ME 355 – System Modeling and Numerical Methods
Fall 2021

Project 1

Due Monday, September 13 by 11:59 pm

This project must be turned in on Blackboard.

You are a new hire at Engineering Consultants LLC, and your first project is a contract to develop a solution to track local airspace movement. The hardware engineer has already scoped out the hardware necessary, an FR24 Box Receiver coupled with a GPS antenna, and you are told that the receiver returns longitude and latitude data of all aircraft within the vicinity. The computer scientist (CS) in the group has told everyone he will write a program that parses the longitude and latitude data and return tracking data for each aircraft that enters within the antenna range. His function will track each aircraft by a unique ID, and once the aircraft has left the antenna range, return a two-dimensional array of columns time, horizontal distance from the radar (r), and angle from east (θ). An r of 0 corresponds to the location of the antenna. It can be assumed that vertical distance is irrelevant. However, the CS is unsure of the best way to convert this data into velocity, and thus, has requested your help.

Your task is to develop a function which takes in the two-dimensional array the CS's function returns, calculate the velocity in x- and y-directions at each time step, and return a two-dimensional array with columns time, velocity in x-direction (v_x), and velocity in y-direction (v_y). As this code will be delivered to the customer you are contracted with, the code needs to be well documented and readable. You also must submit validation and verification (V&V) documentation, showing that your code works.

To assist you in your V&V, the CS gives you a set of test data as well as a function developed by a previously disgruntled employee who quit which converts polar coordinates to cartesian coordinates (r,theta data to x,y data). The CS assures you the time data will always have a consistent timestep (step size), however, it is not always guaranteed the timestep will be two (step size could be 3 or 1.5 or 7 ect.).

Table 1: Test data of the array your function will take in as an input.

time, [seconds]	r, [meters]	θ, [radians]
168	5300	0.85
170	5560	0.82
172	5790	0.80
174	6070	0.78
176	6350	0.77

Table 2: Example format of the output.

time, [s]	v_x, [m/s]	v_y, [m/s]
168		
170		
172		
174		
176		

Functions

To complete this task, you will need to develop **4** MATLAB functions.

1. **forward.m**
   This file is a general **function** so that a functional call of **fPrime = forward(h, f0, f1)** will return the value of f'(x0) calculated using the forward difference method.

2. **backward.m**
   This file is a general **function** so that a functional call of **fPrime = backward(h, fn1, f0)** will return the value of f'(x0) calculated using the forward difference method.

3. **center.m**
   This file is a general **function** so that a functional call of **fPrime = center(h, fn1, f1)** will return the value of f'(x0) calculated using the forward difference method.

4. **velocity.m**
   This file is a general **function** given a functional call of **output = velocity(input)**
   input is a n x 3 array, where n is the number of samples, the first column is the time in seconds, the second column is the radius in meters, and the third column is the angle in radians.
   output should be an n x 3 array, where n is the number of samples, the first column is the time in seconds, the second column is the velocity in the x-direction in meters per second, and the third column is the velocity in the y-direction in meters per second.
   You may find it useful to call functions (1) through (3) above and the given function to assist in making **velocity.m**. Use the most accurate method when possible. Also, make sure your code can handle edge cases. (What will happen if n = 1?)

V&V Document

The V&V documentation will be comprised of a **project1.m file** (which will make use of the function velocity.m) and a **PDF**. Please use the project1.m file to code everything you will need for the V&V PDF. You will need to run two tests. The first test is using the test data in Table 1 above. The second test is using a set of data you make up with only 1 sample (n = 1).

<u>To include in your V&V PDF</u>

For the test data in Table 1, you should document the test data (as the customer will not have access to this PDF), the expected output to your velocity.m function (by hand calculations which shows the expected results), and the results of your velocity.m function (a screenshot of the output from MATLAB). You should also plot (in the project1.m file) the time versus x-position, time versus y-position, time versus x-velocity, and time versus y-velocity; please comment on how these plots show validity to your results.

For the 1 x 3 data you make up, you should document the data, discuss how your code handles data such as this, and then demonstrate the results from MATLAB (a screenshot of the output from MATLAB).

Deliverables

Be sure to submit all 6 files!

1. forward.m
2. backward.m
3. center.m
4. velocity.m
5. project1.m
6. V&V PDF

Rubric (Total 100 Points)

Functions 1., 2., and 3. – **10 Points Each**
Function 4. – **20 Points**
V&V Documentation – **50 Points**

> Professional Format – **15 Points**
> Adequately demonstrates the code works for the data in Table 1 – **20 Points**
> Adequately demonstrates the code works for the edge case of n = 1 – **15 Points**

Notes for Report

For any equations, please use the equation editor.
For Figures and Tables, please follow the guidelines outlined in the example report on Blackboard.
Include a title page.

Notes for Functions

These notes do not apply to the **project1.m** file.
All functions must be named EXACTLY as listed above. This includes capitalization.
Functional inputs and outputs must be EXACTLY as defined in the Functions section.

Test Data

If you run the following code below in the MATLAB command window, you should get the following output. Do note, this does NOT guarantee your code is correct.

```
forward(2, 7, 1)
backward(0.5, 1, 4)
center(10, 2, 3.25)
```

```
ans = -3
ans = 6
ans = 0.0625
```