FinalVersion

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1 Take Your Shot

1.1 Final Submission

1.1.1 Jacob Brown, Avery Smith, and Kyle Salisbury

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Video Presentation Link: https://www.youtube.com/watch?v=HDrmcKn1qhI

1.1.2 Primary Questions:

What are the natural groupings/clusters of shots on a basketball court?

Which combinations of player and shooting location have the highest expected value (shooting pct * points)?

Are the differences in shooting percentage statistically significant?

How does shooting pct vary at Home vs. Away?

Given only the location and shooters for a game not in our dataset, can we predict the final score of the Jazz, the amount of points each player scored, and whether or not they won?

1.2 Accomplished:

- Web scraped all data from sources and created "final" csv
- Obtained key data points using Regex
- Cleaned data and created various dataframes
- Unsupervised clustering (k-means) to divide court into 6 clusters (futher divided by 2 pointer and 3 pointer)
- Calculated expected value for each player in each court position and reported them on shot charts
- Calculated significance for shooting percentages by player and location

- Explored expected value difference for Home VS Away games
- Predicted the score of Jazz game, along with individual player totals.

1.2.1 Methods Used:

- Web scraping
- Regex
- Dataframes (including masking)
- Unsupervised clustering (k-means)
- Loops and logic
- Hypothesis Testing
- Visualizations (Scatter plots, heat maps)
- Predictions via pseduo-model

1.3 Programming and Methods:

```
In [3]: # Import All Library Packages

        from bs4 import BeautifulSoup
        import requests
        import urllib.request
        import re
        import time
        import numpy as np
        import pandas as pd
        import matplotlib.pyplot as plt
        from matplotlib.colors import ListedColormap
        from sklearn.cluster import KMeans, AgglomerativeClustering
        from sklearn import metrics
        from sklearn.metrics import silhouette_samples, silhouette_score
        import math
        import scipy as sc
        from scipy.stats import norm

        # Develop some color maps
        seven_colors = ListedColormap(["#e41a1c","#984ea3","#a65628","#377eb8","#ff
        cmap_bold = ListedColormap(['#FF0000', '#00FF00'])

        # Load in the court picture
        img = plt.imread('JazzCortHalf.png')
```

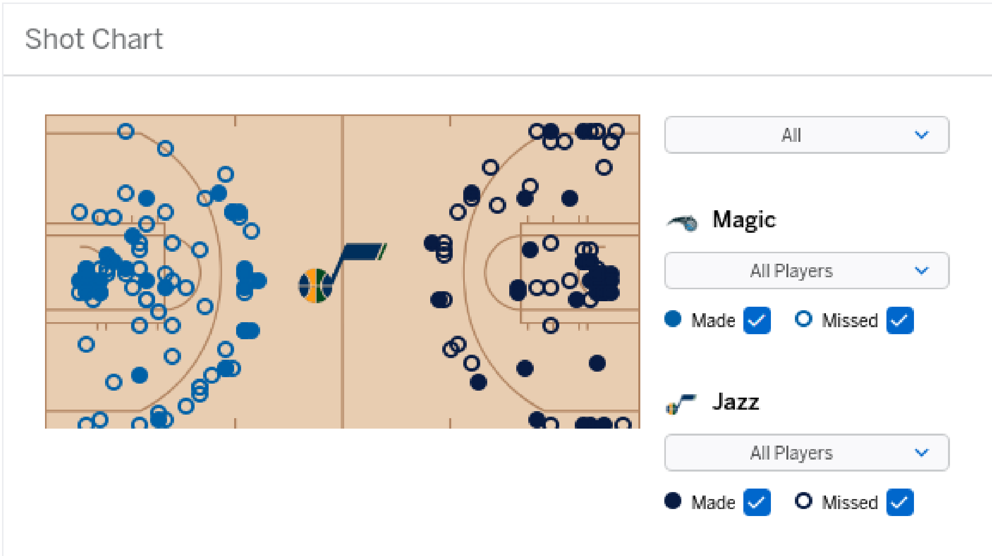
1.3.1 Data Aquisition Process

(This may take quite a while to run. It also saves local htmls so it is suggested, if running the code, to start later at Exploratory Analysis section) We scraped shot charts for the Utah Jazz from http://www.espn.com . We used the hyperlinks on the Jazz schedule page to find all the Jazz games for the entire season. We saved each page as a .html file so we could interact with them without having to scrape them over and over again.

```
In [ ]: # Function to get soups for a given URL
        def getWebsiteAsSoup(url):
            """
            Retrieve a website and return it as a BeautifulSoup object.
            """

            req = urllib.request.Request(url)
            with urllib.request.urlopen(req) as response:
                classlist_html = response.read()

            class_soup = BeautifulSoup(classlist_html, 'html.parser')
            with open('class_list.html', 'w') as new_file:
                new_file.write(str(class_soup))

            return class_soup
```

```
In [ ]: # url for the jazz schedule
        schedule_url = "http://www.espn.com/nba/team/schedule/_/name/utah/utah-jazz
        schedule_soup = getWebsiteAsSoup(schedule_url)
        base_url = "http://www.espn.com/nba/game?gameId="  # append url_endings to
        url_endings = []
        regex = '//www.espn.com/nba/recap/_/id/(\d+)"'
        for a_element in schedule_soup.find_all('a'):  # find all elements of type
            ending = re.findall(regex, str(a_element))
            if ending != []:  # many of these elements won't contain the regular ex
                url_endings.append(ending[0])

        print('Number of Jazz Games:')
        print(len(url_endings))  # shows how many games the Jazz have played so far
```

```
In [ ]: # Function to save html for a given URL
        def saveWebsiteToLocal(url, number):
            """
            Retrieve a website and save it locally as an html.
            """

            req = urllib.request.Request(url)
            with urllib.request.urlopen(req) as response:
                classlist_html = response.read()

            # print(classlist_html)
```



ESPN Shot Chart

```
        class_soup = BeautifulSoup(classlist_html, 'html.parser')
        with open('html/game_' + str(number) + '.html', 'w') as new_file:
            new_file.write(str(class_soup))

        return
```

```
In [ ]: # download all the games to a local copy
        i = 1
        for game in url_endings:
            saveWebsiteToLocal(base_url+url_endings[i-1], i)
            i+=1
            time.sleep(10)
```

1.3.2 Data Processing

The following image was screenshotted from the url http://www.espn.com/nba/game?gameId=400975701 . Each of the dots is an element of type 'li' which can be scraped.

We used beautiful soup to identify the html element for each shot, and used regular expressions to extract the interesting data from each shot. This is what the HTML looks like. We were mostly interested in data-text, data-homeaway, data-shooter, and left and top positions.

```
In [4]: # regular expressions to obtain key data
        utah_regex = 'utah.png'
        made_missed_regex = r'class="(\w+)"'
        period_regex = r'data-period="(\d)"'
        shooter_regex = r'data-shooter="(\d+)"'
        blocks_regex = r'blocks'
        blocks_shooter_name_regex = r"blocks (\w+ \w+)"
        shooter_name_regex = r'data-text="(\w+ \w+)'
```

```
▶<li id="shot34" class="made" data-text="Derrick Favors makes 7-foot two point
shot (Joe Ingles assists)" data-homeaway="home" data-period="2" data-shooter="4257"
style="border-color:#06143F;background-color:#06143F;left:86.88888888888889%;top:
42.0%;">…</li>
▶<li id="shot35" class="missed" data-text="Dante Exum misses driving layup" data-
homeaway="home" data-period="2" data-shooter="3102528" style="border-color:#06143F;
left:92.44444444444444%;top:54.0%;">…</li>
▶<li id="shot36" class="made" data-text="Jonas Jerebko makes 25-foot three point
jumper (Joe Ingles assists)" data-homeaway="home" data-period="2" data-shooter=
"3998" style="border-color:#06143F;background-color:#06143F;left:
84.66666666666667%;top:2.0%;">…</li>
▶<li id="shot37" class="made" data-text="Royce O'Neale makes two point shot (Joe
Ingles assists)" data-homeaway="home" data-period="2" data-shooter="2583632" style=
"border-color:#06143F;background-color:#06143F;left:91.33333333333333%;top:54.0%;">
…</li>
▶<li id="shot38" class="made" data-text="Royce O'Neale makes 27-foot three point
jumper (Dante Exum assists)" data-homeaway="home" data-period="2" data-shooter=
"2583632" style="border-color:#06143F;background-color:#06143F;left:
65.77777777777777%;top:30.0%;">…</li> == $0
▶<li id="shot39" class="made" data-text="Royce O'Neale makes two point shot" data-
homeaway="home" data-period="2" data-shooter="2583632" style="border-color:#06143F;
background-color:#06143F;left:91.33333333333333%;top:54.0%;">…</li>
▶<li id="shot40" class="missed" data-text="Ricky Rubio misses 25-foot three point
jumper" data-homeaway="home" data-period="2" data-shooter="4011" style="border-
color:#06143F;left:65.77777777777777%;top:44.0%;">…</li>
▶<li id="shot41" class="made" data-text="Derrick Favors makes layup" data-
homeaway="home" data-period="2" data-shooter="4257" style="border-color:#06143F;
background-color:#06143F;left:91.33333333333333%;top:46.0%;">…</li>
▶<li id="shot42" class="made" data-text="Ricky Rubio makes 26-foot three point
shot" data-homeaway="home" data-period="2" data-shooter="4011" style="border-color:
#06143F;background-color:#06143F;left:71.33333333333333%;top:18.0%;">…</li>
▶<li id="shot43" class="missed" data-text="Rudy Gobert misses 10-foot hook shot"
data-homeaway="home" data-period="2" data-shooter="3032976" style="border-color:
#06143F;left:82.44444444444444%;top:44.0%;">…</li>
```

HTML for Shot Chart

```
distance_regex = r' (\d+-foot)'
type_regex = r'foot ([\w ]+)[ "]'
alt_type_regex = r'e*s ([\w ]+)["\(]'
assist_regex = r'\((\w+ \w+) assists\)'
left_regex = r'left:(\d+.\d+)%'
top_regex = r'top:(\d+.\d+)%'
three_regex = r'three'
```

In [5]:
```
# Obtaining key words from scraping
start = time.clock()
array = []
tot_games = 80
for i in range(1, tot_games+1):
    GameWebsite = BeautifulSoup(open("html/game_" + str(i) + ".html"), "htm
    court_symbol = GameWebsite.select('.shot-chart > .team-logo')
    home_team = re.findall(utah_regex, str(court_symbol))
    if home_team:
        AllJazzShots = GameWebsite.find_all(class_="shots home-team")[0]
        homeaway = 1
    else:
        AllJazzShots = GameWebsite.find_all(class_="shots away-team")[0]
        homeaway = 0
    for j in range(0, 300):
        Shot = AllJazzShots.find(id="shot" + str(j))
        if Shot == None:
            continue
        game = i
        shot = j
        made_missed = re.findall(made_missed_regex, str(Shot))[0]
        if made_missed == "made":
            made_missed = 1
        else:
            made_missed = 0
        period = re.findall(period_regex, str(Shot))[0]
        shooter =  re.findall(shooter_regex, str(Shot))[0]
        block = re.findall(blocks_regex, str(Shot))
        shooter_name = re.findall(shooter_name_regex, str(Shot))
        if block:
            shooter_name = re.findall(blocks_shooter_name_regex, str(Shot))
        elif shooter_name == []:
            shooter_name = None
        else:
            shooter_name = shooter_name[0]
        distance = re.findall(distance_regex, str(Shot))
        if distance == []:
            distance = None
        else:
            distance = distance[0]
```

```
                shot_type = re.findall(type_regex, str(Shot))
                if shot_type == []:
                    shot_type = re.findall(alt_type_regex, str(Shot))
                    #if shot_type == []:
                    #    shot_type = "deviant"
                shot_type = shot_type[0]
                # clears out some problems associated with greedy regex
                start = shot_type.find("makes ") + len("makes ")
                if start >= len("makes "):
                    shot_type = shot_type[start:]
                start = shot_type.find("misses ") + len("misses ")
                if start >= len("misses "):
                    shot_type = shot_type[start:]
                assist = re.findall(assist_regex, str(Shot))
                if assist == []:
                    assist = None
                else:
                    assist = assist[0]
                left = float(re.findall(left_regex, str(Shot))[0])
                # one axis needs to be flipped depending on if it is home or away
                if (homeaway == 0):
                    left = 100-left
                    #print('away')
                top = float(re.findall(top_regex, str(Shot))[0])
                if homeaway:
                    top = 100-top
                three = re.findall(three_regex, shot_type)
                if three == []:
                    three = 0
                else:
                    three = 1
                game_array = [game, shot, homeaway, made_missed, period, shooter, s
                             assist, left, top, three]
                array.append(game_array)
        end = time.clock()
        print("This took " + str(end-start) + " seconds to run")
```

```
This took 41.315738 seconds to run
```

```
In [6]: columns = ["game", "shot", "home/away", "made/missed", "period", "shooter",
                   "distance", "shot_type", "assist", "left", "top", "ThreePt"]
        print('Total Number of Shots: ' + str(len(array)))   # total number of shots
        print('Average Shots Per Game: ' + str(len(array)/tot_games))   # avg shots
```

```
Total Number of Shots: 6630
Average Shots Per Game: 82.875
```

```
In [7]: panda_dataframe = pd.DataFrame(array, columns=columns)
        panda_dataframe.head()

Out[7]:    game  shot  home/away  made/missed period  shooter      shooter_name  \
        0     1     0          0            0      1     4011       Ricky Rubio
        1     1     1          0            1      1  2968436        Joe Ingles
        2     1     2          0            1      1  3908809  Donovan Mitchell
        3     1     3          0            1      1  3032976       Rudy Gobert
        4     1     4          0            0      1     4011       Ricky Rubio

          distance          shot_type            assist       left   top  ThreePt
        0  17-foot  pullup jump shot              None  76.666667  58.0        0
        1  24-foot  three point shot  Donovan Mitchell  90.000000   2.0        1
        2     None              dunk       Ricky Rubio  94.444444  50.0        0
        3     None              dunk    Derrick Favors  95.555556  50.0        0
        4     None    two point shot              None  95.555556  52.0        0

In [8]: panda_dataframe.to_csv("shots_dataframe_final.csv")
```

2 Exploratory Analysis

Data can be read from here without having to run the top half of the notebook - (which could take a while)

```
In [9]: # data can be read from here without having to run the top half of the note
        # (which could take a while)
        ShotsPD = pd.read_csv("shots_dataframe.csv")

In [10]: # Describe Data Set
         ShotsPD.describe()

Out[10]:         Unnamed: 0         game         shot    home/away  made/missed  \
         count  6793.000000  6793.000000  6793.000000  6793.000000  6793.000000
         mean   3396.000000    41.636096    49.889445     0.496688     0.462093
         std    1961.114522    23.667811    30.681017     0.500026     0.498598
         min       0.000000     1.000000     0.000000     0.000000     0.000000
         25%    1698.000000    21.000000    23.000000     0.000000     0.000000
         50%    3396.000000    42.000000    49.000000     0.000000     0.000000
         75%    5094.000000    62.000000    75.000000     1.000000     1.000000
         max    6792.000000    82.000000   133.000000     1.000000     1.000000

                     period       shooter         left          top      ThreePt
         count  6793.000000  6.793000e+03  6793.000000  6793.000000  6793.000000
         mean      2.474901  1.736174e+06    83.788835    50.669071     0.342264
         std       1.129431  1.664691e+06    10.165391    21.980889     0.474502
         min       1.000000  1.007000e+03    48.000000     2.000000     0.000000
         25%       1.000000  4.257000e+03    74.666667    44.000000     0.000000
         50%       2.000000  2.581177e+06    87.777778    50.000000     0.000000
         75%       3.000000  3.032976e+06    92.444444    60.000000     1.000000
         max       5.000000  4.065673e+06    98.888889    98.000000     1.000000
```

```
In [11]: print('Number of Shots Taken by Each Player:')
         print('----------------------------------------')
         ShotsPD = ShotsPD.replace("Royce O", "Royce O'Neale")
         print(ShotsPD['shooter_name'].value_counts(), '\n')
```

```
Number of Shots Taken by Each Player:
----------------------------------------
Donovan Mitchell    1361
Ricky Rubio          827
Joe Ingles           718
Derrick Favors       702
Rodney Hood          552
Rudy Gobert          442
Alec Burks           413
Jonas Jerebko        341
Jae Crowder          295
Royce O'Neale        285
Thabo Sefolosha      240
Joe Johnson          226
Raul Neto            151
Ekpe Udoh            119
Dante Exum            87
Tony Bradley          11
Georges Niang         11
Nate Wolters           6
David Stockton         3
Erik McCree            2
Naz Mitrou             1
Name: shooter_name, dtype: int64
```

```
In [12]: # filter out any shooter with less than 100 shots for the season
         ShotsPD = ShotsPD[ShotsPD["shooter_name"]!="Dante Exum"]
         ShotsPD = ShotsPD[ShotsPD["shooter_name"]!="Tony Bradley"]
         ShotsPD = ShotsPD[ShotsPD["shooter_name"]!="Nate Wolters"]
         ShotsPD = ShotsPD[ShotsPD["shooter_name"]!="David Stockton"]
         ShotsPD = ShotsPD[ShotsPD["shooter_name"]!="Georges Niang"]
         ShotsPD = ShotsPD[ShotsPD["shooter_name"]!="Erik McCree"]
         ShotsPD = ShotsPD[ShotsPD["shooter_name"]!="Naz Mitrou"]
```

```
In [13]: print('Types of Shots Taken:')
         print('----------------------------------------')
         print(ShotsPD['shot_type'].value_counts(), '\n')
```

```
Types of Shots Taken:
----------------------------------------
three point jumper                2004
two point shot                     901
```

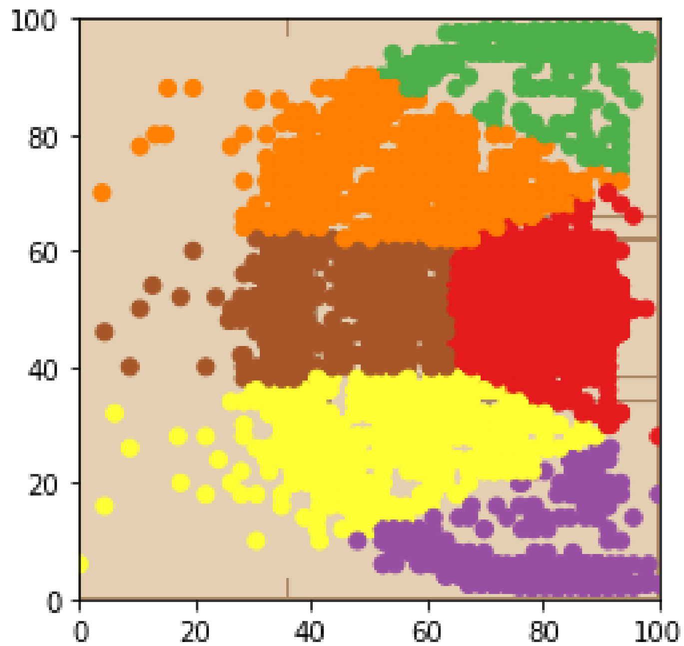
```
driving layup                    590
jumper                           533
pullup jump shot                 490
layup                            371
dunk                             235
step back jumpshot               190
layup                            185
driving floating jump shot       141
three point pullup jump shot     135
dunk                             131
tip shot                         118
driving layup                    103
two point shot                    90
three pointer                     84
hook shot                         70
three point jumper                55
jump bank shot                    36
driving dunk                      34
alley oop dunk shot               28
alley oop layup                   26
alley oop dunk shot               26
jumper                            21
three point shot                  20
alley oop layup                   10
finger roll layup                 10
running pullup jump shot           9
driving dunk                       9
finger roll layup                  4
pullup jump shot                   4
hook shot                          3
shot                               3
jump bank shot                     1
driving floating jump shot         1
step back jumpshot                 1
Name: shot_type, dtype: int64
```

2.0.1 Unsupervised clustering via kmeans to find natural clusters of the shots

We ultimately wanted to group the shots into different clusters for further analysis as groups. We wanted to try an unsupervised clustering algorithm to give us some insight into how the computer might see the court. We used kmeans because it was easy to implement, and because we were interested only in x and y location as our variables, so kmeans seemed like it would naturally lend itself to our analysis.

We used kmeans to cluster the basketball shots based on their X and Y locations on the court. We chose to use 6 different clusters, because that lead to results that were the most easily identifiable by humans. We were quite happy with our results. One group was right by the rim in the area called the key/paint/post. There were 5 other regions spanning the court that included both 2 pointers and 3 pointers. These zones correlated quite nicely with what we would naturally identify as the left and right corners, wings, and the middle of the court. Further dividing the groups into two-pointers and three-pointers gives us 11 separate clusters for further analysis.

```
In [14]: # Show the Natural Clusterings on the court with colors
         X = np.zeros( (len(ShotsPD), 2) )
         X[:, 0] = ShotsPD['left']
         X[:, 1] = ShotsPD['top']
         y_pred = KMeans(n_clusters=6, n_init=10, init='random', max_iter=300).fit_

         # Saves these locations to the dataframe
         ShotsPD['LocationCluster'] = y_pred
         ShotsPD.to_csv("location_dataframe_final.csv")

         # Redistribute the left data to be on scale of 0-100 (to plot on court pic
         xNorm = 100*(ShotsPD['left'] - min(ShotsPD['left'])) / (max(ShotsPD['left'

         plt.scatter(xNorm[:], X[:, 1], c=ShotsPD['LocationCluster'],  marker="o",
         plt.imshow(img, zorder=0, extent=[0, 100, 0, 100.0])
         plt.grid(False)
         plt.show()
```

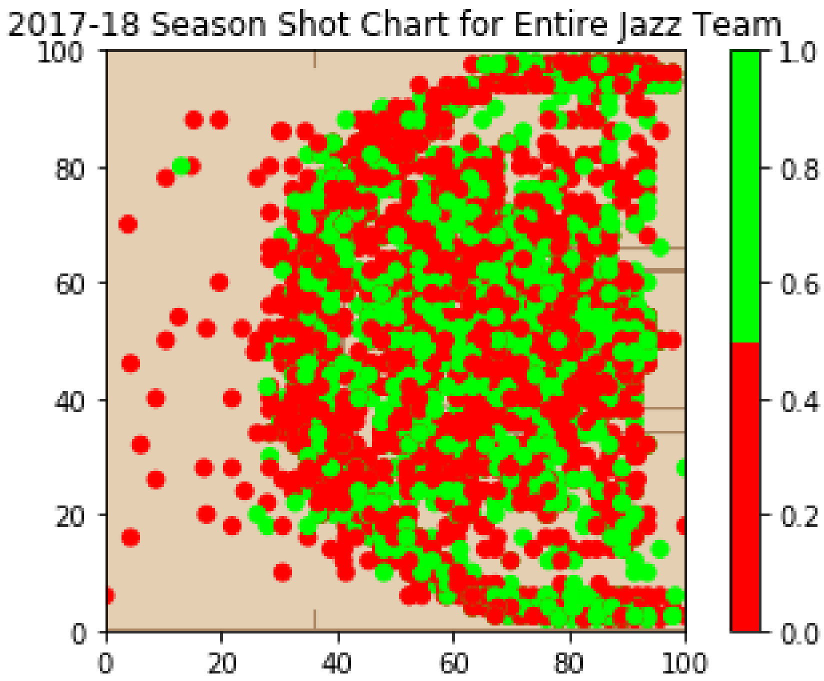


These clusters are interesting. They naturally appear to match what we would identify as the key, the left and right corners, the wings, and the middle of the court. We added these groupings to our dataset

2.0.2 We created shot charts for the team as a whole, and for each individual player

In [15]:
```
# unsupervised clustering can give different labels
# so read in already clustered data for consistency

ShotsPD = pd.read_csv("location_dataframe_final.csv")
ShotsPD = ShotsPD.replace("Royce O", "Royce O'Neale")

# Redistribute the left data to be on scale of 0-100
xNorm = 100*(ShotsPD['left'] - min(ShotsPD['left'])) / (max(ShotsPD['left'
ShotsPD['left'] = xNorm
```

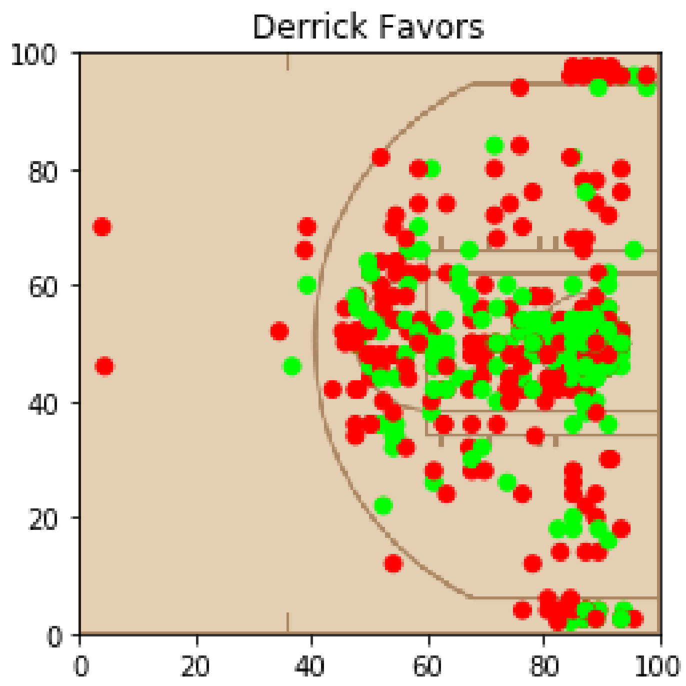
In [16]:
```
# Entire shots by Jazz by location, makes and misses
# greens are makes, reds are misses
cmap_bold = ListedColormap(['#FF0000', '#00FF00'])
plt.scatter(ShotsPD['left'],ShotsPD['top'],c=ShotsPD['made/missed'],cmap=c
plt.colorbar()
plt.imshow(img, zorder=0, extent=[0, 100, 0, 100.0])
plt.title('2017-18 Season Shot Chart for Entire Jazz Team')
plt.grid(False)
plt.show()
```

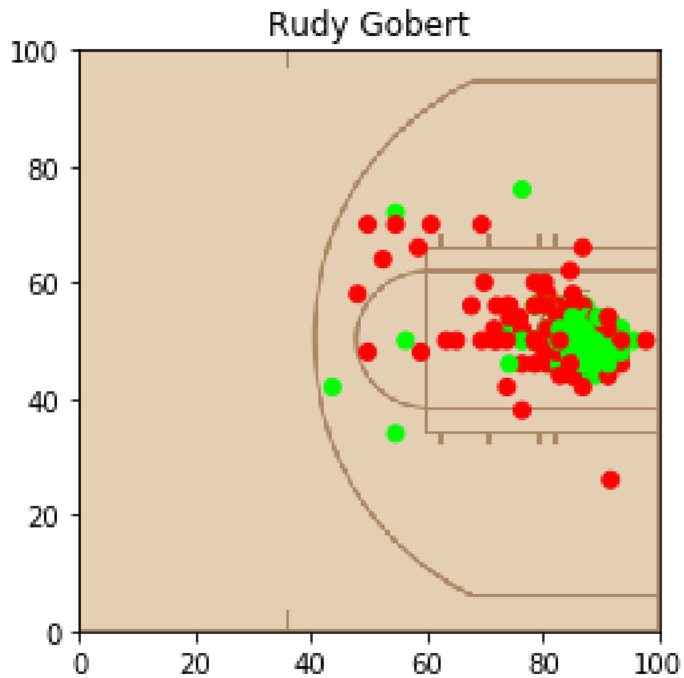


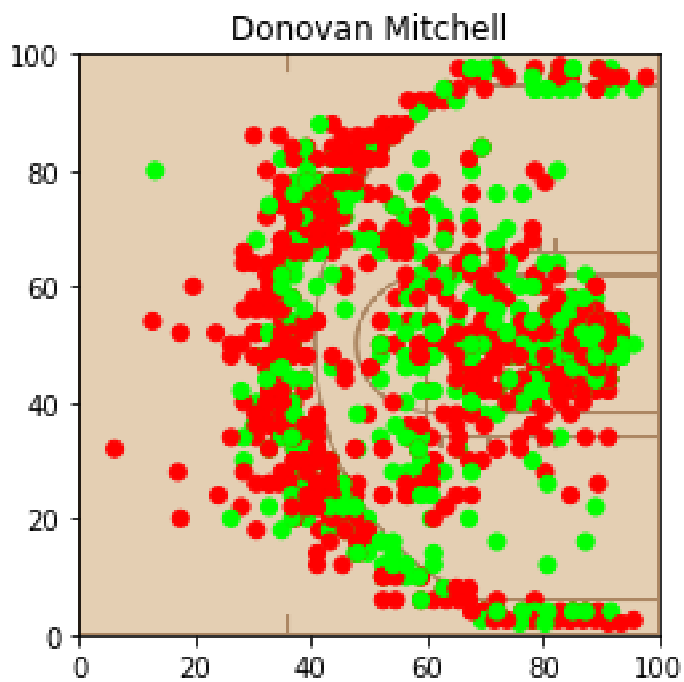
Individual players

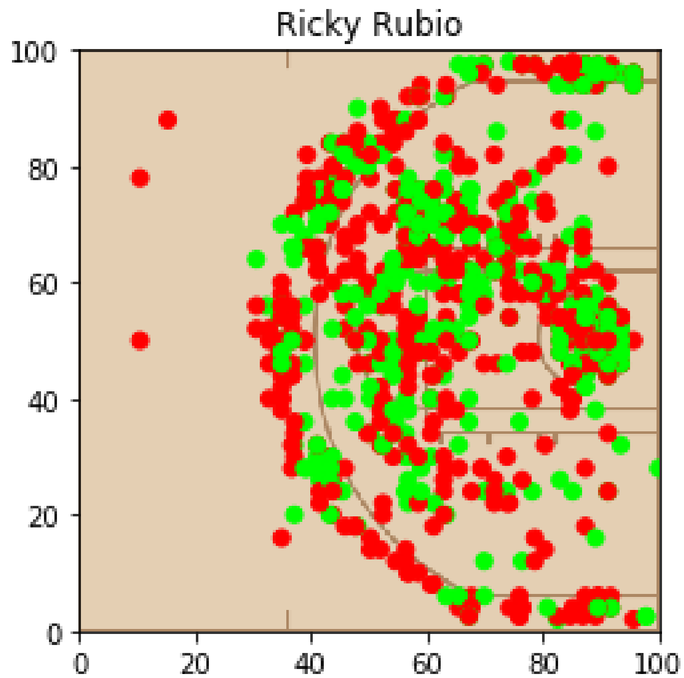
In [17]:
```
# shot chart for every player on the Jazz
# greens are makes, reds are misses
```

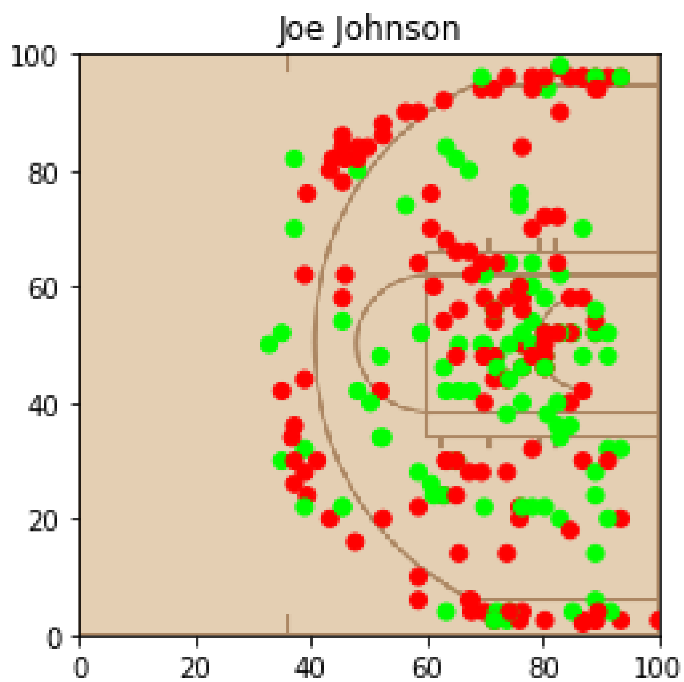
```
for shooter_name in ShotsPD['shooter_name'].unique():
    shooter_shots = ShotsPD[ShotsPD['shooter_name'] == shooter_name]
    plt.scatter(shooter_shots['left'], shooter_shots['top'], c=shooter_sho
    plt.title(str(shooter_name))
    plt.imshow(img, zorder=0, extent=[0, 100, 0, 100.0])
    plt.grid(False)
    plt.show()
```

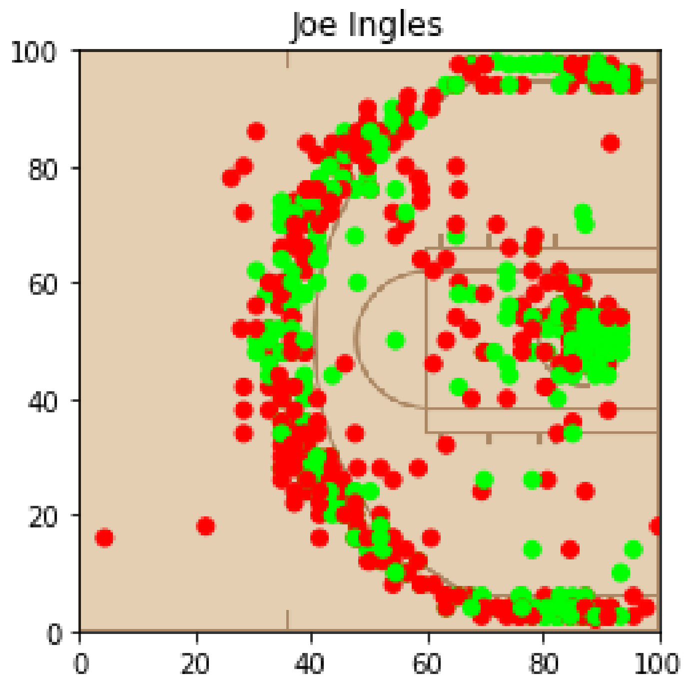


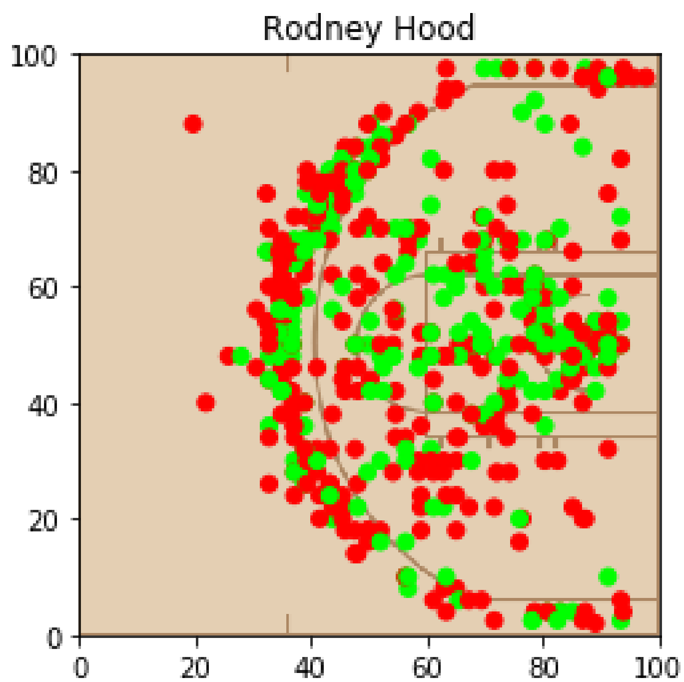

Rudy Gobert
0
20
40
60
80
100

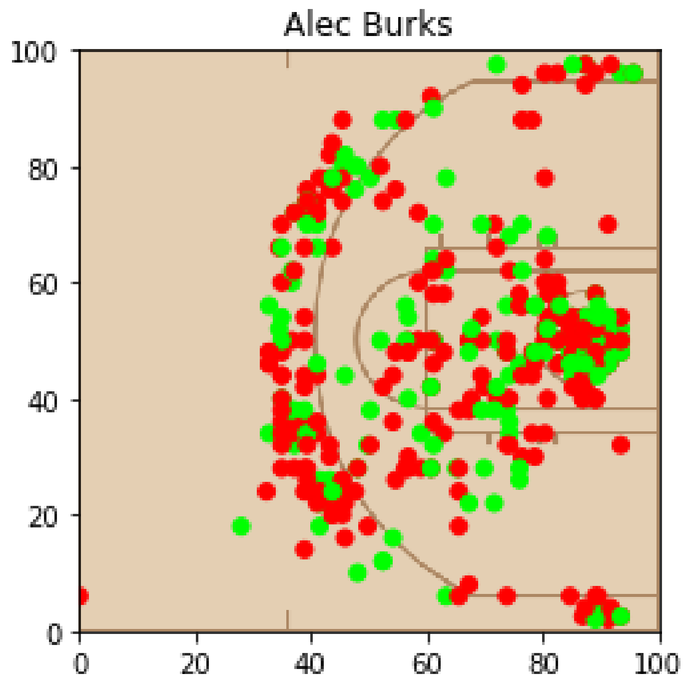

Donovan Mitchell
0
20
40
60
80
100

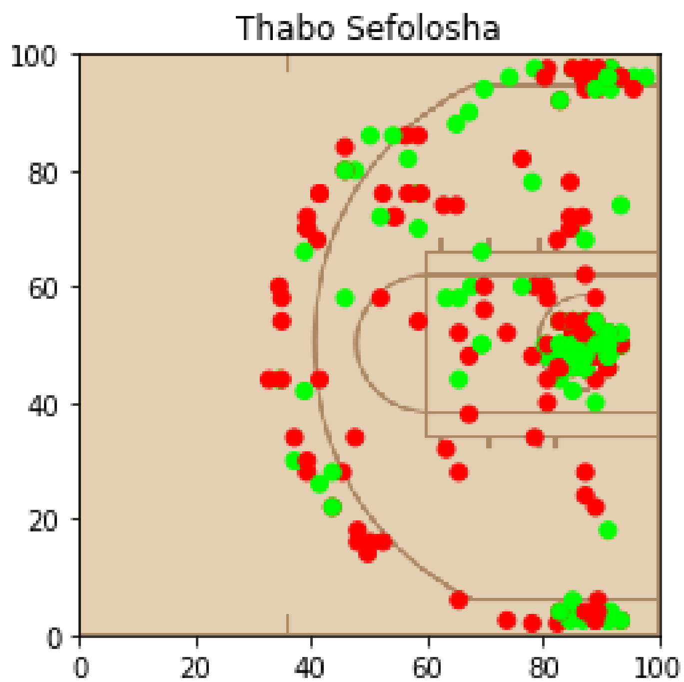

Ricky Rubio
100
80
60
40
20
0
0
20
40
60
80
100

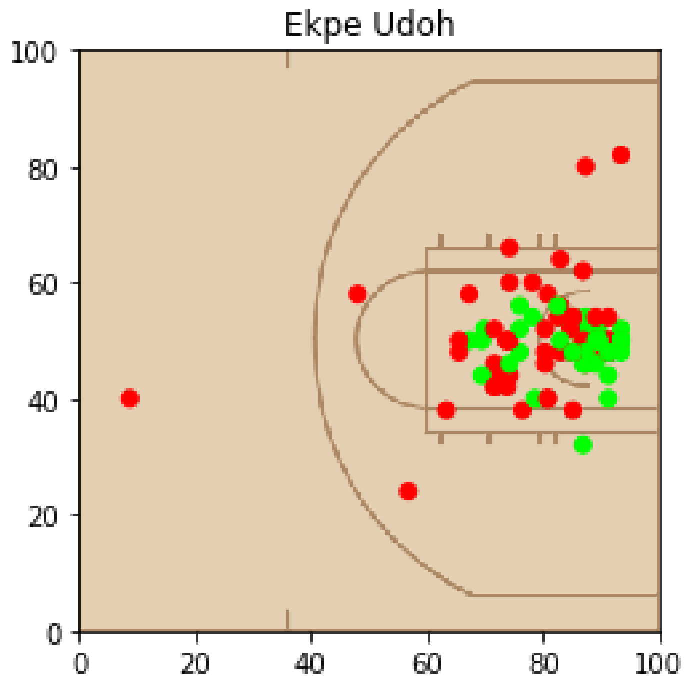

Joe Johnson
100
80
60
40
20
0
0
20
40
60
80
100

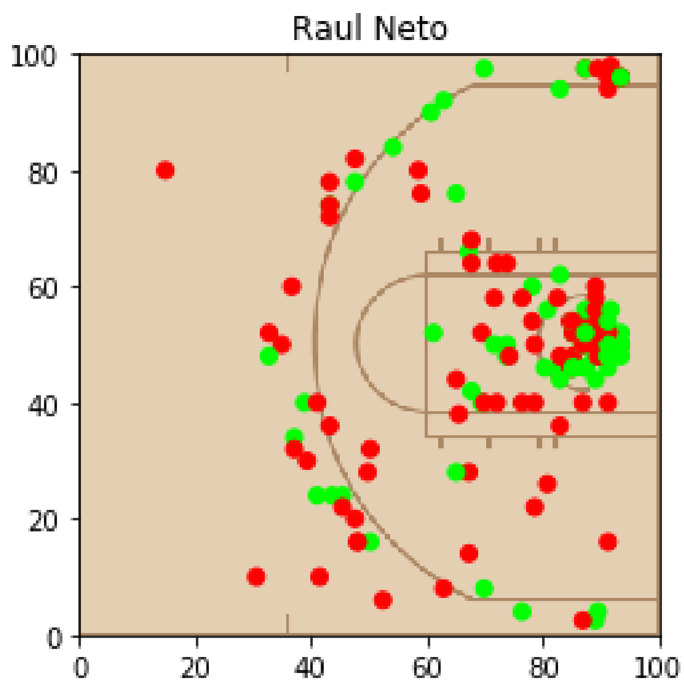

Joe Ingles
100
80
60
40
20
0
0
20
40
60
80
100

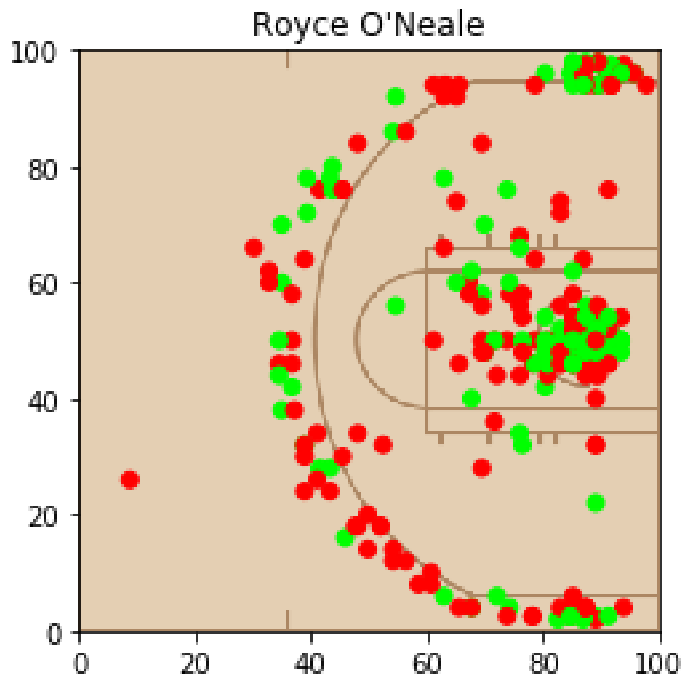

Rodney Hood
100
80
60
40
20
0
0
20
40
60
80
100


Alec Burks
100
80
60
40
20
0
0
20
40
60
80
100

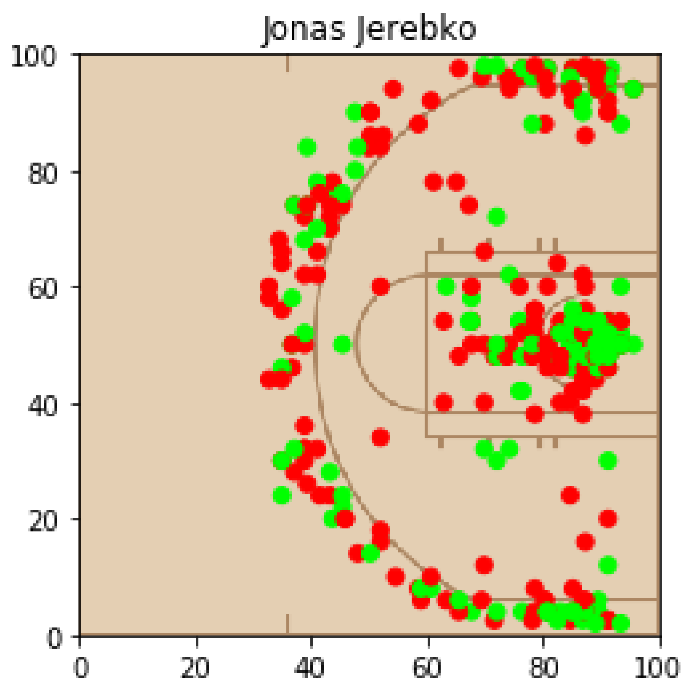

Thabo Sefolosha
100
80
60
40
20
0
0
20
40
60
80
100


Ekpe Udoh
100
80
60
40
20
0
0
20
40
60
80
100

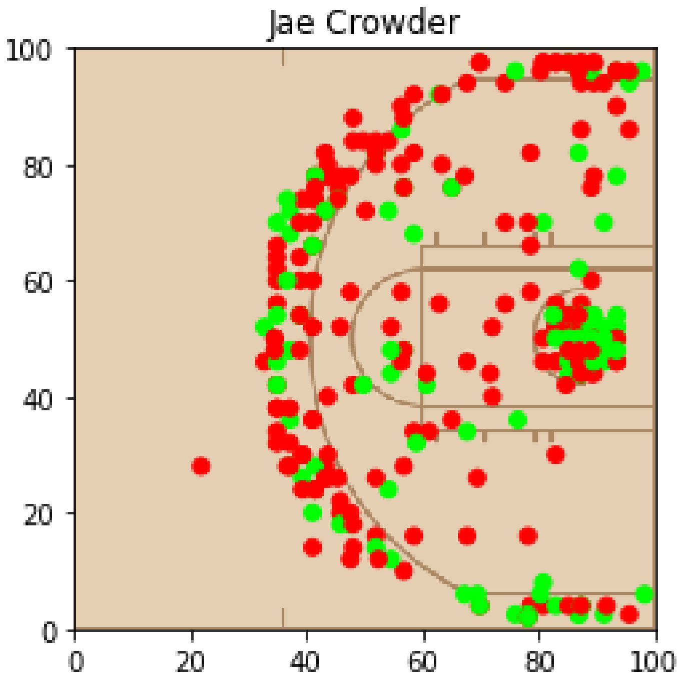

Raul Neto
100
80
60
40
20
0
0
20
40
60
80
100



Royce O'Neale
100
80
60
40
20
0
0
20
40
60
80
100



Jonas Jerebko
100
80
60
40
20
0
0
20
40
60
80
100



We can use simple data frame masking and math to compute some simple statistics for individual players

```
In [18]: mitchell_shots = ShotsPD[ShotsPD["shooter_name"]=="Donovan Mitchell"]
         print('Number of Shots Mitchell has shot: ' + str(len(mitchell_shots)))
         mitchell_makes = mitchell_shots[mitchell_shots["made/missed"]==1]
         mitchell_misses = mitchell_shots[mitchell_shots["made/missed"]==0]
         print('Number of Shots Mitchell has made: ' + str(len(mitchell_makes)))
         print('Number of Shots Mitchell has missed: ' + str(len(mitchell_misses)))
         print('Mitchell Field Goal Percentage: ' + str(len(mitchell_makes)/len(mit
```

```
Number of Shots Mitchell has shot: 1361
Number of Shots Mitchell has made: 595
Number of Shots Mitchell has missed: 766
Mitchell Field Goal Percentage: 0.4371785451873622
```

```
In [19]: mitchell_threes = mitchell_shots[mitchell_shots["ThreePt"]==1]
         mitchell_twos = mitchell_shots[mitchell_shots["ThreePt"]==0]
         two_pt_pct = len(mitchell_twos[mitchell_twos["made/missed"]==1])/len(mitch
         three_pt_pct = len(mitchell_threes[mitchell_threes["made/missed"]==1])/len
         print("Mitchell's two point percentage is: " + str(round(two_pt_pct*100, 2
         print("Mitchell's three point percentage is: " + str(round(three_pt_pct*10
```

```
Mitchell's two point percentage is: 49.71 %
Mitchell's three point percentage is: 33.79 %
```

We try to get an idea of which regions have the highest expected value (for the team as a whole). We'll plot them later as well. This shows the expected values for 3 pointers and then two pointers

```
In [20]: ## Team Stats -- 3 Pointers
         # 3 pointers
         PercMadeDif3 = []
         NumShots = []
         NumMade = []
         ExpectedValue3 =[]
         AvLeft3 = []
         AvTop3 =[]
         PtVal = 3
         for i in range(0,6):
             Location = ShotsPD[(ShotsPD['LocationCluster']==i) & (ShotsPD['ThreePt
             NumShots.append(len(Location['made/missed']))
             NumMade.append(len(Location[Location['made/missed']==1]))
             if NumShots[i] > 1:
                 PercMade = NumMade[i] / NumShots[i]
                 PercMadeDif3.append(PercMade)
             else:
                 PercMadeDif3.append(0)

             ExpectedValue3.append(PercMadeDif3[i]*PtVal)

             AvLeft3.append(np.mean(Location['left']))
             AvTop3.append(np.mean(Location['top']))

         print('---- 3 Pointers ----')
         print('Percentages')
         print(PercMadeDif3)
         print('---------------------')
         print('Expected Values')
         print(ExpectedValue3)
```

```
---- 3 Pointers ----
Percentages
[0, 0.4004474272930649, 0.35537190082644626, 0.3146551724137931, 0.398210290827740
---------------------
Expected Values
[0, 1.2013422818791946, 1.0661157024793388, 0.9439655172413792, 1.1946308724832215,
```

```
In [21]: ## Team Stats -- 2 Pointers
         # 2 pointers
         PercMadeDif2 = []
         NumShots = []
         NumMade = []
         ExpectedValue2 =[]
```

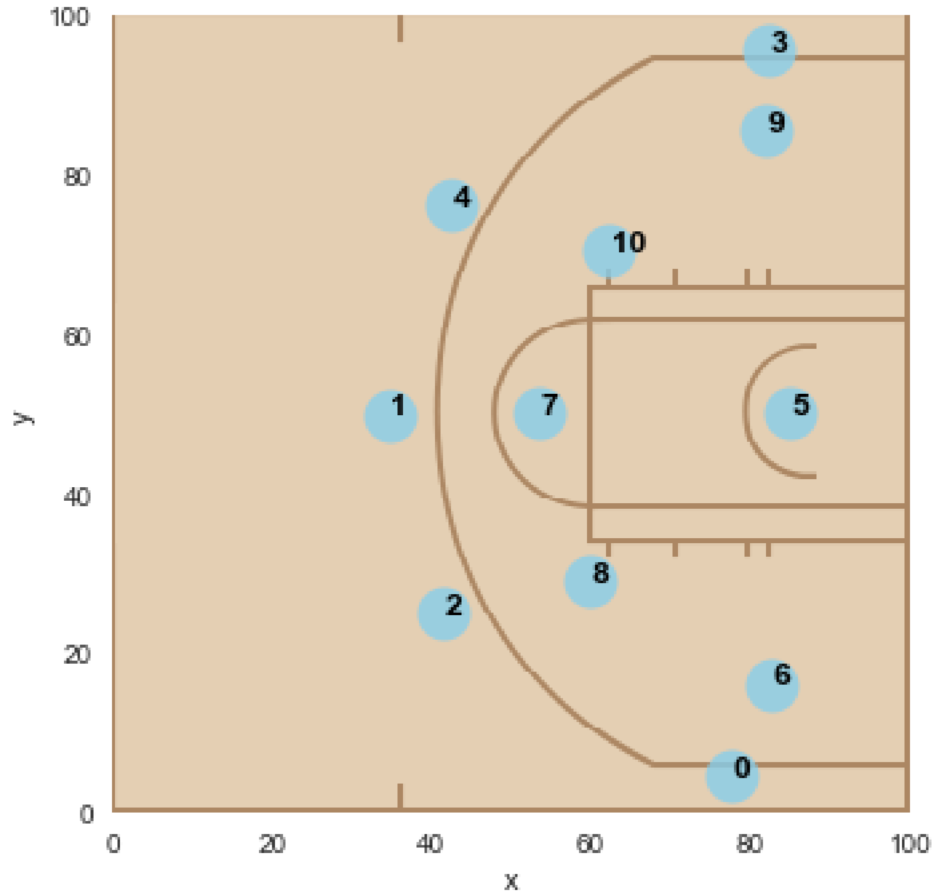
```
        PtVal = 2
        AvLeft2 = []
        AvTop2 =[]

        for i in range(0,6):
            Location = ShotsPD[(ShotsPD['LocationCluster']==i) & (ShotsPD['ThreePt
            NumShots.append(len(Location['made/missed']))
            NumMade.append(len(Location[Location['made/missed']==1]))
            PercMade = NumMade[i] / NumShots[i]
            PercMadeDif2.append(PercMade)
            ExpectedValue2.append(PercMadeDif2[i]*PtVal)

            AvLeft2.append(np.mean(Location['left']))
            AvTop2.append(np.mean(Location['top']))

        print('---- 2 Pointers ----')
        print('Percentages')
        print(PercMadeDif2)
        print('---------------------')
        print('Expected Values')
        print(ExpectedValue2)
```

```
---- 2 Pointers ----
Percentages
[0.564875491480996, 0.4235294117647059, 0.44141689373297005, 0.34770114942528735, 0
---------------------
Expected Values
[1.129750982961992, 0.8470588235294118, 0.8828337874659401, 0.6954022988505747, 0.7
```

```
In [22]: ## Delete some parts mostly because the paint (key) cluster won't have a 3
         xx = np.isnan(AvLeft3)
         DeleteVar = []
         for i in range(0, len(AvLeft3)):
             if  xx[i] == True:
                 DeleteVar = i
         DeleteVar
         del AvLeft3[DeleteVar]
         del AvTop3[DeleteVar]
```

```
In [23]: # Show where each cluster is located on the court (the means!)
         import seaborn as sns

         df = pd.DataFrame({
         'x': AvLeft3 + AvLeft2,
         'y': AvTop3 + AvTop2,
         'group': ['0','1', '2','3','4','5','6','7','8','9','10']
         })
```

```
p1=sns.regplot(data=df, x="x", y="y", fit_reg=False, marker="o", color="sk
for line in range(0,df.shape[0]):
    p1.text(df.x[line]+0.2, df.y[line], df.group[line], horizontalalignmen
            color='black', weight='semibold')

plt.imshow(img, zorder=0, extent=[0, 100, 0, 100.0])
plt.grid(False)
plt.show()
```

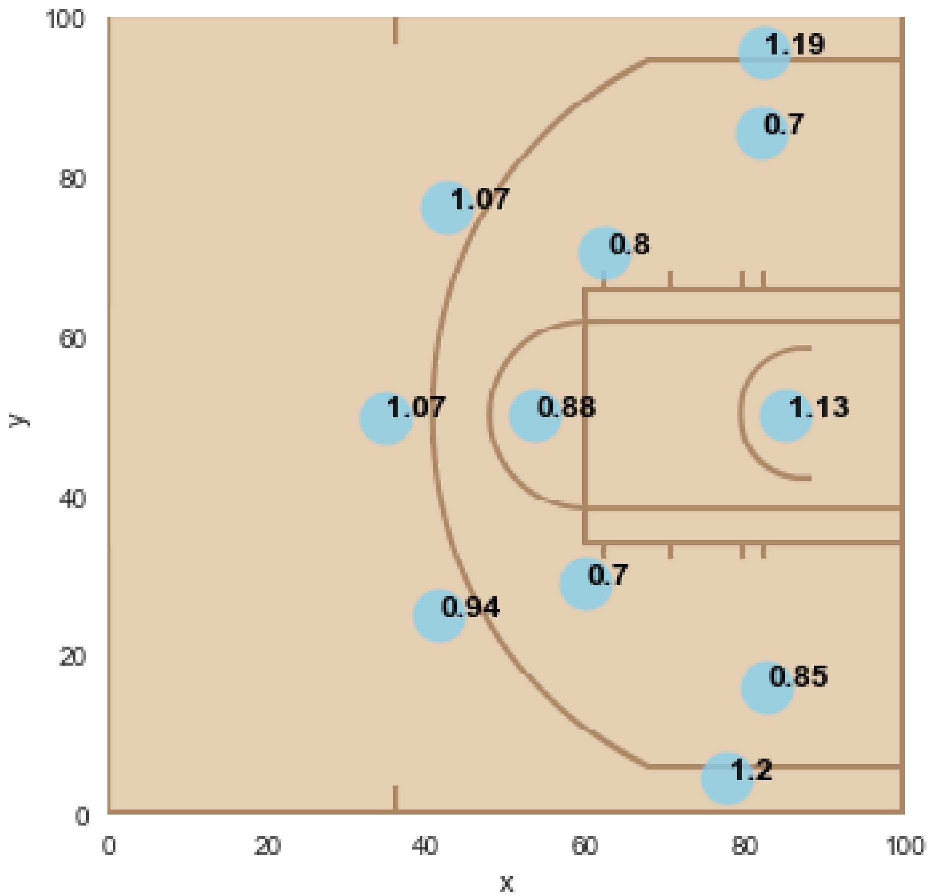



```
In [24]: ## Delete the 3's for the parents of cluster 5
         for i in range(0,len(ExpectedValue3)):
             if ExpectedValue3[i] == 0:
                 Extra = i
         del ExpectedValue3[Extra]

         # Create expected values and round it for simplicity
         ExpectedValue = ExpectedValue3 + ExpectedValue2
         ExpectedValueRound = np.round_(ExpectedValue, decimals=2)
```

2.1 Analysis

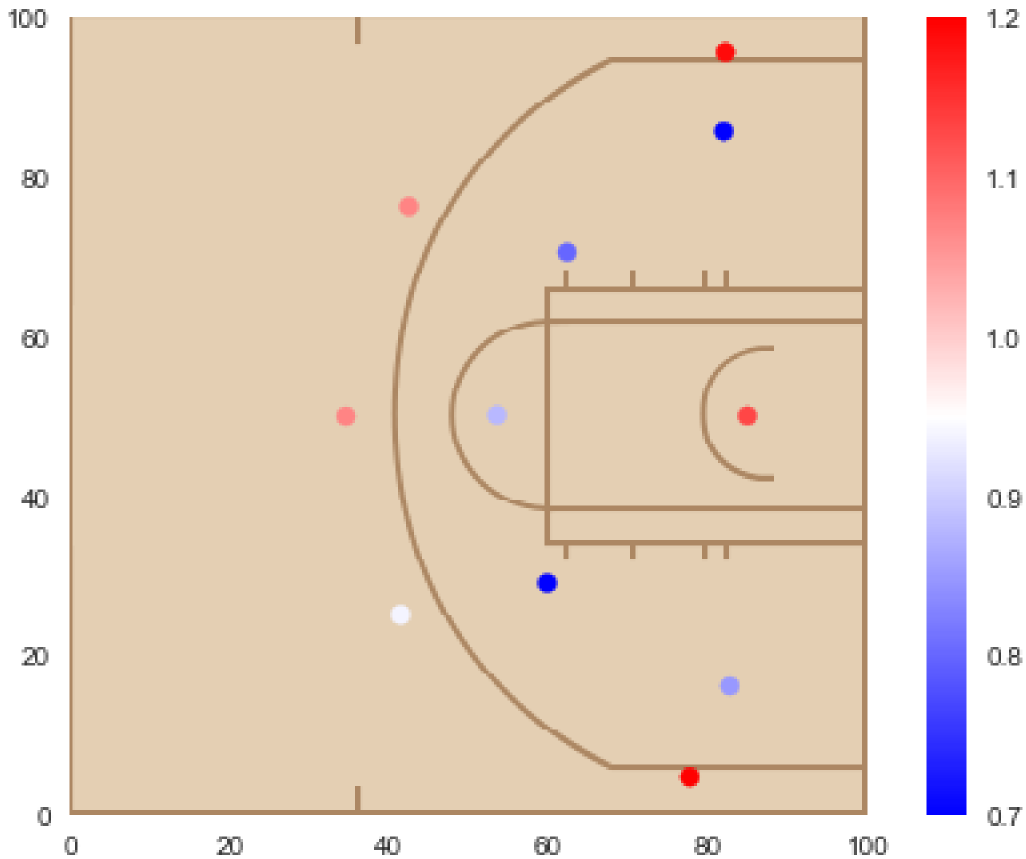
Plot the expected values for the team

```
In [25]: ## Team chart with expected values
         ExpectedValue = ExpectedValue3 + ExpectedValue2
         df = pd.DataFrame({
         'x': AvLeft3 + AvLeft2,
         'y': AvTop3 + AvTop2,
         'group': [str(ExpectedValueRound[0]),str(ExpectedValueRound[1]),str(Expect
                   str(ExpectedValueRound[3]),str(ExpectedValueRound[4]),str(Expect
                   str(ExpectedValueRound[6]),str(ExpectedValueRound[7]),str(Expect
                   str(ExpectedValueRound[9]),str(ExpectedValueRound[10])]
         })

         p1=sns.regplot(data=df, x="x", y="y", fit_reg=False, marker="o", color="sk
         for line in range(0,df.shape[0]):
             p1.text(df.x[line]+0.2, df.y[line], df.group[line], horizontalalignmen
                     size='medium', color='black', weight='semibold')

         plt.imshow(img, zorder=0, extent=[0, 100, 0, 100.0])
         plt.grid(False)
         sns.plt.show()
```



Heat map for the team with color scale

```
In [26]: x = AvLeft3 + AvLeft2
         y = AvTop3 + AvTop2
         B = ExpectedValueRound
         low = np.min(B)
         high = np.max(B)
         cs = plt.scatter(x,y,c=B,cmap=plt.cm.bwr,vmin=low,vmax=high)

         plt.colorbar(cs)
         plt.imshow(img, zorder=0, extent=[0, 100, 0, 100.0])
         plt.grid(False)
         plt.show()
         # red is hot--high expected value.  blue is cool--low expected value
```



As we can see, corner threes and twos in the key are the most efficient shots for the Jazz team overall. The longer jumper two's are the worst shot the Jazz can shoot as a team. Hence, from this plot we can take it that shooting a two pointer isn't really worth it, unless it is inside the paint. Using masking and loops with added logic, we are able to look at all the expected values on the court for each player. We will also print out the values and player name

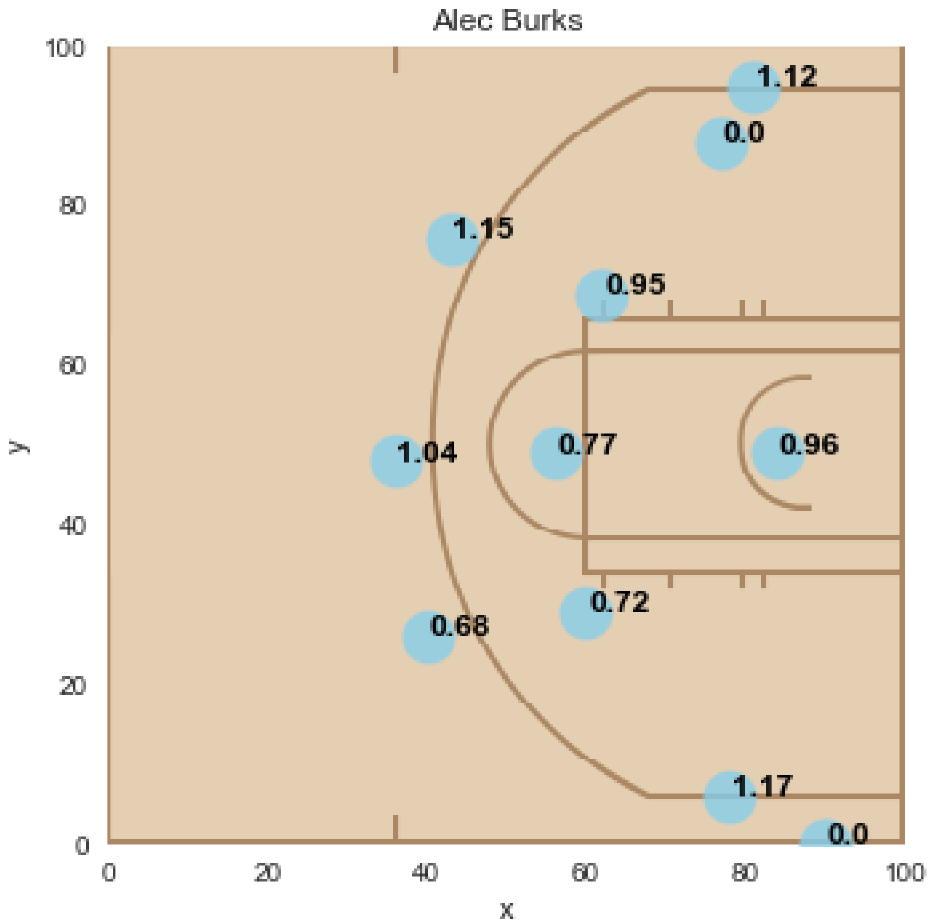
```
In [27]: # 3 pointers
         PlayerIDs = np.unique(ShotsPD['shooter'])
         PlayerNames = np.unique(ShotsPD['shooter_name'])
         NumOPlayers = len(PlayerNames)
         for Name in range(0,NumOPlayers):
             PercMadeDif3 = []
             NumShots = []
             NumMade = []
             ExpectedValue3 =[]
             AvLeft3 = []
             AvTop3 =[]
             PtVal3 = 3
             PtVal2 = 2
```

```
PercMadeDif2 = []
NumShots3 = []
NumShots2 = []
NumMade3 = []
NumMade2 = []
ExpectedValue2 =[]
ExpectedValueRound = []

AvLeft2 = []
AvTop2 =[]

for i in range(0,6):
    Location = ShotsPD[(ShotsPD['LocationCluster']==i) & (ShotsPD['Thr
                      & ( ShotsPD['shooter_name'] == PlayerNames[Name
    NumShots3.append(len(Location['made/missed']))
    NumMade3.append(len(Location[Location['made/missed']==1]))
    PercMade3 = 0
    if NumShots3[i] > 1:
        PercMade3 = NumMade3[i] / NumShots3[i]
        PercMadeDif3.append(PercMade3)
    else:
        PercMadeDif3.append(0)

    ExpectedValue3.append(PercMadeDif3[i]*PtVal3)

    AvLeft3.append(np.mean(Location['left']))
    AvTop3.append(np.mean(Location['top']))




    Location = ShotsPD[(ShotsPD['LocationCluster']==i) & (ShotsPD['Thr
                      & ( ShotsPD['shooter_name'] == PlayerNames[Name
    NumShots2.append(len(Location['made/missed']))
    NumMade2.append(len(Location[Location['made/missed']==1]))
    PercMade2 = 0
    if NumShots2[i] > 1:
            PercMade2 = NumMade2[i] / NumShots2[i]
            PercMadeDif2.append(PercMade2)
    else:
            PercMadeDif2.append(0)
    ExpectedValue2.append(PercMadeDif2[i]*PtVal2)

    AvLeft2.append(np.mean(Location['left']))
    AvTop2.append(np.mean(Location['top']))

print('----------------------------------------------------------------
```

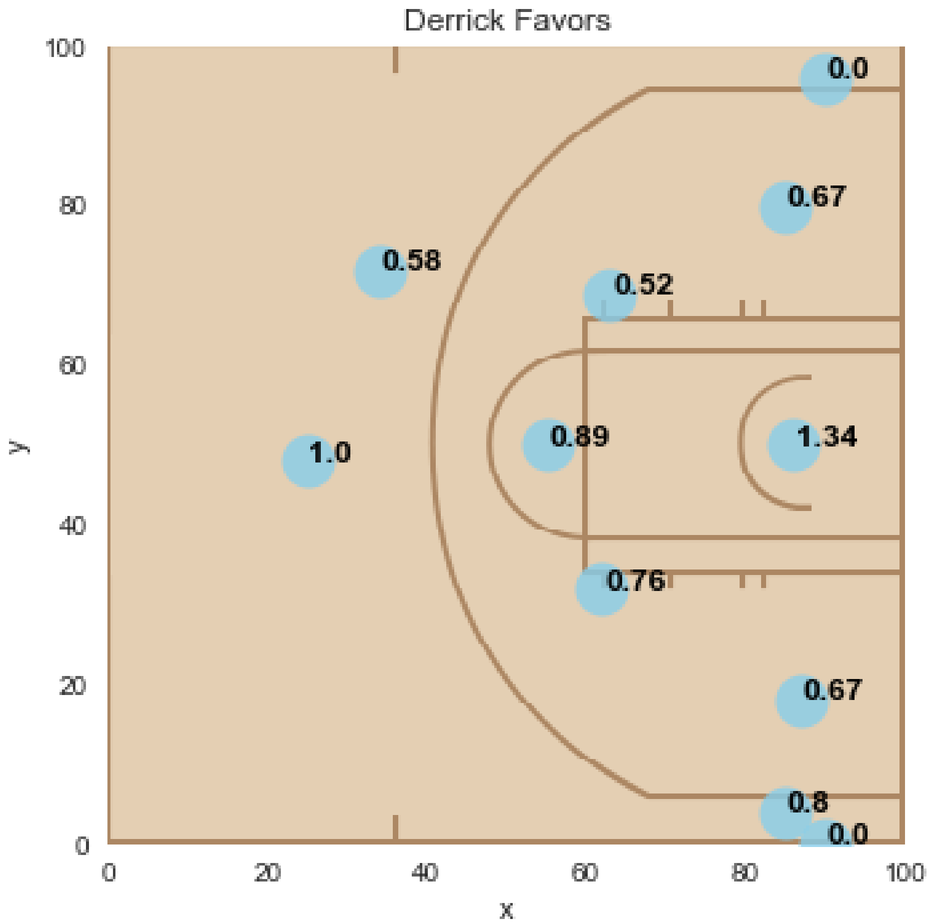
```
print(PlayerNames[Name])
print('---------------------')
print('---- 3 Pointers ----')
print('Percentages')
print(PercMadeDif3)
print('---------------------')
print('Expected Values')
print(ExpectedValue3)



print('---- 2 Pointers ----')
print('Percentages')
print(PercMadeDif2)
print('---------------------')
print('Expected Values')
print(ExpectedValue2)

for mm in range(0,len(ExpectedValue3)):
    if ExpectedValue3[mm] == 0:
        Extra = mm
del ExpectedValue3[Extra]

xx = np.isnan(AvLeft3)
for mm in range(0, len(AvLeft3)):
    if  xx[mm] == True:
        DeleteVar = mm

del AvLeft3[DeleteVar]
del AvTop3[DeleteVar]

ExpectedValue = ExpectedValue3 + ExpectedValue2
ExpectedValueRound = np.round_(ExpectedValue, decimals=2)

AvLefts = AvLeft3 + AvLeft2
AvTops = AvTop3 + AvTop2

for u in range(0,len(AvLefts)):
    if math.isnan(AvLefts[u]):
        AvLefts[u]=90
    if math.isnan(AvTops[u]):
        AvTops[u]= 0


x = np.round(AvLefts,decimals=0)
y = np.round(AvTops,decimals=0)
valz = [str(ExpectedValueRound[0]),str(ExpectedValueRound[1]),str(Expe
        str(ExpectedValueRound[3]),str(ExpectedValueRound[4]),str(Expe
```

```
            str(ExpectedValueRound[6]),str(ExpectedValueRound[7]),str(Expe
            str(ExpectedValueRound[9]),str(ExpectedValueRound[10])]
    df = pd.DataFrame({
    'x': x,
    'y': y,
    'group': valz
    })

    p1=sns.regplot(data=df, x="x", y="y", fit_reg=False, marker="o", color
    for line in range(0,df.shape[0]):
        p1.text(df.x[line]+0.2, df.y[line], df.group[line], horizontalalig
                size='medium', color='black', weight='semibold')

    plt.title(PlayerNames[Name])
    plt.imshow(img, zorder=0, extent=[0, 100, 0, 100.0])
    plt.grid(False)
    plt.show()
```

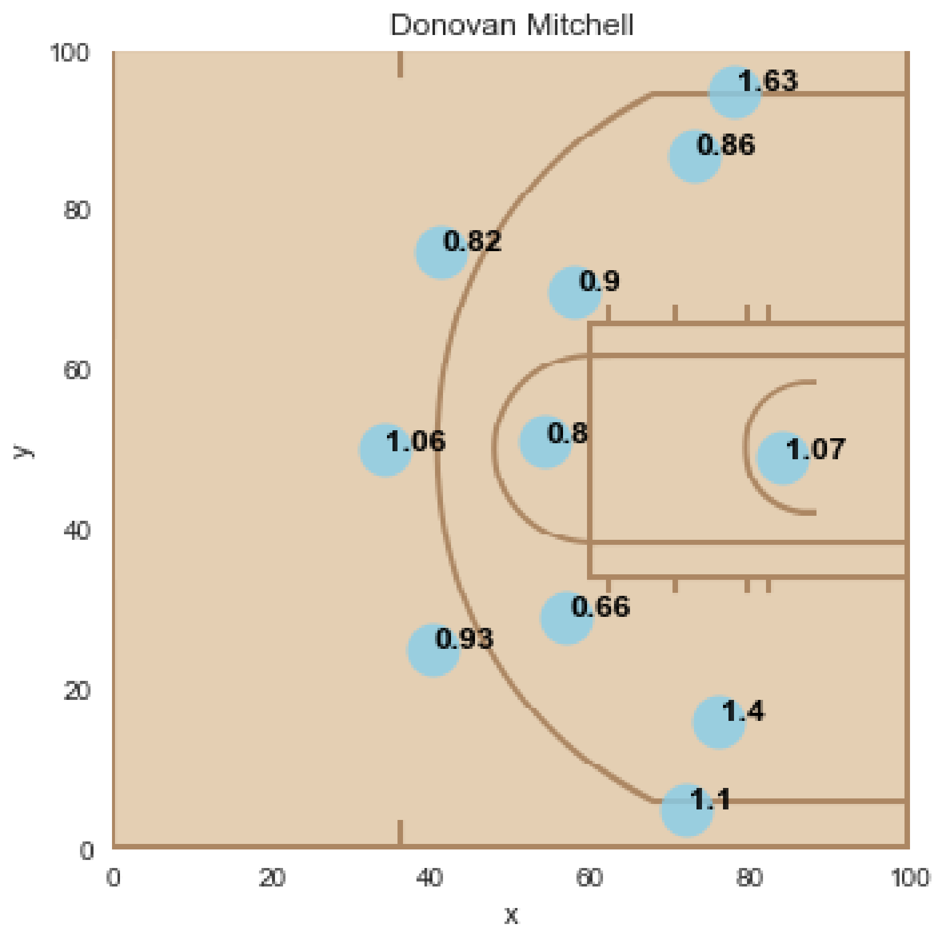
```
---------------------------------------------------------------
Alec Burks
---------------------
---- 3 Pointers ----
Percentages
[0, 0.3888888888888889, 0.34615384615384615, 0.225, 0.375, 0.38235294117647056]
---------------------
Expected Values
[0, 1.1666666666666667, 1.0384615384615383, 0.675, 1.125, 1.1470588235294117]
---- 2 Pointers ----
Percentages
[0.4816753926701571, 0, 0.38461538461538464, 0.358974358974359, 0.0, 0.476190476190
---------------------
Expected Values
[0.9633507853403142, 0, 0.7692307692307693, 0.717948717948718, 0.0, 0.952380952380
```



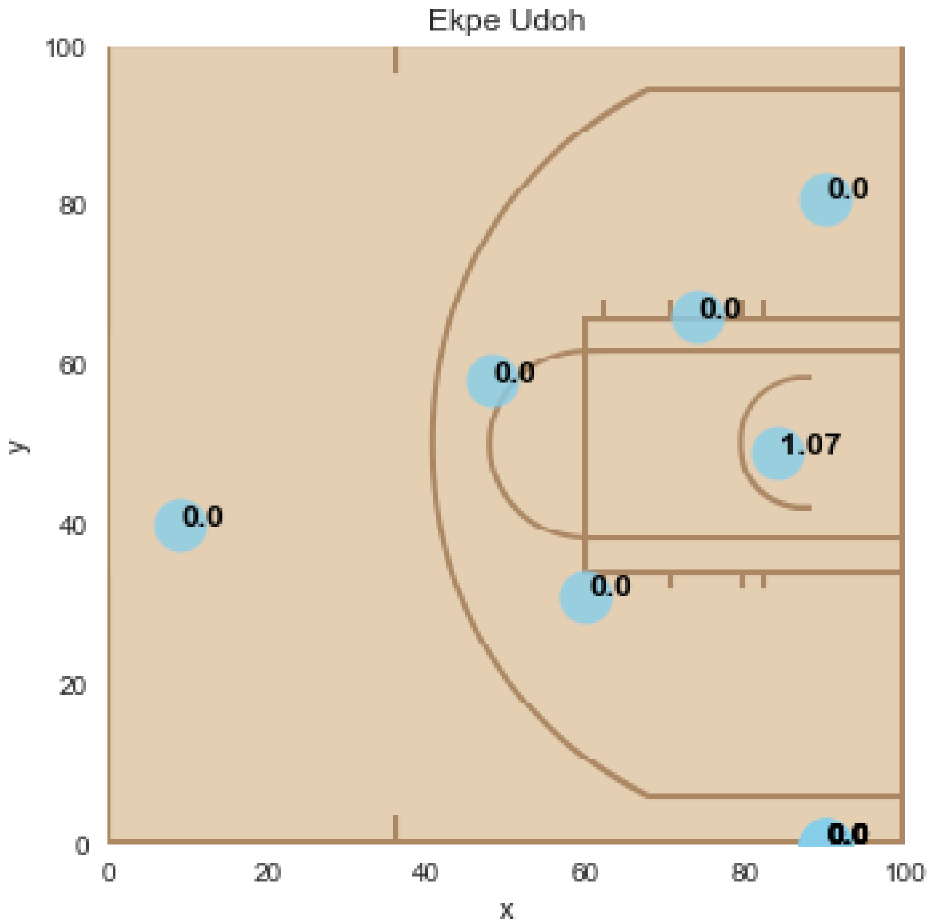

```
-----------------------------------------------------------------
Derrick Favors
----------------------
---- 3 Pointers ----
Percentages
[0, 0.26666666666666666, 0.3333333333333333, 0, 0.19230769230769232, 0.0]
----------------------
Expected Values
[0, 0.8, 1.0, 0, 0.576923076923077, 0.0]
---- 2 Pointers ----
Percentages
[0.6680584551148225, 0.3333333333333333, 0.4473684210526316, 0.3793103448275862, 0.
----------------------
Expected Values
[1.336116910229645, 0.6666666666666666, 0.8947368421052632, 0.7586206896551724, 0.
```



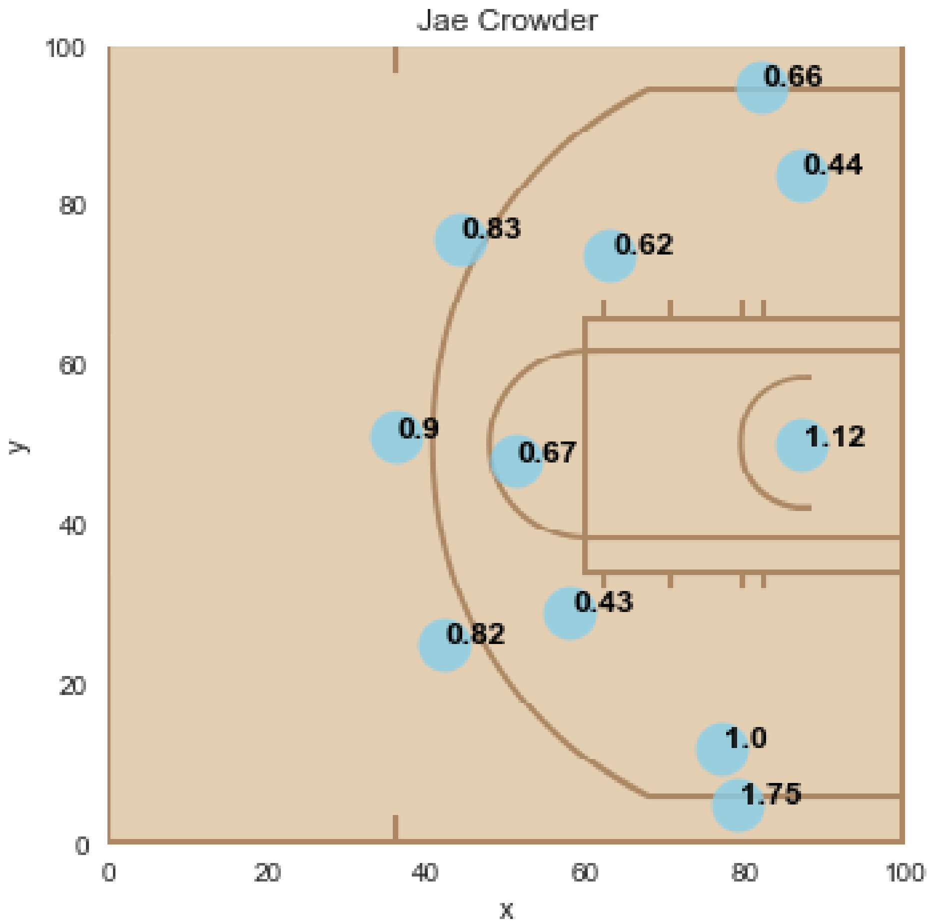

```
---------------------------------------------------------------
Donovan Mitchell
---------------------
---- 3 Pointers ----
Percentages
[0, 0.36764705882352944, 0.35454545454545455, 0.3115942028985507, 0.543478260869565
---------------------
Expected Values
[0, 1.1029411764705883, 1.0636363636363637, 0.9347826086956521, 1.6304347826086956,
---- 2 Pointers ----
Percentages
[0.5358931552587646, 0.7, 0.4, 0.32941176470588235, 0.42857142857142855, 0.4487179
---------------------
Expected Values
[1.0717863105175292, 1.4, 0.8, 0.6588235294117647, 0.8571428571428571, 0.897435897
```



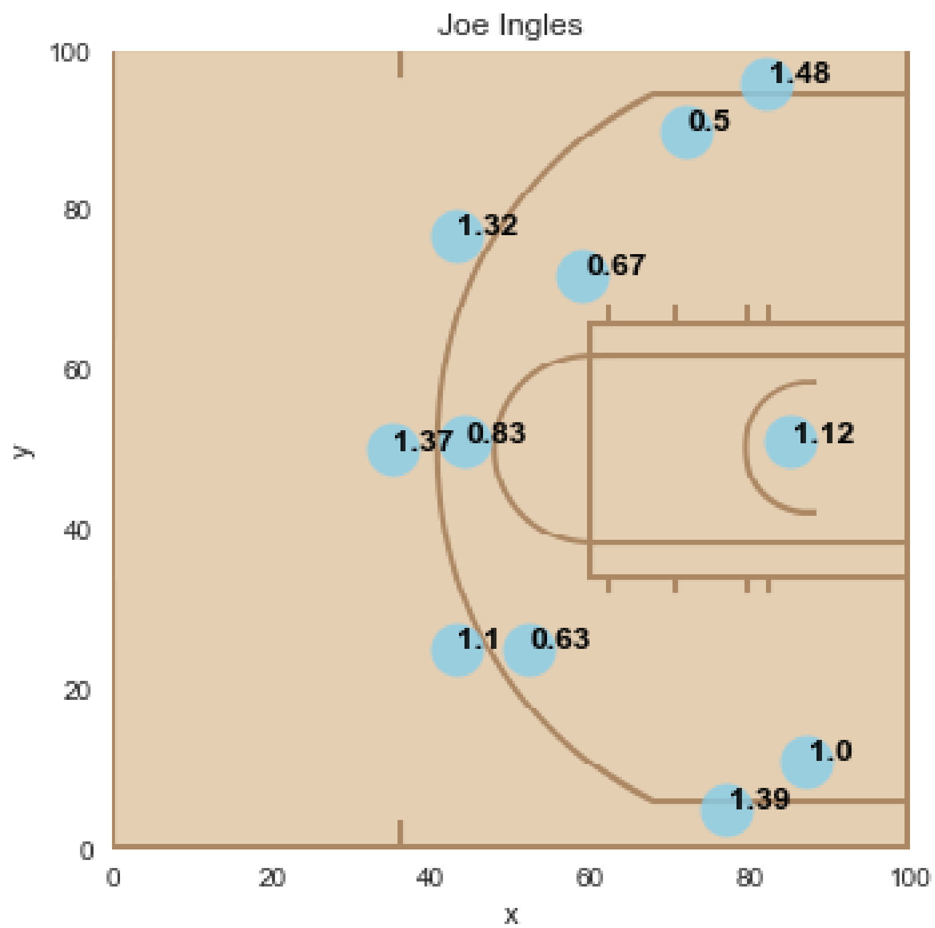

```
---------------------------------------------------------------
Ekpe Udoh
---------------------
---- 3 Pointers ----
Percentages
[0, 0, 0, 0, 0, 0]
---------------------
Expected Values
[0, 0, 0, 0, 0, 0]
---- 2 Pointers ----
Percentages
[0.5357142857142857, 0, 0, 0.0, 0.0, 0]
---------------------
Expected Values
[1.0714285714285714, 0, 0, 0.0, 0.0, 0]
```



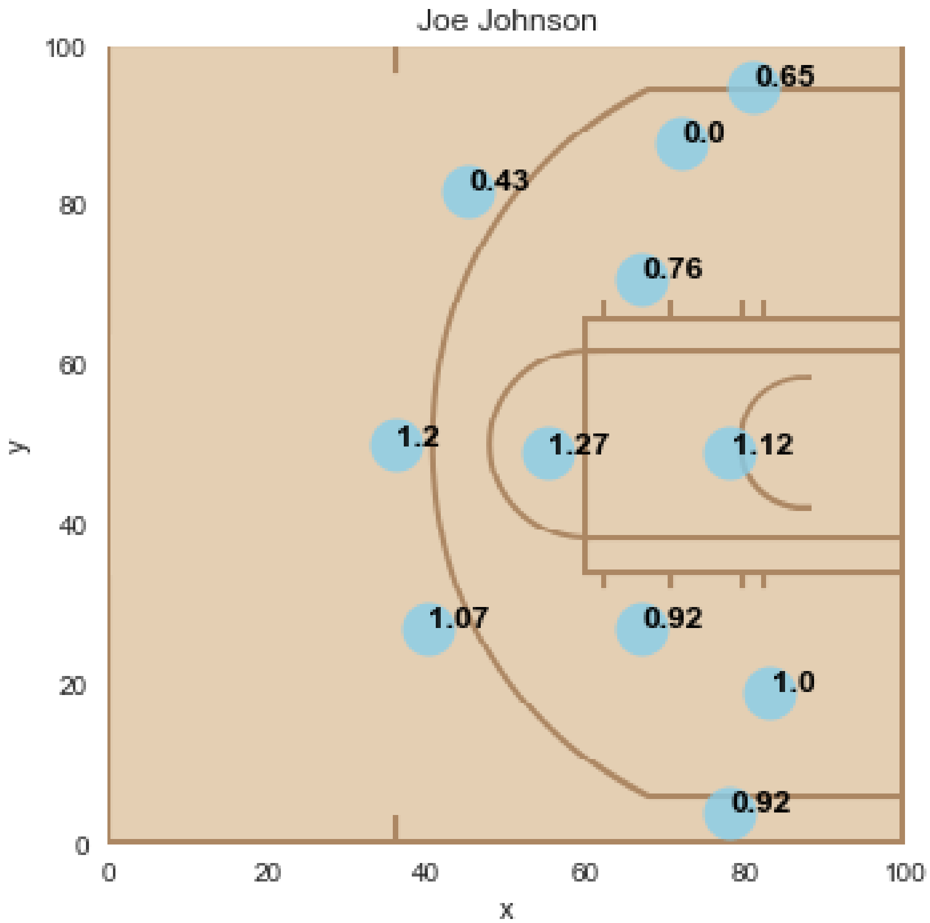

```
---------------------------------------------------------------
Jae Crowder
---------------------
---- 3 Pointers ----
Percentages
[0, 0.5833333333333334, 0.3, 0.2727272727272727, 0.21875, 0.2777777777777778]
---------------------
Expected Values
[0, 1.75, 0.8999999999999999, 0.8181818181818181, 0.65625, 0.8333333333333334]
---- 2 Pointers ----
Percentages
[0.5617977528089888, 0.5, 0.3333333333333333, 0.21428571428571427, 0.2222222222222
---------------------
Expected Values
[1.1235955056179776, 1.0, 0.6666666666666666, 0.42857142857142855, 0.4444444444444
```



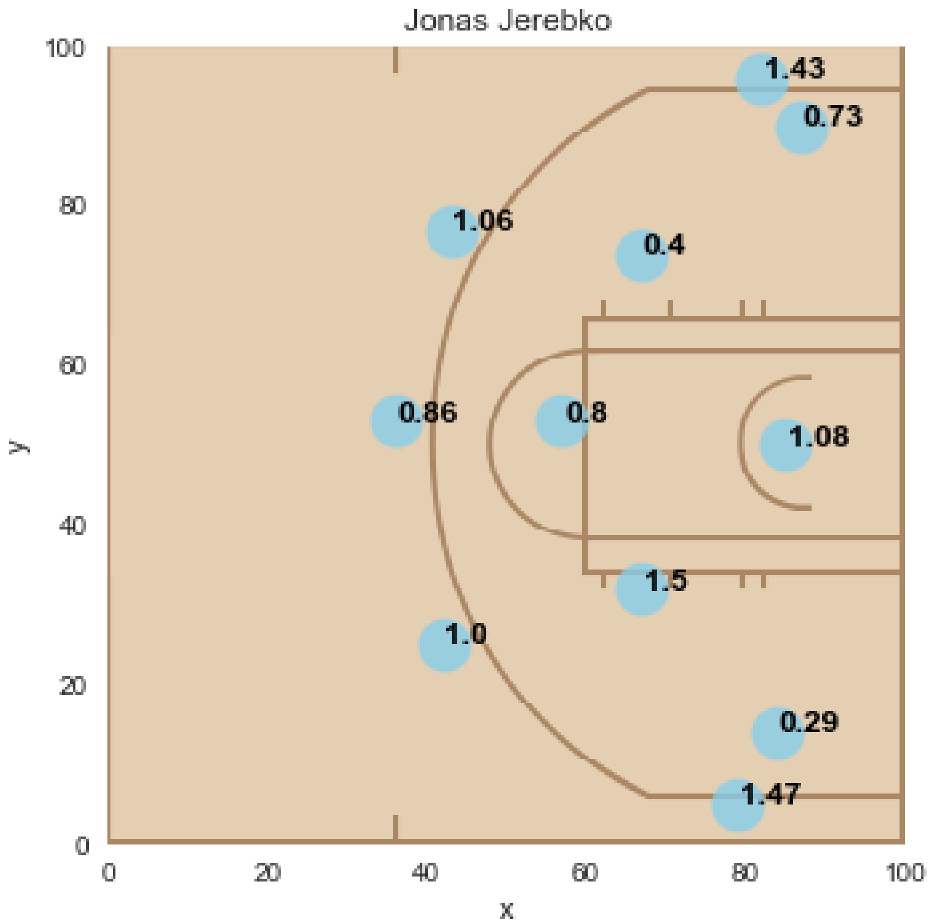

```
--------------------------------------------------------------
Joe Ingles
---------------------
---- 3 Pointers ----
Percentages
[0, 0.46296296296296297, 0.45614035087719296, 0.3655913978494624, 0.49397590361445
---------------------
Expected Values
[0, 1.3888888888888888, 1.3684210526315788, 1.096774193548387, 1.4819277108433735,
---- 2 Pointers ----
Percentages
[0.5621890547263682, 0.5, 0.4166666666666667, 0.3157894736842105, 0.25, 0.33333333
---------------------
Expected Values
[1.1243781094527363, 1.0, 0.8333333333333334, 0.631578947368421, 0.5, 0.6666666666
```



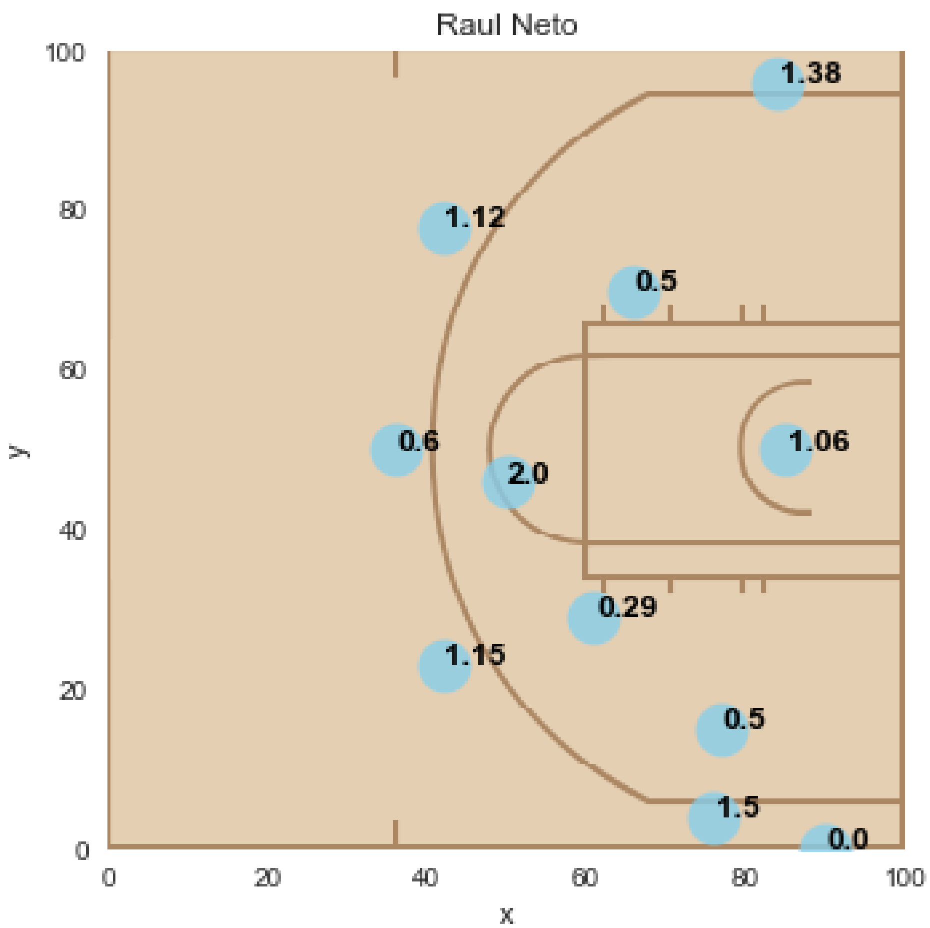

```
--------------------------------------------------------------
Joe Johnson
---------------------
---- 3 Pointers ----
Percentages
[0, 0.3076923076923077, 0.4, 0.35714285714285715, 0.21739130434782608, 0.1428571428
---------------------
Expected Values
[0, 0.9230769230769231, 1.2000000000000002, 1.0714285714285714, 0.6521739130434783,
---- 2 Pointers ----
Percentages
[0.56, 0.5, 0.6363636363636364, 0.4583333333333333, 0.0, 0.38095238095238093]
---------------------
Expected Values
[1.12, 1.0, 1.2727272727272727, 0.9166666666666666, 0.0, 0.7619047619047619]
```



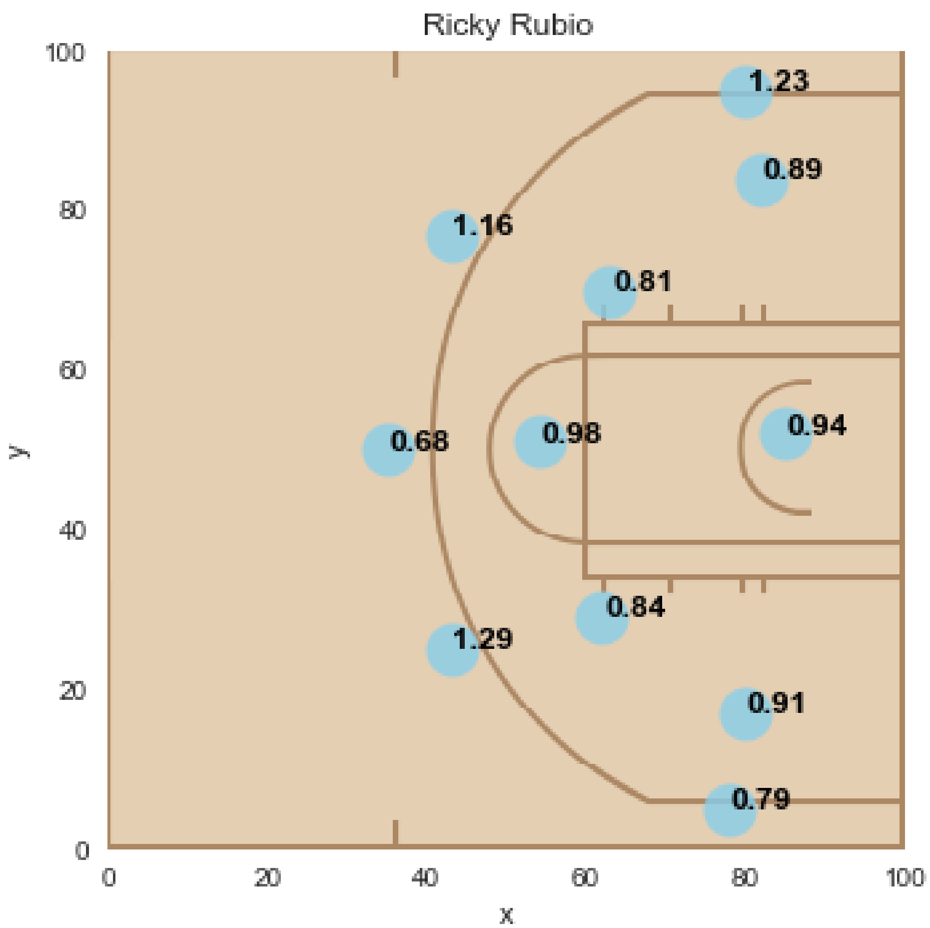

```
------------------------------------------------------------------
Jonas Jerebko
----------------------
---- 3 Pointers ----
Percentages
[0, 0.4883720930232558, 0.2857142857142857, 0.3333333333333333, 0.4772727272727273,
----------------------
Expected Values
[0, 1.4651162790697674, 0.8571428571428571, 1.0, 1.4318181818181819, 1.064516129032
---- 2 Pointers ----
Percentages
[0.5424836601307189, 0.14285714285714285, 0.4, 0.75, 0.36363636363636365, 0.2]
----------------------
Expected Values
[1.0849673202614378, 0.2857142857142857, 0.8, 1.5, 0.7272727272727273, 0.4]
```



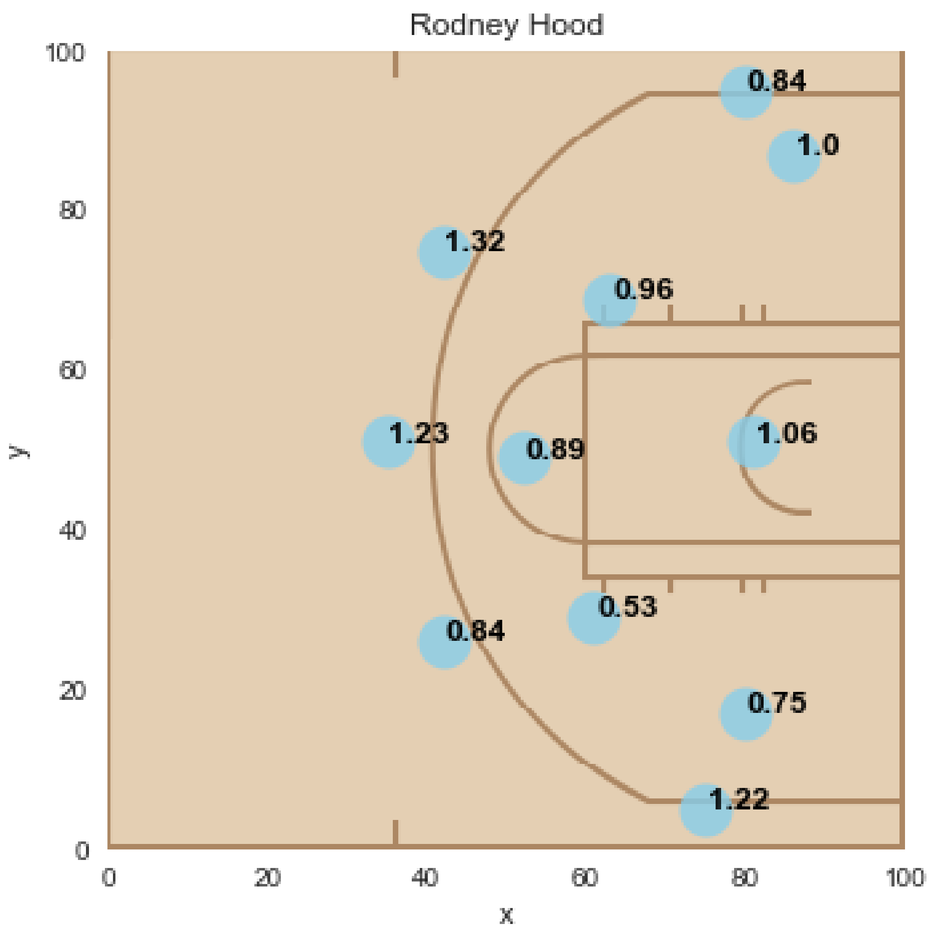

```
------------------------------------------------------------
Raul Neto
--------------------
---- 3 Pointers ----
Percentages
[0, 0.5, 0.2, 0.38461538461538464, 0.46153846153846156, 0.375]
--------------------
Expected Values
[0, 1.5, 0.6000000000000001, 1.153846153846154, 1.3846153846153846, 1.125]
---- 2 Pointers ----
Percentages
[0.5294117647058824, 0.25, 1.0, 0.14285714285714285, 0, 0.25]
--------------------
Expected Values
[1.0588235294117647, 0.5, 2.0, 0.2857142857142857, 0, 0.5]
```




```
----------------------------------------------------------------
Ricky Rubio
---------------------
---- 3 Pointers ----
Percentages
[0, 0.2619047619047619, 0.22727272727272727, 0.42857142857142855, 0.40909090909090909
---------------------
Expected Values
[0, 0.7857142857142858, 0.6818181818181818, 1.2857142857142856, 1.2272727272727273,
---- 2 Pointers ----
Percentages
[0.47107438016528924, 0.45454545454545453, 0.4883720930232558, 0.41935483870967744,
---------------------
Expected Values
[0.9421487603305785, 0.9090909090909091, 0.9767441860465116, 0.8387096774193549, 0.
```




```
----------------------------------------------------------------
Rodney Hood
---------------------
---- 3 Pointers ----
Percentages
[0, 0.4074074074074074, 0.4098360655737705, 0.27906976744186046, 0.28125, 0.4395604
---------------------
Expected Values
[0, 1.2222222222222222, 1.2295081967213115, 0.8372093023255813, 0.84375, 1.318681318
---- 2 Pointers ----
Percentages
[0.5289855072463768, 0.375, 0.4444444444444444, 0.2653061224489796, 0.5, 0.48]
---------------------
Expected Values
[1.0579710144927537, 0.75, 0.8888888888888888, 0.5306122448979592, 1.0, 0.96]
```

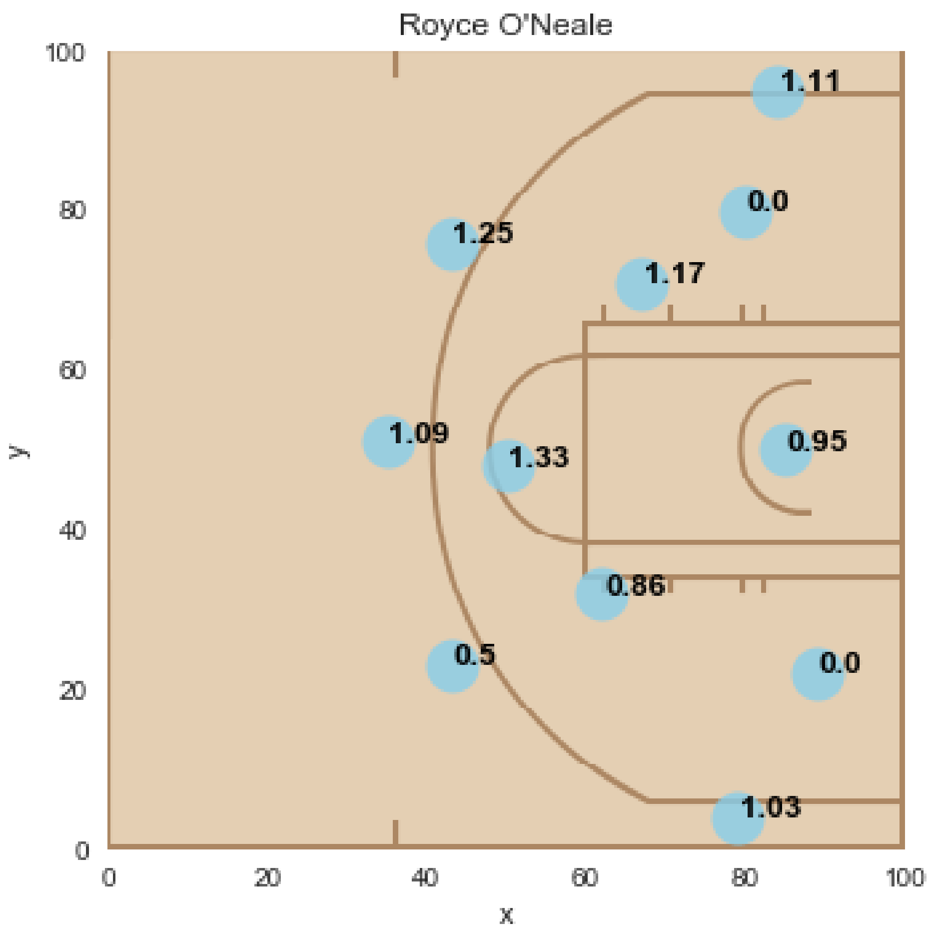


Royce O'Neale

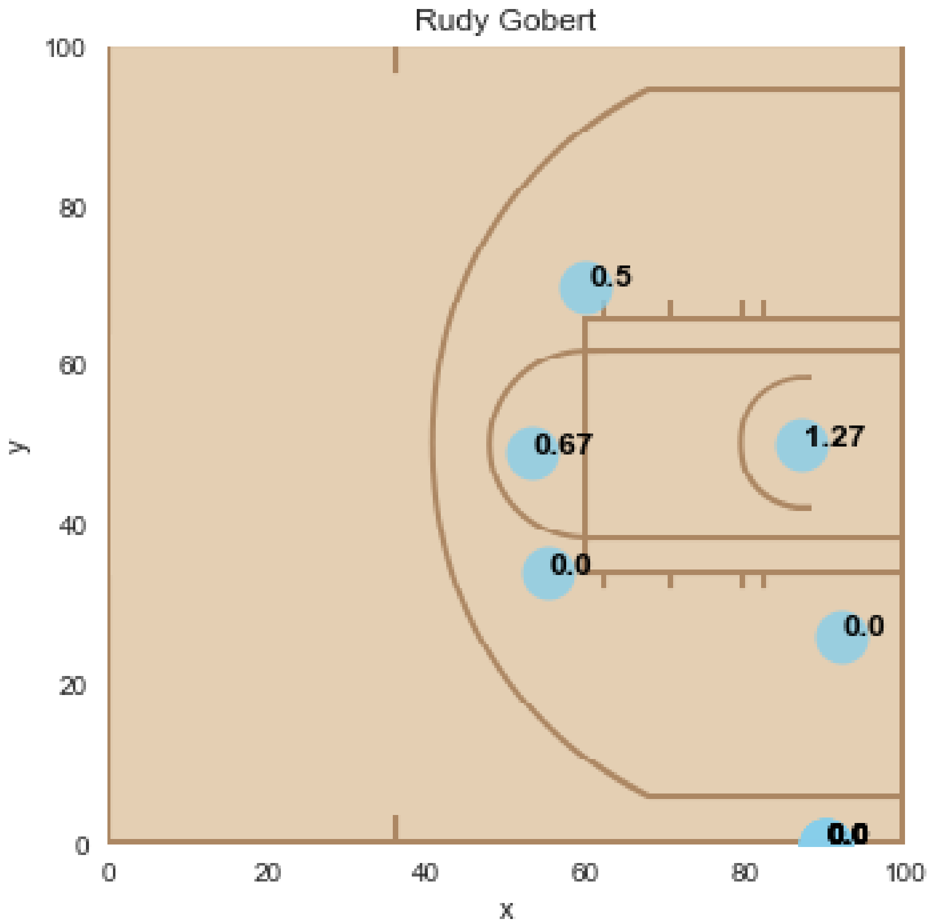
---- 3 Pointers ----
Percentages
[0, 0.34285714285714286, 0.36363636363636365, 0.16666666666666666, 0.368421052631578

Expected Values
[0, 1.0285714285714285, 1.0909090909090908, 0.5, 1.1052631578947367, 1.25]
---- 2 Pointers ----
Percentages
[0.4726027397260274, 0, 0.6666666666666666, 0.42857142857142855, 0.0, 0.58333333333

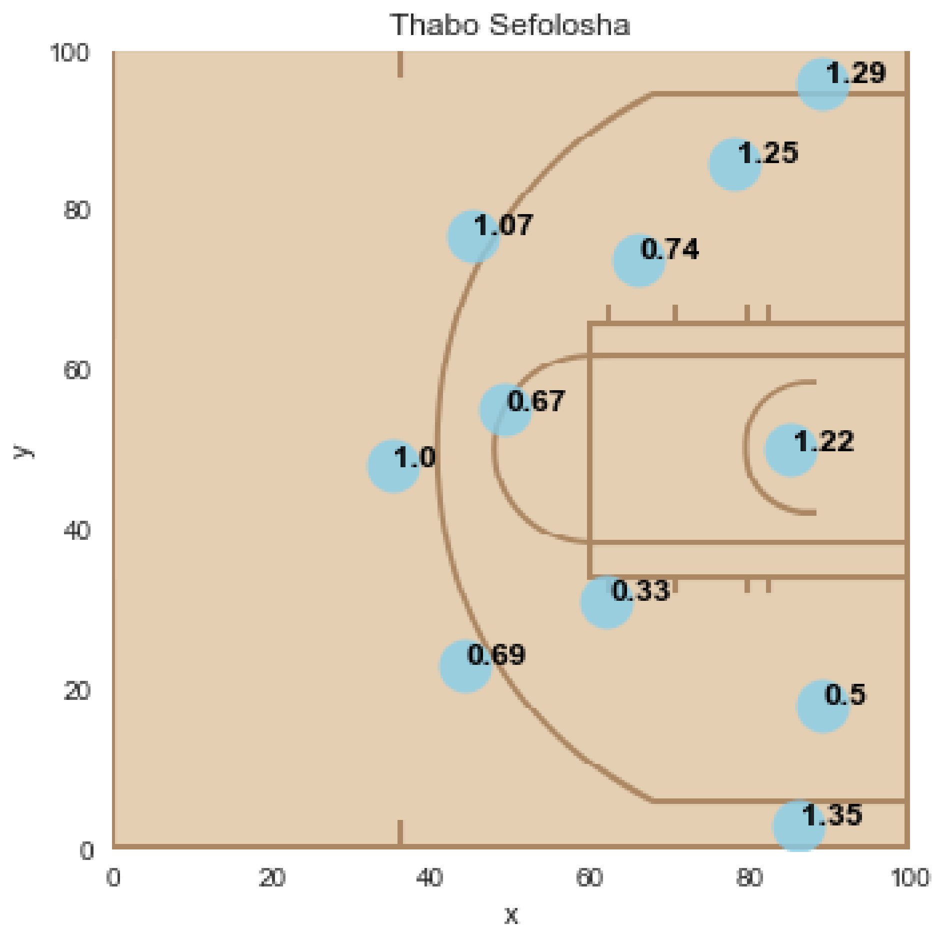
Expected Values
[0.9452054794520548, 0, 1.3333333333333333, 0.8571428571428571, 0.0, 1.16666666666




```
----------------------------------------------------------------
Rudy Gobert
---------------------
---- 3 Pointers ----
Percentages
[0, 0, 0, 0, 0, 0]
---------------------
Expected Values
[0, 0, 0, 0, 0, 0]
---- 2 Pointers ----
Percentages
[0.636150234741784, 0, 0.3333333333333333, 0, 0, 0.25]
---------------------
Expected Values
[1.272300469483568, 0, 0.6666666666666666, 0, 0, 0.5]
```




```
-----------------------------------------------------------------
Thabo Sefolosha
----------------------
---- 3 Pointers ----
Percentages
[0, 0.45, 0.3333333333333333, 0.23076923076923078, 0.42857142857142855, 0.35714285
----------------------
Expected Values
[0, 1.35, 1.0, 0.6923076923076923, 1.2857142857142856, 1.0714285714285714]
---- 2 Pointers ----
Percentages
[0.6120689655172413, 0.25, 0.3333333333333333, 0.16666666666666666, 0.625, 0.368421
----------------------
Expected Values
[1.2241379310344827, 0.5, 0.6666666666666666, 0.3333333333333333, 1.25, 0.73684210
```



2.2 Statistical Significance

At low sampling rates, a given shot could have a high expected value purely by chance. For example, 25% of the time, a 50% shooter will make two shots in a row. If those two shots are the only sample we have, we might conclude that the shooter is a 100% shooter. For this reason, it is important to determine if results are statistically significant, or if they most likely occured by chance. Hypothesis testing is a good way to measure statistical significance. It involves formulating a null hypothesis that you would like to disprove, calculating the probability of a given result occurring if you were to assume that the null hypothesis is true, and rejecting the null hypothesis if that probability is sufficiently low.

2.2.1 Hypothesis Testing:

Player p-test: - Take as the null hypothesis that the shooting percentage for a given shot is less than or equal to the average percentage for that player for threes or twos.

Team p-test: - Take as the null hypothesis that the shooting percentage for a given shot is less than or equal to the average percentage for the whole team for threes or twos.

Location p-test: - Take as the null hypothesis that the shooting percentage for a given shot is less than or equal to the average percentage for the whole team from that location.

```
In [28]: shots_array = np.array([["shooter", "three", "cluster", 'num_shots', "num_
                                  "Player_p", "Team_p", "Location_p"]])
         threemask = ShotsPD["ThreePt"] == 1
         twomask = ShotsPD["ThreePt"] == 0
         threePD = ShotsPD[threemask]
         twoPD = ShotsPD[twomask]

         for shooter in threePD["shooter_name"].unique():
             mask = threePD["shooter_name"] == shooter
             ShooterShots = threePD[mask]
             for cluster in ShooterShots["LocationCluster"].unique():
                 mask2 = ShooterShots["LocationCluster"] == cluster
                 ClusterShots = ShooterShots[mask2]
                 num_shots =  len(ClusterShots)
                 mask_made =ClusterShots["made/missed"] == 1
                 num_makes = len(ClusterShots[mask_made])
                 pct = num_makes/num_shots
                 expectedval = pct*3
                 # player p-value
                 avg_pct = len(ShooterShots[ShooterShots["made/missed"]==1])/len(Sh
                 # total 3 pt avg for this player
                 mu = num_shots*avg_pct  # mean number of makes for this cluster as
                 sigma = sc.sqrt(mu*(1-avg_pct))  # standard deviation?
                 player_p = 1-norm.cdf(num_makes, loc=mu, scale=sigma)
                 # team p-value
                 avg_pct = len(threePD[threePD["made/missed"]==1])/len(threePD)   #
                 mu = num_shots*avg_pct
                 sigma = sc.sqrt(mu*(1-avg_pct))
                 team_p = 1-norm.cdf(num_makes, loc=mu, scale=sigma)
                 # location p-value
                 teamClusterPD = threePD[threePD["LocationCluster"] == cluster]
                 avg_pct = len(teamClusterPD[teamClusterPD["made/missed"]==1])/len(
                 # team 3 pt avg from this cluster
                 mu = num_shots*avg_pct
                 sigma = sc.sqrt(mu*(1-avg_pct))
                 location_p = 1-norm.cdf(num_makes, loc=mu, scale=sigma)

                 shots_array = np.append(shots_array, [[shooter, 1, cluster, num_sh
                                                        num_makes, pct, expectedval
                                                        team_p, location_p]], axis=

         for shooter in twoPD["shooter_name"].unique():
             mask = twoPD["shooter_name"] == shooter
             ShooterShots = twoPD[mask]
             for cluster in ShooterShots["LocationCluster"].unique():
```

```
                mask2 = ShooterShots["LocationCluster"] == cluster
                ClusterShots = ShooterShots[mask2]
                num_shots =  len(ClusterShots)
                mask_made =ClusterShots["made/missed"] == 1
                num_makes = len(ClusterShots[mask_made])
                pct = num_makes/num_shots
                expectedval = pct*2

                avg_pct = len(ShooterShots[ShooterShots["made/missed"]==1])/len(Sh
                #total 3 pt avg for this player
                mu = num_shots*avg_pct  # mean number of makes for this cluster
                sigma = sc.sqrt(mu*(1-avg_pct))  # standard deviation?
                player_p = 1-norm.cdf(num_makes, loc=mu, scale=sigma)
                # team p-value
                avg_pct = len(twoPD[twoPD["made/missed"]==1])/len(twoPD)  # total
                mu = num_shots*avg_pct
                sigma = sc.sqrt(mu*(1-avg_pct))
                team_p = 1-norm.cdf(num_makes, loc=mu, scale=sigma)
                # location p-value
                teamClusterPD = twoPD[twoPD["LocationCluster"] == cluster]
                avg_pct = len(teamClusterPD[teamClusterPD["made/missed"]==1])/len(
                # team 3 pt avg from this cluster
                mu = num_shots*avg_pct
                sigma = sc.sqrt(mu*(1-avg_pct))
                location_p = 1-norm.cdf(num_makes, loc=mu, scale=sigma)

                shots_array = np.append(shots_array, [[shooter, 0, cluster, num_sh
                                                       num_makes, pct, expectedval
                                                       team_p, location_p]], axis=
```

```
/Users/averysmith/anaconda/lib/python3.6/site-packages/scipy/stats/_distn_infrastru
  x = np.asarray((x - loc)/scale, dtype=dtyp)
```

```
In [29]: NewLocationPD = pd.DataFrame(data=shots_array[1:],
                                      columns=shots_array[0])
```

```
In [30]: NewLocationPD["three"] = NewLocationPD["three"].map(int)
         NewLocationPD["cluster"] = NewLocationPD["cluster"].map(int)
         NewLocationPD["num_shots"] = NewLocationPD["num_shots"].map(int)
         NewLocationPD["num_makes"] = NewLocationPD["num_makes"].map(int)
         NewLocationPD["pct"] = NewLocationPD["pct"].map(float)
         NewLocationPD["expectedval"] = NewLocationPD["expectedval"].map(float)
         NewLocationPD["Player_p"] = NewLocationPD["Player_p"].map(float)
         NewLocationPD["Team_p"] = NewLocationPD["Team_p"].map(float)
         NewLocationPD["Location_p"] = NewLocationPD["Location_p"].map(float)
         print(NewLocationPD.dtypes, '\n')
```

```
shooter          object
three             int64
```

```
cluster          int64
num_shots        int64
num_makes        int64
pct            float64
expectedval    float64
Player_p       float64
Team_p         float64
Location_p     float64
dtype: object
```

```
In [31]: # print the 40 best expected value shots()
         NewLocationPD.sort_values(by=["expectedval"], ascending=False).head(40)
```

```
Out[31]:              shooter  three  cluster  num_shots  num_makes       pct  \
         120       Raul Neto      0        2          2          2  1.000000
         68      Rudy Gobert      0        3          1          1  1.000000
         127   Royce O'Neale      0        1          1          1  1.000000
         56      Jae Crowder      1        1         24         14  0.583333
         15  Donovan Mitchell      1        4         46         25  0.543478
         43        Raul Neto      1        1          6          3  0.500000
         133   Jonas Jerebko      0        3          4          3  0.750000
         2       Joe Ingles      1        4         83         41  0.493976
         53    Jonas Jerebko      1        1         43         21  0.488372
         51    Jonas Jerebko      1        4         44         21  0.477273
         76  Donovan Mitchell      0        1         10          7  0.700000
         1       Joe Ingles      1        1        108         50  0.462963
         41        Raul Neto      1        4         13          6  0.461538
         4       Joe Ingles      1        2         57         26  0.456140
         31  Thabo Sefolosha      1        1         20          9  0.450000
         60   Derrick Favors      0        0        479        320  0.668058
         125   Royce O'Neale      0        2          3          2  0.666667
         10     Rodney Hood      1        5         91         40  0.439560
         3       Joe Ingles      1        5         98         43  0.438776
         27     Ricky Rubio      1        3         35         15  0.428571
         30  Thabo Sefolosha      1        4         28         12  0.428571
         85      Joe Johnson      0        2         11          7  0.636364
         66      Rudy Gobert      0        0        426        271  0.636150
         48    Royce O'Neale      1        5         12          5  0.416667
         104 Thabo Sefolosha      0        4          8          5  0.625000
         13     Rodney Hood      1        2         61         25  0.409836
         24     Ricky Rubio      1        4         66         27  0.409091
         100 Thabo Sefolosha      0        0        116         71  0.612069
         12     Rodney Hood      1        1         27         11  0.407407
         6       Joe Johnson      1        2          5          2  0.400000
         126   Royce O'Neale      0        5         12          7  0.583333
         37      Alec Burks      1        1         18          7  0.388889
```

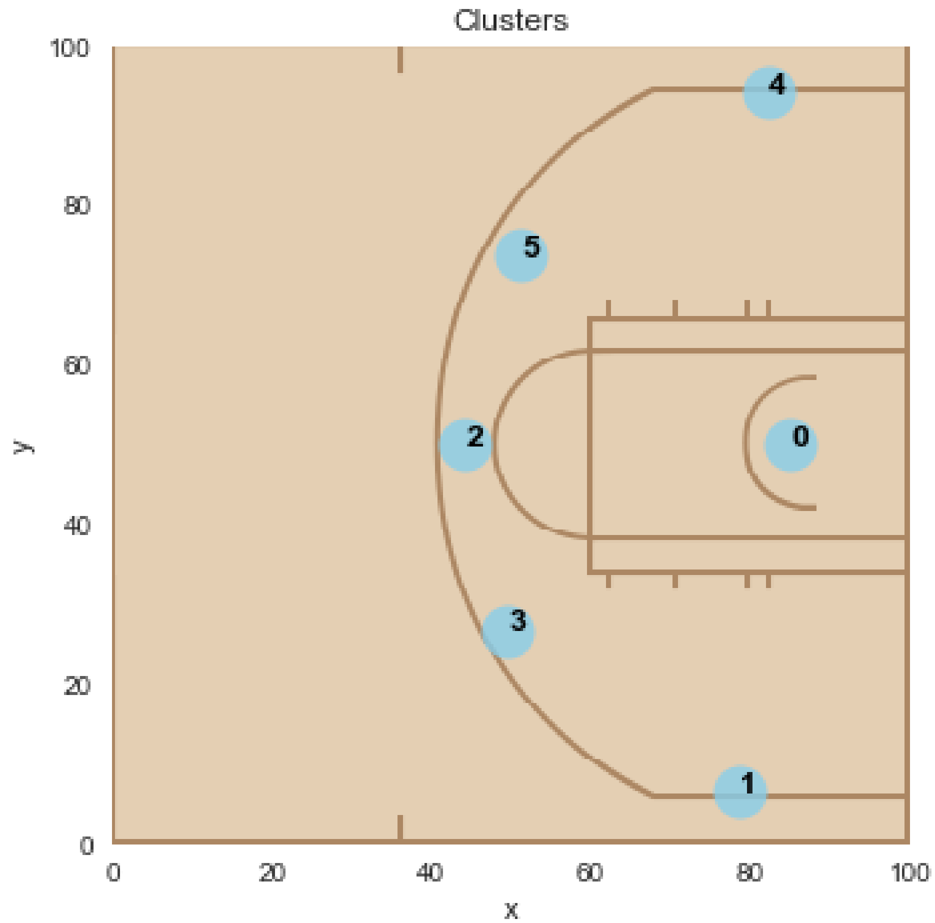
26	Ricky Rubio	1	5	85	33	0.388235
42	Raul Neto	1	3	13	5	0.384615
35	Alec Burks	1	5	34	13	0.382353
38	Alec Burks	1	4	16	6	0.375000
40	Raul Neto	1	5	8	3	0.375000
106	Joe Ingles	0	0	201	113	0.562189
135	Jae Crowder	0	0	89	50	0.561798
83	Joe Johnson	0	0	75	42	0.560000

	expectedval	Player_p	Team_p	Location_p
120	2.000000	0.070967	8.451872e-02	0.055820
68	2.000000	0.219013	1.654043e-01	0.085393
127	2.000000	0.148750	1.654043e-01	0.121673
56	1.750000	0.002547	1.302116e-02	0.033736
15	1.630435	0.001599	5.874529e-03	0.022075
43	1.500000	0.308538	2.455023e-01	0.309358
133	1.500000	0.166598	1.724358e-01	0.045564
2	1.481928	0.169766	7.192182e-03	0.037354
53	1.465116	0.170106	4.596406e-02	0.119662
51	1.431818	0.207412	6.035049e-02	0.142014
76	1.400000	0.099649	1.195645e-01	0.038416
1	1.388889	0.329792	1.690596e-02	0.092435
41	1.384615	0.325306	2.340261e-01	0.320453
4	1.368421	0.414382	7.567107e-02	0.055972
31	1.350000	0.267932	2.139309e-01	0.325538
60	1.336117	0.000679	7.471357e-12	0.000003
125	1.333333	0.258235	2.983175e-01	0.216022
10	1.318681	0.128747	6.886178e-02	0.050148
3	1.316327	0.524938	6.372811e-02	0.045587
27	1.285714	0.174564	2.160885e-01	0.073353
30	1.285714	0.308814	2.411689e-01	0.371386
85	1.272727	0.195294	2.082976e-01	0.096441
66	1.272300	0.308772	2.249937e-07	0.001502
48	1.250000	0.270146	3.541097e-01	0.333140
104	1.250000	0.329155	2.648511e-01	0.052477
13	1.229508	0.326626	2.317928e-01	0.187069
24	1.227273	0.169904	2.266797e-01	0.428352
100	1.224138	0.080125	1.723821e-02	0.152624
12	1.222222	0.392461	3.222499e-01	0.470582
6	1.200000	0.253123	4.348063e-01	0.417421
126	1.166667	0.235837	3.152880e-01	0.096841
37	1.166667	0.292241	4.154618e-01	0.539860
26	1.164706	0.247965	3.258260e-01	0.274026
42	1.153846	0.545075	4.406020e-01	0.293500
35	1.147059	0.251295	4.151666e-01	0.378921
38	1.125000	0.345582	4.657783e-01	0.575210
40	1.125000	0.557383	4.757867e-01	0.457732
106	1.124378	0.053589	8.558441e-02	0.530618

```
135     1.123596  0.019917  1.832057e-01    0.523351
83      1.120000  0.179038  2.124386e-01    0.533935
```

In [32]:
```
# identify the mean location for each of the six clusters identified throu
# (ignoring two and three point differences)
left_coordinates = np.array([])
top_coordinates = np.array([])
clusters = np.arange(0, 6)
for cluster in clusters:
    cluster_mask = ShotsPD['LocationCluster'] == cluster
    cluster_df = ShotsPD[cluster_mask]
    left_coord = cluster_df["left"].mean()
    top_coord = cluster_df["top"].mean()
    left_coordinates = np.append(left_coordinates, left_coord)
    top_coordinates = np.append(top_coordinates, top_coord)
```

In [33]:
```
# plot the mean location of each cluster on the court for reference purpos
import seaborn as sns

df = pd.DataFrame({
'x': left_coordinates,
'y': top_coordinates,
'group': clusters
})

p1=sns.regplot(data=df, x="x", y="y", fit_reg=False, marker="o", color="sk
for line in range(0,df.shape[0]):
    p1.text(df.x[line]+0.2, df.y[line], df.group[line], horizontalalignmen
            size='medium', color='black', weight='semibold')

plt.title('Clusters')
plt.imshow(img, zorder=0, extent=[0, 100, 0, 100.0])
plt.grid(False)
plt.show()
```



We choose a threshold for significance of $p < .05$ in order to reject the null hypothesis.

For each p-test we used, we filter the results for only the statistically significant shots.

The way to interpret these p-values is: if that location was not better than average (for the player or team as a whole), then the p-value represents the probability that the player would still, by coincidence, shoot as well from that location as they did.

Player p-test

```
In [34]: statistically_significant_mask = NewLocationPD["Player_p"] < .05
         SignificantPD = NewLocationPD[statistically_significant_mask]
         SignificantPD.sort_values(by=["expectedval"], ascending=False)
```

```
Out[34]:                shooter  three  cluster  num_shots  num_makes       pct  \
         56         Jae Crowder      1        1         24         14  0.583333
         15    Donovan Mitchell      1        4         46         25  0.543478
         60      Derrick Favors      0        0        479        320  0.668058
         135        Jae Crowder      0        0         89         50  0.561798
         71    Donovan Mitchell      0        0        599        321  0.535893
```

```
     expectedval  Player_p        Team_p  Location_p
56      1.750000  0.002547  1.302116e-02    0.033736
15      1.630435  0.001599  5.874529e-03    0.022075
60      1.336117  0.000679  7.471357e-12    0.000003
135     1.123596  0.019917  1.832057e-01    0.523351
71      1.071786  0.028644  1.412531e-01    0.923749
```

This indicates that Jae Crowder shoots significantly better from the right corner than he does from any other three point location, and Donovan Mitchell shoots significantly better from the left corner than he does from any other three point location. This information could help coaches modify the offense so that Crowder and Mitchell spend more time on the right and left side respectively.

Unsurprisingly, we found that Derrick Favors, Jae Crowder, and Donovan Mitchell all shoot better from the post than they do from any other two-point position. That is unsurprising because the post is much closer to the basket than other locations, and is expected to have a better shooting percentage.

```
In [35]: statistically_significant_mask = NewLocationPD["Team_p"] < .05
         TeamSignificantPD = NewLocationPD[statistically_significant_mask]
         TeamSignificantPD.sort_values(by=["expectedval"], ascending=False)
```

```
Out[35]:             shooter  three  cluster  num_shots  num_makes       pct  \
         56      Jae Crowder      1        1         24         14  0.583333
         15  Donovan Mitchell     1        4         46         25  0.543478
         2        Joe Ingles      1        4         83         41  0.493976
         53    Jonas Jerebko      1        1         43         21  0.488372
         1        Joe Ingles      1        1        108         50  0.462963
         60   Derrick Favors      0        0        479        320  0.668058
         66      Rudy Gobert      0        0        426        271  0.636150
         100  Thabo Sefolosha     0        0        116         71  0.612069

              expectedval  Player_p        Team_p  Location_p
         56      1.750000  0.002547  1.302116e-02    0.033736
         15      1.630435  0.001599  5.874529e-03    0.022075
         2       1.481928  0.169766  7.192182e-03    0.037354
         53      1.465116  0.170106  4.596406e-02    0.119662
         1       1.388889  0.329792  1.690596e-02    0.092435
         60      1.336117  0.000679  7.471357e-12    0.000003
         66      1.272300  0.308772  2.249937e-07    0.001502
         100     1.224138  0.080125  1.723821e-02    0.152624
```

This indicates that the three point shots noted above for Jae Crowder and Donovan Mitchell are also significantly better than the team average for three point shots. Joe Ingles (an excellent three point shooter) also shoots significantly better from both corners than the team three point average (although he does not shoot significantly better from the corners than he does from the other three point spots because his overall three point shooting percentage is so high). Jonas Jerebko also shoots significantly better from the right corner than the team average for three pointers.

For two pointers, we now find that Derrick Favors, Rudy Gobert, and Thabo Sefolosha all shoot significantly better from the post than the team average for two pointers. The p-values for Derrick

Favors and Rudy Gobert are extremely small, partially due to the large number of shots taken by both players from that location (>400). Rudy Gobert likely didn't show up on the previous list because such a high percentage of his shots are taken from the post that his two point percentage is effectively the same as his shooting percentage from the post.

```
In [36]: statistically_significant_mask = NewLocationPD["Location_p"] < .05
         LocationSignificantPD = NewLocationPD[statistically_significant_mask]
         LocationSignificantPD.sort_values(by=["expectedval"], ascending=False)
```

```
Out[36]:              shooter  three  cluster  num_shots  num_makes       pct  \
         56       Jae Crowder      1        1         24         14  0.583333
         15   Donovan Mitchell      1        4         46         25  0.543478
         133     Jonas Jerebko      0        3          4          3  0.750000
         2         Joe Ingles      1        4         83         41  0.493976
         76   Donovan Mitchell      0        1         10          7  0.700000
         60     Derrick Favors      0        0        479        320  0.668058
         3         Joe Ingles      1        5         98         43  0.438776
         66        Rudy Gobert      0        0        426        271  0.636150

              expectedval  Player_p        Team_p  Location_p
         56      1.750000  0.002547  1.302116e-02    0.033736
         15      1.630435  0.001599  5.874529e-03    0.022075
         133     1.500000  0.166598  1.724358e-01    0.045564
         2       1.481928  0.169766  7.192182e-03    0.037354
         76      1.400000  0.099649  1.195645e-01    0.038416
         60      1.336117  0.000679  7.471357e-12    0.000003
         3       1.316327  0.524938  6.372811e-02    0.045587
         66      1.272300  0.308772  2.249937e-07    0.001502
```

The last hypothesis tested was whether certain players shot much better than the team average for that specific location. Apart from identifying some of the same shots as above, this test would be expected to ffind some players who shoot exceptionally well from more difficult spots.

Jonas Jerebko shooting two pointers from the right wing, Donovan Mitchell shooting two pointers from the right corner, Joe Ingles shooting from the top of the three-point arc, and Rodney Hood shooting three pointers from the left wing would all appear to fit in this category, although each falls just at the limits of statistical significance ($.4 < p < .5$).

Conclusions This information can help coaches and decision-makers design offensive sets and plays, and can help players with shot-selection.
For example, for the first p-test, we would advise Donovan Mitchell to take more three point shots from the left corner, and Jae Crowder to take more from the right corner. Coaches could design their offense so both players spend more time on those sides. We would also advise Donovan Mitchell to drive all the way to the basket when taking a two-point shot.

For the second p-test, we would advise the coaches to develop their offense to maximize corner threes by Crowder, Mitchell, Ingles, and Jerebko, and post shots by Favors and Gobert.

2.3 Some additional Analysis

2.3.1 Home and Away Differences

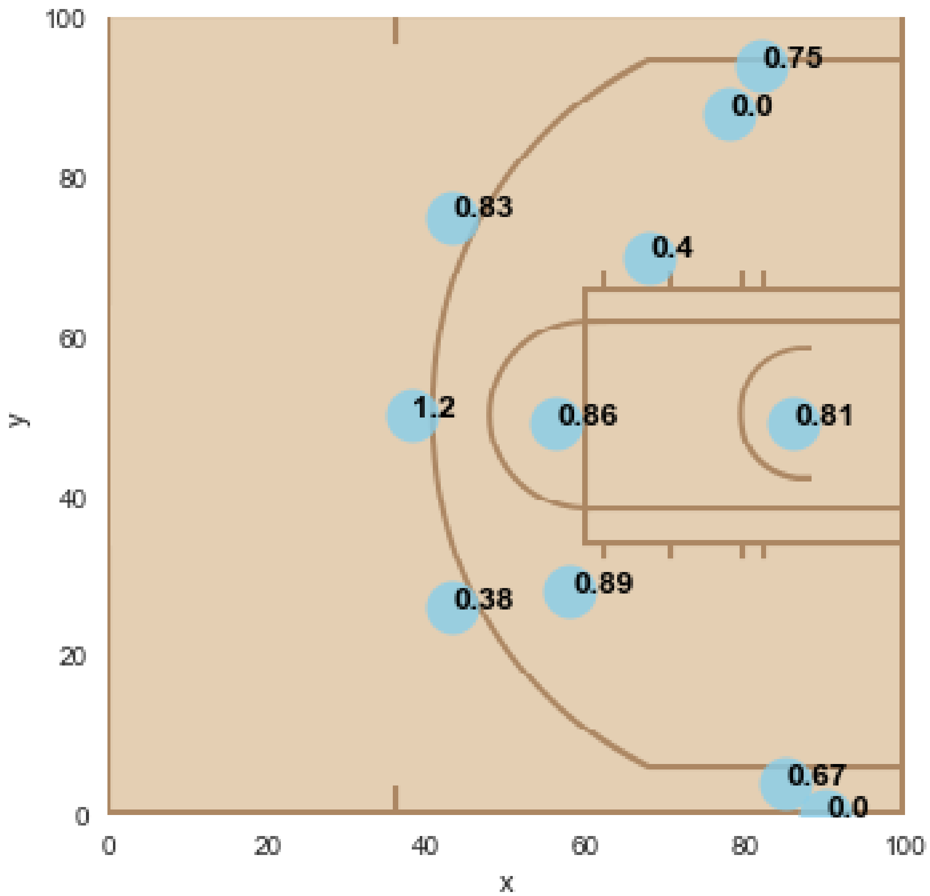
- We wanted to explore how the expected values for each player differ in home games vs away games. Once agian, we used simple masking to compare how players shoot at home and away.

```
In [38]: ## HOME

         # 3 pointers
         PlayerIDs = np.unique(ShotsPD['shooter'])
         PlayerNames = np.unique(ShotsPD['shooter_name'])
         NumOPlayers = len(PlayerNames)
         for Name in range(0,NumOPlayers):
             PercMadeDif3 = []
             NumShots = []
             NumMade = []
             ExpectedValue3 =[]
             AvLeft3 = []
             AvTop3 =[]
             PtVal3 = 3
             PtVal2 = 2
             PercMadeDif2 = []
             NumShots3 = []
             NumShots2 = []
             NumMade3 = []
             NumMade2 = []
             ExpectedValue2 =[]
             ExpectedValueRound = []

             AvLeft2 = []
             AvTop2 =[]

             for i in range(0,6):
                 Location = ShotsPD[(ShotsPD['LocationCluster']==i) & (ShotsPD['Thr
                                    & ( ShotsPD['shooter_name'] == PlayerNames[Name
                 NumShots3.append(len(Location['made/missed']))
                 NumMade3.append(len(Location[Location['made/missed']==1]))
                 PercMade3 = 0
                 if NumShots3[i] > 1:
                     PercMade3 = NumMade3[i] / NumShots3[i]
                     PercMadeDif3.append(PercMade3)
                 else:
                     PercMadeDif3.append(0)

                 ExpectedValue3.append(PercMadeDif3[i]*PtVal3)

                 AvLeft3.append(np.mean(Location['left']))
```

```
        AvTop3.append(np.mean(Location['top']))




        Location = ShotsPD[(ShotsPD['LocationCluster']==i) & (ShotsPD['Thr
                           & ( ShotsPD['shooter_name'] == PlayerNames[Name
        NumShots2.append(len(Location['made/missed']))
        NumMade2.append(len(Location[Location['made/missed']==1]))
        PercMade2 = 0
        if NumShots2[i] > 1:
                PercMade2 = NumMade2[i] / NumShots2[i]
                PercMadeDif2.append(PercMade2)
        else:
                PercMadeDif2.append(0)
        ExpectedValue2.append(PercMadeDif2[i]*PtVal2)

        AvLeft2.append(np.mean(Location['left']))
        AvTop2.append(np.mean(Location['top']))

    print('-------------------------------------------------------------------
    print(PlayerNames[Name])
    print('---------------------')
    print('---- 3 Pointers ----')
    print('Percentages')
    print(PercMadeDif3)
    print('---------------------')
    print('Expected Values')
    print(ExpectedValue3)



    print('---- 2 Pointers ----')
    print('Percentages')
    print(PercMadeDif2)
    print('---------------------')
    print('Expected Values')
    print(ExpectedValue2)

    for mm in range(0,len(ExpectedValue3)):
        if ExpectedValue3[mm] == 0:
            Extra = mm
    del ExpectedValue3[Extra]

    xx = np.isnan(AvLeft3)
    for mm in range(0, len(AvLeft3)):
        if  xx[mm] == True:
```

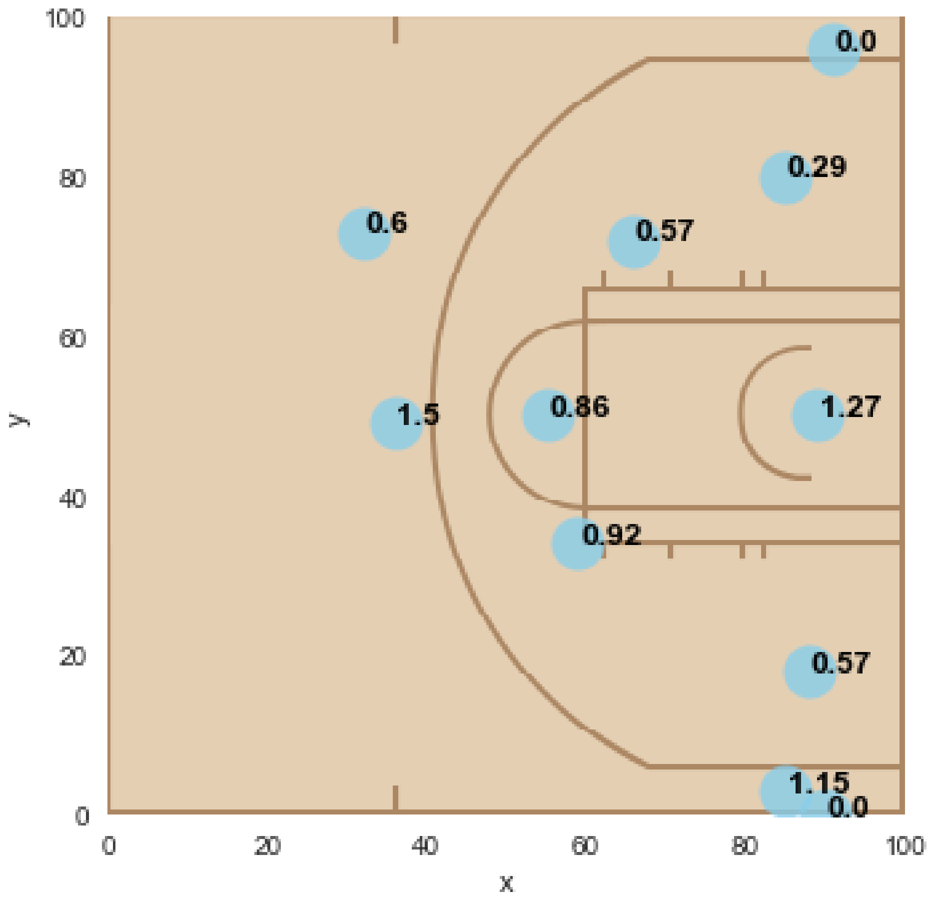
```
                DeleteVar = mm

        del AvLeft3[DeleteVar]
        del AvTop3[DeleteVar]

        ExpectedValue = ExpectedValue3 + ExpectedValue2
        ExpectedValueRound = np.round_(ExpectedValue, decimals=2)

        AvLefts = AvLeft3 + AvLeft2
        AvTops = AvTop3 + AvTop2

        for u in range(0,len(AvLefts)):
            if math.isnan(AvLefts[u]):
                AvLefts[u]=90
            if math.isnan(AvTops[u]):
                AvTops[u]= 0


        x = np.round(AvLefts,decimals=0)
        y = np.round(AvTops,decimals=0)
        valz = [str(ExpectedValueRound[0]),str(ExpectedValueRound[1]),str(Expe
                str(ExpectedValueRound[3]),str(ExpectedValueRound[4]),str(Expe
                str(ExpectedValueRound[6]),str(ExpectedValueRound[7]),str(Expe
                str(ExpectedValueRound[9]),str(ExpectedValueRound[10])]
        df = pd.DataFrame({
        'x': x,
        'y': y,
        'group': valz
        })

        p1=sns.regplot(data=df, x="x", y="y", fit_reg=False, marker="o", color
        for line in range(0,df.shape[0]):
            p1.text(df.x[line]+0.2, df.y[line], df.group[line], horizontalalig
                    size='medium', color='black', weight='semibold')
        plt.imshow(img, zorder=0, extent=[0, 100, 0, 100.0])
        plt.grid(False)

        plt.show()

---------------------------------------------------------------
Alec Burks
---------------------
---- 3 Pointers ----
Percentages
[0, 0.2222222222222222, 0.4, 0.125, 0.25, 0.2777777777777778]
---------------------
Expected Values
[0, 0.6666666666666666, 1.2000000000000002, 0.375, 0.75, 0.8333333333333334]
```

```
---- 2 Pointers ----
Percentages
[0.40540540540540543, 0, 0.42857142857142855, 0.4444444444444444, 0, 0.2]
---------------------
Expected Values
[0.8108108108108109, 0, 0.8571428571428571, 0.8888888888888888, 0, 0.4]
```



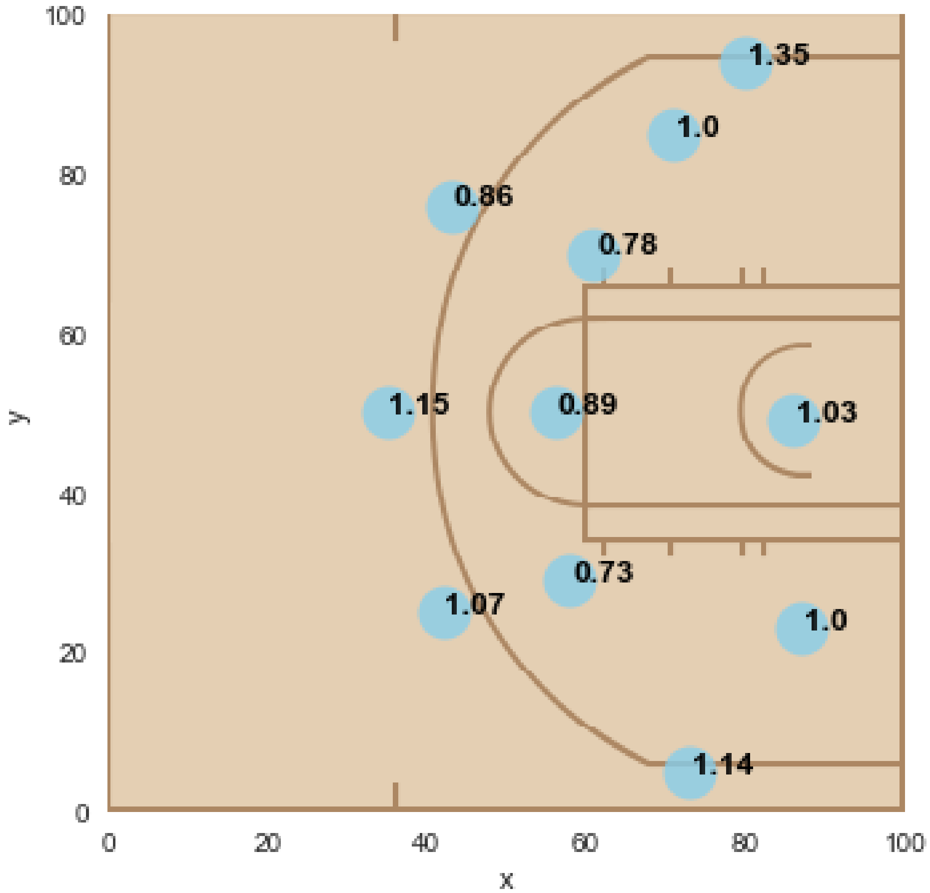

```
---------------------------------------------------------------
Derrick Favors
---------------------
---- 3 Pointers ----
Percentages
[0, 0.38461538461538464, 0.5, 0, 0.2, 0.0]
---------------------
Expected Values
[0, 1.153846153846154, 1.5, 0, 0.6000000000000001, 0.0]
---- 2 Pointers ----
Percentages
```

```
[0.6329113924050633, 0.2857142857142857, 0.42857142857142855, 0.46153846153846156, 
---------------------
Expected Values
[1.2658227848101267, 0.5714285714285714, 0.8571428571428571, 0.9230769230769231, 0.
```

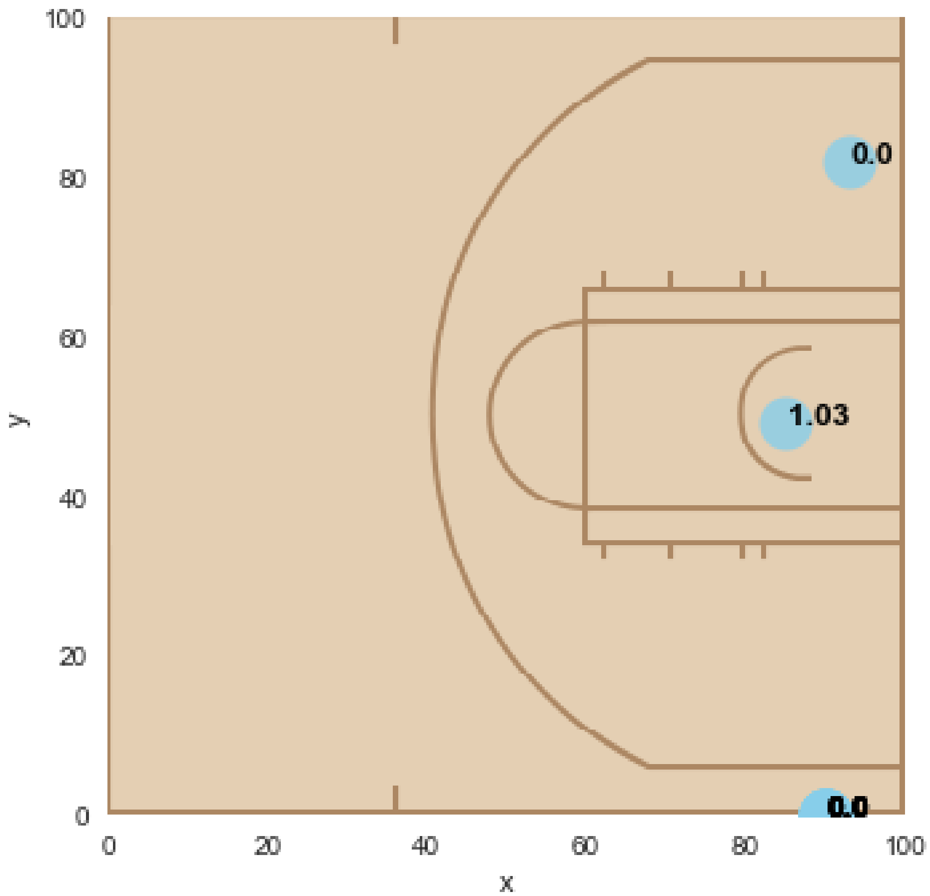



```
---------------------------------------------------------------
Donovan Mitchell
---------------------
---- 3 Pointers ----
Percentages
[0, 0.3793103448275862, 0.38181818181818183, 0.35526315789473684, 0.45, 0.287878787
---------------------
Expected Values
[0, 1.1379310344827585, 1.1454545454545455, 1.0657894736842106, 1.35, 0.863636363636
---- 2 Pointers ----
Percentages
[0.5144694533762058, 0.5, 0.4444444444444444, 0.36585365853658536, 0.5, 0.388888888
---------------------
```

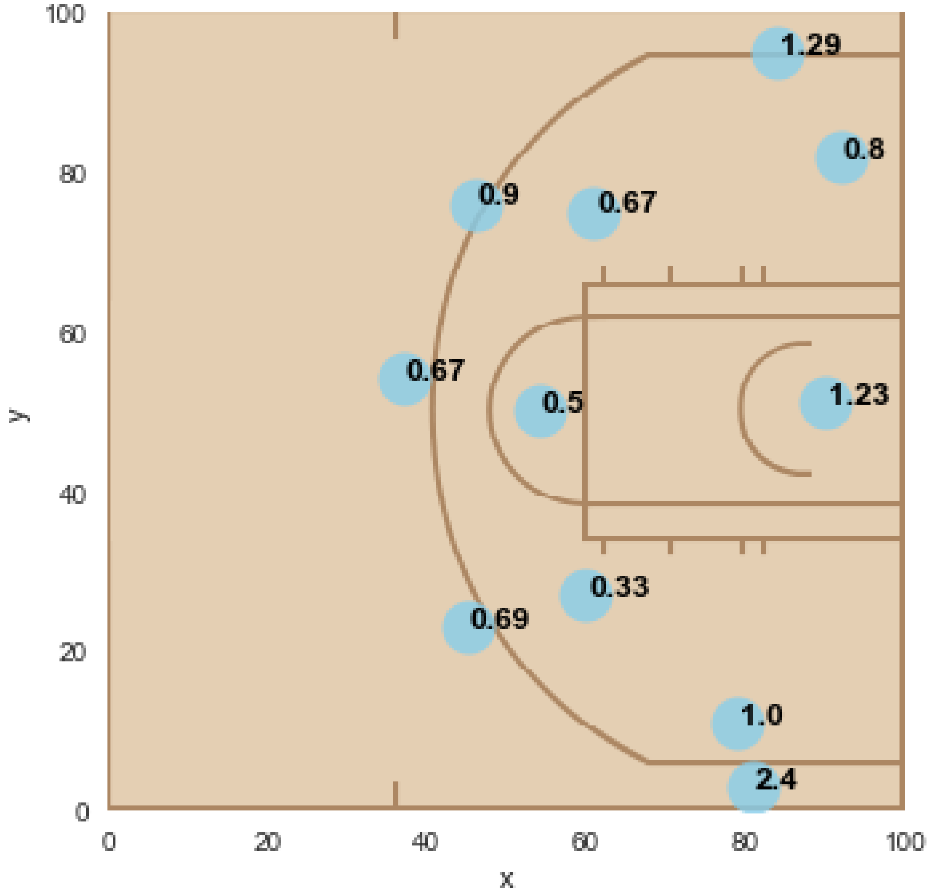
```
Expected Values
[1.0289389067524115, 1.0, 0.8888888888888888, 0.7317073170731707, 1.0, 0.7777777777
```



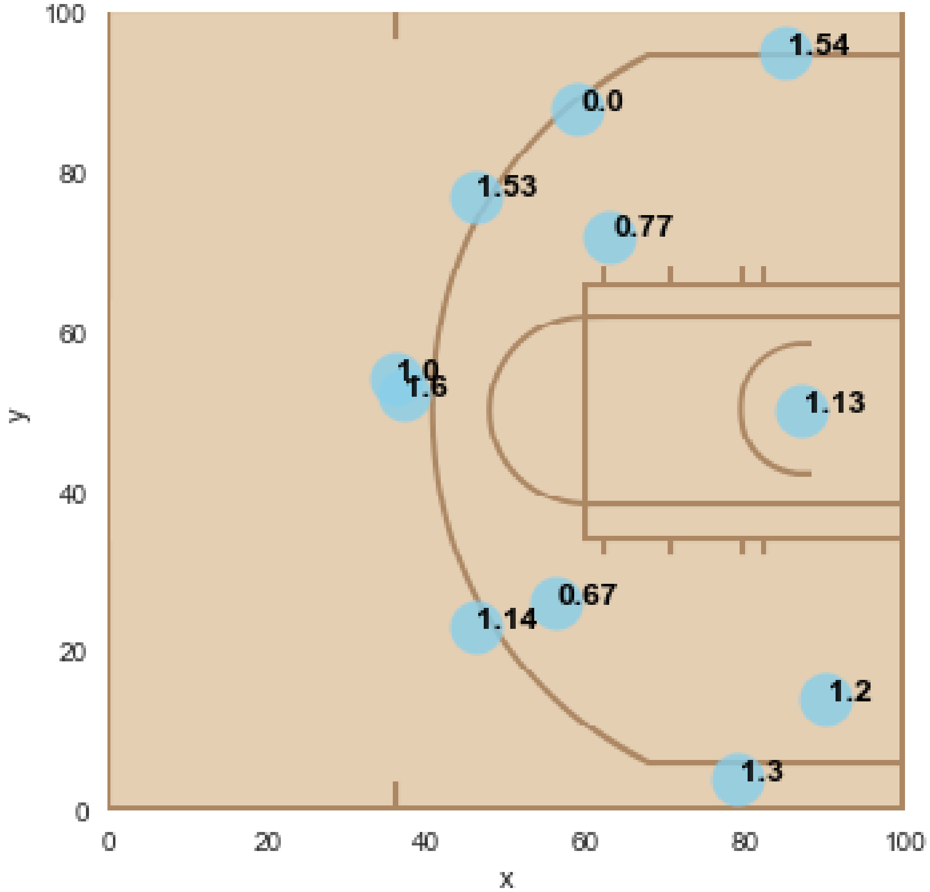

```
------------------------------------------------------------
Ekpe Udoh
---------------------
---- 3 Pointers ----
Percentages
[0, 0, 0, 0, 0, 0]
---------------------
Expected Values
[0, 0, 0, 0, 0, 0]
---- 2 Pointers ----
Percentages
[0.515625, 0, 0, 0, 0, 0]
---------------------
Expected Values
[1.03125, 0, 0, 0, 0, 0]
```



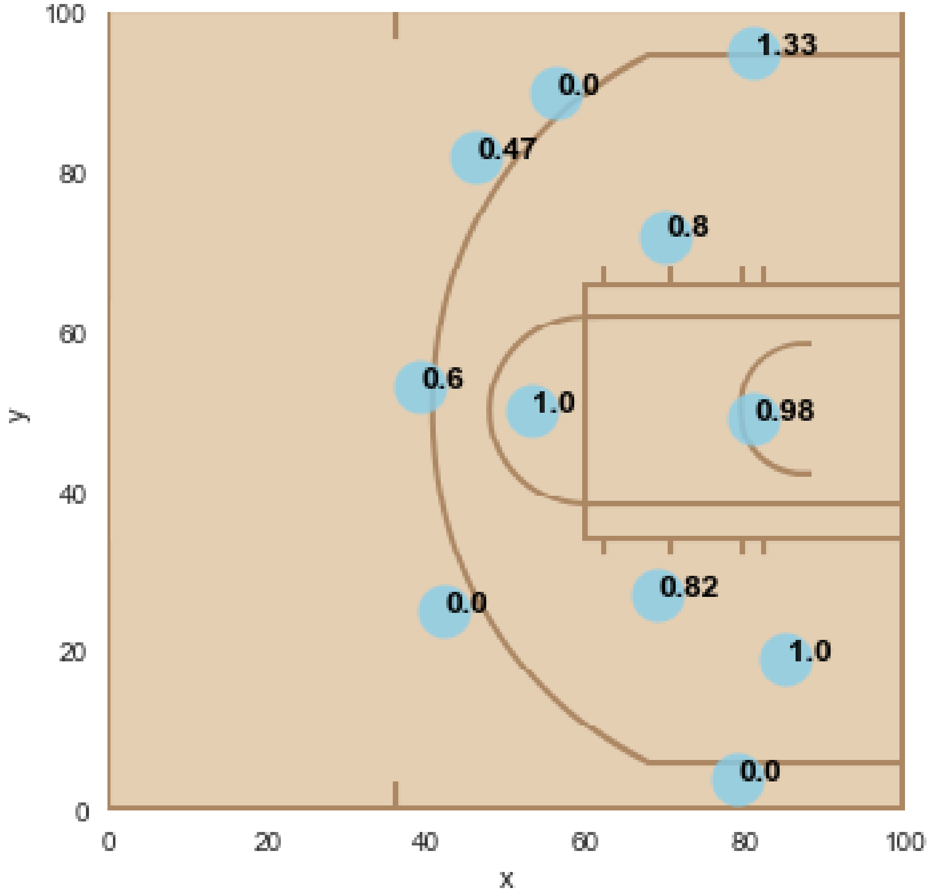

```
------------------------------------------------------------
Jae Crowder
--------------------
---- 3 Pointers ----
Percentages
[0, 0.8, 0.2222222222222222, 0.23076923076923078, 0.42857142857142855, 0.3]
--------------------
Expected Values
[0, 2.4000000000000004, 0.6666666666666666, 0.6923076923076923, 1.2857142857142856,
---- 2 Pointers ----
Percentages
[0.6129032258064516, 0.5, 0.25, 0.16666666666666666, 0.4, 0.3333333333333333]
--------------------
Expected Values
[1.2258064516129032, 1.0, 0.5, 0.3333333333333333, 0.8, 0.6666666666666666]
```



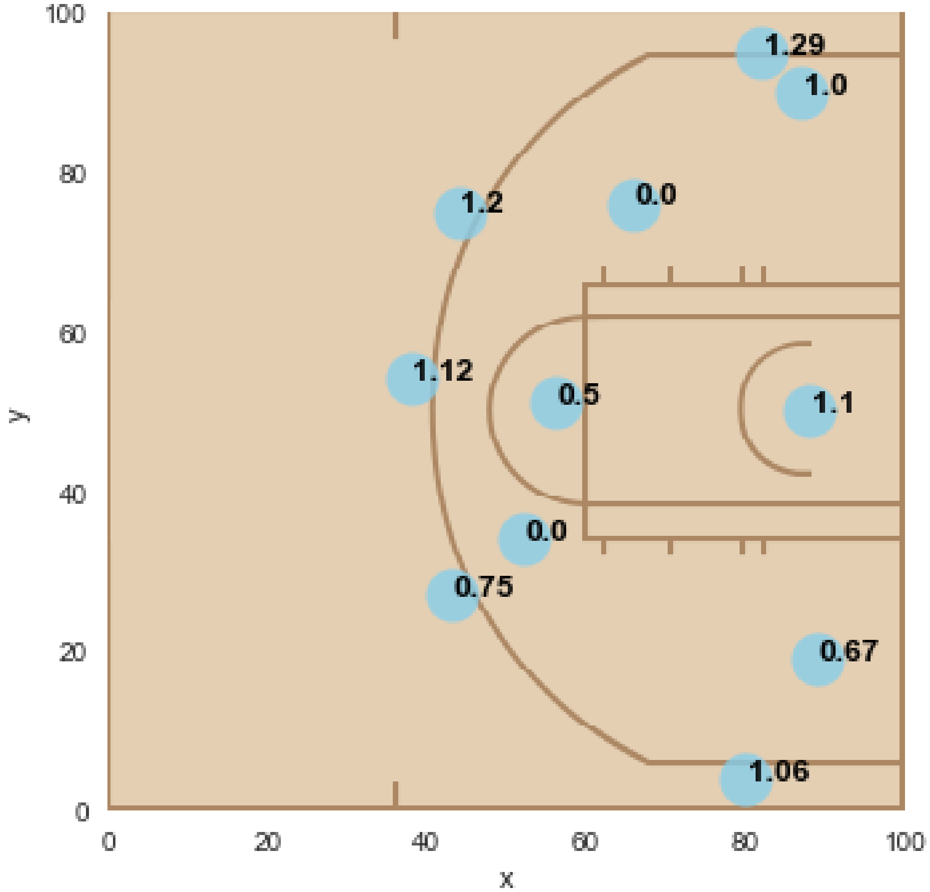

```
------------------------------------------------------------
Joe Ingles
--------------------
---- 3 Pointers ----
Percentages
[0, 0.43478260869565216, 0.5333333333333333, 0.38095238095238093, 0.5135135135135135
--------------------
Expected Values
[0, 1.3043478260869565, 1.6, 1.1428571428571428, 1.5405405405405403, 1.5294117647058
---- 2 Pointers ----
Percentages
[0.5670103092783505, 0.6, 0.5, 0.3333333333333333, 0, 0.38461538461538464]
--------------------
Expected Values
[1.134020618556701, 1.2, 1.0, 0.6666666666666666, 0, 0.7692307692307693]
```



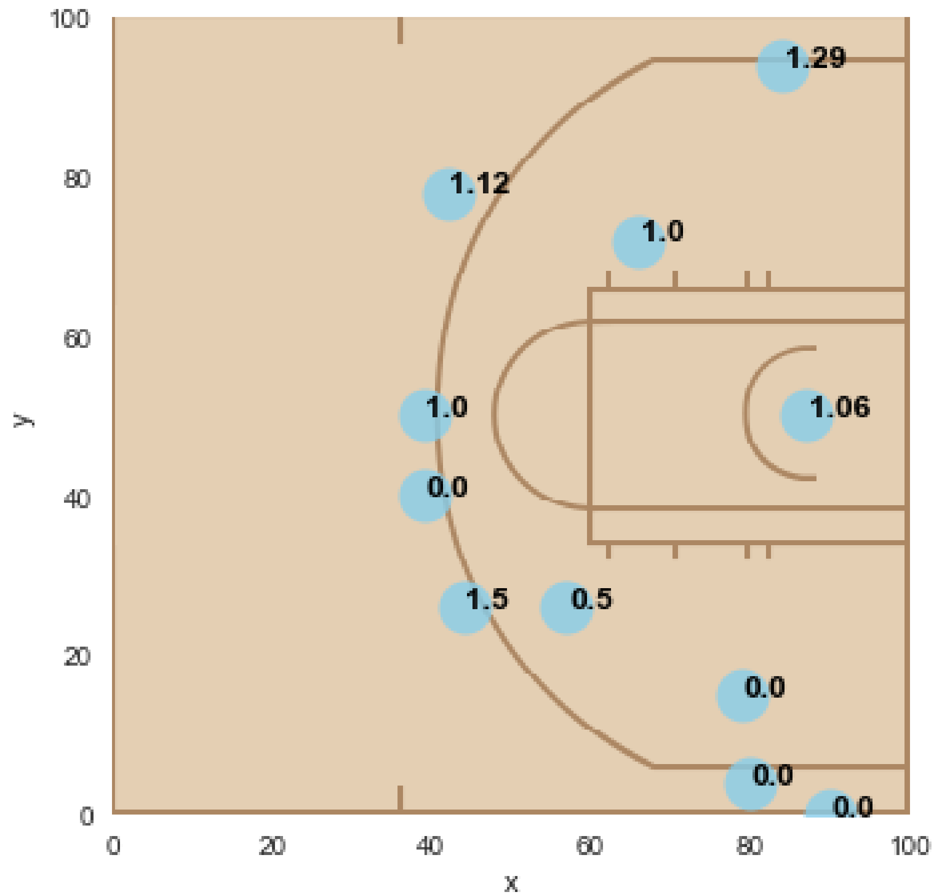

```
---------------------------------------------------------------
Joe Johnson
---------------------
---- 3 Pointers ----
Percentages
[0, 0.2, 0.0, 0.4444444444444444, 0.15789473684210525, 0.0]
---------------------
Expected Values
[0, 0.6000000000000001, 0.0, 1.3333333333333333, 0.47368421052631576, 0.0]
---- 2 Pointers ----
Percentages
[0.48936170212765956, 0.5, 0.5, 0.4117647058823529, 0, 0.4]
---------------------
Expected Values
[0.9787234042553191, 1.0, 1.0, 0.8235294117647058, 0, 0.8]
```



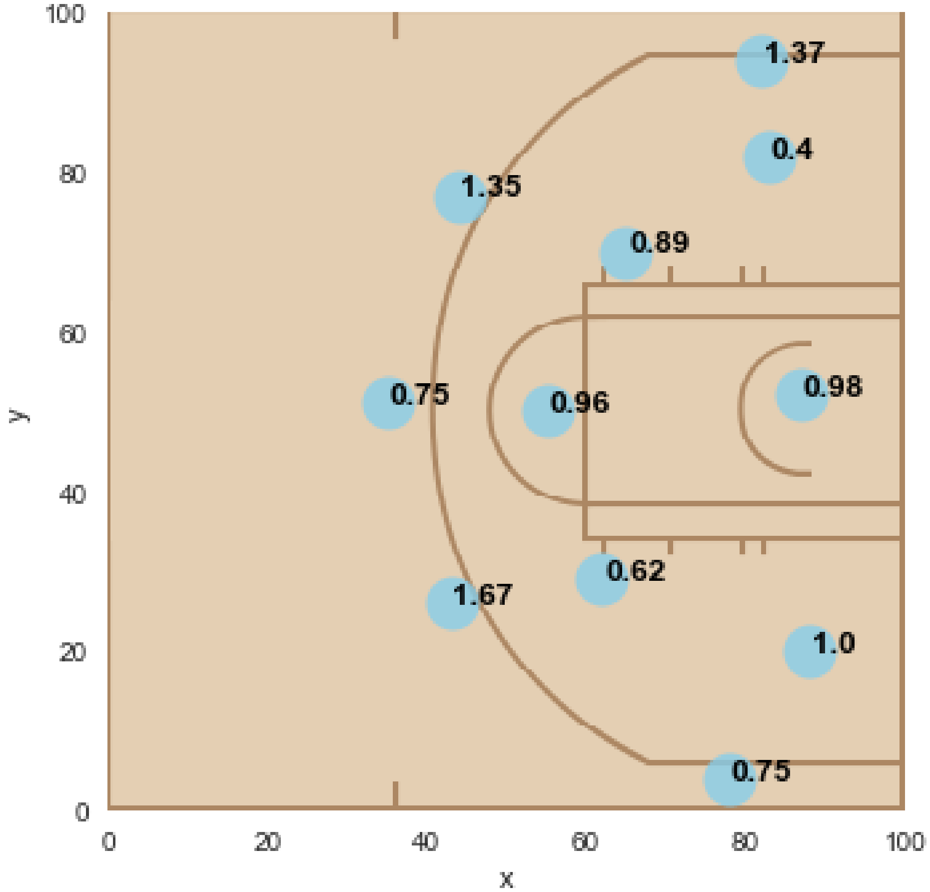

```
-----------------------------------------------------------------
Jonas Jerebko
---------------------
---- 3 Pointers ----
Percentages
[0, 0.35294117647058826, 0.375, 0.25, 0.42857142857142855, 0.4]
---------------------
Expected Values
[0, 1.0588235294117647, 1.125, 0.75, 1.2857142857142856, 1.2000000000000002]
---- 2 Pointers ----
Percentages
[0.5487804878048781, 0.3333333333333333, 0.25, 0, 0.5, 0.0]
---------------------
Expected Values
[1.0975609756097562, 0.6666666666666666, 0.5, 0, 1.0, 0.0]
```



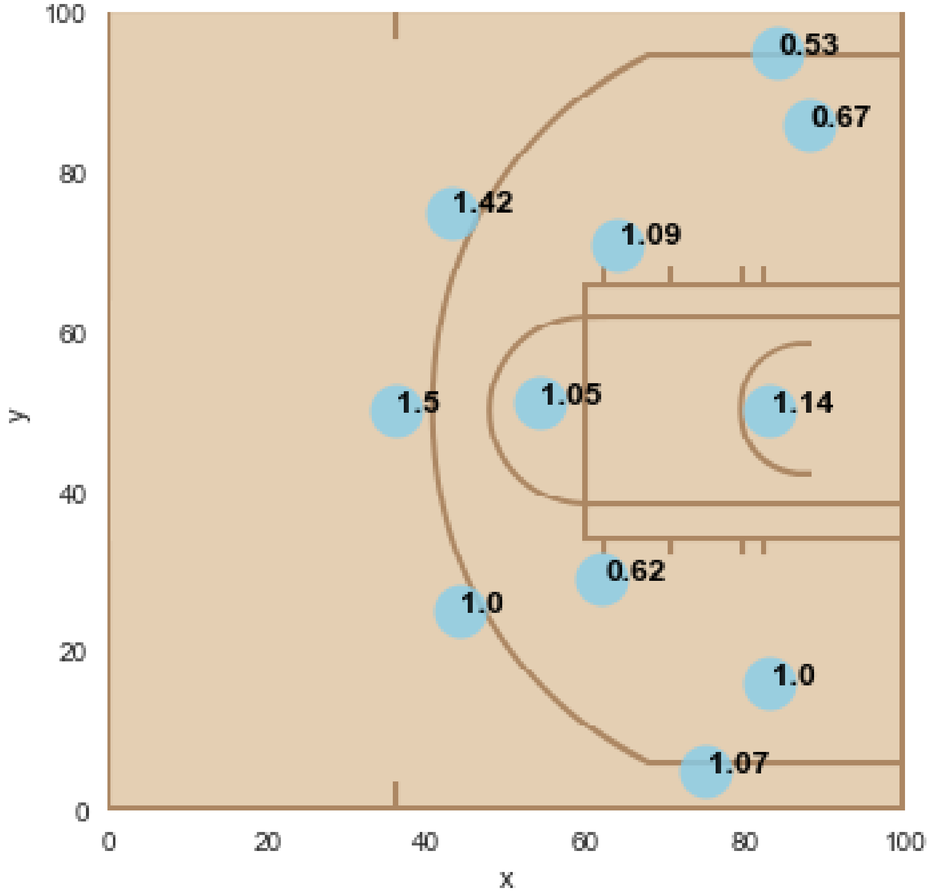

```
--------------------------------------------------------------
Raul Neto
---------------------
---- 3 Pointers ----
Percentages
[0, 0.3333333333333333, 0.0, 0.5, 0.42857142857142855, 0.375]
---------------------
Expected Values
[0, 1.0, 0.0, 1.5, 1.2857142857142856, 1.125]
---- 2 Pointers ----
Percentages
[0.5294117647058824, 0.0, 0, 0.25, 0, 0.5]
---------------------
Expected Values
[1.0588235294117647, 0.0, 0, 0.5, 0, 1.0]
```



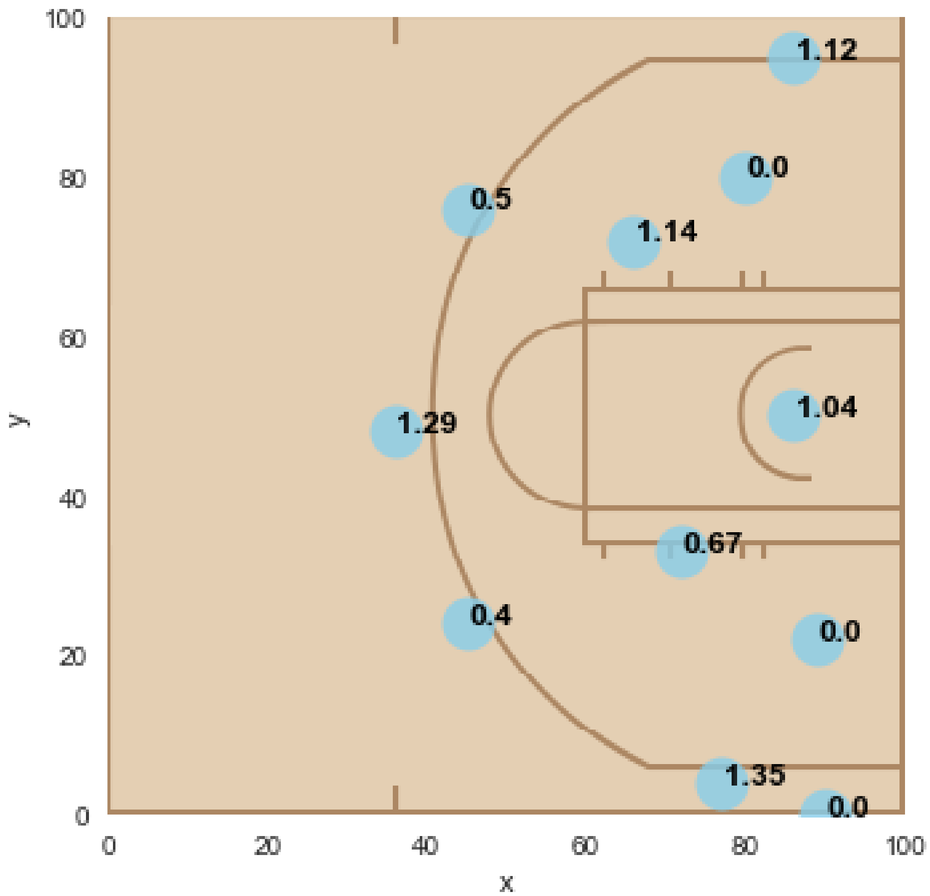

```
---------------------------------------------------------------
Ricky Rubio
---------------------
---- 3 Pointers ----
Percentages
[0, 0.25, 0.25, 0.5555555555555556, 0.45714285714285713, 0.45]
---------------------
Expected Values
[0, 0.75, 0.75, 1.6666666666666667, 1.3714285714285714, 1.35]
---- 2 Pointers ----
Percentages
[0.4892086330935252, 0.5, 0.4782608695652174, 0.3125, 0.2, 0.4457831325301205]
---------------------
Expected Values
[0.9784172661870504, 1.0, 0.9565217391304348, 0.625, 0.4, 0.891566265060241]
```



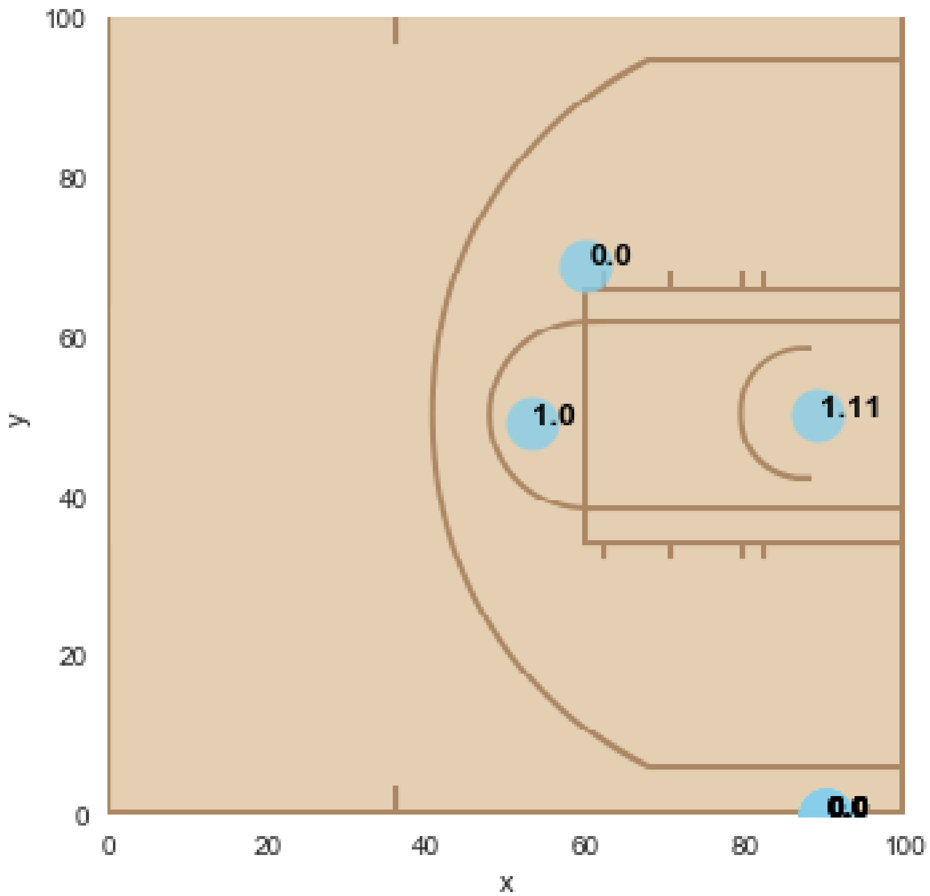

```
------------------------------------------------------------
Rodney Hood
--------------------
---- 3 Pointers ----
Percentages
[0, 0.35714285714285715, 0.5, 0.3333333333333333, 0.17647058823529413, 0.4727272727
--------------------
Expected Values
[0, 1.0714285714285714, 1.5, 1.0, 0.5294117647058824, 1.4181818181818182]
---- 2 Pointers ----
Percentages
[0.5681818181818182, 0.5, 0.5263157894736842, 0.3076923076923077, 0.333333333333333
--------------------
Expected Values
[1.1363636363636365, 1.0, 1.0526315789473684, 0.6153846153846154, 0.666666666666666
```



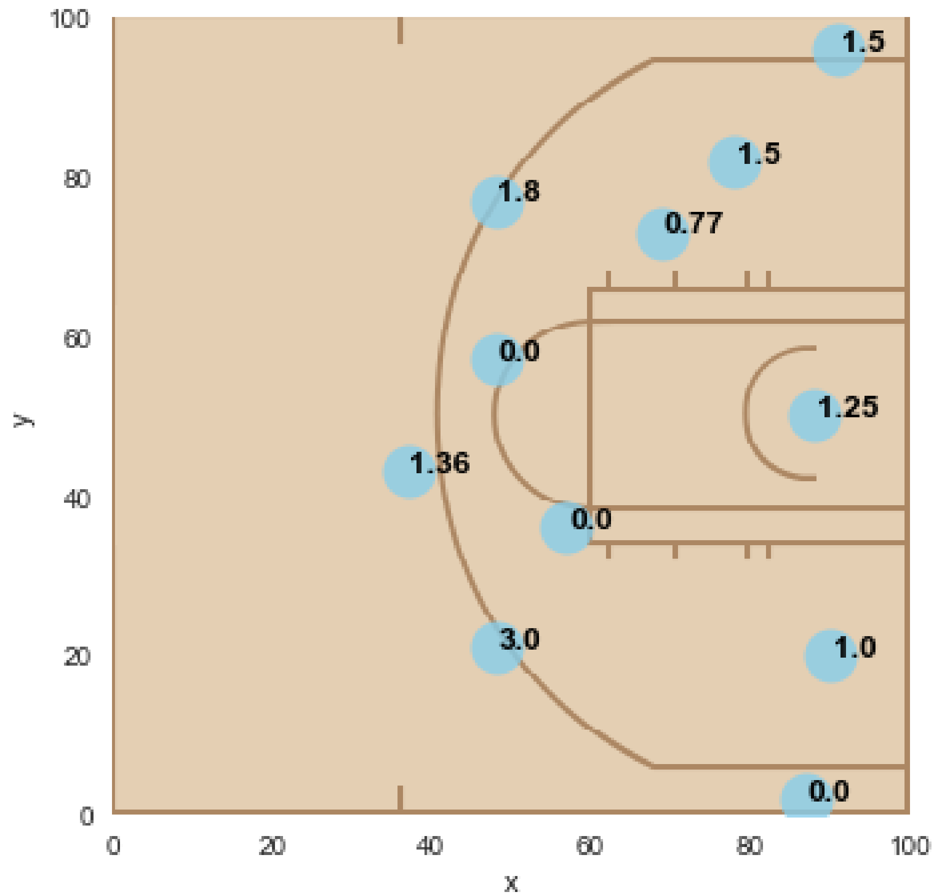

```
----------------------------------------------------------------
Royce O'Neale
---------------------
---- 3 Pointers ----
Percentages
[0, 0.45, 0.42857142857142855, 0.13333333333333333, 0.375, 0.16666666666666666]
---------------------
Expected Values
[0, 1.35, 1.2857142857142856, 0.4, 1.125, 0.5]
---- 2 Pointers ----
Percentages
[0.5194805194805194, 0, 0, 0.3333333333333333, 0.0, 0.5714285714285714]
---------------------
Expected Values
[1.0389610389610389, 0, 0, 0.6666666666666666, 0.0, 1.1428571428571428]
```




```
---------------------------------------------------------------
Rudy Gobert
---------------------
---- 3 Pointers ----
Percentages
[0, 0, 0, 0, 0, 0]
---------------------
Expected Values
[0, 0, 0, 0, 0, 0]
---- 2 Pointers ----
Percentages
[0.5555555555555556, 0, 0.5, 0, 0, 0.0]
---------------------
Expected Values
[1.1111111111111112, 0, 1.0, 0, 0, 0.0]
```




```
-----------------------------------------------------------------
Thabo Sefolosha
---------------------
---- 3 Pointers ----
Percentages
[0, 0.45454545454545453, 1.0, 0.0, 0.5, 0.6]
---------------------
Expected Values
[0, 1.3636363636363635, 3.0, 0.0, 1.5, 1.7999999999999998]
---- 2 Pointers ----
Percentages
[0.6226415094339622, 0.5, 0.0, 0.0, 0.75, 0.38461538461538464]
---------------------
Expected Values
[1.2452830188679245, 1.0, 0.0, 0.0, 1.5, 0.7692307692307693]
```



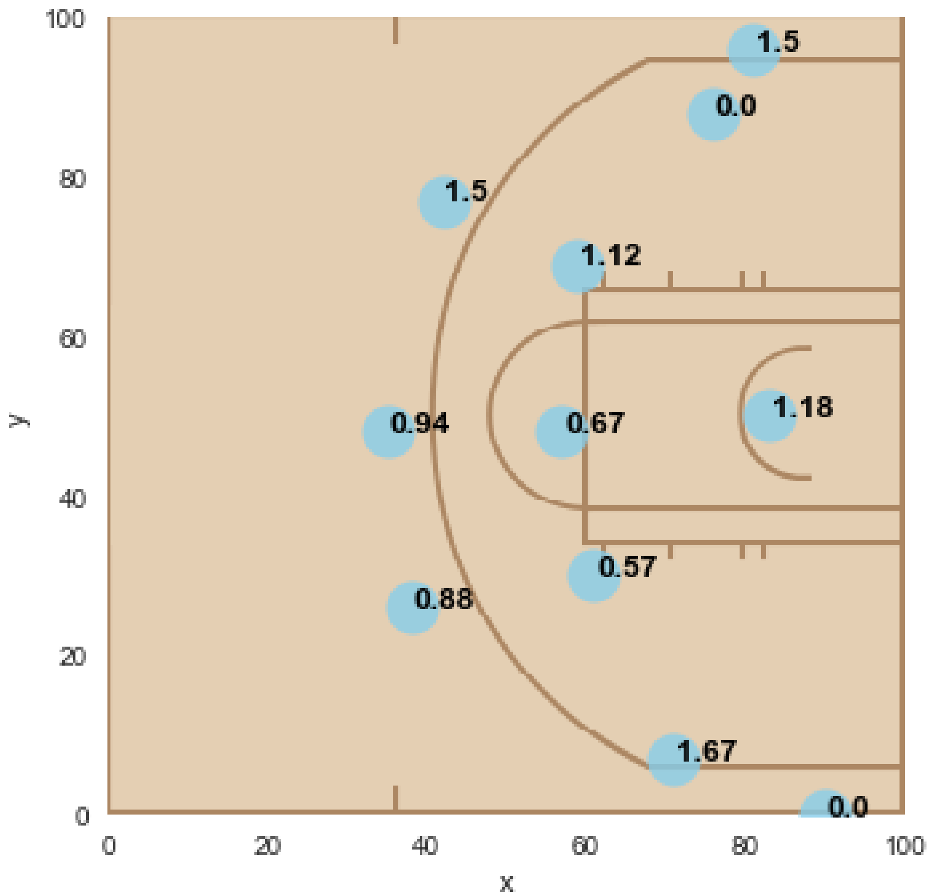

```
In [39]: ## Away

         # 3 pointers
         PlayerIDs = np.unique(ShotsPD['shooter'])
         PlayerNames = np.unique(ShotsPD['shooter_name'])
         NumOPlayers = len(PlayerNames)
         for Name in range(0,NumOPlayers):
             PercMadeDif3 = []
             NumShots = []
             NumMade = []
             ExpectedValue3 =[]
             AvLeft3 = []
             AvTop3 =[]
             PtVal3 = 3
             PtVal2 = 2
             PercMadeDif2 = []
             NumShots3 = []
             NumShots2 = []
             NumMade3 = []
```

```
NumMade2 = []
ExpectedValue2 =[]
ExpectedValueRound = []

AvLeft2 = []
AvTop2 =[]

for i in range(0,6):
    Location = ShotsPD[(ShotsPD['LocationCluster']==i) & (ShotsPD['Thr
                       & ( ShotsPD['shooter_name'] == PlayerNames[Name
    NumShots3.append(len(Location['made/missed']))
    NumMade3.append(len(Location[Location['made/missed']==1]))
    PercMade3 = 0
    if NumShots3[i] > 1:
        PercMade3 = NumMade3[i] / NumShots3[i]
        PercMadeDif3.append(PercMade3)
    else:
        PercMadeDif3.append(0)

    ExpectedValue3.append(PercMadeDif3[i]*PtVal3)

    AvLeft3.append(np.mean(Location['left']))
    AvTop3.append(np.mean(Location['top']))




    Location = ShotsPD[(ShotsPD['LocationCluster']==i) & (ShotsPD['Thr
                       & ( ShotsPD['shooter_name'] == PlayerNames[Name
    NumShots2.append(len(Location['made/missed']))
    NumMade2.append(len(Location[Location['made/missed']==1]))
    PercMade2 = 0
    if NumShots2[i] > 1:
            PercMade2 = NumMade2[i] / NumShots2[i]
            PercMadeDif2.append(PercMade2)
    else:
            PercMadeDif2.append(0)
    ExpectedValue2.append(PercMadeDif2[i]*PtVal2)

    AvLeft2.append(np.mean(Location['left']))
    AvTop2.append(np.mean(Location['top']))

print('--------------------------------------------------------------------
print(PlayerNames[Name])
print('---------------------')
print('---- 3 Pointers ----')
print('Percentages')
```

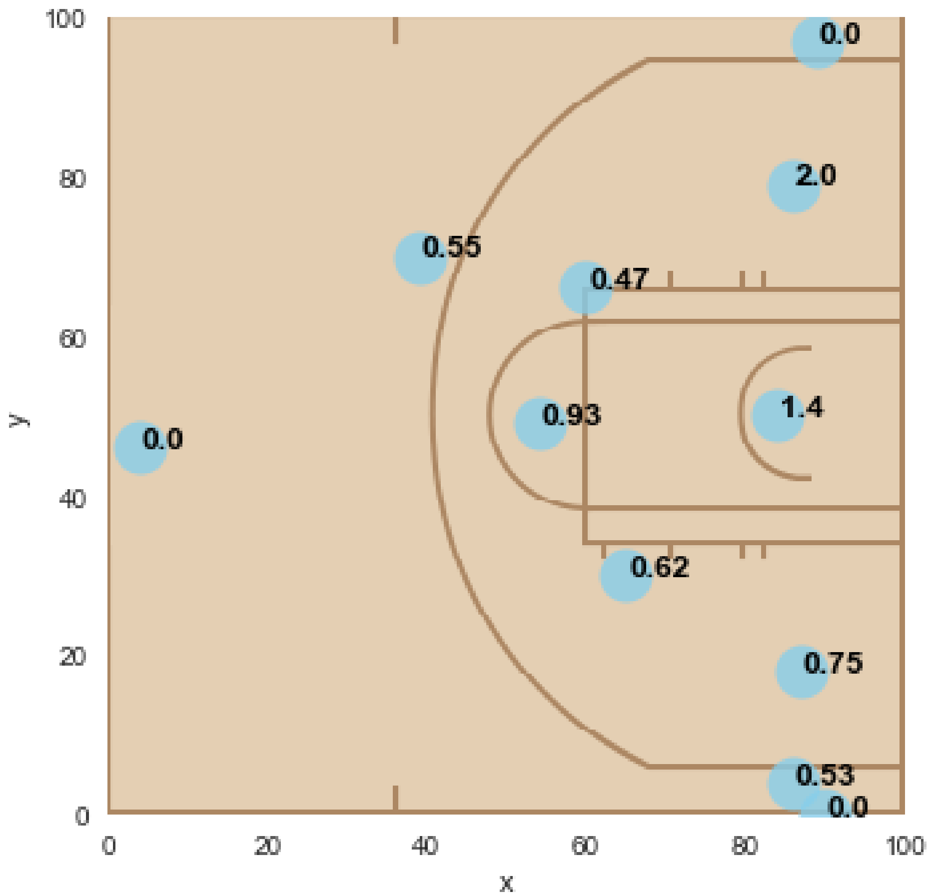
```
print(PercMadeDif3)
print('---------------------')
print('Expected Values')
print(ExpectedValue3)



print('---- 2 Pointers ----')
print('Percentages')
print(PercMadeDif2)
print('---------------------')
print('Expected Values')
print(ExpectedValue2)

for mm in range(0,len(ExpectedValue3)):
    if ExpectedValue3[mm] == 0:
        Extra = mm
del ExpectedValue3[Extra]

xx = np.isnan(AvLeft3)
for mm in range(0, len(AvLeft3)):
    if  xx[mm] == True:
        DeleteVar = mm

del AvLeft3[DeleteVar]
del AvTop3[DeleteVar]

ExpectedValue = ExpectedValue3 + ExpectedValue2
ExpectedValueRound = np.round_(ExpectedValue, decimals=2)

AvLefts = AvLeft3 + AvLeft2
AvTops = AvTop3 + AvTop2

for u in range(0,len(AvLefts)):
    if math.isnan(AvLefts[u]):
        AvLefts[u]=90
    if math.isnan(AvTops[u]):
        AvTops[u]= 0


x = np.round(AvLefts,decimals=0)
y = np.round(AvTops,decimals=0)
valz = [str(ExpectedValueRound[0]),str(ExpectedValueRound[1]),str(Expe
        str(ExpectedValueRound[3]),str(ExpectedValueRound[4]),str(Expe
        str(ExpectedValueRound[6]),str(ExpectedValueRound[7]),str(Expe
        str(ExpectedValueRound[9]),str(ExpectedValueRound[10])]
df = pd.DataFrame({
'x': x,
```

```
            'y': y,
            'group': valz
            })

            p1=sns.regplot(data=df, x="x", y="y", fit_reg=False, marker="o", color
            for line in range(0,df.shape[0]):
                p1.text(df.x[line]+0.2, df.y[line], df.group[line], horizontalalig
                        size='medium', color='black', weight='semibold')

            plt.imshow(img, zorder=0, extent=[0, 100, 0, 100.0])
            plt.grid(False)

            plt.show()
```

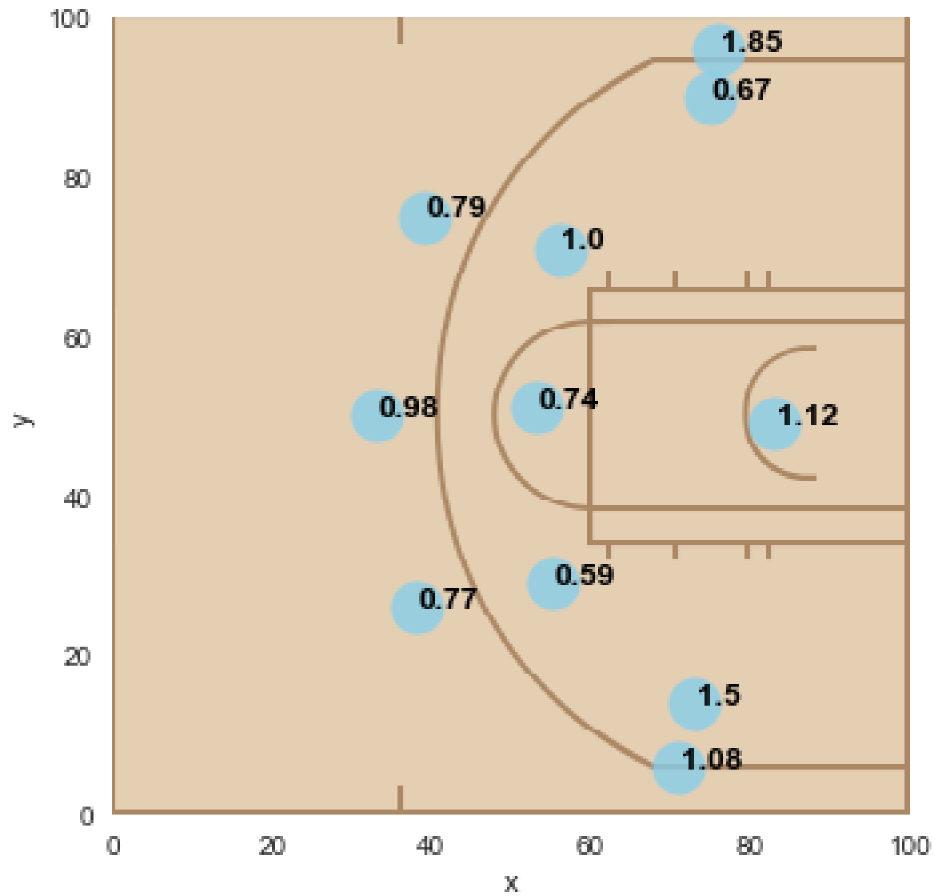
```
---------------------------------------------------------------
Alec Burks
---------------------
---- 3 Pointers ----
Percentages
[0, 0.5555555555555556, 0.3125, 0.2916666666666667, 0.5, 0.5]
---------------------
Expected Values
[0, 1.6666666666666667, 0.9375, 0.875, 1.5, 1.5]
---- 2 Pointers ----
Percentages
[0.5875, 0, 0.3333333333333333, 0.2857142857142857, 0, 0.5625]
---------------------
Expected Values
[1.175, 0, 0.6666666666666666, 0.5714285714285714, 0, 1.125]
```



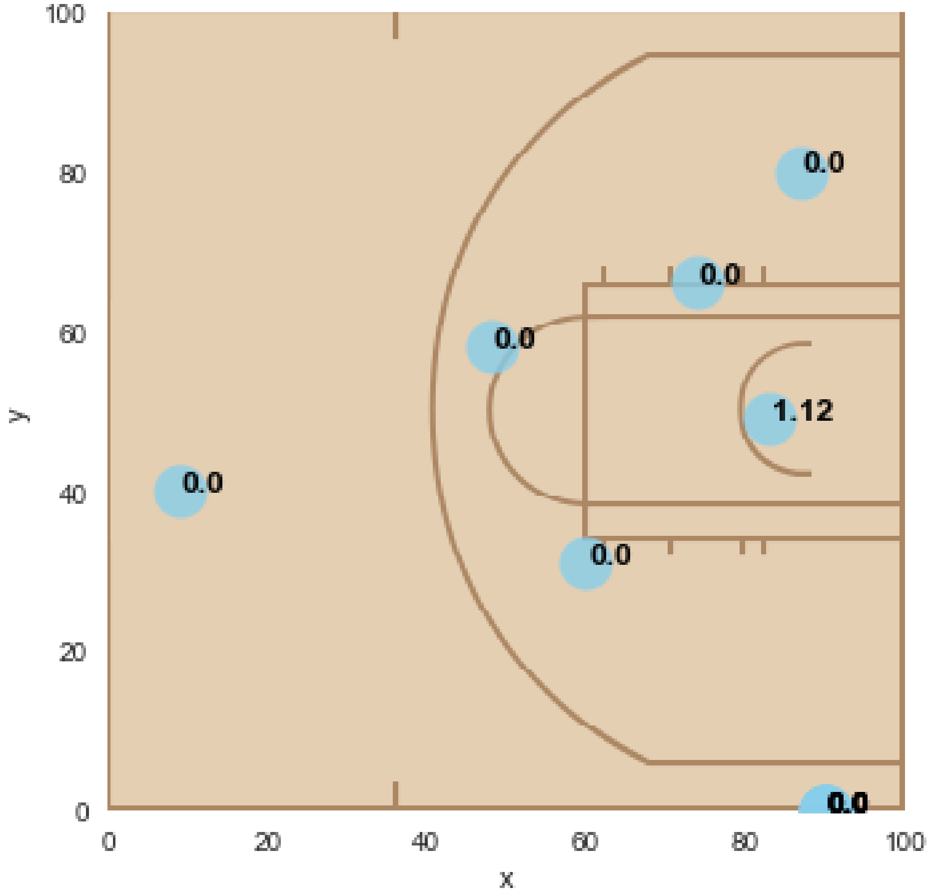

```
---------------------------------------------------------------
Derrick Favors
---------------------
---- 3 Pointers ----
Percentages
[0, 0.17647058823529413, 0, 0, 0.18181818181818182, 0]
---------------------
Expected Values
[0, 0.5294117647058824, 0, 0, 0.5454545454545454, 0]
---- 2 Pointers ----
Percentages
[0.7024793388429752, 0.375, 0.4634146341463415, 0.3125, 1.0, 0.23529411764705882]
---------------------
Expected Values
[1.4049586776859504, 0.75, 0.926829268292683, 0.625, 2.0, 0.47058823529411764]
```



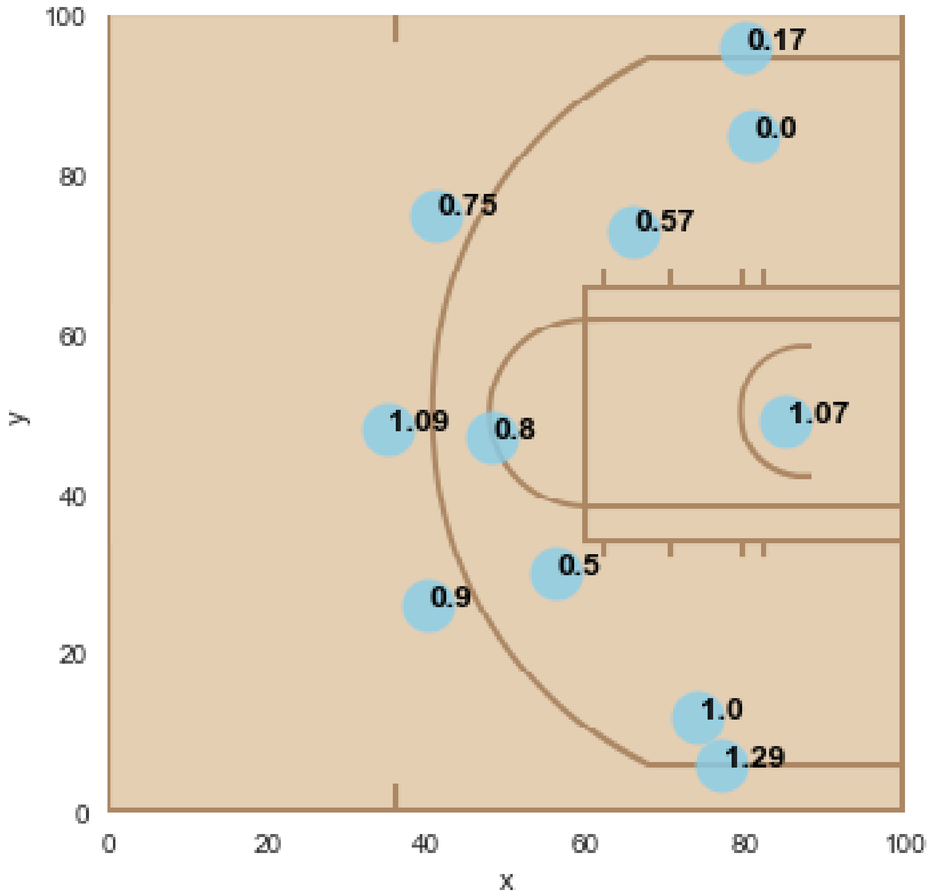

```
----------------------------------------------------------------
Donovan Mitchell
---------------------
---- 3 Pointers ----
Percentages
[0, 0.358974358974359, 0.32727272727272727, 0.25806451612903225, 0.6153846153846154
---------------------
Expected Values
[0, 1.0769230769230769, 0.9818181818181818, 0.7741935483870968, 1.8461538461538463,
---- 2 Pointers ----
Percentages
[0.5590277777777778, 0.75, 0.37209302325581395, 0.29545454545454547, 0.333333333333
---------------------
Expected Values
[1.1180555555555556, 1.5, 0.7441860465116279, 0.5909090909090909, 0.666666666666666
```



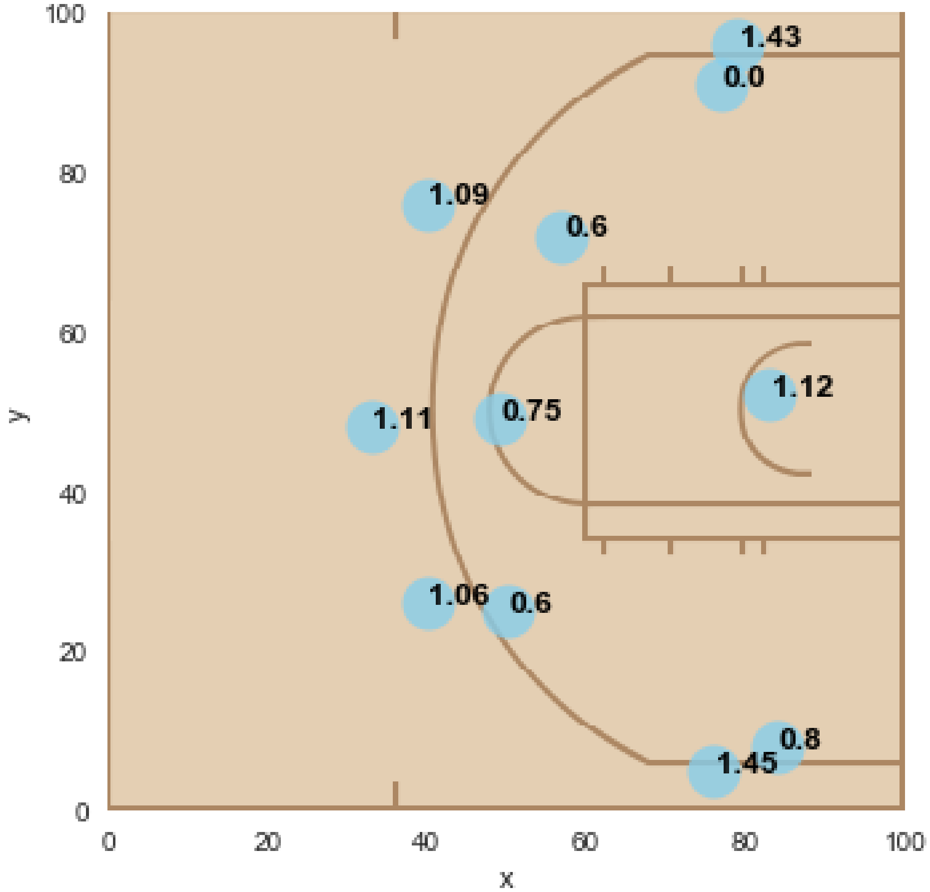

```
--------------------------------------------------------------
Ekpe Udoh
---------------------
---- 3 Pointers ----
Percentages
[0, 0, 0, 0, 0, 0]
---------------------
Expected Values
[0, 0, 0, 0, 0, 0]
---- 2 Pointers ----
Percentages
[0.5625, 0, 0, 0.0, 0, 0]
---------------------
Expected Values
[1.125, 0, 0, 0.0, 0, 0]
```



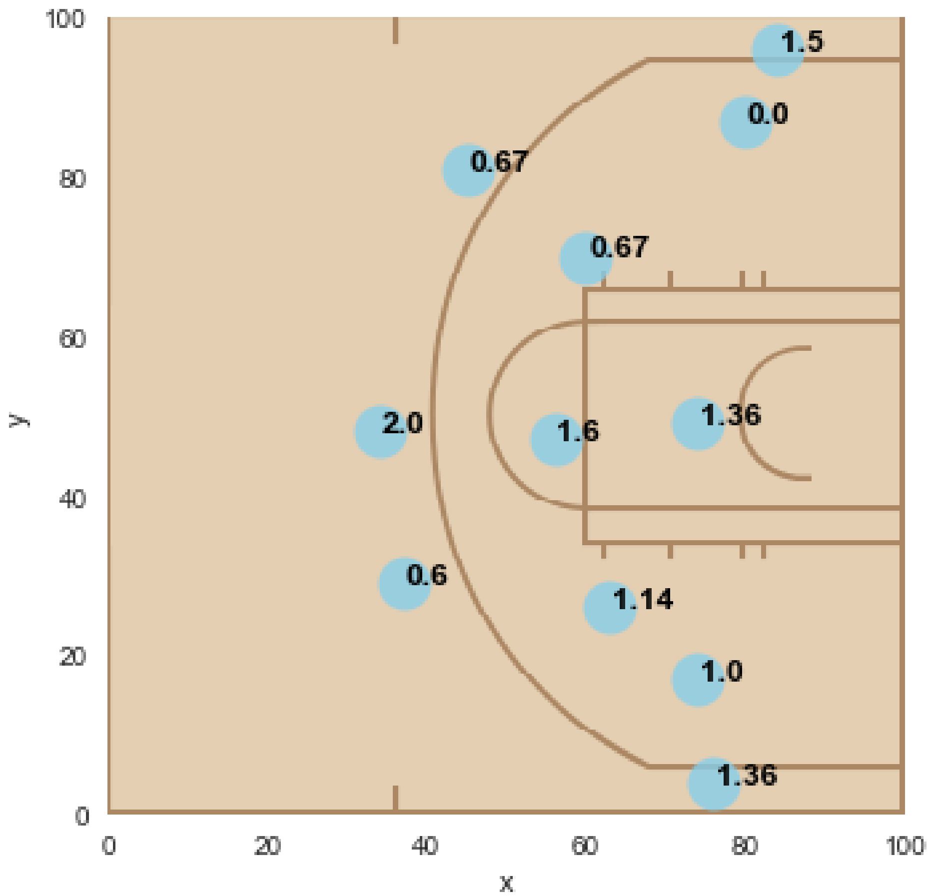

```
------------------------------------------------------------
Jae Crowder
--------------------
---- 3 Pointers ----
Percentages
[0, 0.42857142857142855, 0.36363636363636365, 0.3, 0.05555555555555555, 0.25]
--------------------
Expected Values
[0, 1.2857142857142856, 1.0909090909090908, 0.8999999999999999, 0.166666666666666
---- 2 Pointers ----
Percentages
[0.5344827586206896, 0.5, 0.4, 0.25, 0.0, 0.2857142857142857]
--------------------
Expected Values
[1.0689655172413792, 1.0, 0.8, 0.5, 0.0, 0.5714285714285714]
```



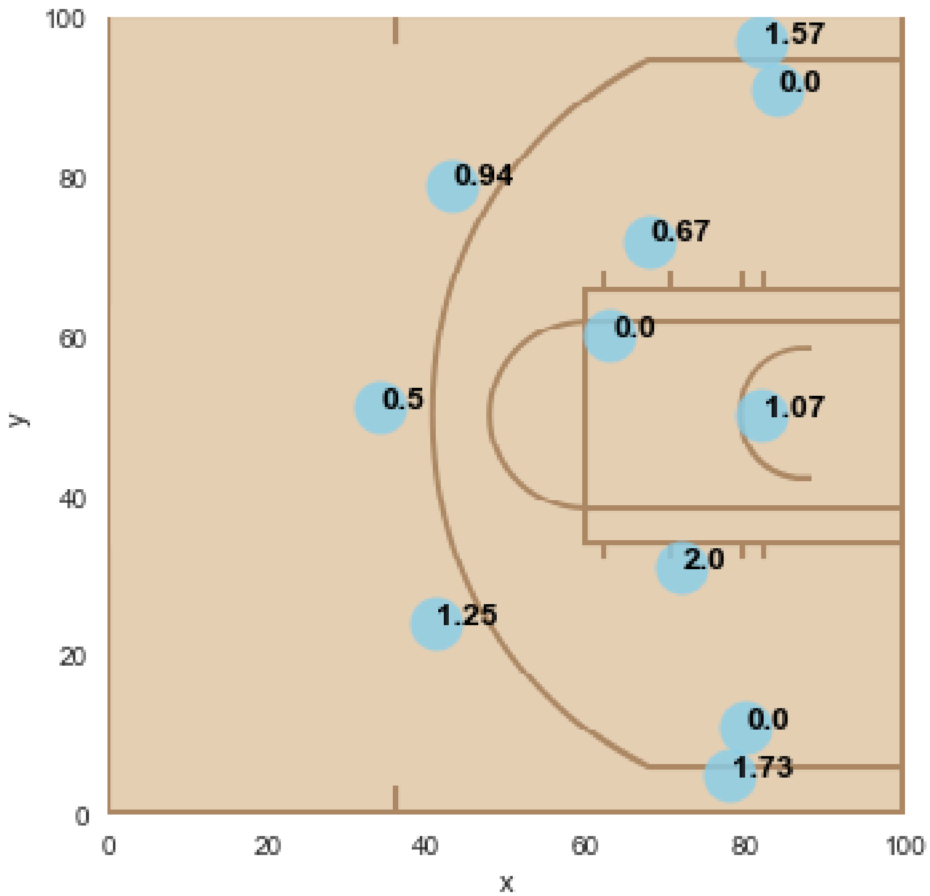

```
--------------------------------------------------------------
Joe Ingles
---------------------
---- 3 Pointers ----
Percentages
[0, 0.4838709677419355, 0.37037037037037035, 0.35294117647058826, 0.4782608695652217
---------------------
Expected Values
[0, 1.4516129032258065, 1.1111111111111112, 1.0588235294117647, 1.4347826086956523,
---- 2 Pointers ----
Percentages
[0.5576923076923077, 0.4, 0.375, 0.3, 0.0, 0.3]
---------------------
Expected Values
[1.1153846153846154, 0.8, 0.75, 0.6, 0.0, 0.6]
```



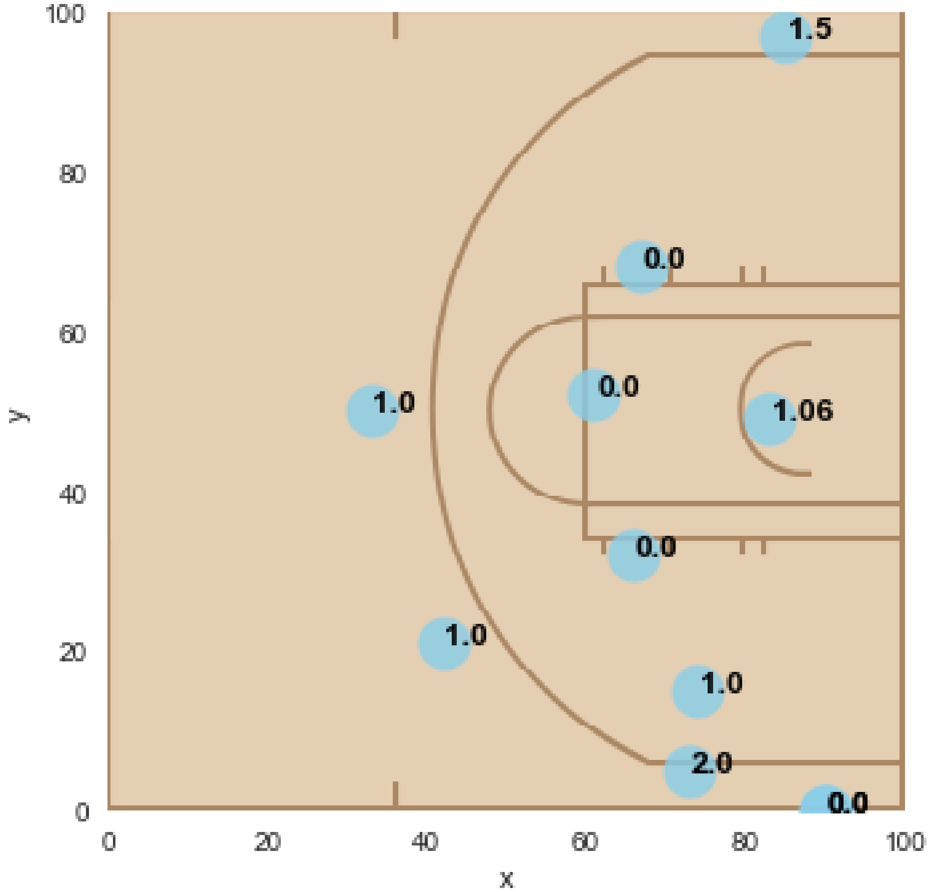

```
---------------------------------------------------------------
Joe Johnson
---------------------
---- 3 Pointers ----
Percentages
[0, 0.45454545454545453, 0.6666666666666666, 0.2, 0.5, 0.2222222222222222]
---------------------
Expected Values
[0, 1.3636363636363635, 2.0, 0.6000000000000001, 1.5, 0.6666666666666666]
---- 2 Pointers ----
Percentages
[0.6785714285714286, 0.5, 0.8, 0.5714285714285714, 0.0, 0.3333333333333333]
---------------------
Expected Values
[1.3571428571428572, 1.0, 1.6, 1.1428571428571428, 0.0, 0.6666666666666666]
```



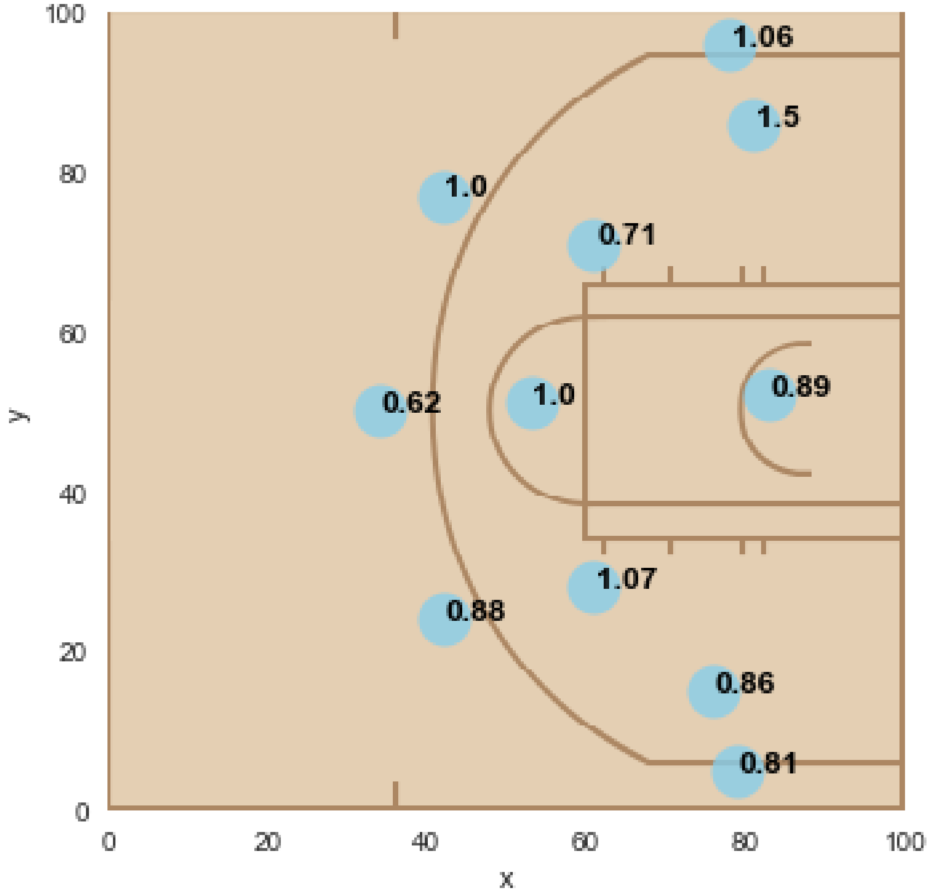

```
---------------------------------------------------------------
Jonas Jerebko
---------------------
---- 3 Pointers ----
Percentages
[0, 0.5769230769230769, 0.16666666666666666, 0.4166666666666667, 0.521739130434782
---------------------
Expected Values
[0, 1.7307692307692306, 0.5, 1.25, 1.5652173913043477, 0.9375]
---- 2 Pointers ----
Percentages
[0.5352112676056338, 0.0, 0, 1.0, 0.0, 0.3333333333333333]
---------------------
Expected Values
[1.0704225352112675, 0.0, 0, 2.0, 0.0, 0.6666666666666666]
```



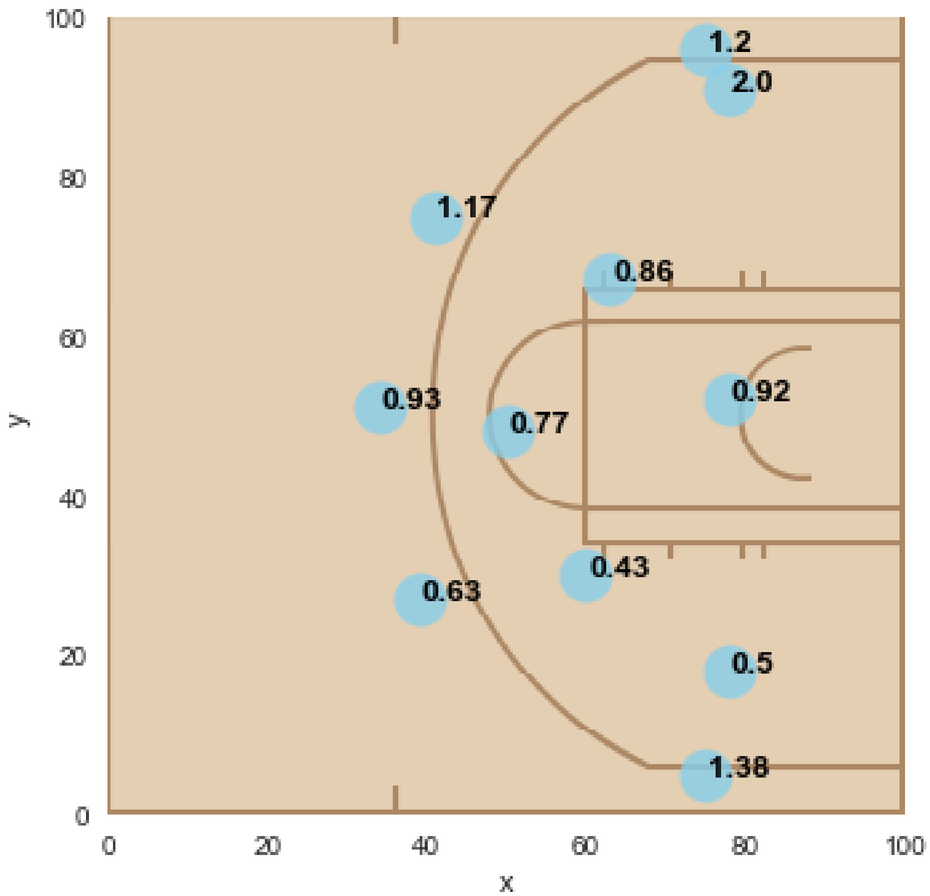

```
----------------------------------------------------------------
Raul Neto
---------------------
---- 3 Pointers ----
Percentages
[0, 0.6666666666666666, 0.3333333333333333, 0.3333333333333333, 0.5, 0]
---------------------
Expected Values
[0, 2.0, 1.0, 1.0, 1.5, 0]
---- 2 Pointers ----
Percentages
[0.5294117647058824, 0.5, 0, 0.0, 0, 0.0]
---------------------
Expected Values
[1.0588235294117647, 1.0, 0, 0.0, 0, 0.0]
```



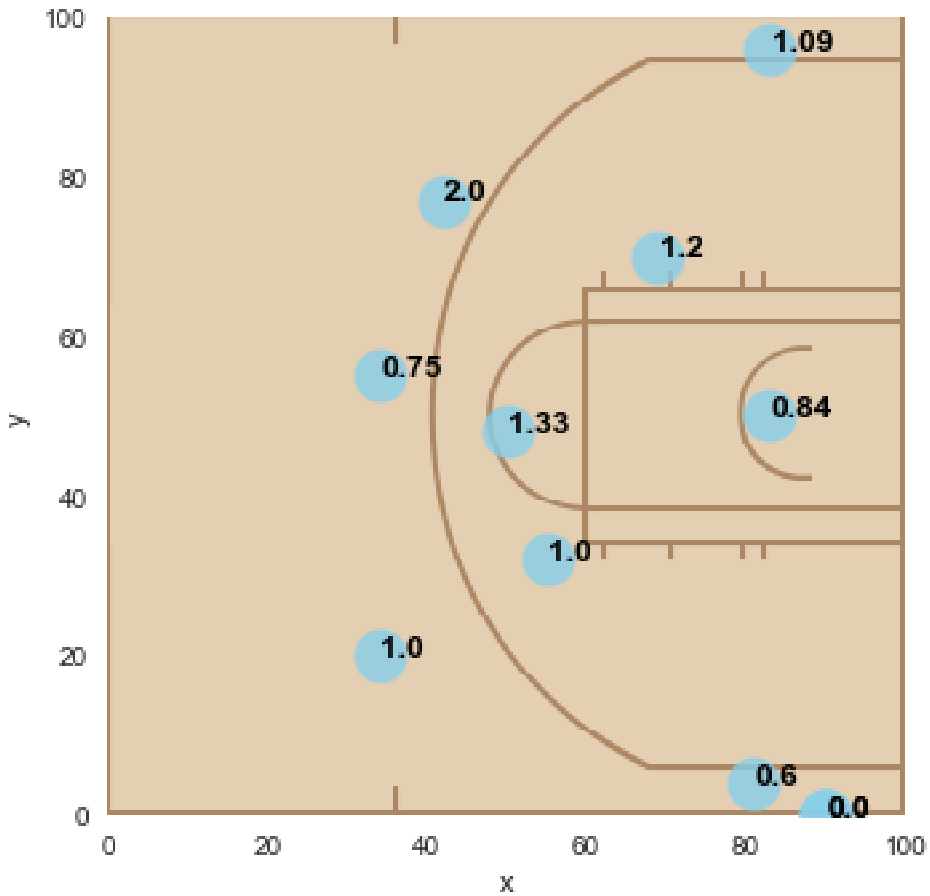

```
--------------------------------------------------------------
Ricky Rubio
---------------------
---- 3 Pointers ----
Percentages
[0, 0.2692307692307692, 0.20833333333333334, 0.29411764705882354, 0.354838709677419
---------------------
Expected Values
[0, 0.8076923076923077, 0.625, 0.8823529411764706, 1.064516129032258, 1.0]
---- 2 Pointers ----
Percentages
[0.44660194174757284, 0.42857142857142855, 0.5, 0.5333333333333333, 0.75, 0.3548387
---------------------
Expected Values
[0.8932038834951457, 0.8571428571428571, 1.0, 1.0666666666666667, 1.5, 0.709677419
```



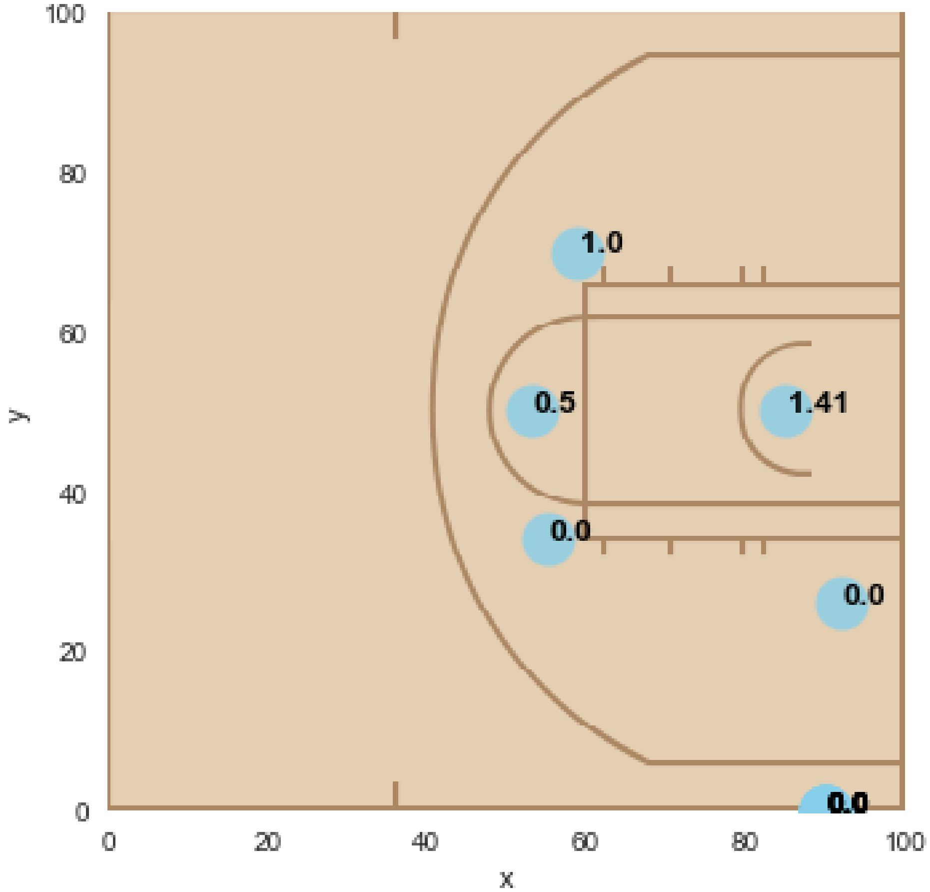

```
-------------------------------------------------------------
Rodney Hood
--------------------
---- 3 Pointers ----
Percentages
[0, 0.46153846153846156, 0.3103448275862069, 0.21052631578947367, 0.4, 0.38888888888
--------------------
Expected Values
[0, 1.3846153846153846, 0.9310344827586208, 0.631578947368421, 1.2000000000000002,
---- 2 Pointers ----
Percentages
[0.46, 0.25, 0.38461538461538464, 0.21739130434782608, 1.0, 0.42857142857142855]
--------------------
Expected Values
[0.92, 0.5, 0.7692307692307693, 0.43478260869565216, 2.0, 0.8571428571428571]
```



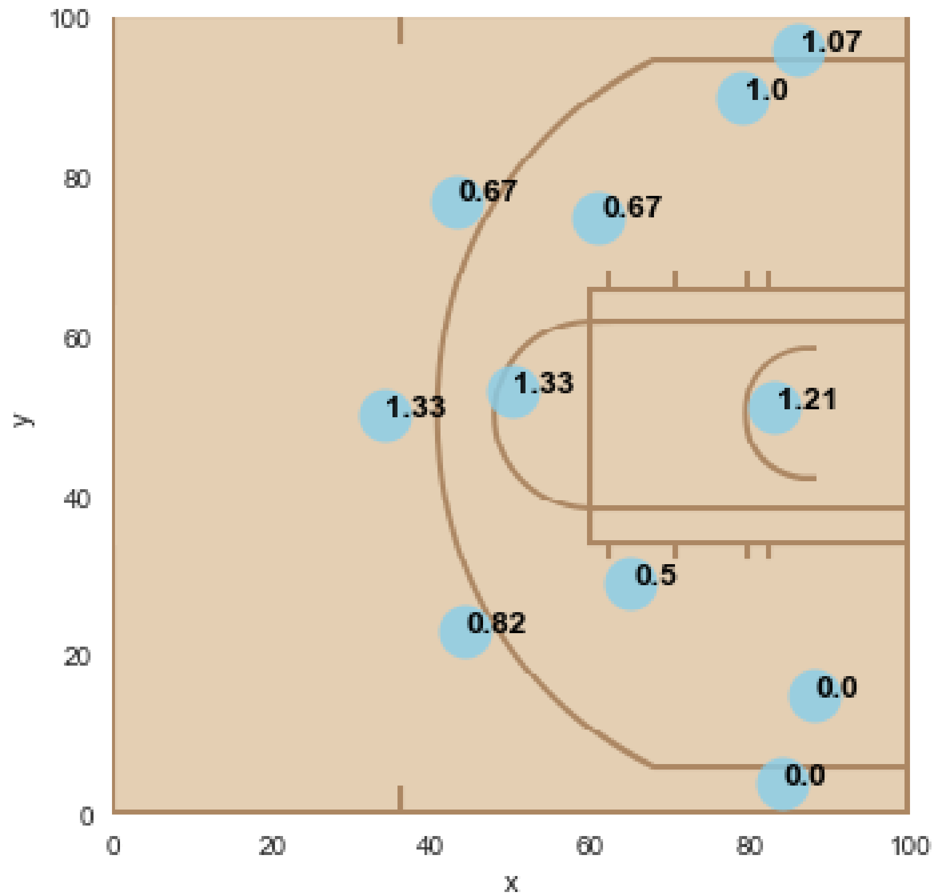

```
----------------------------------------------------------------
Royce O'Neale
---------------------
---- 3 Pointers ----
Percentages
[0, 0.2, 0.25, 0.3333333333333333, 0.36363636363636365, 0.6666666666666666]
---------------------
Expected Values
[0, 0.6000000000000001, 0.75, 1.0, 1.0909090909090908, 2.0]
---- 2 Pointers ----
Percentages
[0.42028985507246375, 0, 0.6666666666666666, 0.5, 0, 0.6]
---------------------
Expected Values
[0.8405797101449275, 0, 1.3333333333333333, 1.0, 0, 1.2]
```




```
----------------------------------------------------------------
Rudy Gobert
---------------------
---- 3 Pointers ----
Percentages
[0, 0, 0, 0, 0, 0]
---------------------
Expected Values
[0, 0, 0, 0, 0, 0]
---- 2 Pointers ----
Percentages
[0.706140350877193, 0, 0.25, 0, 0, 0.5]
---------------------
Expected Values
[1.412280701754386, 0, 0.5, 0, 0, 1.0]
```




```
---------------------------------------------------------------
Thabo Sefolosha
---------------------
---- 3 Pointers ----
Percentages
[0, 0.4444444444444444, 0.0, 0.2727272727272727, 0.35714285714285715, 0.22222222222
---------------------
Expected Values
[0, 1.3333333333333333, 0.0, 0.8181818181818181, 1.0714285714285714, 0.66666666666
---- 2 Pointers ----
Percentages
[0.6031746031746031, 0.0, 0.6666666666666666, 0.25, 0.5, 0.3333333333333333]
---------------------
Expected Values
[1.2063492063492063, 0.0, 1.3333333333333333, 0.5, 1.0, 0.6666666666666666]
```

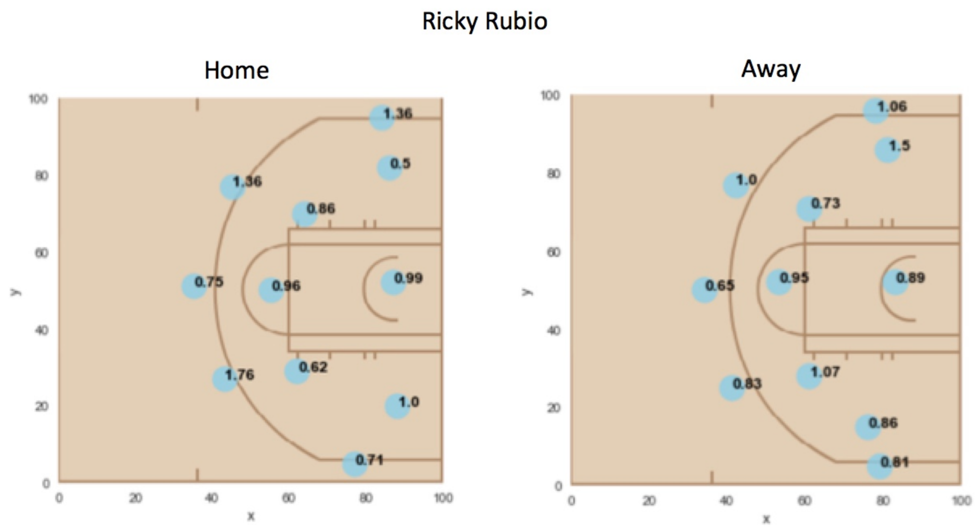


** Conclusions**

From this, we can see that some players shoot different shots at much different expected values based on whether they are home or away. This could come from players having more nerves at away games and shooting worse altogether, or from being more comfortable with certain courts and stadiums. In the comparison below, we can see that Ricky Rubio is a much better 3-point shooter at home; but interestingly enough, he shoots the baseline jumper 3x better away than at home. It is interesting to think players can shoot better or worse just depending on whether it is a home or an away game.

2.3.2 Score Prediction

Finally, we were able to look at predicting a game based on the knowledge of the shot attempts to guess the team score and individual scores. We actually did quite well by looking at the boxscore listed below. This was the first game of the season. We over predicted Donovan Mitchell's score, probably as this was his first game in the NBA, and he may have shot worse due to nerves and getting used to the flow. Alec Burks was playing better at the time, so he actually did better than we predicted. We were able to decently predict a score based upon the expected values we found. However, our methods don't take into account free throws, so our final scores will be a little off depending on free throws.



Ricky Rubio

We were able to be within 7 points for each player. The model predicted Joe Johnson's score perfectly while we were 7 off of Alec Burks actual total. We were 8 short of the team total.

```
In [40]: GameOfInterest = 1
         GameX = ShotsPD[ShotsPD['game'] == GameOfInterest]

In [41]: # Predicting a game
         # 3 pointers
         PlayerIDs = np.unique(GameX['shooter'])
         PlayerNames = np.unique(GameX['shooter_name'])
         NumOPlayers = len(PlayerNames)
         TotalPts = []
         PlayerToalPts = []
         PlayerToalPtsActual = []
         TotalPtsActual = []
         TotalTotalPts = []
         for Name in range(0,NumOPlayers):
             PercMadeDif3 = []
             NumShots = []
             NumMade = []
             ExpectedValue3 =[]
             PtVal3 = 3
             PtVal2 = 2
             PercMadeDif2 = []
             NumShots3 = []
             NumShots2 = []
             NumMade3 = []
             NumMade2 = []
             ExpectedValue2 =[]
             ExpectedValueRound = []
```

```
NumShotsRecreate3 = []
NumShotsRecreate2 = []
LocationRecreate2 = []
LocationRecreate3 = []
ExpectedPoints3Recreate = []
ExpectedPoints2Recreate= []
PlayerToalPts = []


NumShotsRecreate3Actual = []
NumShotsRecreate2Actual = []
LocationRecreate2Actual = []
LocationRecreate3Actual = []
ExpectedPoints3RecreateActual = []
ExpectedPoints2RecreateActual= []
PlayerToalPts = []


for i in range(0,6):
    Location = ShotsPD[(ShotsPD['LocationCluster']==i) & (ShotsPD['Thr
                       & ( ShotsPD['shooter_name'] == PlayerNames[Name
    NumShots3.append(len(Location['made/missed']))
    NumMade3.append(len(Location[Location['made/missed']==1]))
    PercMade3 = 0
    if NumShots3[i] > 1:
        PercMade3 = NumMade3[i] / NumShots3[i]
        PercMadeDif3.append(PercMade3)
    else:
        PercMadeDif3.append(0)

    ExpectedValue3.append(PercMadeDif3[i]*PtVal3)

    AvLeft3.append(np.mean(Location['left']))
    AvTop3.append(np.mean(Location['top']))




    Location = ShotsPD[(ShotsPD['LocationCluster']==i) & (ShotsPD['Thr
                       & ( ShotsPD['shooter_name'] == PlayerNames[Name
    NumShots2.append(len(Location['made/missed']))
    NumMade2.append(len(Location[Location['made/missed']==1]))
    PercMade2 = 0
    if NumShots2[i] > 1:
```

```
            PercMade2 = NumMade2[i] / NumShots2[i]
            PercMadeDif2.append(PercMade2)
    else:
            PercMadeDif2.append(0)
    ExpectedValue2.append(PercMadeDif2[i]*PtVal2)

    AvLeft2.append(np.mean(Location['left']))
    AvTop2.append(np.mean(Location['top']))









for i in range(0,6):
    LocationRecreate3 = GameX[(GameX['LocationCluster']==i)& (GameX['T
                                & ( GameX['shooter_name'] == PlayerNames
    NumShotsRecreate3.append(len(LocationRecreate3['made/missed']))
    ExpectedPoints3Recreate.append(NumShotsRecreate3[i]*ExpectedValue3

for i in range(0,6):
    LocationRecreate2 = GameX[(GameX['LocationCluster']==i)& (GameX['T
                                & ( GameX['shooter_name'] == PlayerNames
    NumShotsRecreate2.append(len(LocationRecreate2['made/missed']))
    ExpectedPoints2Recreate.append(NumShotsRecreate2[i]*ExpectedValue2


Player3pts = np.sum(ExpectedPoints3Recreate)
Player2pts = np.sum(ExpectedPoints2Recreate)

PlayerToalPts = Player3pts + Player2pts

TotalPts.append(int(PlayerToalPts))



## Actual Results of the Game

for i in range(0,6):
```

```
            LocationRecreate3Actual = GameX[(GameX['LocationCluster']==i)& (Ga
                                              & ( GameX['shooter_name'] == Playe
                                              & ( GameX['made/missed'] == 1)]
            NumShotsRecreate3Actual.append(len(LocationRecreate3Actual['made/m
            ExpectedPoints3RecreateActual.append(NumShotsRecreate3Actual[i]*3)

        for i in range(0,6):
            LocationRecreate2Actual = GameX[(GameX['LocationCluster']==i)& (Ga
                                              & ( GameX['shooter_name'] == Playe
                                              & ( GameX['made/missed'] == 1)]
            NumShotsRecreate2Actual.append(len(LocationRecreate2Actual['made/m
            ExpectedPoints2RecreateActual.append(NumShotsRecreate2Actual[i]*2)


        Player3ptsActual = np.sum(ExpectedPoints3RecreateActual)
        Player2ptsActual = np.sum(ExpectedPoints2RecreateActual)

        PlayerToalPtsActual = Player3ptsActual + Player2ptsActual

        TotalPtsActual.append(int(PlayerToalPtsActual))



        print('-----------------------------------------------------------------
        print(PlayerNames[Name])
        print('Predicted: ' + str(int(PlayerToalPts)))
        print('Actual: ' + str(PlayerToalPtsActual))



    TotalTotalPts = np.sum(TotalPts)
    TotalTotalPtsActual = np.sum(TotalPtsActual)
    print('---------------------------------------------------------------')
    print('---------------------------------------------------------------')
    print('Final Jazz Score:')
    print('Predicted: ' + str(TotalTotalPts))
    print('Actual: ' + str(TotalTotalPtsActual))
```

```
---------------------------------------------------------------
Alec Burks
Predicted: 9
Actual: 16
---------------------------------------------------------------
Derrick Favors
Predicted: 13
Actual: 14
```

```
---------------------------------------------------------------
Donovan Mitchell
Predicted: 12
Actual: 6
---------------------------------------------------------------
Ekpe Udoh
Predicted: 0
Actual: 0
---------------------------------------------------------------
Joe Ingles
Predicted: 7
Actual: 11
---------------------------------------------------------------
Joe Johnson
Predicted: 10
Actual: 10
---------------------------------------------------------------
Ricky Rubio
Predicted: 8
Actual: 7
---------------------------------------------------------------
Rodney Hood
Predicted: 4
Actual: 6
---------------------------------------------------------------
Rudy Gobert
Predicted: 11
Actual: 14
---------------------------------------------------------------
Thabo Sefolosha
Predicted: 7
Actual: 6
---------------------------------------------------------------
---------------------------------------------------------------
Final Jazz Score:
Predicted: 81
Actual: 90
```

2.4 Conclusion:

We successfully were able to: - Acquire the data needed from ESPN - Clean the data to extract the needed values for analysis - Cluster the shots into natural groupings - Look at expected values for both the team and individuals - Perform significance testing on the data - Compare expected values between home and away games - Predict a Jazz game outcome using a model

Jazz

STARTERS	MIN	FG	3PT	FT	OREB	DREB	REB	AST	STL	BLK	TO	PF	+/-	PTS
D. Favors PF	28	7-14	0-1	0-0	0	4	4	4	1	0	1	4	+4	14
J. Ingles SF	33	4-6	3-5	0-0	0	5	5	6	2	0	0	3	-6	11
R. Gobert C	35	7-9	0-0	4-4	3	7	10	1	0	1	6	4	-14	18
R. Rubio PG	32	3-9	1-5	2-3	0	5	5	10	2	0	3	1	-14	9
D. Mitchell SG	26	3-11	0-2	4-4	0	1	1	4	0	1	3	1	+22	10
BENCH	MIN	FG	3PT	FT	OREB	DREB	REB	AST	STL	BLK	TO	PF	+/-	PTS
T. Sefolosha SF	21	3-7	0-2	1-1	0	2	2	2	2	0	0	0	+25	7
E. Udoh C	13	0-1	0-0	2-2	1	1	2	0	0	3	1	0	+24	2
J. Johnson SG	20	5-10	1-4	2-2	2	2	4	1	1	0	1	3	+6	13
A. Burks SG	15	7-10	2-2	0-0	0	1	1	0	1	0	0	1	+16	16
R. Hood SG	18	2-4	2-3	0-0	0	2	2	0	0	0	0	1	-13	6
J. Jerebko PF					DNP-COACH'S DECISION									
R. O'Neale SF					DNP-COACH'S DECISION									
N. Wolters PG					DNP-COACH'S DECISION									
TEAM		41-81	9-24	15-16	6	30	36	28	9	5	15	18		106
		50.6%	37.5%	93.8%										

JazzFirstGame

2.4.1 Ideas for future study:

- Effects of fatigue and overshooting in locations
- Correlation between shot selection and winning
- Compare Jazz's losing streak with winning streak
- Predict fouls and foul shots
- Evolution of Donovan Mitchell over the season