MTRX5700

Experimental Robotics

Assignment 3

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1 Data Fusion

Our aim was to read the measured observation data from all four sources and fuse them appropriately in order to ascertain a real representation of the robot's path. This section of the report details the methods we employed to conduct this data fusion step. The Velocity observations would provide internal data of the robot's velocities (linear and turn rate) so that its position can be segmentally ascertained using the dead reckon approximation method. However in order to account for issues such as slip (on the wheels or motors) and observational error we need to incorporate compass and GPS readings and use corrective alterations to our position prediction. Using the retro-reflective beacon readings and positions would have added an extra level of position determination by allowing us to use a local triangulation & trilateration method using the angle & distance of the beacons with respect to the robot.

1.a Program Flow & Observation Scheduling

The program requires a structure that would allow us to access different courses of action based on the input received at any given time because the order of observations being made is critical to the flow of the program. We can consider this to be four different lists of inputs that need to be scheduled which can be done with a set of flag variables which was stored in an array where if a particular type of observational event was perceived to occur a corresponding array element would be driven high. On testing this element we can allow sections of the code to be run or block them from running so that only the necessary processes occur at any given time. We detect the "next" action by storing all data in a matrix which is ordered by time and an array storing the index (with respect to that matrix) of the next event and these values increment as we access each observation. Using these indices we put the timestamps of each next event into an array, detect the smallest timestamps and test each event time (for coincidental events) for procedures that need to occur.

Iters stores the index of the next even in each observational data set that we are yet to "perceive"

$$iters = \begin{bmatrix} itersVel & itersGPS & itersComp & itersmeasurementn \end{bmatrix}$$

time stores the timestamps for the next index in each observational data set. This is so that we can use the $min()$ function in matlab as opposed to writing the min finding code ourselves (a more elegant solution for adapting to a system with more sensors).

$$time = \begin{bmatrix} timestamp(s) & measurement1 & measurement2 & ... & measurementn \end{bmatrix}$$

Figure 1: Data I/O Process

1.a.i Data I/O

Having to store each set of data separately while still having easily accessible data (for ease of writing the code and minimization of code runtime) we needed to filter the data into a series of structural arrays with the following template:

$$ObservationDataStructure = \begin{bmatrix} timestampVel(s) & timestampGPS & timestampComp & timestamp... & measurementn \end{bmatrix}$$

Process Descriptions:

1) Parse Input: Takes in the columns of data with space delimiting input saving the first column to "Seconds", second column to "Microseconds", and each subsequent observation column into a Measurements vector. In Figure 2 we see the structural flow for an 2-parameter data set such as Velocity Observations where Velocity would be Measurements 1 and Turn Rate would be Measurements 2.

2) Merge Time Stamps: An implementation of the following equation: $ts1 + ts2^{10-6} - FirstTimeStamp$ This effectively "zeroes" the events so that the very first event occurs at $t = 0$

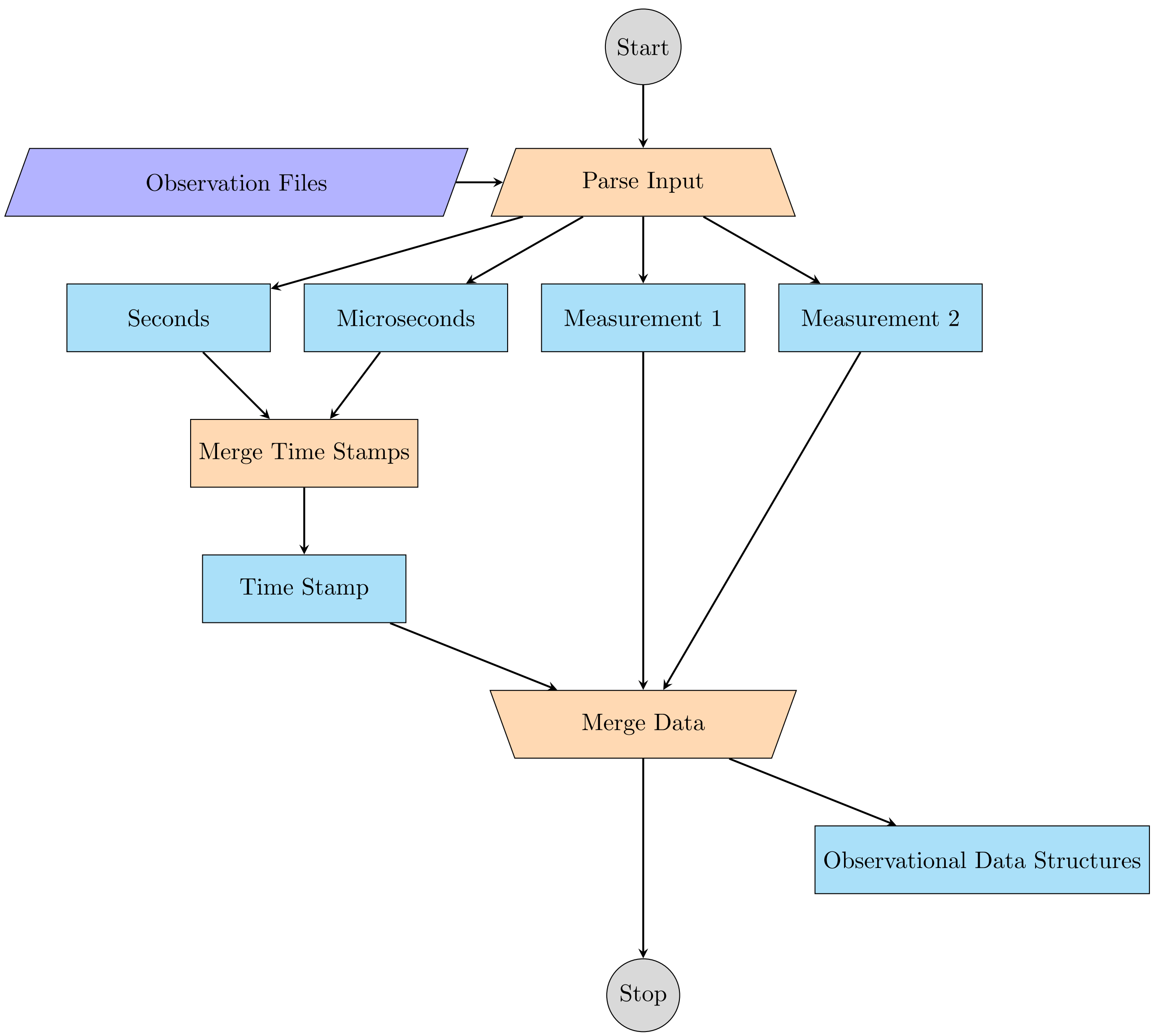

Figure 2: Data I/O Process

1.b Prediction Stage Implementation

1.c Observation Stage Implementation

1.d Update Stage Implementation

1.e Code Listing

1.e.i Demonstration Code

```
clear
% close all
clc

DEGREES = 180/pi;
RADIANS = pi/180;
SUN = 1.496*10^8;
% % Prediction Stage
% diary './q1output'
%Load observational data
velocityObs = load('velocityObs.txt');
positionObs = load('positionObs.txt');
compassObs = load('compassObs.txt');
laserObs = load('laserObs.txt');

%Get velocity data
time1 = velocityObs(:,1) + (velocityObs(:,2)*10^-6) - 1115116000;%get in microseconds
velocity = velocityObs(:,3);
turnRate = velocityObs(:,4);

velObs = [time1 velocity turnRate];

%Get GPS position data
time2 = positionObs(:,1) + (positionObs(:,2)*10^-6) - 1115116000;
xPos = positionObs(:,3);
yPos = positionObs(:,4);

posObs = [time2 xPos yPos];

%Get GPS compass data
time3 = compassObs(:,1) + (compassObs(:,2)*10^-6) - 1115116000;
heading = compassObs(:,3);

compObs = [time3 heading];

% % %get laser data
time4 = laserObs(:,1) + (laserObs(:,2)*10^-6) - 1115116000;
% % i = 1;
% % j = 4;
% % sizeLas = size(laserObs);
% % lasObs = zeros(sizeLas(1, 2));
% % while(i <= sizeLas(1))
% %     lasObs(i, 1) = [time4(i)];
% %     while(j<=sizeLas(2))
% %         lasObs(i, j) = laserObs(i, j);
% %         lasObs(i, j-1) = laserObs(i, j-1);
% %
% %         j = j + 2;
% %     end
% %
% %     i = i + 1;
% % end
% % size(time4)



%%postInput parsing

alphaP = 0.1;
alphaTH = 0.1;

lastTime = 0;
deltaT = 0;

latestVel = 0;
```

```matlab
latestTurnRate = 0;

ourX = 0;
ourY = 0;
ourHeading = 0;

indLengths = [length(time1), length(time2), length(time3), length(time4)];
maxIters = max(indLengths);

% output = [lastTime, ourX, ourY, ourHeading];
output = zeros(maxIters, 6);

% deadreckonedpts = zeros(maxIters, 3);

%iters [velInd, posInd, compInd, lasInd];
iters = [2, 2, 2, 2];
runFlags = [0, 0, 0, 0];
loopFlag = 1;
loopCount = 2;
%%loop starts
while(loopFlag == 1)
    loopCount = loopCount + 1
    time = [time1(iters(1)), time2(iters(2)), time3(iters(3)), time4(iters(4)),];
    nextT = min(time);


    for i = 1:4
        if time(i) == nextT
            runFlags(i) = 1;
        else
            runFlags(i) = 0;
        end
    end

    %if velocityobs
    if(runFlags(1) == 1)
        deltaT = time1(iters(1)) - lastTime;
        latestVel = velObs(iters(1),2);%
        latestTurnRate = velObs(iters(1),3);%
        pr = predictionStage(ourX, ourY, ourHeading, deltaT, latestTurnRate, latestVel);
        ourX = pr(1);
        ourY = pr(2);
        ourHeading = pr(3);

%         deadreckonedpts(1) = ourX;
%         deadreckonedpts(2) = ourY;
%         deadreckonedpts(3) = ourHeading;
        lastTime = time1(iters(1));%
        runFlags(1) = 0;
        if iters(1) == length(time1)
            time1(iters(1)) = SUN;
        else
            iters(1) = iters(1) + 1;
        end
    end

% % if GPS
     if(runFlags(2) == 1)
        deltaT = time2(iters(2)) - lastTime;
        pr = predictionStage(ourX, ourY, ourHeading, deltaT, latestTurnRate, latestVel);
        gUpd = updateStageGPS(pr(1), pr(2), posObs(iters(2),2), posObs(iters(2),3), alphaP); %xvobs and yvobs need to come from the file
        ourX = gUpd(1);
        ourY = gUpd(2);
        ourHeading = pr(3);
        lastTime = time2(iters(2));%
        runFlags(2) = 0;
        if iters(2) == length(time2)
            time2(iters(2)) = SUN;
        else
            iters(2) = iters(2) + 1;
```

```
        end
     end
%
% % if compass
     if(runFlags(3) == 1)
        deltaT = time3(iters(3)) - lastTime;
        pr = predictionStage(ourX, ourY, ourHeading, deltaT, latestTurnRate, latestVel);
        cUpd = updateStageCompass(pr(3), compObs(iters(3),2), alphaTH);
        ourX = pr(1);
        ourY = pr(2);
        ourHeading = cUpd;
        lastTime = time3(iters(3));
        runFlags(3) = 0;
        if iters(3) == length(time3)
            time3(iters(3)) = SUN;
        else
            iters(3) = iters(3) + 1;
        end
    end
%
% % if laser data
    if(runFlags(4) == 1)
% %       fill this in
        runFlags(4) = 0;
        time4(iters(4)) = SUN;   %remove this line
    end

%check loop
    if(time1(iters(1)) == SUN)
        if(time2(iters(2)) == SUN)
            if(time3(iters(3)) == SUN)
                if(time4(iters(4)) == SUN)
                     loopFlag = 0;
                end
            end
        end
    end

%plot stuff
hold on
title('Robot Path');
xlabel('x-axis');
ylabel('y-axis');
% legend('Dead Reckoning');
% drawnow

plot(ourX, ourY, 'r.');
output(loopCount, 1) = lastTime;
output(loopCount, 2) = ourX;
output(loopCount, 3) = ourY;
output(loopCount, 4) = ourHeading;
output(loopCount, 5) = latestVel;
output(loopCount, 6) = latestTurnRate;
end

% diary ON
% output
% diary OFF

output(:,1) = output(:,1); %+ 1115116000;
```

1.e.ii Development Code

This code listing includes a partially complete implementation of fusing the data from the Laser Range Finder detection of retro reflective beacons.

```
clear
close all
clc

DEGREES = 180/pi;
RADIANS = pi/180;
SUN = 1.496*10^8;

%Load observational data
velocityObs = load('velocityObs.txt');
positionObs = load('positionObs.txt');
compassObs = load('compassObs.txt');
laserObs = load('laserObs.txt');
laserFeat = load('laserFeatures.txt');

%get laser features
lasFeat = [laserFeat(:,1) laserFeat(:,2)];

%Get velocity data
time1 = velocityObs(:,1) + (velocityObs(:,2)*10^-6) - 1115116000;%get in microseconds
velocity = velocityObs(:,3);
turnRate = velocityObs(:,4);

velObs = [time1 velocity turnRate];

%Get GPS position data
time2 = positionObs(:,1) + (positionObs(:,2)*10^-6) - 1115116000;
xPos = positionObs(:,3);
yPos = positionObs(:,4);

posObs = [time2 xPos yPos];

%Get GPS compass data
time3 = compassObs(:,1) + (compassObs(:,2)*10^-6) - 1115116000;
heading = compassObs(:,3);

compObs = [time3 heading];

% % %get laser data
time4 = laserObs(:,1) + (laserObs(:,2)*10^-6) - 1115116000;

f1=1;

range = zeros(length(laserObs), (size(laserObs,2)-2)/2);
intensity = zeros(length(laserObs), (size(laserObs,2)-2)/2);

%Extracting range & intensity data from LaserObs
for i=1:length(laserObs)
   for f2=3:2:size(laserObs,2)
    range(i,f1)=laserObs(i,f2);
    intensity(i,f1)=laserObs(i,f2+1);
    f1=f1+1;
   end
   f1=1;
end


% postInput parsing

alphaP = 0.1;
alphaTH = 0.1;

lastTime = 0;
deltaT = 0;

```

```
latestVel = 0;
latestTurnRate = 0;

ourX = 0;
ourY = 0;
ourHeading = 0;

indLengths = [length(time1), length(time2), length(time3), length(time4)];
maxIters = max(indLengths);

% output = [lastTime, ourX, ourY, ourHeading];
output = zeros(maxIters, 6);

% deadreckonedpts = zeros(maxIters, 3);

%iters [velInd, posInd, compInd, lasInd];
iters = [2, 2, 2, 2];
runFlags = [0, 0, 0, 0];
loopFlag = 1;
loopCount = 2;
%%loop starts
while(loopFlag == 1)
    loopCount = loopCount + 1
    time = [time1(iters(1)), time2(iters(2)), time3(iters(3)), time4(iters(4)),];
    nextT = min(time);


    for i = 1:4
        if time(i) == nextT
            runFlags(i) = 1;
        else
            runFlags(i) = 0;
        end
    end

    %if velocityobs
    if(runFlags(1) == 1)
        deltaT = time1(iters(1)) - lastTime;
        latestVel = velObs(iters(1),2);%
        latestTurnRate = velObs(iters(1),3);%
        pr = predictionStage(ourX, ourY, ourHeading, deltaT, latestTurnRate, latestVel);
        ourX = pr(1);
        ourY = pr(2);
        ourHeading = pr(3);

%         deadreckonedpts(1) = ourX;
%         deadreckonedpts(2) = ourY;
%         deadreckonedpts(3) = ourHeading;
        lastTime = time1(iters(1));%
        runFlags(1) = 0;
        if iters(1) == length(time1)
            time1(iters(1)) = SUN;
        else
            iters(1) = iters(1) + 1;
        end
    end

% % if GPS
     if(runFlags(2) == 1)
        deltaT = time2(iters(2)) - lastTime;
        pr = predictionStage(ourX, ourY, ourHeading, deltaT, latestTurnRate, latestVel);
        gUpd = updateStageGPS(pr(1), pr(2), posObs(iters(2),2), posObs(iters(2),3), alphaP); %xvobs and yvobs need to come from the file
        ourX = gUpd(1);
        ourY = gUpd(2);
        ourHeading = pr(3);
        lastTime = time2(iters(2));%
        runFlags(2) = 0;
        if iters(2) == length(time2)
            time2(iters(2)) = SUN;
        else
```

```
            iters(2) = iters(2) + 1;
        end
     end
%
% % if compass
     if(runFlags(3) == 1)
        deltaT = time3(iters(3)) - lastTime;
        pr = predictionStage(ourX, ourY, ourHeading, deltaT, latestTurnRate, latestVel);
        cUpd = updateStageCompass(pr(3), compObs(iters(3),2), alphaTH);
        ourX = pr(1);
        ourY = pr(2);
        ourHeading = cUpd;
        lastTime = time3(iters(3));
        runFlags(3) = 0;
        if iters(3) == length(time3)
            time3(iters(3)) = SUN;
        else
            iters(3) = iters(3) + 1;
        end
    end
%
% % if laser data
    if(runFlags(4) == 1)
%         find beacons
        deltaT = time4(iters(4)) - lastTime;
        pr = predictionStage(ourX, ourY, ourHeading, deltaT, latestTurnRate, latestVel);
        ourX = pr(1);
        ourY = pr(2);
        ourHeading = pr(3);

        intensityTrav = 1;
        beaconCentreInds = 0;
        %find beacon centres
        while(intensityTrav <= 361)
            if(intensity(intensityTrav) == 1)
                iStart = intensityTrav;
                intensityTrav = intensityTrav + 1;
                while(intensity(intensityTrav) == 1 && (abs(range(intensityTrav) - range(
                    ↪ intensityTrav + 1) < 1)))
                    intensityTrav = intensityTrav + 1;
                end
                iEnd = intensityTrav - 1;
                iMid = (iEnd - iStart)/2;
                beaconCentreInds = cat(2, beaconCentreInds, iMid);
            else
                intensityTrav = intensityTrav + 1;
            end
        end
%       project to real world
        mb = matchBeacons(ourX, ourY, ourHeading, lasFeat, range(iters(4),:), beaconCentreInds);
        ourX = mb(1);
        ourY = mb(2);
        ourHeading = mb(3);

        lastTime = time4(iters(4));
        runFlags(4) = 0;
        if iters(4) == length(time4)
            time3(iters(4)) = SUN;
        else
            iters(4) = iters(4) + 1;
        end
    end

%check loop
    if(time1(iters(1)) == SUN)
        if(time2(iters(2)) == SUN)
            if(time3(iters(3)) == SUN)
                if(time4(iters(4)) == SUN)
                     loopFlag = 0;
                end
            end
```

```
        end
    end

%plot stuff
hold on
title('Robot Path');
xlabel('x-axis');
ylabel('y-axis');
% legend('')
% drawnow

plot(ourX, ourY, 'r.');
output(loopCount, 1) = lastTime;
output(loopCount, 2) = ourX;
output(loopCount, 3) = ourY;
output(loopCount, 4) = ourHeading;
output(loopCount, 5) = latestVel;
output(loopCount, 6) = latestTurnRate;
end
```

2 Question 2

2.a Obtaining Obstacle Location from Laser Data

First we start by taking the data output from question one, which consisted of the robot $x - y$ coordinates in the world coordinate system, as well as the velocity and turn rate for that particular timestamp, for each timestamp that occurs in the Velocity observation data, the Compass data and the GPS data.
Similar to the way question one works, we combine this data with the Laser observation data by comparing timestamps, using the Prediction Stage equation to estimate the robots $x - y$ coordinates at the time that the laser data was generated. Combining the robots $x - y$ world coordinates with the relative position of the obstacles obtained from the Laser data.

```
clear
clc
close all

DEGREES = 180/pi;
RADIANS = pi/180;


positionData = load('q1output1.txt');

laserObs = load('laserObs.txt');

%Get output data
time1 = positionData(:,1);
Xpos = positionData(:,2);
Ypos = positionData(:,3);
heading = positionData(:,4);
velocity = positionData(:,5);
turnRate = positionData(:,6);

diary './q2Output4'

%Get laser data
time2 = laserObs(:,1) + (laserObs(:,2)*10^-6) - 1115116000;%get in microseconds


%Extracting range & intensity data from LaserObs

f1=1;
range = zeros(length(laserObs), (size(laserObs,2)-2)/2);
% intensity = zeros(length(laserObs), (size(laserObs,2)-2)/2);

%Extracting range & intensity data from LaserObs
for i=1:length(laserObs)
   for f2=3:2:size(laserObs,2)
%        if(laserObs(i,f2) < 8)
            range(i,f1)=laserObs(i,f2);
        %     intensity(i,f1)=laserObs(i,f2+1);
            f1=f1+1;
%        end
   end
   f1=1;
end

lasersX = 0;
lasersY = 0;

% alphaP = 0.5;
% alphaTH = 0.5;

lastTime = 0;
deltaT = 0;

latestVel = 0;
latestTurnRate = 0;
```

```

ourX = 0;
ourY = 0;
ourHeading = 0;

indLengths = [length(time1), length(time2)];
maxIters = max(indLengths);

interval = 20;

%iters [velInd, posInd, compInd, lasInd];
iters = [2, 2];
runFlags = [0, 0];
loopFlag = 1;
loopCount = 2;
%%loop starts



while(loopFlag == 1)
    loopCount = loopCount + 1;
    time = [time1(iters(1)), time2(iters(2))];
    nextT = min(time);


    for i = 1:2
        if time(i) == nextT
            runFlags(i) = 1;
        else
            runFlags(i) = 0;
        end
    end

    %if Positiondata
    if(runFlags(1) == 1)
        deltaT = time1(iters(1)) - lastTime;
        latestVel = velocity(iters(1));
        latestTurnRate = turnRate(iters(1));
        ourX = Xpos(iters(1));
        ourY = Ypos(iters(1));
        ourHeading = heading(iters(1));

        lastTime = time1(iters(1));%
        runFlags(1) = 0;
        if iters(1) >= length(time1)-interval
            time1(iters(1)) = 1.496*10^8;
        else
            iters(1) = iters(1) + interval;
        end
    end

% % if laser
     if(runFlags(2) == 1)
        deltaT = time2(iters(2)) - lastTime;
        pr = predictionStage(ourX, ourY, ourHeading, deltaT, latestTurnRate, latestVel);
        ourX = pr(1);
        ourY = pr(2);
        ourHeading = pr(3);
        lastTime = time2(iters(2));%
        runFlags(2) = 0;


        % Get X,Y coordinates for laser ob data

        for i = 1:size(range,2)
            if (range(iters(2),i) < 8.0 && range(iters(2),i) > 0.0001)
                lasersX = ourX + range(iters(2),i)*cos(((i-1)*0.5)*RADIANS+ourHeading);
                lasersY = ourY + range(iters(2),i)*sin(((i-1)*0.5)*RADIANS+ourHeading);
                diary ON
                fprintf('%d\t%d\n', lasersX, lasersY);
                diary OFF
```

```
            end
        end

        %increment
        if iters(2) >= length(time2)-interval
            time2(iters(2)) = 1.496*10^8;
        else
            iters(2) = iters(2) + interval;
        end


     end

%check loop
    if(time1(iters(1)) == 1.496*10^8)
        if(time2(iters(2)) == 1.496*10^8)
                     loopFlag = 0;
        end
    end

%plot stuff
% hold on
% title('Obstacles');
% xlabel('x-axis');
% ylabel('y-axis');
% legend('')
% drawnow
end
```

For initial tests to attempt to identify obstacles, any range reading from the Laser data that was less than eight (the maximum range of the sensor) was considered an obstacle. It was intended to apply filters to this data once the Occupancy Grid had been generated. Until then, raw data would be used.

2.b Generate Occupancy Grid

To generate the Occupance Grid, we took the Data set of the X-Y coordinates of all 'Obstacles' detected, and determined the difference between the minimum and maximum x and y values deteced. Given a user defined size for the occupancy grid, we could then determine the $x - y$ range that corresponded to a grid location. Then for every Obstacle $x - y$ coordinate we could determine the grid location it corresponded to, incrementing the grid value to increase the weighting, which would indicate the likelihood of an obstacle being in that region. Some experimenting with the grid size using the data for the Robot path generated in question one indicated that a grid size of $200x200$ would be best, as this resulted in a grid map that, while not extremely sharp, was also not extremely blurred. Ideally, the grid would be vague enough to generalise a position for the obstacles, but not so clear that it simply resulted in a plot of every possible obstacle coordinates. See the figures below:

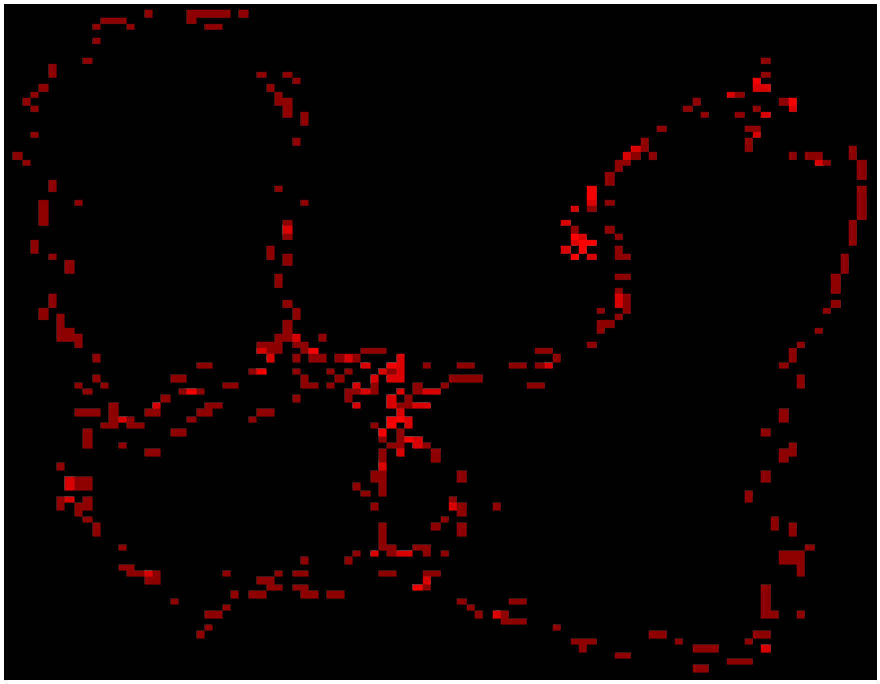

Figure 3: Grid size = 100×100

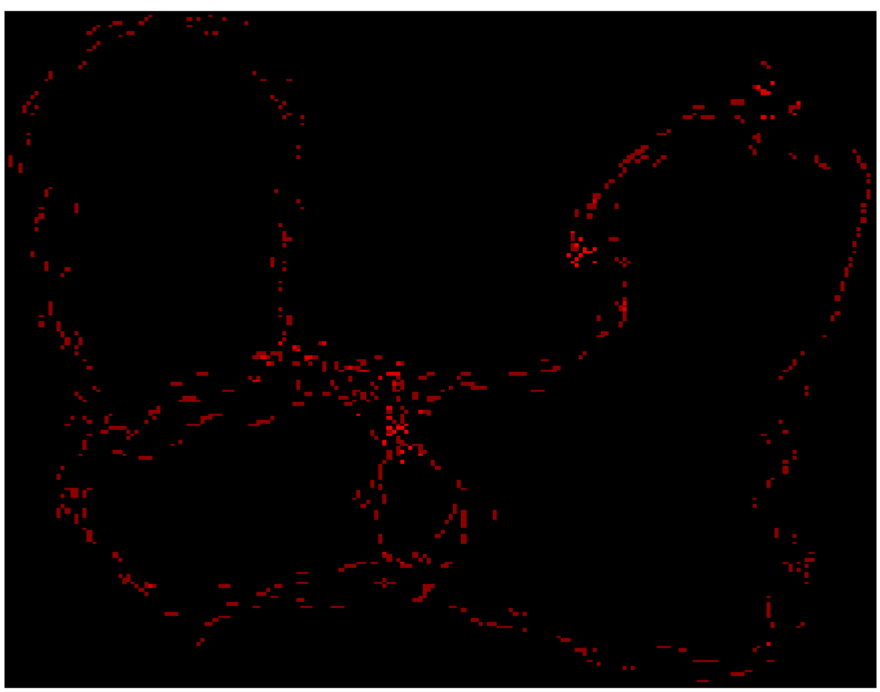

Figure 4: Grid size = 200×200

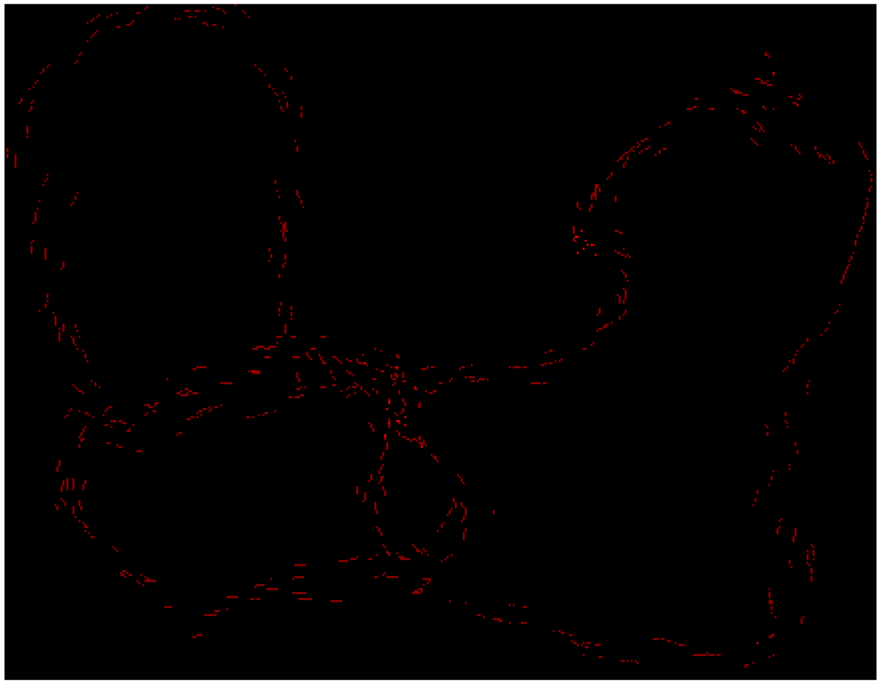

Figure 5: Grid size = 500×500

2.c Results

3 Question 3

Code Listing

See Appendix A [3] for all code used.

4 Appendix A

4.1 Question 1

4.2 Question 2

4.2.i obtainObstacles

4.2.ii obtainObstacles$_v$2

```
clear
clc
close all

DEGREES = 180/pi;
RADIANS = pi/180;


positionData = load('q1output1.txt');

laserObs = load('laserObs.txt');

%Get output data
time1 = positionData(:,1);
Xpos = positionData(:,2);
Ypos = positionData(:,3);
heading = positionData(:,4);
velocity = positionData(:,5);
turnRate = positionData(:,6);

% diary './q2_2Output1'

%Get laser data
time2 = laserObs(:,1) + (laserObs(:,2)*10^-6) - 1115116000;%get in microseconds

lasersX = 0;
lasersY = 0;

% alphaP = 0.5;
% alphaTH = 0.5;

lastTime = 0;
deltaT = 0;

latestVel = 0;
latestTurnRate = 0;

ourX = 0;
ourY = 0;
ourHeading = 0;

indLengths = [length(time1), length(time2)];
maxIters = max(indLengths);

interval = 20;

%iters [velInd, posInd, compInd, lasInd];
iters = [2, 2];
runFlags = [0, 0];
loopFlag = 1;
loopCount = 2;
%%loop starts

xPos = zeros(1);
yPos = zeros(1);

while(loopFlag == 1)
    loopCount = loopCount + 1;
    time = [time1(iters(1)), time2(iters(2))];
    nextT = min(time);


    for i = 1:2
        if time(i) == nextT
```

```
            runFlags(i) = 1;
        else
            runFlags(i) = 0;
        end
    end

    %if Positiondata
    if(runFlags(1) == 1)
        deltaT = time1(iters(1)) - lastTime;
        latestVel = velocity(iters(1));
        latestTurnRate = turnRate(iters(1));
        ourX = Xpos(iters(1));
        ourY = Ypos(iters(1));
        ourHeading = heading(iters(1));

        lastTime = time1(iters(1));%
        runFlags(1) = 0;
        if iters(1) >= length(time1)-interval
            time1(iters(1)) = 1.496*10^8;
        else
            iters(1) = iters(1) + interval;
        end
    end

% % if laser
     if(runFlags(2) == 1)
        deltaT = time2(iters(2)) - lastTime;
        pr = predictionStage(ourX, ourY, ourHeading, deltaT, latestTurnRate, latestVel);
        ourX = pr(1);
        ourY = pr(2);
        ourHeading = pr(3);
        lastTime = time2(iters(2));%
        runFlags(2) = 0;


         xpoint = zeros(1);
         ypoint = zeros(1);
         for j = 4:2:size(laserObs,2)
             range = laserObs(iters(2),j-1);
             bearing = ((j)/2 - 90)*pi/180;
             if (range < 8.0)
                 xpoint = [xpoint  ourX+range*cos(bearing + ourHeading)];
                 ypoint = [ypoint  ourY+range*sin(bearing + ourHeading)];
             end

         end

         xPos = [xPos xpoint];
         yPos = [yPos ypoint];

        plot(xpoint(:), ypoint(:), '.');

        %increment
        if iters(2) >= length(time2)-interval
            time2(iters(2)) = 1.496*10^8;
        else
            iters(2) = iters(2) + interval;
        end


     end

%check loop
    if(time1(iters(1)) == 1.496*10^8)
        if(time2(iters(2)) == 1.496*10^8)
                     loopFlag = 0;
        end
    end

%plot stuff
% hold on
```

```
% title('Obstacles');
% xlabel('x-axis');
% ylabel('y-axis');
% legend('')
drawnow
% pause
end

xpoint(1) = [];
ypoint(1) = [];

xPos(1) = [];
yPos(1) = [];

xMin = min(xPos);
xMax = max(xPos);

yMin = min(yPos);
yMax = max(yPos);


gridSize = 100;

grid = zeros(gridSize);


yDiff = (yMax - yMin)/(gridSize - 2);
xDiff = (xMax - xMin)/(gridSize - 2);

for i = 1:length(xPos)
    tmpX = xPos(i);
    tmpY = yPos(i);
    j = 1;
    while (tmpX > xMin)
        tmpX = tmpX - xDiff;
        j = j + 1;
    end
    k = 1;
    while (tmpY > yMin)
        tmpY = tmpY - yDiff;
        k = k + 1;
    end

    grid(j,k) = grid(j,k) + 1;
end

HeatMap(grid);
```

4.2.iii generateOccupancyGrid

```
clear
close all
clc

% positionData = load('q1output1.txt');
positionData = load('q2Output4.txt');


% xPos = positionData(:,2);
% yPos = positionData(:,3);

xPos = positionData(:,1);
yPos = positionData(:,2);

xMin = min(xPos);
xMax = max(xPos);

yMin = min(yPos);
```

```
yMax = max(yPos);


gridSize = 100;

grid = zeros(gridSize);


yDiff = (yMax - yMin)/(gridSize - 2);
xDiff = (xMax - xMin)/(gridSize - 2);

for i = 1:length(xPos)
    tmpX = xPos(i);
    tmpY = yPos(i);
    j = 1;
    while (tmpX > xMin)
        tmpX = tmpX - xDiff;
        j = j + 1;
    end
    k = 1;
    while (tmpY > yMin)
        tmpY = tmpY - yDiff;
        k = k + 1;
    end

    grid(j,k) = grid(j,k) + 1;
end

% imagesc(grid);
HeatMap(grid);
```

4.3 Question 3

Code Listing

See Appendix A [9.1]