end{bmatrix} \mathbf{x}(t) + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \mathbf{u}(t) \\ \mathbf{y}(t) &= \begin{bmatrix} 10 & 10 & 0 \end{bmatrix} \mathbf{x}(t) \end{aligned}$$