

2.004: Modeling, Dynamics, & CONTROL II

Spring Term 2003

Experiment 1: MatLab Tutorial

Introduction

This is the first tutorial session on MatLab. The goal is to equalize the playing field and make sure that all the students are familiar with this tool. As discussed in the pre-lab exercise, these pre-lab sessions are intended to get you started but you must practice on your own to get familiar with this program. You are required to be proficient in MatLab.

The experimental goals of this tutorial session are:

- (1) MatLab data as matrix.
- (2) Matrix manipulation: submatrix, accessing rows, columns, and elements.
- (3) Arithmetic manipulation of data
- (4) MatLab functions: scalar and vector
- (5) Data plotting and visualization
- (6) MatLab programming: Conditional statements and loop structures
- (7) Develop algorithms to calculate velocity, acceleration, and force.
- (8) Numerical integration of equation of motion to simulate system dynamics

Procedure:

Part A: Basic matrix operations and data visualization

In this tutorial, you are given a data set from a simulated experiment where a ping-pong ball is dropped from a given height and bounces a few time before stopping. This simulated experiment is repeated five times and all the data is recorded in a file. In this file, the first column is time. The other five columns represent the position of the ball during each trial. Please do the following:

- (A1) Plot the ball height as a function of time for trial 1, 3, and 5.
- (A2) You will find that the data is noisy, please average all trials and plot the average.
- (A3) You just learn that there is an experimental error in trial 3 where a student dropped a rubber ball instead of a ping-pong ball. Please repeat (2) after removing trial 3 from the data.
- (A4) Create a new matrix containing the time and the averaged data.
- (A5) The height scale is arbitrary and the table surface does not represent $h=0$. Can you renormalize the height of the averaged data?
- (A6) Please plot the log of the averaged data. The significance of taking a log will be discussed in class and in laboratory 2. Please note that $\log(0)$ is undefined; how do you handle that?

Part B: Deducing kinematic parameters from the object trajectory

In Part A, you were given trajectories of four dropping ball experiments. You have computed the average trajectory. Starting from these results, please complete the following exercise (Hint: Try using a FOR loop):

(B1) Create a “test” particle trajectory. Ask MatLab to create a 2D matrix where the first column is time and the second column position. Please make the time column linear and the position column sinusoidal. The matrix should be long enough to contain at least 3 periods.

(B2) Develop an algorithm to compute the first derivative.

(i) Calculate velocity of the test trajectory

(ii) Calculate velocity of the ball drop data.

(B3) Develop an algorithm to compute the second derivative.

(i) Calculate acceleration of the test trajectory

(ii) Calculate acceleration of the ball drop data.

(B4) Create two graphs. The first graph should contain plots the position, velocity, and acceleration of the test trajectory. The second graph should contain plots of the position, velocity and acceleration of the ball drop data.

Part C: Producing object trajectory from the equation of motion

For a ball dropping under the influence of gravity, the equation of motion is:

$$\ddot{z}(t) = -g \quad (1)$$

Integrating the equation of motion, one can obtain:

$$\dot{z}(t) = -gt + v_0 \quad (2)$$

$$z(t) = -\frac{gt^2}{2} + v_0t + z_0 \quad (3)$$

(C1) Use m-files to define functions to calculate velocity and position as a function of time and initial velocity and position:

$$v(t, v_0)$$

$$z(t, z_0, v_0)$$

(C2) Using initial conditions, $z_0 = 10\text{ m}$ and $v_0 = 0\text{ m/s}$,

Plot $z(t, z_0, v_0)$ for t from 0 to 20 seconds at interval of 0.1 s.

(C3) Find the first collision time t_1 when $z(t_1) = 0$? What happens at this time and beyond?

Hint: Try MatLab function fzero. From the plot in (B2) you can find the initial guess for t_1 .

(C4) Calculate $\dot{z}(t_1)$.

(C5) Use coefficient of restitution equal to 0.8, calculate the rebound velocity $\dot{z}_{rb}(t_1)$.

(C6) Using new initial conditions, $z_0 = 0\text{ m}$, $v_0 = \dot{z}_{rb}(t_1)\text{ m/s}$,

Plot $z(t - t_1, z_0, v_0)$ for t from $t_1 + 0$ to $t_1 + 20$ seconds at interval of 0.1 s.

(C7) Find the second collision time t_2 when $z(t_2) = 0$.

(C8) Repeat and calculate the next cycle.