In [30]:

```python
import pandas as pd
import operator
import matplotlib.pyplot as plt

def plot_color(dict1):
#     print(dict1)
    max_val=max(dict1.items(), key=operator.itemgetter(1))
#     print(max_val)
    color=[]
    for key in dict1:
        if dict1[key] < max_val[1]:
            color.append('b')
        else:
            color.append('r')
    return color

def merge_dict(dict1,dict2):
    return(dict2.update(dict1))

def bayes_filter(bel_x, z,step):
    #bel_x=x
    if step==0:
        print("Initial Position: ")
        for key in bel_x:
            print(f"bel(x{step} = {key}) = ", round(bel_x[key],3))
#     else:
#         for key in bel_x:
#             print(f"bel(x{step} = {key}) = ", round(bel_x[key],3))
    nplt=4
    plt.figure(figsize=(10,10))
    plt.subplot(nplt,1,1)
    w=0.4
    h=10
    plt.title(f"bel(x{step})")
    plt.bar(*zip(*bel_x.items()),color=plot_color(bel_x),width=w)
    first_grid=.7
    same_grid=.2
    second_grid=0.1
    yellow_grid=0.0
    state_trans_prob={f"x{step+1} = p0":[same_grid,0,0,0],f"x{step+1} =
p1":[first_grid,same_grid,0,0],
                      f"x{step+1} = p2":[second_grid,first_grid,same_grid,0],f"x{step+1}
= p3":[0,second_grid,first_grid,same_grid]}
    print(f"\nAt step t={step}, after the control u{step+1}, the robot returns a
measurement of z{step+1} ={z}.\n")
```

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    print("State Transition Probability: ")
    for key in state_trans_prob:
        print(f"({key}|u{step+1},x{step}=p0, x{step}=p1,x{step}=p2, x{step}=p3)=
",state_trans_prob[key])

    door=['p1','p3']
    wall=['p0','p2']
    door_sense={"wall_p0":.3,"door_p1":.8,"wall_p2":.3,"door_p3":.8}
    wall_sense={"wall_p0":.7,"door_p1":.2,"wall_p2":.7,"door_p3":.2}
    #print(bel_x)
    bel_vals=bel_x.values()
    bel_bar={}
    print(f"\nCalculations of bel_bar for all potential locations (p0~p3): ")
    for key in state_trans_prob:
        bel_bar[key[-2:]]=sum([bel*prob for bel,prob in
zip(bel_vals,state_trans_prob[key])])
        print(f"bel_bar(x{step+1}={key[-2:]})= ",round(bel_bar[key[-2:]],3))
   #bel_bar={"p0":bel_bar_x_p0,"p1":bel_bar_x_p1,"p2":bel_bar_x_p2,"p3":bel_bar_x_p3}
    plt.subplot(nplt,1,2)
    plt.title(f"bel_bar(x{step+1})")
    plt.bar(*zip(*bel_bar.items()),color=plot_color(door_sense),width=w)

    sum_bel=[]
    print(f"\nProbability of the robot sensing the {z} at step = {step+1}:")
    if z == "door":
        #print("If Measurement: ", z)
        plt.subplot(nplt,1,3)
        plt.title(f"p(z{step+1}={z}|x{step+1})")
        plt.bar(*zip(*door_sense.items()),color=plot_color(door_sense),width=w)
        for key in door_sense:
            print(f"p(z{step+1} = {z}|x{step+1}={key[-2:]})=", door_sense[key])
        for key in bel_bar:

            if key in door:
                #print("if door: ",key)
                sum_bel.append(bel_bar[key]*.80)
                bel_bar[key]*=.80



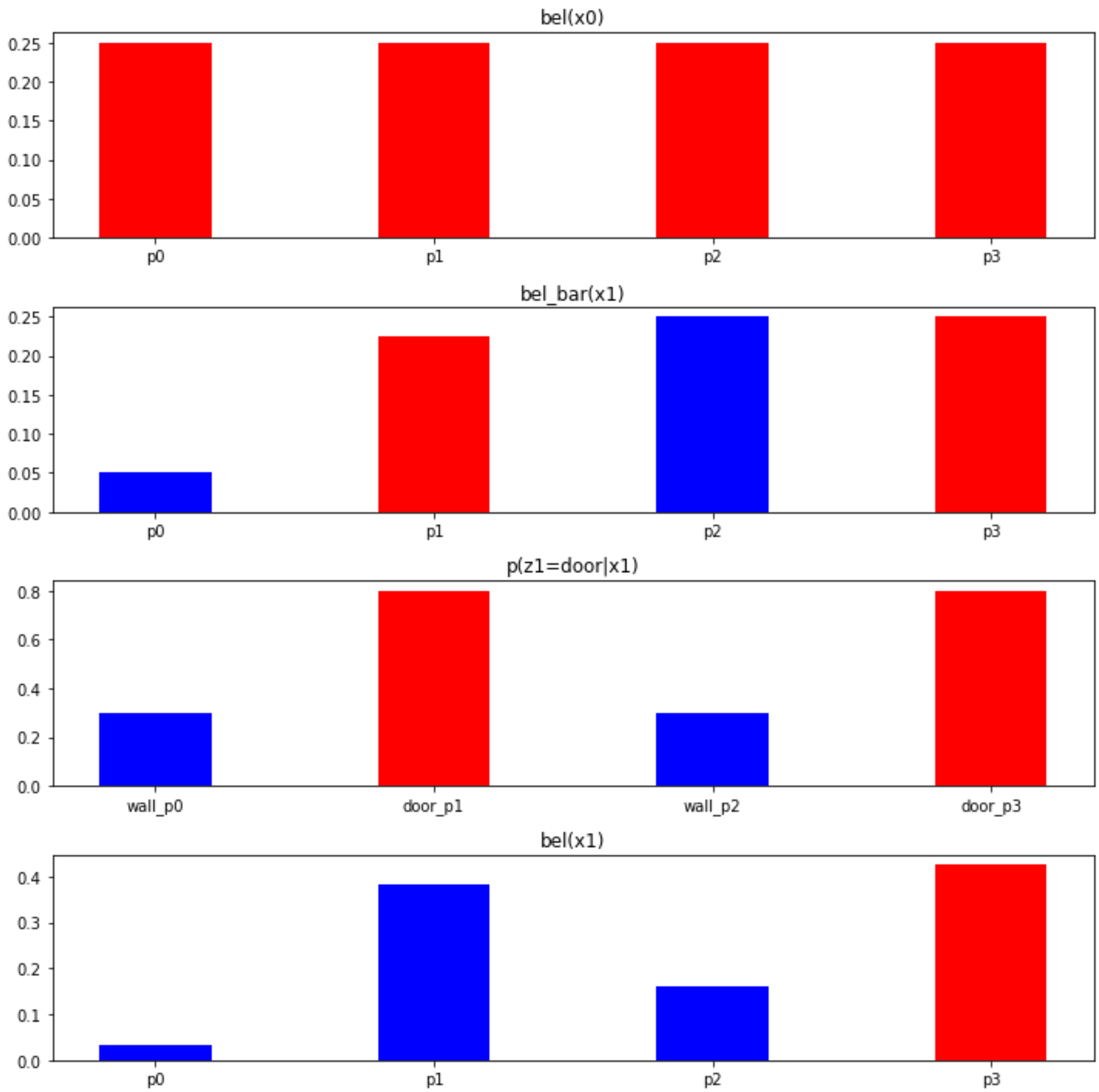
            else:
                #print("else door: ",key)
                sum_bel.append(bel_bar[key]*.30)
                bel_bar[key]*=.30
```

```python
    else:
        plt.subplot(nplt,1,3)
        plt.title(f"p(z{step+1}={z}|x{step+1})")
        plt.bar(*zip(*wall_sense.items()),color=plot_color(wall_sense),width=w)
        #print("Else Measurement: ", z)
        for key in wall_sense:
            print(f"p(z{step+1} = {z}|x{step+1}={key[-2:]})=", wall_sense[key])
        for key in bel_bar:

            if key in wall:
                #print("if wall: ",key)
                sum_bel.append(bel_bar[key]*.70)
                bel_bar[key]*=.70



            else:
                #print("else wall: ",key)
                sum_bel.append(bel_bar[key]*.20)
                bel_bar[key]*=.20

    print(f"\nNormalization and η calculation: ")
    for i in range(len(sum_bel)):
        print(f"bel(x{step+1} = p{i}) = p(z{step+1} = 
{z}|x{step+1}=p{i})*bel_bar(x{step+1} = p{i})*η = {round(sum_bel[i],3)}*η")

    η=1/sum(sum_bel)
    print(f"η = 1/{round(sum(sum_bel),3)} = ", round(η,3))
    η_dict={"η":η}
    step_dict={"step":step+1}
#     print("η: ", η)


    new_bel={key:bel_bar[key]*η for key in bel_x}
    #print(new_bel)
    print(f"\nNew updated belief of the robot's localization probability after step 
{step+1}: ")
    for key in new_bel:
        print(f'bel(x{step+1} = {key}) = ', round(new_bel[key],3))

    plt.subplot(nplt,1,4)
```

```
df=pd.DataFrame.from_dict([bel_x,step_dict,state_trans_prob,bel_bar,η_dict,new_bel,door_se

        return new_bel,df#,state_trans_prob,bel_bar,η_dict,step_dict,new_bel,door_sense
    else:



df=pd.DataFrame.from_dict([bel_x,step_dict,state_trans_prob,bel_bar,η_dict,new_bel,wall_se

        return new_bel,df

sense=["door","wall"]
bel_x=[{"p0":0.25,"p1":0.25,"p2":0.25,"p3":0.25}]
#state_trans_prob,bel_bar,η_dict,step_dict,new_bel,sense=0

dfs=[]
for step in range(2):
    bel,new_df=bayes_filter(bel_x[step],sense[step],step)
    bel_x.append(bel)
    dfs.append(new_df)
#df=pd.DataFrame(dict_list)
#df
```

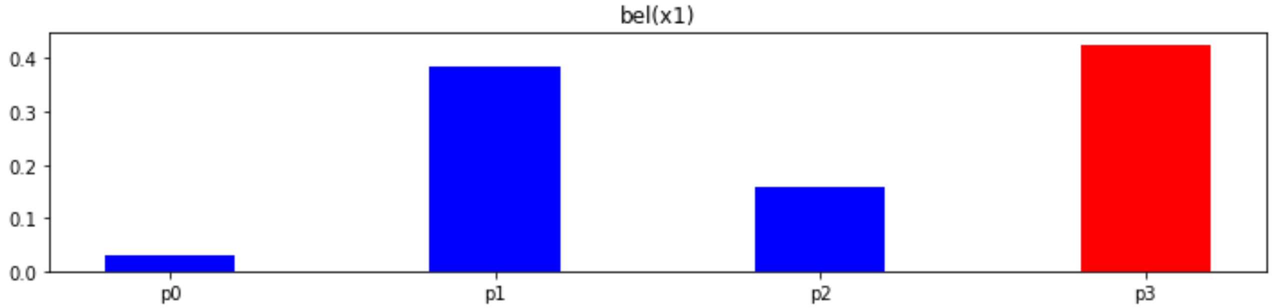
```
bel_bar(x1=p0)=  0.05
bel_bar(x1=p1)=  0.225
bel_bar(x1=p2)=  0.25
bel_bar(x1=p3)=  0.25

Probability of the robot sensing the door at step = 1:
p(z1 = door|x1=p0)= 0.3
p(z1 = door|x1=p1)= 0.8
p(z1 = door|x1=p2)= 0.3
p(z1 = door|x1=p3)= 0.8

Normalization and η calculation:
bel(x1 = p0) = p(z1 = door|x1=p0)*bel_bar(x1 = p0)*η = 0.015*η
bel(x1 = p1) = p(z1 = door|x1=p1)*bel_bar(x1 = p1)*η = 0.18*η
bel(x1 = p2) = p(z1 = door|x1=p2)*bel_bar(x1 = p2)*η = 0.075*η
bel(x1 = p3) = p(z1 = door|x1=p3)*bel_bar(x1 = p3)*η = 0.2*η
η = 1/0.47 =  2.128
```

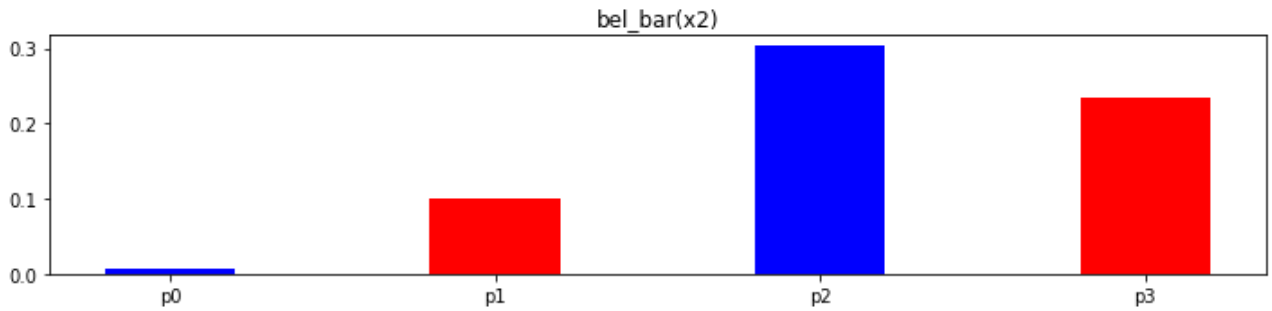
```
New updated belief of the robot's localization probability after step 1:
bel(x1 = p0) =  0.032
bel(x1 = p1) =  0.383
bel(x1 = p2) =  0.16
bel(x1 = p3) =  0.426
```

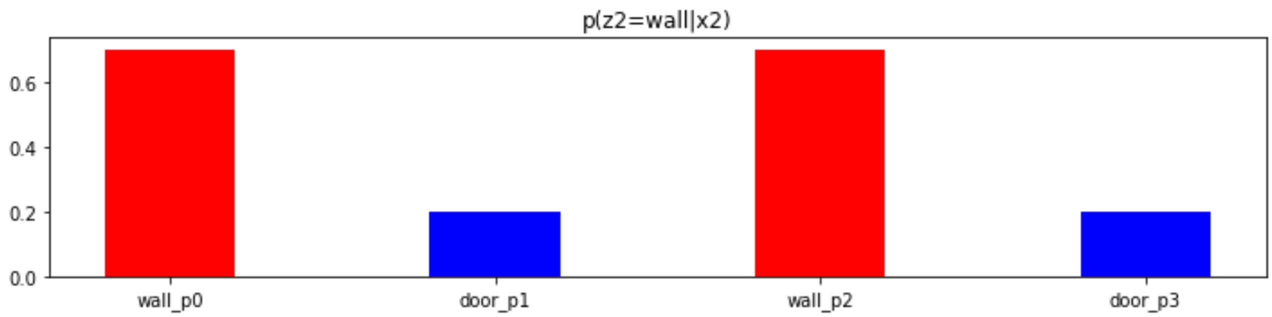


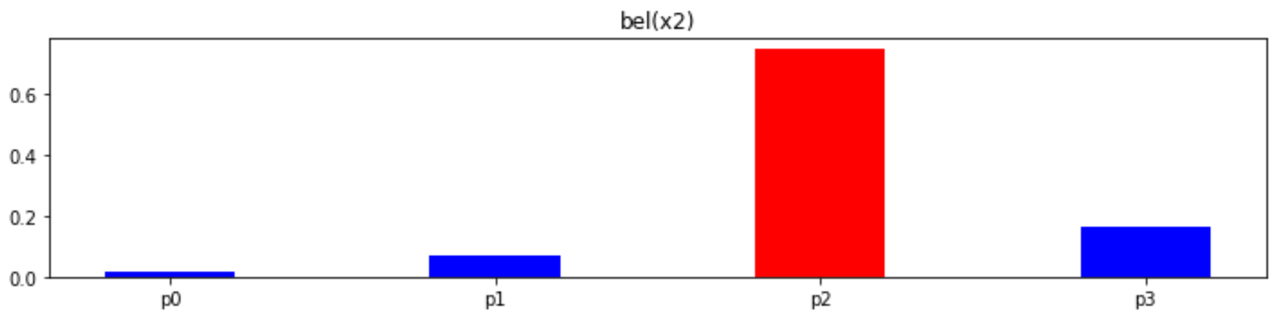

```
At step t=2, after the control u2, the robot returns a measurement of z2 =wall.

State Transition Probability:
(x2 = p0|u2,x1=p0, x1=p1,x1=p2, x1=p3)=  [0.2, 0, 0, 0]
(x2 = p1|u2,x1=p0, x1=p1,x1=p2, x1=p3)=  [0.7, 0.2, 0, 0]
(x2 = p2|u2,x1=p0, x1=p1,x1=p2, x1=p3)=  [0.1, 0.7, 0.2, 0]
(x2 = p3|u2,x1=p0, x1=p1,x1=p2, x1=p3)=  [0, 0.1, 0.7, 0.2]

Calculations of bel_bar for all potential locations (p0~p3):
bel_bar(x2=p0)=  0.006
bel_bar(x2=p1)=  0.099
bel_bar(x2=p2)=  0.303
bel_bar(x2=p3)=  0.235

Probability of the robot sensing the wall at step = 2:
p(z2 = wall|x2=p0)= 0.7
p(z2 = wall|x2=p1)= 0.2
p(z2 = wall|x2=p2)= 0.7
p(z2 = wall|x2=p3)= 0.2
```

```
Normalization and η calculation:
bel(x2 = p0) = p(z2 = wall|x2=p0)*bel_bar(x2 = p0)*η = 0.004*η
bel(x2 = p1) = p(z2 = wall|x2=p1)*bel_bar(x2 = p1)*η = 0.02*η
bel(x2 = p2) = p(z2 = wall|x2=p2)*bel_bar(x2 = p2)*η = 0.212*η
bel(x2 = p3) = p(z2 = wall|x2=p3)*bel_bar(x2 = p3)*η = 0.047*η
η = 1/0.284 =  3.527

New updated belief of the robot's localization probability after step 2:
bel(x2 = p0) =  0.016
bel(x2 = p1) =  0.07
bel(x2 = p2) =  0.749
bel(x2 = p3) =  0.166
```









In [ ]: