ENAE441 Group Project

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Contents

1 Overview

The goal of this project was to tie together many different topics from the course into once large project. Data acquired online about varying GNSS satellites was to be analyzed using trilateration, coordinate transformation, Lambert solvers, and TLEs.

In doing this, we discovered **Things maybe**.

2 Work Done

2.1 Trilateration

2.2 Postition

2.3 Position Vectors

2.4 Solving the Lambert Problem

2.5 Pseudoranges

3 Conclusion

3.1 Results

3.2 Sources of Error

3.3 Limitations

A Code

A.1 Main Analysis Code

```
%% Load data
% clear all
% clc
% close all
run set_data.m
% run set_parameters.m

%% Trilateration
rho_t1_sat1 = Trilateration(rho_obsv_t1_sat1, ref_matrix, 1e-4,
    rho_njtr_t1_sat1)
rho_t2_sat1 = Trilateration(rho_obsv_t2_sat1, ref_matrix, 1e-4,
    rho_njtr_t2_sat1)
rho_t1_sat2 = Trilateration(rho_obsv_t1_sat2, ref_matrix, 1e-4,
    rho_njtr_t1_sat2)
rho_t2_sat2 = Trilateration(rho_obsv_t2_sat2, ref_matrix, 1e-4,
    rho_njtr_t2_sat2)

%% Frame Conversion
gst_t1_sat1 = GST(T1, t1);
gst_t2_sat1 = GST(T2, t2_sat1);
gst_t2_sat2 = GST(T2, t2_sat2);
```

A.2 Parameter Setting

```matlab
% Script to initialize global parameters/formatting for ENAE 404
% Inludes things like fundamental constants, planetary radii, etc.
% Author: Blaire Weinberg

% Formatting
format long g
clc
clear all

% Fundamental Constants
c = 3e5; % km/s

% Gravitational Parameters
mu_earth = 3.986e5; % km^3 / s^2
mu_mars = 4.305e4; % km^3/s^2
mu_saturn = 3.7931187e7; % km^3/s^2
mu_moon = 0.00490e6; % km^3/s^2 (nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html)
mu_jupiter = 126.687e6; % km^2/s^2 (nssdc.gsfc.nasa.gov/planetary/factsheet/jupiterfact.html)
mu_mercury = 0.022032e6; % km^2/s^2 (https://nssdc.gsfc.nasa.gov/planetary/factsheet/mercuryfact.html)
mu_sun = 132712e6; % km^2/s^2 (https://nssdc.gsfc.nasa.gov/planetary/factsheet/sunfact.html)

% Radii
r_earth = 6378; % km
r_moon = 1738.1; % km (nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html)
r_jupiter = 71492; % km (nssdc.gsfc.nasa.gov/planetary/factsheet/jupiterfact.html)
r_mercury = 2439.7; % km (https://nssdc.gsfc.nasa.gov/planetary/factsheet/mercuryfact.html)
r_mars = 3396.2; % km (https://nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.html)
r_geo = 42164; % km

% Semi-major axes
a_mercury = 57.91e6; % km (https://nssdc.gsfc.nasa.gov/planetary/factsheet/mercuryfact.html)
a_earth = 149.6e6; % km (https://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html)
a_jupiter = 778.57e6; % km (nssdc.gsfc.nasa.gov/planetary/factsheet/jupiterfact.html)

% Mass
m_mercury = 0.33011e24;% kg (https://nssdc.gsfc.nasa.gov/planetary/factsheet/mercuryfact.html)
m_jupiter = 1898.19e24; % kg (nssdc.gsfc.nasa.gov/planetary/factsheet/jupiterfact.html)
m_sun = 1988500e24; % kg (nssdc.gsfc.nasa.gov/planetary/factsheet/sunfact.html)

% Gravitational Parameters
g_earth = 9.798e-3; % km/s (https://nssdc.gsfc.nasa.gov/planetary/factsheet/
```

```
    earthfact.html)
```

A.3 Data Setting

```
% This script contains all of the data pulled from online for the project
% Author: Blaire Weinberg

%% G32
t_sat1 = [datetime(2019, 09, 29, 20, 0, 0);
          datetime(2019, 09, 30, 3, 12, 30)]; % YY-MM-DD hh:mm:ss

% [GODE; LYCO; NJTR]
rho_obsv_t1_sat1 = [25051697.711; 25250311.013; 25300673.18]; % m
rho_obsv_t2_sat1 = [24885268.756; 25027333.239; 24905662.38]; % m

rho_gode_t1_sat1 = [-16495.751222; -20282.441992; -4990.466293]; % m
rho_gode_t2_sat1 = [20213.786583; -14550.961176; -8980.879524]; % m

rho_lyco_t1_sat1 = [-16495.751222; -20282.441992; -4990.466293]; % m
rho_lyco_t2_sat1 = [20213.786583; -14550.961176;  -8980.879524]; % m

rho_njtr_t1_sat1 = [-16495.751222; -20282.441992; -4990.466293]; % m
rho_njtr_t2_sat1 = [20213.786583; -14550.961176; -8980.879524]; % m

%% G10
t_sat2 = [datetime(2019, 09, 29, 20, 0, 0);
          datetime(2019, 09, 30, 1, 22, 30)]; % YY-MM-DD hh:mm:ss

% [GODE; LYCO; NJTR]
rho_obsv_t1_sat2 = [23211963.276; 23183895.657; 23332124.46]; % m
rho_obsv_t2_sat2 = [24741064.469; 24965346.244; 24859334.14]; % m

rho_gode_t1_sat2 = [-16660.548228; -11669.484643; 17253.892228]; % m
rho_gode_t2_sat2 = [11443.232098; -19758.768196; -13321.664005]; % m

rho_lyco_t1_sat2 = [-16660.548228; -11669.484643; 17253.892228]; % m
rho_lyco_t2_sat2 = [11443.232098; -19758.768196; -13321.664005]; % m

rho_njtr_t1_sat2 = [-16660.548228; -11669.484643; 17253.892228]; % m
rho_njtr_t2_sat2 = [11443.232098; -19758.768196; -13321.664005]; % m

%% Ground Stations
% ECEF XYZ
GODE = [1130774.439; -4831255.071; 3994200.558]; % m
LYCO = [1080274.057; -4680045.229; 4182682.6660]; % m
NJTR = [1278261.278; -4703708.0040; 4099884.5550]; % m

ref_matrix = [GODE'; LYCO'; NJTR'];

%% Times
t1 = 20 * 3600; % s
t2_sat1 = (3 * 3600) + (12 * 60) + 30; % s
t2_sat2 = 3600 + (22 * 60) + 30; % s

```

```
T1 = (7181 + 29 + 0.5) / 32525;
T2 = (7181 + 30 + 0.5) / 32525;
```

A.4 Trilateration

```
function [r] = Trilateration(rho_obsv,ref,tolerance, r_guess)
% Determines the location of a satellite given reference information
% Inputs:
    % rho_obsv: vector containing observed ranges
    % ref: matrix containing all of the [X Y Z] information for the
    % reference locations for the observations
    % r_guess: guess [X Y Z] vector for where the satellite should be located

% Outputs:
    % r: [X Y Z] vector containing the iterated solution for where the
    % satellite is

% Author: Blaire Weinberg

r = r_guess;

rho_pred = sqrt((ref(:, 1)-r(1,1)).^2+(ref(:, 2)-r(2,1)).^2+(ref(:, 3)-r(3,1))
    .^2);
e = (rho_obsv-rho_pred);
while (norm(e)>tolerance)
    A = [(r(1,1)-ref(1, 1))/rho_pred(1),(r(2,1)-ref(1, 2))/rho_pred(1),(r(3,1)
        -ref(1, 3))/rho_pred(1);
          (r(1,1)-ref(2, 1))/rho_pred(2),(r(2,1)-ref(2, 2))/rho_pred(2),(r(3,1)
              -ref(2, 3))/rho_pred(2);
          (r(1,1)-ref(3, 1))/rho_pred(3),(r(2,1)-ref(3, 2))/rho_pred(3),(r(3,1)
              -ref(3, 3))/rho_pred(3)];
    rho_pred = sqrt((ref(:, 1)-r(1,1)).^2+(ref(:, 2)-r(2,1)).^2+(ref(:, 3)-r
        (3,1)).^2);
    e = (rho_obsv-rho_pred);
    r = r+(A\e);
    disp(e);
end
```

A.5 Piece of Code 4

A.6 Piece of Code 5

B Group Work Distribution

B.1 Tyler Chotoo

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B.2 Abubakr Hamid

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B.3 Richard Quarles

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B.4 Blaire Weinberg

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