University of Colorado Boulder

ASEN 4057: Aerospace Software

Homework 4

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I. Program Details

A. Subroutines Overview

The program developed by the team members consists of several subroutines and a main driver function. The subroutines consist of the following:

- **eulerFunc**: a function which uses eomFunc to integrate a three body system given a certain set of initial conditions and predefined timestep and timespan. This function also breaks if certain conditions are met (i.e. two objects colliding)
- **eomFunc**: a function which takes in the state (position and velocity) of a three body system and returns the derivatives (velocity and acceleration) of that system
- **OptimizationFunction**: and function that utilizes eulerFunc to integrate the system given some set of initial conditions and determine the outcome of the system
- **GridSearch**: a rudimentary numerical optimization function that can minimize both time and change in velocity of the spacecraft returning to Earth.
- **saveFile**: a basic function that saves the output of an integration to a csv file for plotting in MATLAB

B. Flowchart Visualization

A visualization of the program structure and how the different subroutines interact with each other can be seen below in Fig. 1

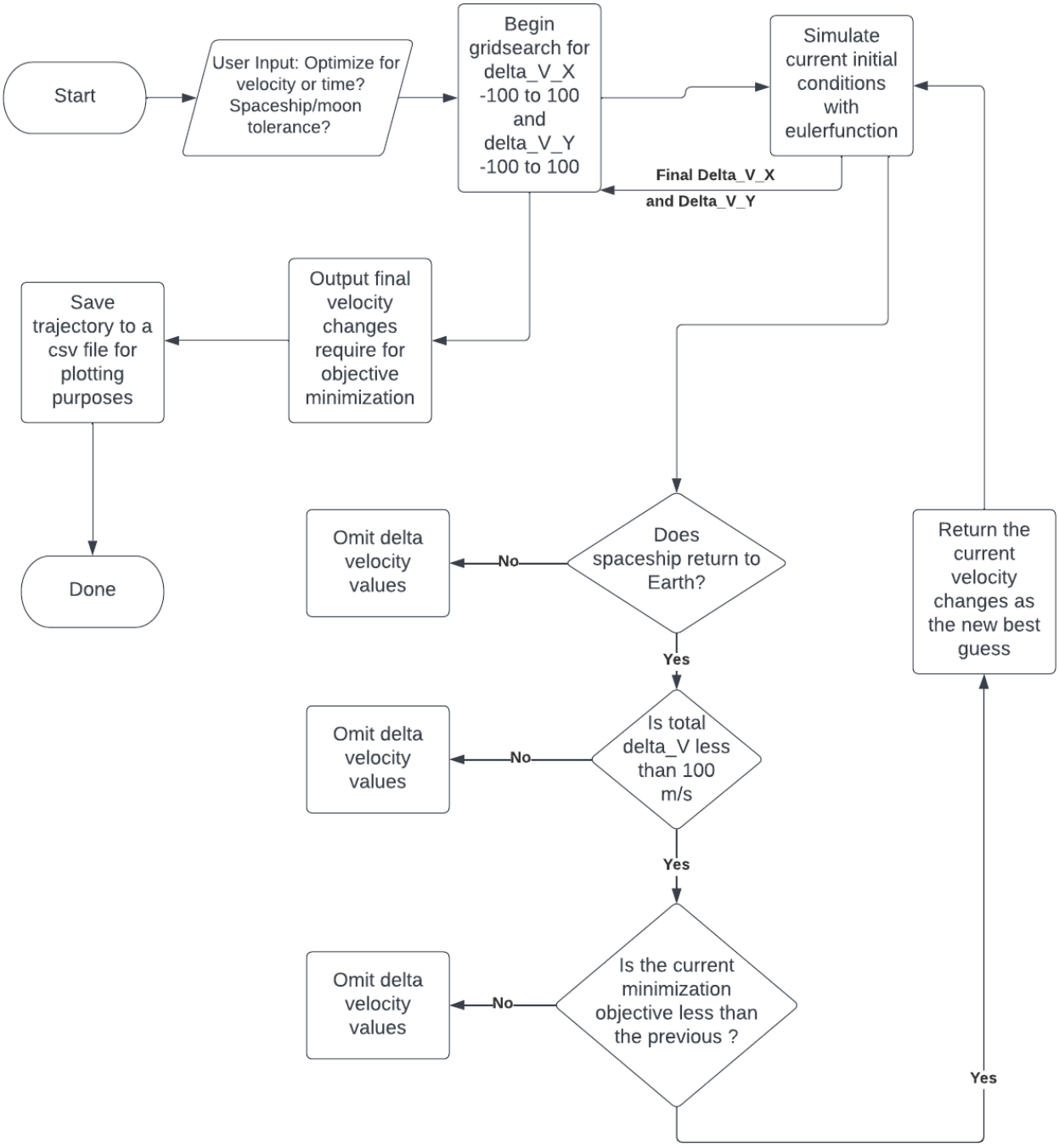

Fig. 1 C Program Flowchart

II. Test Cases

The C Program that the team developed was tested on two separate test cases to ensure its viability. With a user prescribed moon-spacecraft tolerance of 10,000 meters the program was implemented to minimize both time to return as well as change in velocity required to return.

A. Case 1: Velocity Minimization

The minimum velocity change that resulted in the spacecraft rendezvous'ing with Earth was:

Delta VX = 0 m/s
Delta VY = -59 m/s
Magnitude of Delta V = 59 m/s

A trajectory of this flight can be seen below in figure 2

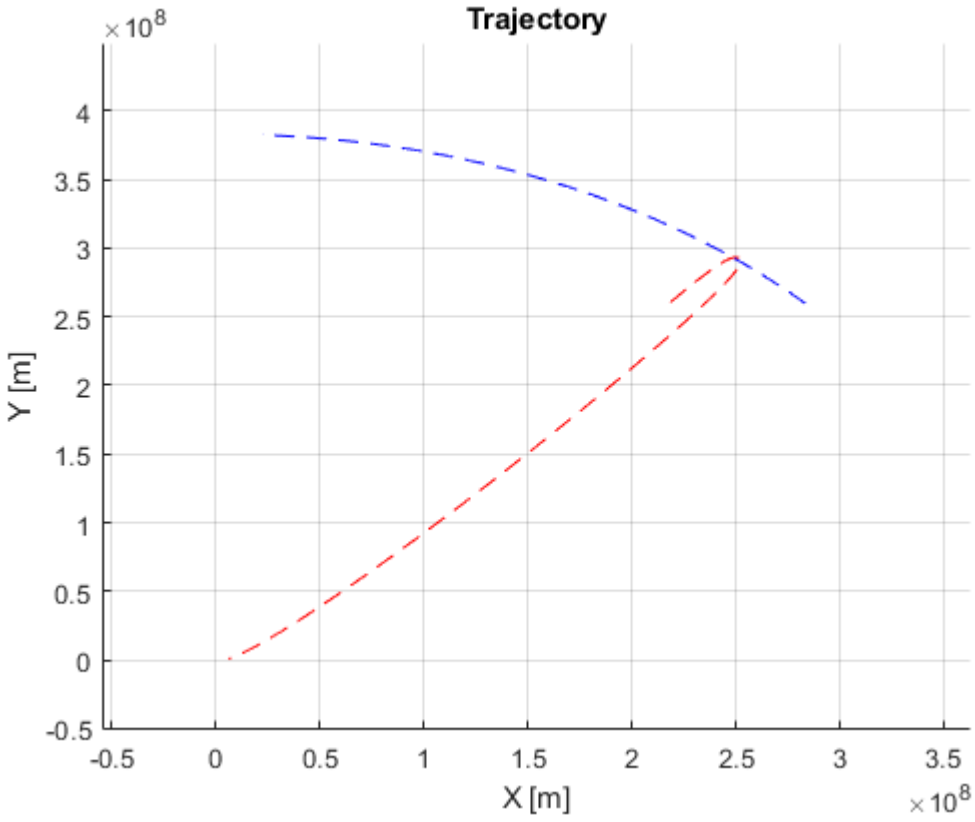

Fig. 2 Caption

B. Case 2: Time minimization

The velocity change that resulted in shortest time for the spacecraft to rendezvous with Earth was:

Delta VX = -81.000000 m/s
Delta VY = 50.000000 m/s
Magnitude of Delta V = 95.189285 m/s

A trajectory of this flight can be seen below in figure 5

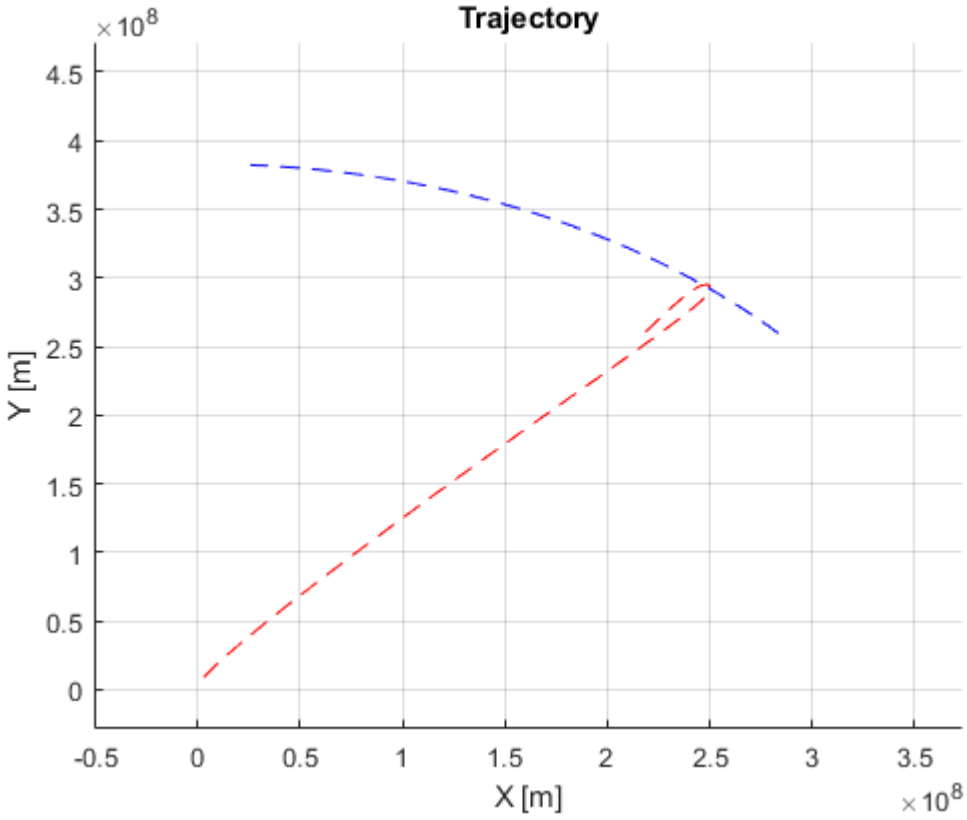

Fig. 3 Caption

III. Profile Report

Using gprof, the team's c program was testing and timed for objective 1 with a moon-spacecraft clearance of 100 meters and a tolerance of 0.5. It was determined that the program took a cumulative time of 1.02s to run, with 60% of this being from the equations of motion function as the eulerFunc integrator function had to call this several thousand times for each integration. In total, eomFunc was called 14424654 times while the eulerFunc function was called 575 times. From this profile, calling eomFunc as well as eulerFunc proves to be the most time expensive functions in the overall script, therefore if an effort was made to further optimize the script, an overall reduction in the use of said functions would be required. These measures would involve the future algorithm to reduce the overall time scale resolution and grid search area.

% time	cumulative seconds	self seconds	calls	self s/call	total s/call	name
60.28	0.62	0.62	14424654	0.00	0.00	eomFunc
38.89	1.02	0.40	575	0.00	0.00	eulerFunc
0.00	1.02	0.00	575	0.00	0.00	OptimizationFunction
0.00	1.02	0.00	1	0.00	1.02	GridSearch
0.00	1.02	0.00	1	0.00	0.00	saveFile

Fig. 4 GPROF Flat Profile

```
index % time    self  children    called     name
                0.00    1.02     575/575         GridSearch [3]
[1]    100.0    0.00    1.02     575         OptimizationFunction [1]
                0.40    0.62     575/575         eulerFunc [2]
-----------------------------------------------
                0.40    0.62     575/575         OptimizationFunction [1]
[2]    100.0    0.40    0.62     575         eulerFunc [2]
                0.62    0.00 14424654/14424654     eomFunc [5]
-----------------------------------------------
                0.00    1.02       1/1           main [4]
[3]    100.0    0.00    1.02       1         GridSearch [3]
                0.00    1.02     575/575         OptimizationFunction [1]
                0.00    0.00       1/1           saveFile [6]
-----------------------------------------------
                                                <spontaneous>
[4]    100.0    0.00    1.02                 main [4]
                0.00    1.02       1/1           GridSearch [3]
-----------------------------------------------
                0.62    0.00 14424654/14424654     eulerFunc [2]
[5]     60.8    0.62    0.00 14424654          eomFunc [5]
-----------------------------------------------
                0.00    0.00       1/1           GridSearch [3]
[6]      0.0    0.00    0.00       1         saveFile [6]
-----------------------------------------------
```

Fig. 5 GPROF Callgraph Profile