Assignment 1
Orbit Simulation and Determination
AERO4701 Space Engineering 3

February 28, 2016

In this assignment you will explore different approaches to satellite orbit simulation and implement basic algorithms for orbit determination. You are expected to perform your own research on the dependencies between satellite mission objectives and the orbital parameters, the effect of orbit perturbations and the different methods for orbit determination of a real satellite system.

General

- This assignment contributes 30% to your final mark.
- Late submission will result in a 20% (20 marks out of a possible 100) reduction for each day late, starting from 5pm on the day the assignment is due and including weekends.
- Any special consideration requires you to go through the Special Consideration form process. Only major illnesses/misadventures will be considered.
- Minor Plagiarism will attract 0 marks for all those involved for the whole assignment along with the issue being followed up with the T&L Director and then onto the University Registrar. Likewise with major plagiarism except that an automatic failure of the whole course will be sought. No assignment will be marked unless the Student Plagiarism Compliance Sheet is filled out and submitted (the sheet can be downloaded from this course's website).
- This assignment should take the average student 30 hours to complete.

Submission

- This assignment is due on Thursday 24th March 2016, at 5pm by email to Kelvin Hsu (yhsu9975@uni.sydney.edu.au) and submission .
- You will provide one document/report file for the assignment in PDF format and named report.pdf. The report will include the sections Question 1, Question 2 , Question 3 and Appendix with subsections for each question. Each question will contain the subsections Introduction, Methodology, and Results/Discussion.
- Use plots from your MATLAB code to illustrate your findings. You may use an appendix at the end of your report for your figures and reference them in the body of your report. The page limit **per each section** is 4 pages (not including the appendix). Pages over the limit will not be marked.

- For each question you will submit working MATLAB code. For each question, make sure there is a main file named mainQN.m where N is the question number. This main script will be the ONLY script run by the tutor during marking and this script should run all of your code and produce all of your plots and simulations for the questions.
- All MATLAB code must be commented so that the code can be read and understood without the aid of the report.
- If your code does not work, you will receive 0 marks for the code section of the marking unless you provide a valuable explanation in the report as to why it didnt work.
- Place all of your code for each question and your report in one .zip file. Name the .zip file SID_Assignment1.zip where SID is your student number. Email this file to the tutor when submitting your assignment.
- It is your responsibility to check that you have sent all the files for each question. We will not follow you up if we find the code or report missing from any of the questions in the email, and if it is not there, we will assume you did not attempt that question.

Preliminaries (Code: 10 pts)

In this part of the assignment you will develop a set of MATLAB-functions that will be needed in the process of answering questions 1-3. No report is requested for this part; however, it is required that the requested functions work correctly in order to receive full marks. Complete the conversion function stubs provided in the folder `Preliminaries` and run the provided test script to check whether your functions work correctly (2 Pts for all conversion functions working correctly).

While the test function will work using $n \times 1$ vector inputs you should develop your methods in vectorised form (i.e. $n \times m$) for later use.

Use the implemented methods to answer the following questions:

- A ground station located in the Sydney CBD makes an observation of a satellite at $[\psi = 27.5°, \theta = 72.1°, r = 1970\text{km}]$ in local geodetic NED co-ordinates. (3 Pts altogether)

  (1) Compute the ECEF position of the satellite.

  (2) Compute the ECI position of the satellite given that the observation was made at 5pm local time. Assume that the Greenwich meridian passed the vernal equinox at midnight on the same day but at Greenwich Mean Time (GMT).

- A satellite in orbit around the Earth makes a radar observation of a landmark on the earths surface. The ECEF co-ordinates of the satellite are [-6763200, 3940900, 5387700] when the observation is made and the observation is $[\psi = -131.57°, \theta = -30.40°, r = 3970\text{km}]$ in local geocentric NED co-ordinates. Compute the geocentric and geodetic latitude, longitude and altitude of the landmark. (3 Pts altogether)

- In the case of an angle-only observation (as obtained with a camera, for example), compute the geodetic and geocentric latitude and longitude of the landmark. Assume that the landmark is known to be at sea-level. Note that this questions requires some coding effort additional to the conversion functions. (2 Pts)

Question 1 (Code: 12 pts, Report: 15 pts)

In this question you will research into two satellites, one in LEO, one in MEO. The aim of this question is to acquire the orbital parameters for the satellites you have chosen, simulate the satellite orbits and to comment on why the orbits were chosen based on the mission objectives for the satellites.

- Find two real satellites used for earth sensing or communication, one stationed in a LEO and one in a MEO. The orbital parameters of the satellites should be obtained in the form of TLEs from your own research.

- Simulate the orbit for each satellite using the orbital parameters over a 24 hour period. Implement the basic Keplerian orbital model. Compute the orbital period, show 3D plots of the satellites' orbits in an ECI frame and produce a ground trace of the orbits (your MATLAB code should generate these plots and they should also be provided in the appendix of your report).

- In the report you will describe the satellites chosen, discuss the relationship between the missions of the satellite and the orbit properties (for example, but not limited to, orbital period, Earth/Sun orientation, inclination and ground trace).

Question 2 (Code: 12 pts, Report: 15 pts)

In this question you will investigate the effect of perturbations on the satellite orbit.

- For your LEO satellite in Question 1, research into different perturbing sources and their potential effects on the orbital motion of your satellite.
- From your research, select the dominant perturbing source and express it as a perturbing acceleration on the two-body equation of motion.
- Implement the modified equinoctial elements model. Simulate the orbit of the satellite by numerically integrating the equation of motion over a 24 hour period. Compute the orbital period, show 3D plots of the satellite's orbit in an ECI frame and produce a ground trace of the orbit.
- In the report you will compare your results to those generated in Question 1 (without perturbing source) and document your findings. Discuss how the perturbations affect the properties of the original orbit.

Question 3 (Code: 16 pts, Report: 20 pts)

In this question you will research into real systems and methods used to determine the orbit of your satellite in Question 1.

- For your LEO satellite in Question 1, choose a ground station location (latitude, longitude and altitude) somewhere in view of the satellite. Produce range, azimuth and elevation plots of the satellite's trajectory over the sky above the ground station. Note the maximum elevation of the satellite and the percentage of time the satellite is in view over the 24 hour period.
- Take several observations from your ground tracking station and use them to predict the orbital parameters of the satellite. You should implement a Herrick-Gibbs technique using three sets of range, azimuth and elevation observations. Add tracking errors (range, azimuth and elevation errors) to your simulated tracking readings and provide plots of the effect the errors have on the accuracy of the predicted orbital parameters.
- In your report discuss the orbit determination and tracking of your satellite system. Detail what real systems are used in practice (i.e. radar/laser/optical/radio/other satellites etc.), and their accuracy. Discuss your tracking results, the effect of tracking errors and ways you could improve tracking performance in light of error sources.