# Grid Localization

November 12, 2017

#### 0.0.1 Libraries

```
In [254]: import numpy as np
          import matplotlib.pyplot as plt
          from pylab import rcParams
          from scipy import ndimage

          import shapely.geometry as geom
          import pandas as pd
          import geopandas as gpd

          import math
          import time
          import pickle
          from collections import namedtuple


          %matplotlib inline
          plt.rcParams["figure.figsize"] = (20,7)
```

## 0.1 Load from disk

```
In [255]: poses = pickle.load(open("poses.df", 'rb'))
          arena_d = pickle.load(open("arena_d.df", 'rb'))
          arena_g = pickle.load(open("arena_g.gdf", 'rb'))

          # Convert Pandas DataFrame to NumPy array
          poses_np = np.array(poses.values)
```

## 0.2 Variables

```
In [256]: Measurement = namedtuple('Measurement', ['sonar', 'IR_L', 'IR_R'])
          Motion = namedtuple('Motion', ['distance', 'angle'])
          Pose = namedtuple("Pose", ['x', 'y', 'theta'])
```

## 0.3 Copy parameters!!!

```
In [257]: # THOSE HAVE TO MATCH EXACTLY PARAM IN MAP
```

```
RESOLUTION_POS = round(0.1,1)
RESOLUTION_ROT = round(30,1)

W = 4.25
H = 3.2
OFFSET = 0.01
```

## 0.4 Parameters

In [258]:
```
SENSORS_VARIANCE = {
    'sonar': 0.1,
    'IR_L' : 0.4,
    'IR_R' : 0.4
}

# Further than SENSORS_CUTOFF_STD standard deviations from the mean,
# we say the sensor readings are improbable for a given pose
SENSORS_CUTOFF_STD = 0.7

CONFIDENCE_SENSORS = 0.6
CONFIDENCE_ODOMETRY = 0.6
```

## 0.5 Playground

### 0.5.1 Arena

In [259]:
```
# mock_position = geom.Point(0.01, 0.81)
# # theta = geom.Point(0, 6)
# # mock_circle = geom.Point(0,0).buffer(6, resolution=30)

# # scan = geom.LineString((mock_position, theta))
# # arena_d.loc[len(arena_d)] = ["scan", scan]

# arena_d.loc[len(arena_d)] = ['test', mock_position]
# arena_g = gpd.GeoDataFrame(arena_d)
# arena_g.plot()


# # cleat the dataframe
# arena_d.drop(arena_d.index[arena_d['type'] == 'test'], inplace=True)
# print(arena_g)
```

### 0.5.2 Probability

In [260]:
```
# sigma = 0.05
# mean = 0.5

# sigma = 1/sigma
```

```
# x = np.linspace(0,1,500) # 100 linearly spaced numbers
# y = sigma*2.5*(1/(sigma*math.sqrt(2*math.pi))*np.exp( -(1/2*sigma**2)*((x - mean))

# a = 0.55
# b = sigma*2.5*(1/(sigma*math.sqrt(2*math.pi))*np.exp( -(1/2*sigma**2)*((a - mean))

# plt.plot(x,y)
# plt.plot(a,b,'co')
```

## 0.6 Grid Localization

```
In [271]: def _match(sensor, reading, lookup_value):
              """
              Determines if a reading from the sensors matches a value
              in the lookup table with some probability.
              This is useful to find the exact values of 'x' and 'y' as recorded in the lookup

              """
              SENSORS_CUTOFF_STD = 0.6
              if reading == None:
                  if math.isnan(lookup_value):
                      return True
                  else:
                      return False
              elif sensor == "sonar":
                  SIGMA = SENSORS_VARIANCE['sonar']
              elif sensor == "IR_L":
                  SIGMA = SENSORS_VARIANCE['IR_L']
              elif sensor == "IR_R":
                  SIGMA = SENSORS_VARIANCE['IR_R']

              sigma = 1/SIGMA
              mean = lookup_value
              x = reading
              y = sigma*2.5*(1/(sigma*math.sqrt(2*math.pi))*np.exp( -(1/2*sigma**2)*((x - mean
              if y > SENSORS_CUTOFF_STD:
                  return True
              return False


          def _closest(number, divider):
              """
              Returns the closest number to 'number'
              divisible without remainder by 'divider'.
              """

              mod = number % divider        # 28
```

```
    low = number - mod            # 90
    high = number - mod + divider # 120
    if high - number < number - low:
        return high
    else:
        return low

def locate_row_in_table(x, y, theta):
    largest_y = poses_np[0][2]

    y_block = (360/RESOLUTION_ROT)*(np.ceil(W/RESOLUTION_POS))*(largest_y-y)/RESOLUTI
    x_block = (360/RESOLUTION_ROT)*(x-OFFSET)/RESOLUTION_POS
    theta_block = theta/RESOLUTION_ROT
    return int(round(y_block + x_block + theta_block))


def localize(poses_np, motion, measurement):
    """
    poses_np    :: a lookup table of possible poses and sensor readings. Columns: op
    measurement :: a tuple of readings from (sonar, IR_L, IR_R).

    """

    def move_belief():
        """
        Finds posterior probability, given
            distance traveled in a straight line ('x' and 'y' chnge), OR
            rotation on the spot.
        Posterior poses_np = [prior] X [probability after motion model]

        """
        prob_sum = 0

        for i in range(len(poses_np)): # iterate rows
            if poses_np[i][0] == 1: # open space, i.e. not coordinates of an obstacl
                theta = poses_np[i][3]

                # determine most likely pose where we were before the movement
                delta_x = math.sin((theta + motion.angle) % 360) * motion.distance
                delta_y = math.cos((theta + motion.angle) % 360) * motion.distance

                prev_x = _closest(poses_np[i][1] - delta_x, RESOLUTION_POS) + OFFSET
                prev_y = _closest(poses_np[i][2] - delta_y, RESOLUTION_POS) + OFFSET
                prev_theta = _closest((theta - motion.angle) % 360, RESOLUTION_ROT)

                # unless previous positions is outside the boundaries of the arena
                if prev_x > 0 and prev_y > 0:
                    row_idx = locate_row_in_table(prev_x, prev_y, prev_theta)
```

```
                # look up the probability of the previous pose
                prev_prob = poses_np[row_idx][7]

                # update the probability of the current pose accordingly
                poses_np[i][7] = CONFIDENCE_ODOMETRY * poses_np[i][7] + (1-CONFIDENC

                # update running tally
                prob_sum += poses_np[i][7]

        # normalize--> total probability theory
        for i in range(len(poses_np)):
            poses_np[i][7] = poses_np[i][7] / prob_sum

    def sense_belief():
        """
        Finds posterior = [prior] X [probability after measurement]

        """

        prob_sum = 0

        for i in range(len(poses_np)): # iterate rows
            if poses_np[i][0] == 1: # of open space, i.e. not coordinates of an obst
                match_all = False
                if _match('sonar', measurement.sonar, poses_np[i][4]):
                    if _match('IR_L', measurement.IR_L, poses_np[i][5]):
                        if _match('IR_R', measurement.IR_R, poses_np[i][6]):
                            match_all = True

                poses_np[i][7] = (poses_np[i][7] * (match_all * CONFIDENCE_SENSORS +
                prob_sum += poses_np[i][7]

        # normalize--> total probability theory
        for i in range(len(poses_np)):
            poses_np[i][7] = poses_np[i][7] / prob_sum

    sense_belief()
    move_belief()
    return poses_np
```

### 0.7 Heatmap

```
In [272]: def heatmap(poses_np):
              """
              The heatmap relies on the following sorting of the array:
              'y' descending (primary sort)
              'x' ascending (secondary sort)
```

```
    'theta' ascending (tertiary sort)

    """

    plt.rcParams["figure.figsize"] = (10,5)
    heatmap = []
    y = poses_np[0][2]
    row = []

    # iterate through lookup table
    for i in range(len(poses_np)):
        # True while we're moving horizontally to the right  x increases, y stays co
        if y == poses_np[i][2]:
            if poses_np[i][3] == 0:  # if theta == 0
                row.append(poses_np[i][7]) # append probability
            else:
            # theta is some rotation, we're at same square still
                row[-1] += poses_np[i][7] # saturate probability here
        # y changes  we're one row lower
        else:
            heatmap.append(row)
            row = []
            y = poses_np[i][2]
            row.append(poses_np[i][7])

    # Make plot with vertical (default) colorbar
    fig, ax = plt.subplots()

    cax = ax.imshow(heatmap, interpolation='nearest', cmap=plt.cm.coolwarm)
    ax.set_title('Probabalistic location')

    # Add colorbar, make sure to specify tick locations to match desired ticklabels
    cbar = fig.colorbar(cax, ticks=[-1, 0, 1])
    cbar.ax.set_yticklabels(['< -1', '0', '> 1'])  # vertically oriented colorbar

    plt.show()
```

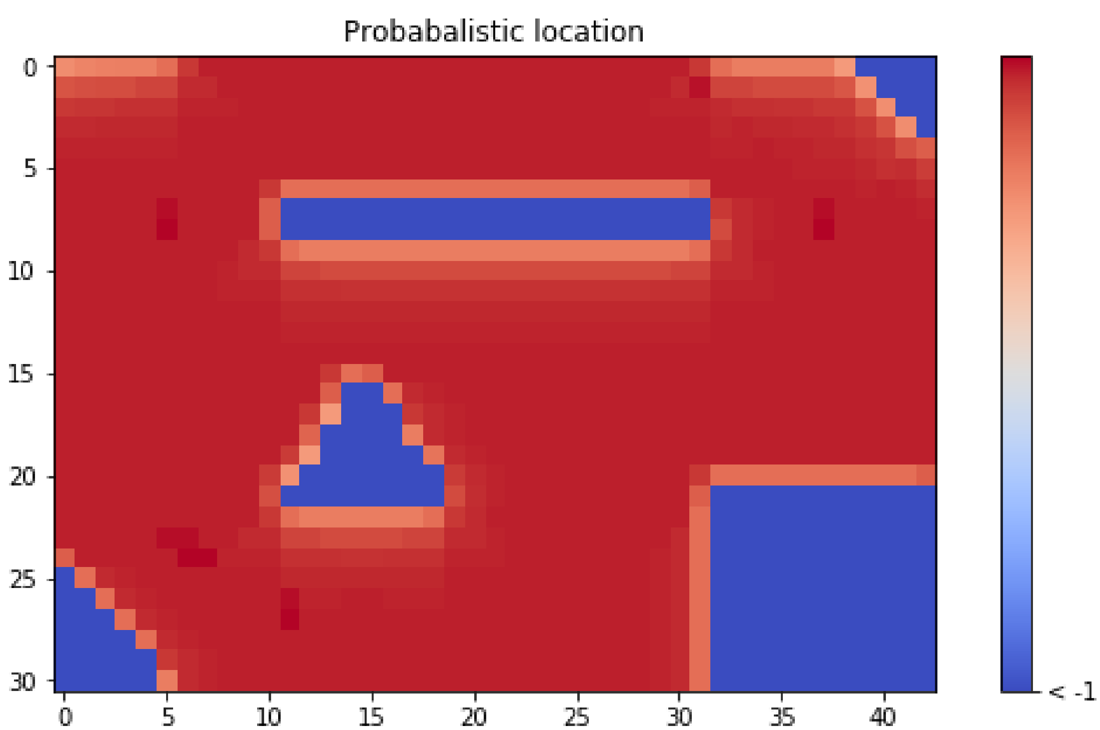
# 1 Run

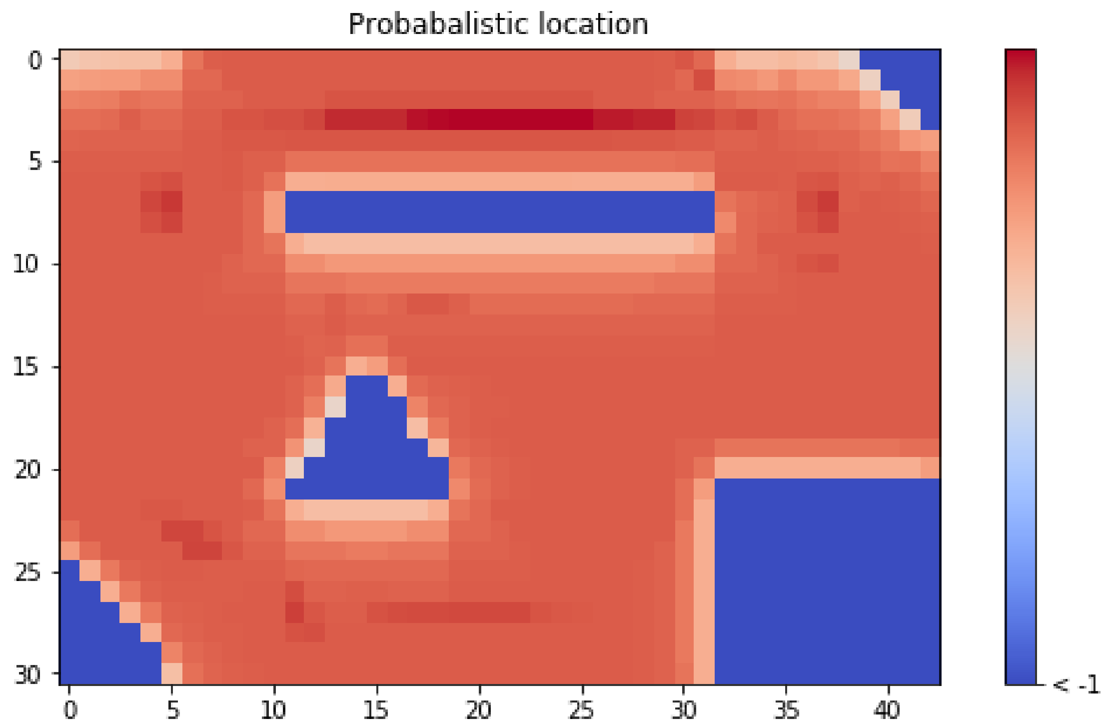
```
In [273]: def refresh(poses_np):
    """
    Takes all rows where 0-indexed column 1 one,
    and change 7-indexed column to the prior probability.

    """
    prob = 1.0 / len(poses_np[:,0])
    poses_np[poses_np[:, 0] == 1, 7] = prob
```

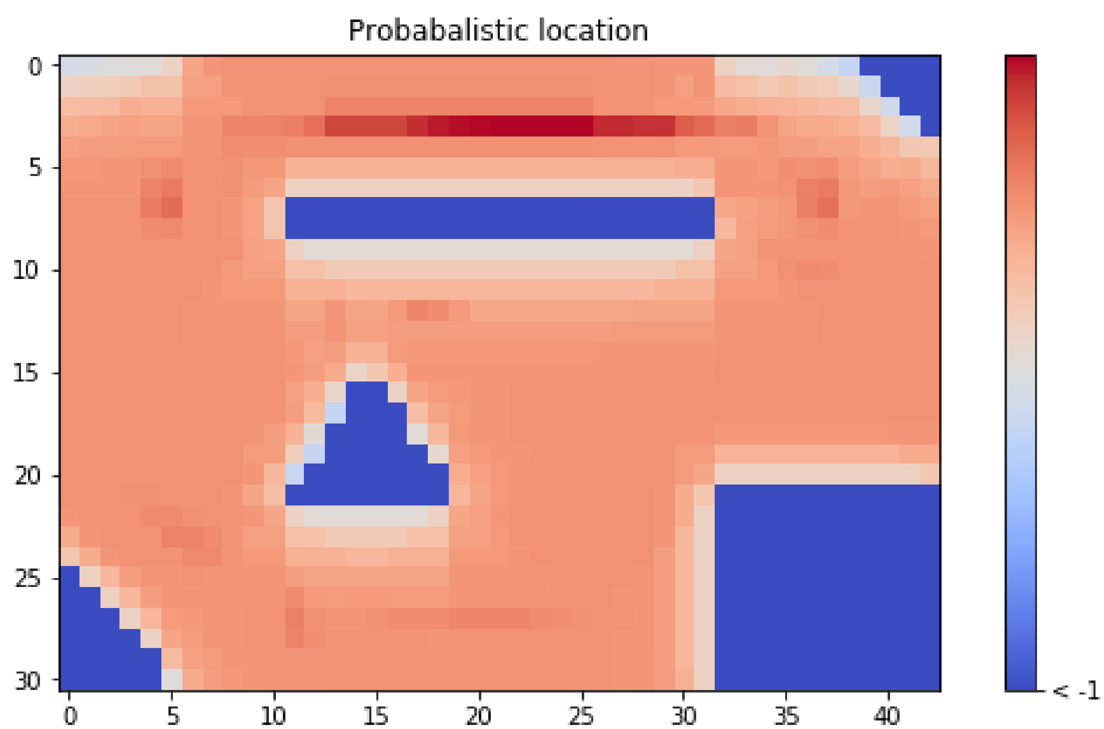
```
        return poses_np

    def run(poses_np, motions, measurements):
        for i in range(len(measurements)):
            poses_np = localize(poses_np, motions[i], measurements[i])
            heatmap(poses_np)
        return poses_np
```

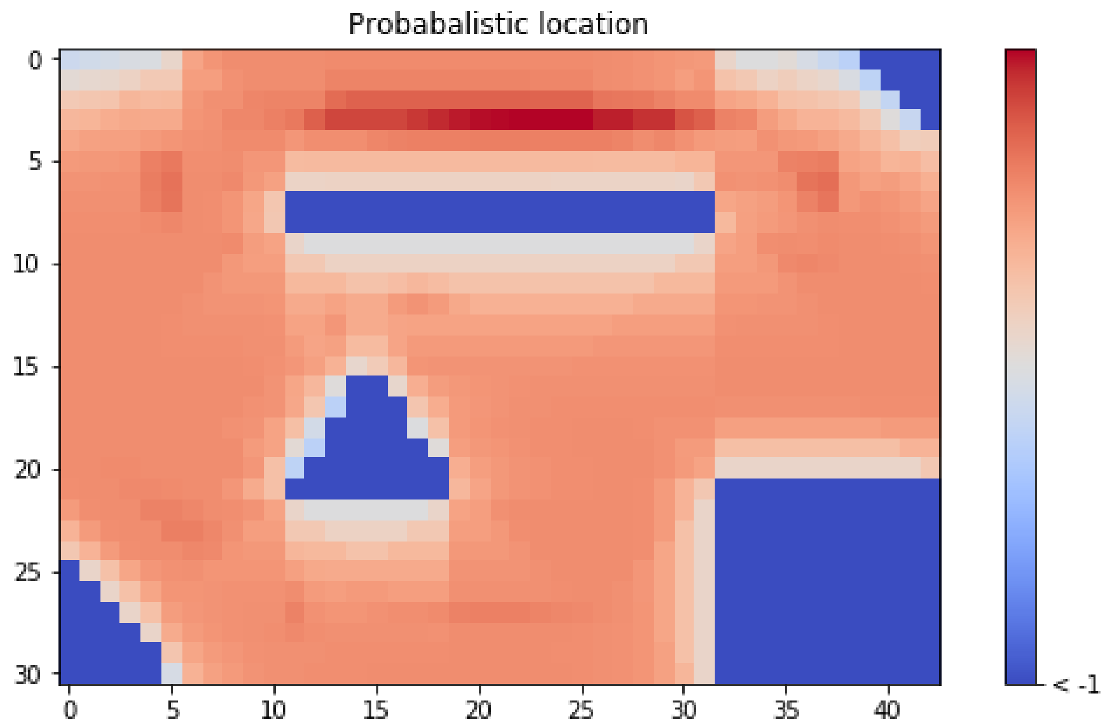
In [276]:
```
measurements = [Measurement(0.9, 0.2, 0.2),
                Measurement(0.8, 0.2, 0.3),
                Measurement(0.7, 0.2, 0.3),
                Measurement(0.6, 0.2, 0.3),
                Measurement(0.5, 0.2, 0.3),
               ]

motions      = [Motion(0.1, 0),
                Motion(0.1, 0),
                Motion(0.1, 0),
                Motion(0.1, 0),
                Motion(0.1, 0),
               ]
```

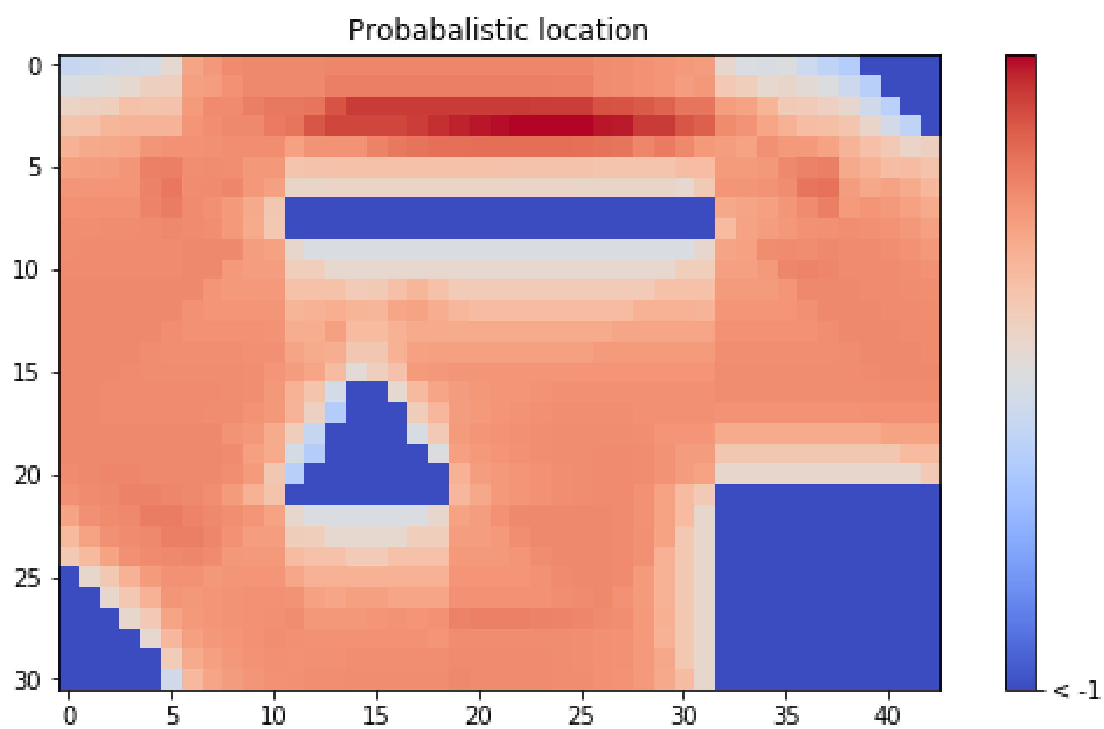
In [277]:
```
# refresh
poses_np = refresh(poses_np)
# GO!
poses_np = run(poses_np, motions, measurements)
```




Probabalistic location
0
5
10
15
20
25
30
0
5
10
15
20
25
30
35
40
< -1


Probabalistic location
0
5
10
15
20
25
30
0
5
10
15
20
25
30
35
40
< -1


Probabalistic location
0
5
10
15
20
25
30
0
5
10
15
20
25
30
35
40
< -1


Probabalistic location
0
5
10
15
20
25
30
0
5
10
15
20
25
30
35
40
< -1

In [211]:
```
# MUST-DOS
# find sensible sigma
# IR adjust for different variance furhter out
# implement IR
# cut off high readings beyond sensor's reach
# maybe change to Log sum? Underflow problem
# plot on heatmat most likely pose + draw lines which show likely orientations

# SIMULATE

# EXTRAS
# plot orientation on the map somehow
# draw most likely location
# posterior() returning a probability? instead of True / False?
```

In [193]:
```
W/RESOLUTION_POS
```

Out[193]: 21.25

In [197]:
```
x = 4.21
y = 2.81
theta = 0
largest_y = poses_np[0][2]
int(round((360/RESOLUTION_ROT)*(np.ceil(W/RESOLUTION_POS))*(largest_y-y)/RESOLUTION_I
```

Out[197]: 516

In [192]:
```
i = 516
print(poses_np[i][1])
print(poses_np[i][2])
print(poses_np[i][3])
```

```
4.21
2.81
0.0
```