Final Project Redo

December 11, 2018

1 Goals and Abstract

All Languages use vowels, each vowel takes up a general area within the vowel space. Vowels can generally be classified based upon their first two formants, reffered to as F1 and F2 respectively.

Given that Iquito has not had a phonetic analysis of the vowel formant space, the goal of this report is to determine both the distribution of the 8 contrastive forms and determine if there is a significance in discrepency between the short and long forms of a vowel, other than the vowel length.

Hopefully, these results can be a springboard for future work and to help guide current work.

2 Methods and Assumptions

Given my prior experience with recording vowel formant, I had decided to check at about 1/4 - 1/3 of the way through the vowel utterance, then record the time of the formant and F1 and F2. I used Praat, setting the maximum format to 5500.0 HZ, a window length of 0.025, a dynmic range of 30.8 dB, and a dot size of 1.0 mm. I would then write these into separate microsoft word documents, and then transfer them into a large excel spreadsheet which contains the data for all of the vowels. From there, I would load them into my graphs, using matplotlib and pandas in order to read and plot the data. I would get the averages and check to see if there were any additional data sets.

My assumptions were that a vowel would be relatively constant at the location I am checking, along with the fact that the envirnment would not drastically siginificantly change the vowel qualities. Other than that no other assumptions were originally made upon the data.

It would turn out that some of these assumptions would not be correct, which would lead me to change my assumptions and methods, which will be detailed in another section.

3 Data Points

Drawning from the files listed within pnik_+ ++, pnik_i_ii, pnik_u_uu, pnik_a_aa, I measured from one vowel within each word. All in all, I was able to aquire 20 short i's, 14 long i's, 18 short a's, 14 long a's, 20 short u's, 17 long u's, 14 short 's, and 20 long 's.

4 Preliminary Observations and Method Changes

I originally started recording the high central vowels, simply finding a spot that appeared to be 1/4-1/3 of the way into the vowel, record the formants and time, and then move onto the next one.

After a sanity check, I found that the high central vowels were scattered entirely within the upper section of the graph, bleeding into the spaces of the high front vowels and high back vowels. I then redid those recordings, looking at the range of formant points within the vowel. There were points which fluctuated wildly even between very short intervals of time. As such, after scanning the vowel, I would see if there were a stable location within the vowel, and use that vowel within in question.

It also became painfully obvious that coarticulation was very active in shaping the vowel qualities, so I took that into account in my analysis, rather than assuming that the envirnment did not affect the vowel. However, I would still assume there would be an average vowel quality that was independent of

One problem with choosing points blind includes unluckily picking a single errenous point, such from the clip of ijuuti_t++.

Time_sec Formant 2

0.188722 2625.995866
0.194972 2643.959925
0.201222 2677.623153
0.207472 759.761043 <——
0.213722 2696.327321
0.219972 2706.738702
0.226222 2680.168161
0.232472 2714.770682

As we can see, there is a F2 measurement that differes wildly from the others, this occurs in several places, thus checking to see if there were any plateus where the formants appeared releavtively stable for any amount of time.

A second problem occured with the articulation, where before and after the vowel, the formants would be distored to reflect the oral articulation before and after the vowel. As such, it would become difficult to tell what the actual formants were, rather than just the result of articulation near the previous or preceeding phone, such as in the clip of ap++si, which very smoothly climbs 600 HZ with F2

Time_sec Formant_2

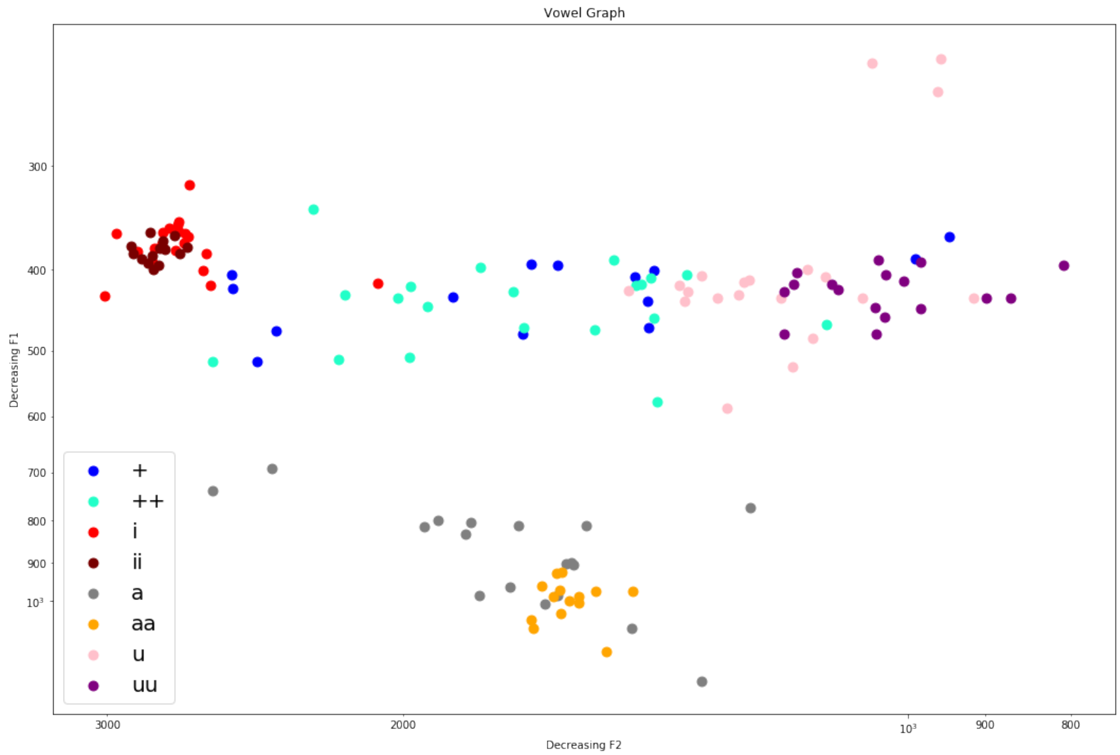
0.490283 1164.508383
0.496533 1190.188276
0.502783 1241.240196
0.509033 1320.807620
0.515283 1390.795844
0.521533 1427.026758
0.527783 1439.227943
0.534033 1451.586850
0.540283 1472.991990
0.546533 1488.530800
0.552783 1495.507117
0.559033 1502.307782
0.565283 1557.371520
0.571533 1626.403760
0.577783 1702.796117
0.584033 1785.846678

```
In [126]: import matplotlib.pyplot as plt
```

```
import numpy as np
import pandas as pd
import matplotlib.ticker as mticker


#We first want to import our data.
excel_file = 'Audio_Formants/Core_Vowel_Distribution.xlsx'

centralshortold = pd.read_excel(excel_file, sheet_name="+_old")
centrallongold = pd.read_excel(excel_file, sheet_name="++_old")

centralshort = pd.read_excel(excel_file, sheet_name="+")
centrallong = pd.read_excel(excel_file, sheet_name="++")

frontshort = pd.read_excel(excel_file, sheet_name="i")
frontlong = pd.read_excel(excel_file, sheet_name="ii")

openshort = pd.read_excel(excel_file, sheet_name="a")
openlong = pd.read_excel(excel_file, sheet_name="aa")

backshort = pd.read_excel(excel_file, sheet_name="u")
backlong = pd.read_excel(excel_file, sheet_name="uu")

datasheets = [centralshort, centrallong, frontshort, frontlong, openshort, openlong,

colors = ["blue", "#22ffc8", "red", "#780000", "grey", "orange", "pink", "purple"]

colLength = ["#808080", "black", "#808080", "black", "#808080", "black", "#808080", "

markers = ["+", "++", "i", "ii", "a", "aa", "u", "uu"]
```

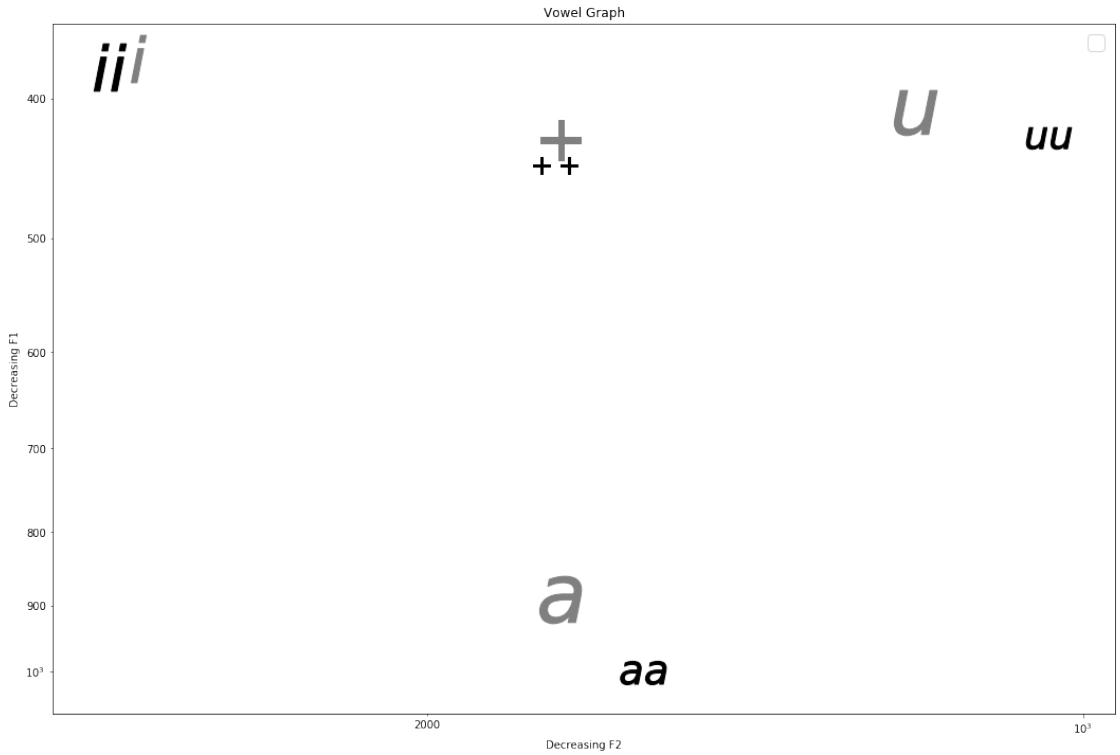
```
In [127]: #Given a data array, we plot a graph for it.

          def plotVowels(excelsheet, mark, lab, size, col ):

              #This shall be our F1
              Yvector = []

              #This shall be our F2
              Xvector = []

              #We append F1 and F2 to our respective vectors
              for index, row in excelsheet.iterrows():
                  Yvector.append(row['F1'])
                  Xvector.append(row['F2'])

              #Now we want to plot these upon our graph
              plt.scatter(Xvector,Yvector, marker=mark, label=lab, s=size, color=col)
```

```
In [132]: fig = plt.figure()
          ax = plt.gca()


          #We set up our axis information
          plt.gca().invert_xaxis()
          plt.gca().invert_yaxis()

          ax.set_yscale('log')
          ax.set_xscale('log')

          ax.xaxis.set_minor_formatter(mticker.ScalarFormatter())
          ax.yaxis.set_minor_formatter(mticker.ScalarFormatter())

          fig_size = plt.rcParams["figure.figsize"]

          fig_size[0] = 18
          fig_size[1] = 12
          plt.rcParams["figure.figsize"] = fig_size

          plt.xlabel('Decreasing F2')
          plt.ylabel('Decreasing F1')
          plt.title('Vowel Graph')

          #Now we plot our graph
          for i in range(8):
              plotVowels(datasheets[i], ".", markers[i], 320, colors[i])


          ax.legend(prop={'size': 20})
          plt.show()
```




```
In [129]: #Given a data array, we plot the average

          def plotAverage(excelsheet, mark, size, col ):

              #This shall be our F1 average
              Yav = 0

              #This shall be our F2 average
              Xav = 0

              num = 0;

              #We append F1 and F2 to our respective vectors
              for index, row in excelsheet.iterrows():
                  Yav += row['F1']
                  Xav += row['F2']
                  num +=1

              #Now we want to plot these upon our graph
              plt.scatter([Xav/num],[Yav/num], marker=mark, s=size, color=col)

In [130]: fig = plt.figure()
          ax = plt.gca()
```

```
#We set up our axis information
plt.gca().invert_xaxis()
plt.gca().invert_yaxis()

ax.set_yscale('log')
ax.set_xscale('log')

ax.xaxis.set_minor_formatter(mticker.ScalarFormatter())
ax.yaxis.set_minor_formatter(mticker.ScalarFormatter())

fig_size = plt.rcParams["figure.figsize"]

fig_size[0] = 18
fig_size[1] = 12
plt.rcParams["figure.figsize"] = fig_size

plt.xlabel('Decreasing F2')
plt.ylabel('Decreasing F1')
plt.title('Vowel Graph')

#Now we plot our graph
for i in range(8):
    #plotVowels(datasheets[i], ".", markers[i], 320, colors[i])
    plotAverage(datasheets[i], "${0}$".format(markers[i]), 2000, colLength[i])


ax.legend(prop={'size': 20})
plt.show()
```



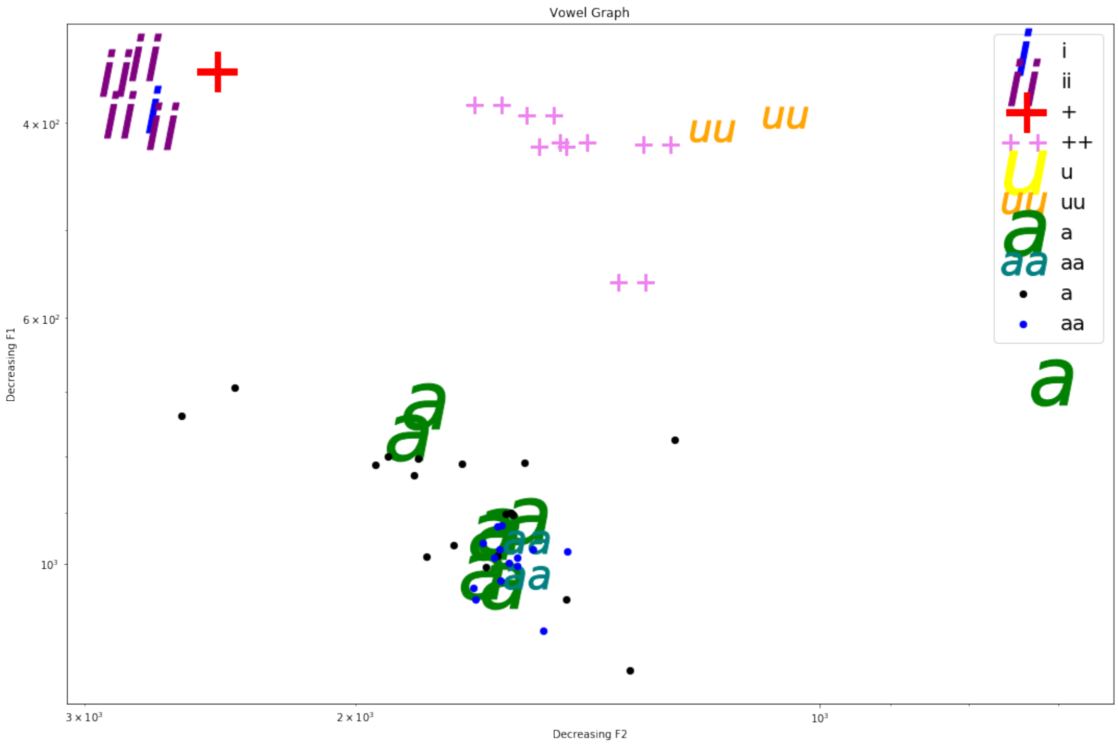
In [131]:

```
#plotVowels(centralshort, "+", "+", 2000, "blue" )

i = [(388.575612, 2708.090360, "t_t")]
ii = [(349.057630, 2744.307910, "#_k"), (402.318030, 2674.163772, "#_k"), (392.71995
      (360.695704, 2867.363532, "#_s")]

i_ = [(359.334921, 2473.461170, "s_i")]
i_i_ = [(393.639886, 1519.849962, "#_t"), (385.051655, 1643.353328, "#_t"), (556.679
        (418.351683,1277.242468, "m_k"), (420.583844, 1491.334871, "p_s"), (416.4012

u = []
uu = [(395.602847, 1053.834300, "s_j"), (407.262791, 1175.388390, "s_j")]

a = [(1026.829041, 1662.364976, "#_m"), (686.770761, 708.640118, "k_#"), (1048.14635
     (915.035277, 1554.570931, "#_p"), (935.793450, 1621.648499, "#_p"), (770.055058
     (721.840664, 1809.078128, "k_#"), (946.403980, 1637.373664, "j_#") ]
aa = [(1028.522617, 1552.661581, "#_k"), (956.150664, 1552.097186, "#_k")]


vowels = ["i", "ii", "+", "++", "u", "uu", "a", "aa"]

vowelInfo = [i, ii, i_, i_i_, u, uu, a, aa]
```

```
vowelColor = ["blue", "purple", "red", "violet", "yellow", "orange", "green", "teal"]

fig = plt.figure()
ax = plt.gca()


#We set up our axis information
plt.gca().invert_xaxis()
plt.gca().invert_yaxis()

ax.set_yscale('log')
ax.set_xscale('log')

fig_size = plt.rcParams["figure.figsize"]

fig_size[0] = 18
fig_size[1] = 12
plt.rcParams["figure.figsize"] = fig_size

plt.xlabel('Decreasing F2')
plt.ylabel('Decreasing F1')
plt.title('Vowel Graph')

#We are going to loop through all of our vowels
for j in range(8):

    #This shall be our F1
    Yvector = []

    #This shall be our F2
    Xvector = []

    #We append F1 and F2 to our respective vectors
    for qual in vowelInfo[j]:
        Yvector.append(qual[0])
        Xvector.append(qual[1])

    #Now we want to plot these upon our graph
    plt.scatter(Xvector,Yvector, marker="${0}$".format(vowels[j]), label=vowels[j], s

#This shall be our F1
Yvector = []

#This shall be our F2
Xvector = []

#We append F1 and F2 to our respective vectors
```

```python
for index, row in centralshort.iterrows():
    Yvector.append(row['F1'])
    Xvector.append(row['F2'])

#Now we want to plot these upon our graph
#plt.scatter(Xvector,Yvector, label = "+", s=20, color="blue")

#This shall be our F1
Yvector = []

#This shall be our F2
Xvector = []

for index, row in centrallong.iterrows():
    Yvector.append(row['F1'])
    Xvector.append(row['F2'])



#plt.scatter(Xvector,Yvector, label = "++", s=20, color="magenta")

#This shall be our F1
Yvector = []

#This shall be our F2
Xvector = []

for index, row in frontlong.iterrows():
    Yvector.append(row['F1'])
    Xvector.append(row['F2'])



#plt.scatter(Xvector,Yvector, label = "ii", s=40, color="blue")


#This shall be our F1
Yvector = []

#This shall be our F2
Xvector = []

for index, row in frontshort.iterrows():
    Yvector.append(row['F1'])
    Xvector.append(row['F2'])
```

```
#plt.scatter(Xvector,Yvector, label = "i", s=40, color="black")


#This shall be our F1
Yvector = []

#This shall be our F2
Xvector = []

for index, row in openshort.iterrows():
    Yvector.append(row['F1'])
    Xvector.append(row['F2'])



plt.scatter(Xvector,Yvector, label = "a", s=40, color="black")


#This shall be our F1
Yvector = []

#This shall be our F2
Xvector = []

for index, row in openlong.iterrows():
    Yvector.append(row['F1'])
    Xvector.append(row['F2'])



plt.scatter(Xvector,Yvector, label = "aa", s=40, color="blue")


ax.legend(prop={'size': 20})
plt.show()
```

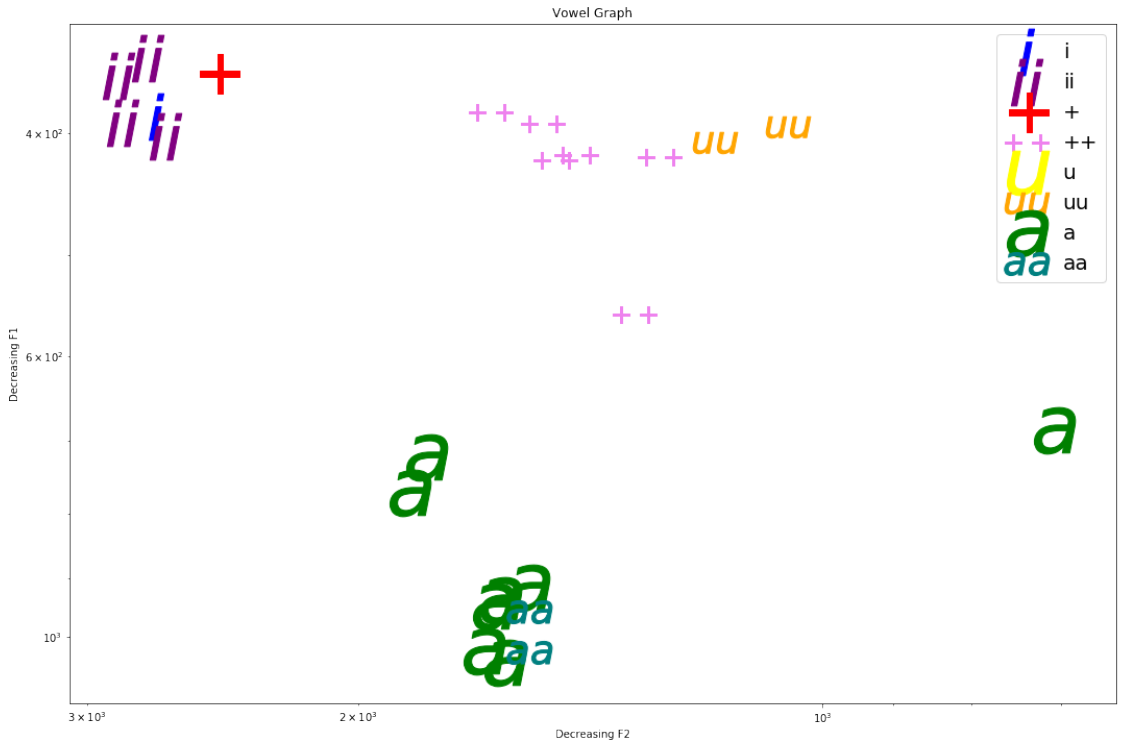


4.1 Vowel Chart

Here we graph all of the vowels we recorded, labeling them with either one or two letters to represent whether they are long or short, each with a different color.

```
In [7]: #Now, we want to load them up into our vectors

        vowels = ["i", "ii", "+", "++", "u", "uu", "a", "aa"]

        vowelInfo = [i, ii, i_, i_i_, u, uu, a, aa]

        vowelColor = ["blue", "purple", "red", "violet", "yellow", "orange", "green", "teal"]

        fig = plt.figure()
        ax = plt.gca()


        #We set up our axis information
        plt.gca().invert_xaxis()
        plt.gca().invert_yaxis()

        ax.set_yscale('log')
        ax.set_xscale('log')
```

```
fig_size = plt.rcParams["figure.figsize"]

fig_size[0] = 18
fig_size[1] = 12
plt.rcParams["figure.figsize"] = fig_size

plt.xlabel('Decreasing F2')
plt.ylabel('Decreasing F1')
plt.title('Vowel Graph')

#We are going to loop through all of our vowels
for j in range(8):

    #This shall be our F1
    Yvector = []

    #This shall be our F2
    Xvector = []

    #We append F1 and F2 to our respective vectors
    for qual in vowelInfo[j]:
        Yvector.append(qual[0])
        Xvector.append(qual[1])

    #Now we want to plot these upon our graph
    plt.scatter(Xvector,Yvector, marker="${0}$".format(vowels[j]), label=vowels[j], s=

ax.legend(prop={'size': 20})
plt.show()
```



4.2 Analysis

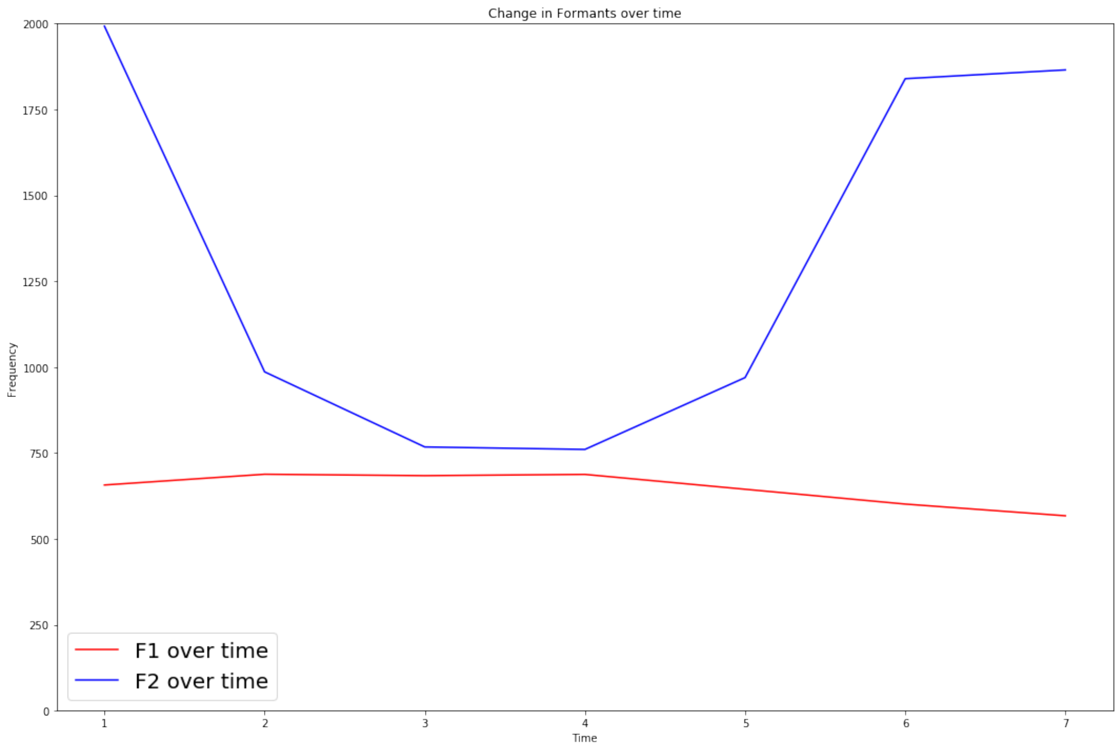
Judging from the graph, from the (albeit limited) samples so far, we have what appears to be a pretty standard vowel distribution space. From the looks of it, the low front vowel "a" apperas to be a bit more central than front.

The central closed vowel does appear to be closer to the back closed vowel, though this could just be a case of not having many samples.

What perked my curiosity however, was the "a" with a much lower F2 than all of the others. As such I took the liberty in order to look at that specific vowel more closely.

```
In [11]: #Now we want to make the plot in question


         fig = plt.figure()
         ax = plt.gca()

         ax.set_ylim([1,2000])

         plt.title("Change in Formants over time")

         overTime = [(656.913252, 1992.748835), (688.160865, 986.364033), (684.065166, 767.701
                     (687.746652, 760.478687), (644.505308, 969.590753), (601.382857, 1839.774
                     (567.250982, 1865.346908)]
```

```
plt.plot([i for i in range(1,8)], [el[0] for el in overTime], label="F1 over time", co
plt.plot([i for i in range(1,8)], [el[1] for el in overTime], label="F2 over time", co

ax.legend(prop={'size': 20})

plt.xlabel('Time')
plt.ylabel('Frequency')

plt.show()
```



4.3 Analysis

I measured the vowel in question at seven even intervals. The vowel itself, even while short, was shorter than most other, it being produced in only about a twentieth of a second. My concern was that my methods of measuring the formants.

While Formant 1 appears to be relatively stable over time over time, there does appear to be a dip within the F2 formant. However, I sampled from the beginning to the ending of the vowel, so the higher formant values are caused by the starting and ending. At the center of the vowel, the value of F2 is relatively stable. As such, it will be important for me to sample within that area where the line is flat, which rough 1/3 the distance away from the starting location.

My original thought was that this vowel measurment was a fluke, or the value I got was simply due to a lot of noise within the measurement. But this is just a very far back “a”.

4.4 Points of interest

Originally, my goal would have been to just focus on the vowel qualitites. But given just how different the very short “a” was, which was shorter than the others, it may also be important to take into account vowel length in order to do a full analysis.