Systems and Control Theory

Master Degree in ELECTRONICS ENGINEERING

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

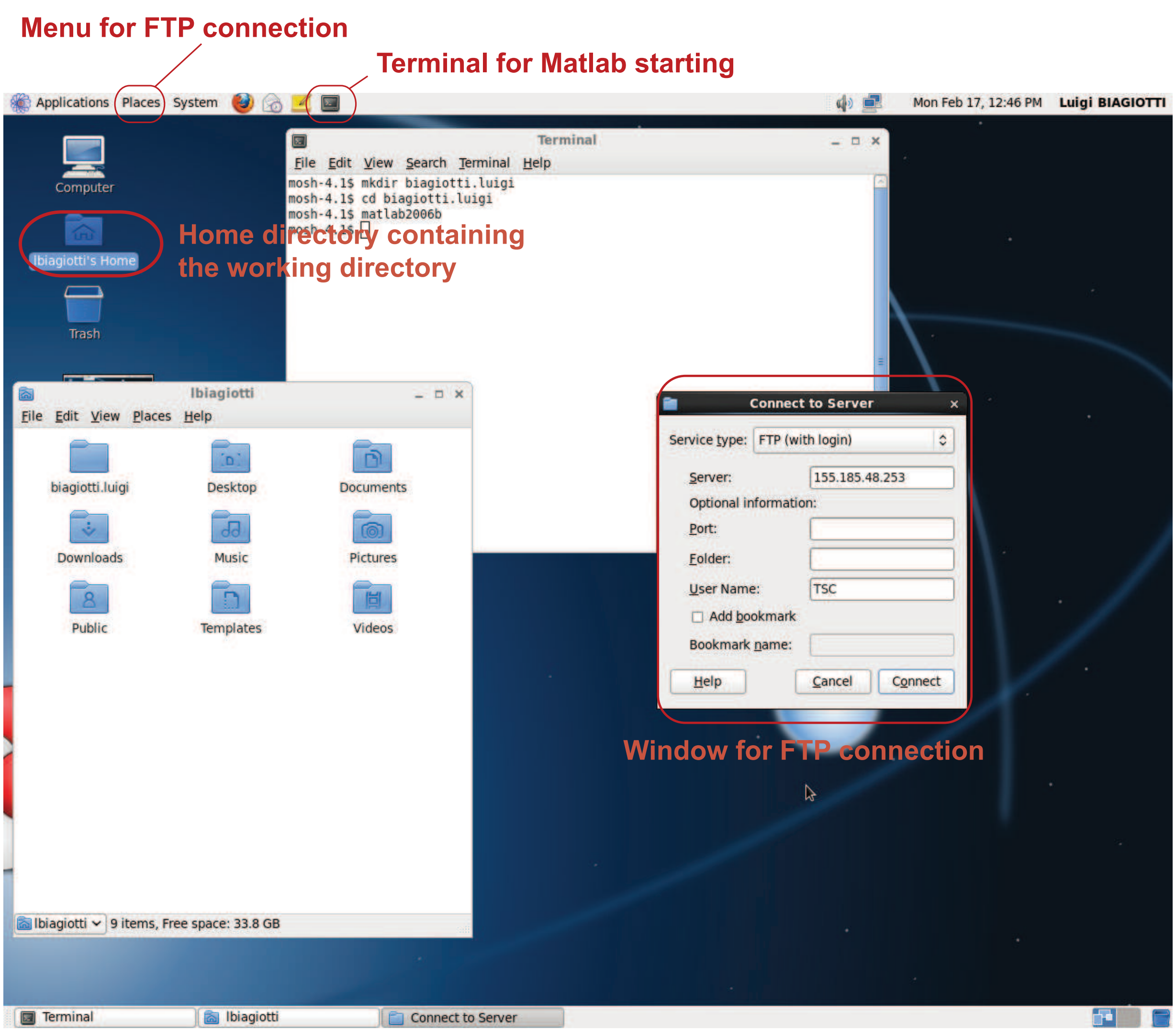
Practical test - February 23, 2017

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).

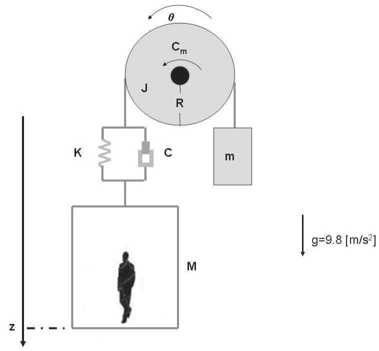
Conclusion of the examination. At the end of the exam, it is necessary to save the directory (`surname.name`) on a FTP server located at the address 155.185.48.253, which can be reached with the option `Connect to server` of the dropdown menu `Places`. The options of the command `Connect to server` are 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.]

The goal is to design a (discrete-time) controller for an elevator.



Parameters value

r	0.25	m
j	10	$Kg\,m^2$
m	1000	Kg
c	100	$N\,sec/m$
k	5000	N/m

Given the model of the elevator shown in the figure it is possible to obtain the following linear model

$$\dot{\mathbf{x}}(t) = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -\frac{k\,r^2}{j} & \frac{k\,r}{j} & -\frac{c\,r^2}{j} & \frac{c\,r}{j} \\ \frac{k\,r}{m} & -\frac{k}{m} & \frac{c\,r}{m} & -\frac{c}{m} \end{bmatrix} \mathbf{x}(t) + \begin{bmatrix} 0 \\ 0 \\ \frac{1}{j} \\ 0 \end{bmatrix} u(t) \tag{1}$$

where the state vector $\mathbf{x}(t)$ is $\mathbf{x} = [\theta,\, z,\, \dot{\theta},\, \dot{z}]^T$, and the control input $u(t)$ is the motor torque ($= C_m$) acting on the elevator. The height z of the cage is assumed as output variable.

1. Define the state-space model of the system in the Matlab environment, and discretize it by assuming a sampling time $T_s = 0.1$ s.

2. After having analyzed the controllability of the discrete-time system (unless otherwise specified consider the discrete-time system), design an optimal controller that penalizes the output and the control variables according to the weights $\mathbf{Q}_y = 20$ and $\mathbf{R} = 0.1$, respectively. Simulate the free evolution of the system with the optimal state feedback control from the initial condition $\mathbf{x}_0 = [0.5,\, 0.2,\, 0,\, 0]^T$ (duration of the simulation 30 s). Plot in the same figure (2 distinct subplots) the evolution of the control variable and of the output signal.

3. In order to build a regulator based on the (dynamic) feedback of the output y only, design a state estimator (with suitable eigenvalues), after having verified the complete observability of the system. Simulate the evolution of the system from the initial condition $\mathbf{x}_0 = [0.5,\, 0.2,\, 0,\, 0]^T$, by considering the feedback of the estimated state in place of the actual state. Plot in a new figure the control variable and the output signal, like in the previous point. In a second figure, compare the components of the actual state and those of the estimated state (4 distinct subplots).

4. Add to the regulation scheme an auxiliary input used to impose a desired reference value for the output variable. In particular, simulate the behavior of the system when it is fed with a step input of amplitude 3 applied at time-instant $t_0 = 5$ s from zero initial conditions (duration of the simulation 50 s). Plot in a new figure (2 distinct subplots) the output signal y (superimposed to the reference signal) and the control variable u.

5. Apply the discrete-time controller designed in previous points to the continuous-time plant and plot in a new figure (2 distinct subplots) the output signal y (superimposed to the reference signal) and the control variable u.