16.07 Flight Simulation Laboratory

Lab II

Issued: Sep 28, 2004
Due: Oct 15, 2004

In this part of the laboratory, you will investigate the dynamics of an aircraft flying a loop in the vertical plane and simulate the flight using a modified version of your Lab I code.

First you will fly an ideal circular loop as the one shown in Figure 1.

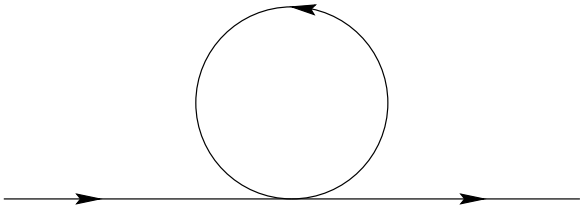

Figure 1: Flight path containing an ideal circular loop

We are interested in the constant energy case, so assume that thrust cancels drag at all times. Here, you can either calculate the drag vector at and apply a thrust that is equal in magnitude and opposite in direction, or simply remove the drag and thrust contributions from your state derivative function.

1. Determine an expression for the lift and angle of attack required to fly the circular loop.

2. Modify your code from Lab I so that the aircraft with less fuel ($m =$ 21000 kg) first flies in a steady level flight at altitude of 10000 m and ground speed 185 m/s, then goes into a perfectly circular loop with radius 800 m at time $t = 20$ seconds, and after completing exactly one loop, continues on a steady level flight at the same altitude as before (see Figure 1). The simulation should last a total of 100 seconds.

   You will need several `if` statements in order to switch from the straight flight path to the loop and back. We recommend that you avoid using `==` and prefer `<,<=,>` and `>=` instead (because of the rounding errors present in the computer). You may find it easier to control the flight

path based on the time variable rather than position/velocity variables because time is unique (always increases), while there is the possibility of the aircraft ending up at the same point twice (it will when you fly the loop).

3. The angle of attack which you used in the previous part is dependent on the position of the aircraft. We would like to "simplify" the simulation and use a constant angle of attack. The loop will not be circular any more. By trial and error, find the constant value of the angle of attack α which will make the aircraft reach the same maximum altitude as in the case of the circular loop.

4. For both loops, turn in a plot of the flight path (y vs. x) and plots of the velocity magnitude, tangential acceleration, normal acceleration, and radius of curvature versus time. Have a separate set of figures for each loop; you will definitely find it easier to write two state derivative functions (the code will be mostly identical) instead of looking for a way to create both loops in one function. Use the MATLAB `axis equal` command on the flight path plot so that it is scaled correctly. Use the MATLAB `subplot` command to place the flight path and velocity plot on the same figure. Also use `subplot` to place both accelerations and the radius of curvature on the same figure. To find the two components of the acceleration first differentiate the velocity using the `derivative(t,y)` function provided on the website and then decompose it into normal and tangential components. The function has two parameters t and y which must be column vectors with equal length. It returns a column vector containing the derivative of y with respect to t at the specified times t. Determine the radius of curvature from the normal component of the acceleration and the velocity. Verify that for the circular loop the number that you obtain is approximately equal to the radius of the loop.

   Note: since the accelerations are found by taking the derivatives of discrete data, it will be slightly noisy and may have spikes at discontinuities. Use the MATLAB `axis` command to adjust the radius of curvature plot so that the range is from 0 to 2000 m.

5. Considering the demands on the aircraft structure, which of the two flight paths is preferable? Why?

You must turn in electronic versions of your MATLAB code for **both loops** on the server ; no paper copies of the code will be accepted and the server will not accept electronic turn-ins after the due date and time. If you have to turn in several files please submit them separately in raw form the way they are, do not put them together in a zip or other type of archive. Your code must produce all figures requested in part 4 in a single run without any manual changes in it, and all plots should be titled, with all axes labeled, and with a grid. All calculations, derivations and plots must be turned in on paper by the due date.