Q1 same speaker different story

April 5, 2021

Comparing vocoid heatmaps for the same speaker

I'd like to find out whether there is a noticeable difference in the vocoid heatmap that is produced when the same speaker tells two different stories. I can imagine that a different prevalence of vocabulary in different stories might end up creating different vocoid heatmaps, at times that are on the order of minutes. I'll be using two recorded stories from storyteller D01-ST01 (a woman).

[1]:
```
# Importing the needed modules
import parselmouth
import tgt
import csv
import io
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns

sns.set() # Use seaborn's default style to make attractive graphs

# INFO HERE: https://python-graph-gallery.com/85-density-plot-with-matplotlib/
from scipy.stats import kde
from scipy.spatial import ConvexHull

from scipy.signal import savgol_filter
```

A function to calculate formants:

[2]:
```
def get_formants(path, gender):
    """Return the cleaned formants from a sound file: smoothed, and
    voiced intervals only

    Returned as a Pandas dataframe with the following columns:
    "row", "time(s)", "nformants", "F1(Hz)", "F2(Hz)", "F3(Hz)", "F4(Hz)",␣
 ↪"F5(Hz)"

    keyword arguments:
    path -- the path to a sound file whose formants will be found
    gender -- the gender of the (single) speaker in the sound file
```

```
            (used to tailor some formant calculation parameters)
    """

    # CONSTANTS

    # Formant analysis parameters
    time_step = 0.005
    max_formant_num = 5
    if gender == "male":
        max_formant_freq = 5500
    elif gender == "female":
        max_formant_freq = 5000
    else:
        sys.exit("get_formants: Improper gender: {}".format(gender))
    window_length = 0.025
    preemphasis = 50

    # Pitch analysis parameters
    pitch_time_step = 0.005
    pitch_floor = 60
    max_candidates = 15
    very_accurate = False
    silence_thresh = 0.03
    voicing_thresh = 0.7
    octave_cost = 0.01
    oct_jump_cost = 0.35
    vuv_cost = 0.14
    pitch_ceiling = 600.0
    max_period = 0.02

    # Other constants
    tier = 1

    # Get raw formants
    sound = parselmouth.Sound(path)
    raw_formants = sound.to_formant_burg(time_step, max_formant_num,
                                         max_formant_freq, window_length,
                                         preemphasis)

    formant_table = parselmouth.praat.call(raw_formants, "Down to Table...",
                                           False, True, 6, False, 3, True, 3,
                                           False)

    formant_df = pd.read_csv(io.StringIO(parselmouth.praat.call(formant_table,
                                                                "List", True)),
                             sep='\t')
```

```
    # Smooth formants: window size 5, polynomial order 3

    formant_df["F1(Hz)"] = savgol_filter(formant_df["F1(Hz)"], 5, 3)
    formant_df["F2(Hz)"] = savgol_filter(formant_df["F2(Hz)"], 5, 3)
    formant_df["F3(Hz)"] = savgol_filter(formant_df["F3(Hz)"], 5, 3)

    # Get voiced intervals:
    pitch = sound.to_pitch_ac(pitch_time_step, pitch_floor, max_candidates,
                              very_accurate, silence_thresh, voicing_thresh,
                              octave_cost, oct_jump_cost, vuv_cost, pitch_ceiling)

   mean_period = 1/parselmouth.praat.call(pitch, "Get quantile", 0.0, 0.0, 0.5,␣
↪"Hertz")
    pulses = parselmouth.praat.call([sound, pitch], "To PointProcess (cc)")
    tgrid = parselmouth.praat.call(pulses, "To TextGrid (vuv)", 0.02,␣
↪mean_period)
    VUV = pd.DataFrame(pd.read_csv(io.StringIO(tgt.io.export_to_table(tgrid.
↪to_tgt(),
                                                                  separator=','))))
    voiced_interval_array = pd.IntervalIndex.
↪from_arrays(VUV['start_time'][VUV["text"] == "V"],
                                                   VUV['end_time'][VUV["text"]␣
↪== "V"],
                                                    closed='left')
    formant_voiced = formant_df[voiced_interval_array.
↪get_indexer(formant_df["time(s)"].values) != -1]

    # TODO: Add formant range checking here
    # For now: remove any rows where less than four formants were found
    filter = formant_voiced["nformants"] > 3
    return formant_voiced[filter]
```

Getting the data

Read in the formant data from CSV files into two NumPy arrays.

[3]:
```
# File 1 is , File 2 is
path1 = "test1.wav"
path2 = "test2n.wav"

file1_title = 'D01-ST01-RTTCandidate'
file2_title = 'D01-ST01-RTT01'

formants1 = get_formants(path1, "female")
formants2 = get_formants(path2, "female")
```

[4]:
```
formants1
```

[4]:
```
         row    time(s)  nformants      F1(Hz)      F2(Hz)      F3(Hz)  \
216      217   1.105615          4  483.173000  2249.441314  3088.106200
217      218   1.110615          4  480.296914  2282.784429  3093.487457
218      219   1.115615          4  478.961943  2335.281029  3100.089057
219      220   1.120615          4  474.985429  2377.352571  3109.803000
220      221   1.125615          4  465.454800  2393.424629  3120.700857
…          …          …          …         …            …            …
25609  25610  128.070615          5  537.233514  1489.763914  2040.811629
25610  25611  128.075615          4  627.464571  1559.527086  2449.833914
25611  25612  128.080615          4  680.518029  1547.352429  2993.827143
25612  25613  128.085615          4  661.291971  1514.037086  2888.433857
25613  25614  128.090615          4  618.659429  1501.347057  2881.246086

         F4(Hz)         F5(Hz)
216    4071.770  --undefined--
217    4045.339  --undefined--
218    4048.476  --undefined--
219    4077.945  --undefined--
220    4093.573  --undefined--
…           …              …
25609  2834.477       3897.068
25610  3816.326  --undefined--
25611  3812.763  --undefined--
25612  3904.840  --undefined--
25613  3920.092  --undefined--

[14156 rows x 8 columns]
```

[5]:
```
formants2
```

[5]:
```
         row    time(s)  nformants      F1(Hz)      F2(Hz)      F3(Hz)  \
36        37   0.206125          5  259.619971  1608.766943  2736.520571
37        38   0.211125          5  284.714943  1654.981657  2744.307114
38        39   0.216125          5  315.448429  1781.165886  2793.104571
39        40   0.221125          4  354.112657  1802.510000  2778.130629
40        41   0.226125          4  383.846600  1639.902429  2685.364143
…          …          …          …         …            …            …
25543  25544  127.741125          5  413.804057  1635.534429  2721.144400
25544  25545  127.746125          4  415.984057  1551.674286  2828.643457
25545  25546  127.751125          5  421.675314  1035.278457  2704.662286
25546  25547  127.756125          5  434.122143  1078.263800  2643.685000
25547  25548  127.761125          4  443.209486  2120.264171  3103.293886

         F4(Hz)    F5(Hz)
36     3544.549  4661.790
37     3568.744  4463.170
38     2928.488  4334.039
```

```
39     4198.303  --undefined--
40     3959.942  --undefined--
…         …           …
25543  3358.220       3935.011
25544  3930.549  --undefined--
25545  3368.003       3920.753
25546  3395.524       3912.248
25547  3851.776  --undefined--

[14260 rows x 8 columns]
```

Normalizing the data

For comparison, we need to normalize data:

$$F_j^*(n) = \frac{F_j(n) - F_j^{median}}{F_j^{median}} \text{ , for } j = \{1,2\} \text{ , } n = \{1...N\}$$

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5724721/

[6]:
```
def normalize(frame):
    """Return a dataframe of normalized formant values"""
    return (frame - frame.median()) / frame.median()
```

[7]:
```
formants1["F1n"], formants1["F2n"] = normalize(formants1["F1(Hz)"]),␣
↪normalize(formants1["F2(Hz)"])
formants1
```

[7]:
```
         row     time(s)  nformants      F1(Hz)       F2(Hz)       F3(Hz)  \
216      217    1.105615          4  483.173000  2249.441314  3088.106200
217      218    1.110615          4  480.296914  2282.784429  3093.487457
218      219    1.115615          4  478.961943  2335.281029  3100.089057
219      220    1.120615          4  474.985429  2377.352571  3109.803000
220      221    1.125615          4  465.454800  2393.424629  3120.700857
…         …          …          …         …           …           …
25609  25610  128.070615          5  537.233514  1489.763914  2040.811629
25610  25611  128.075615          4  627.464571  1559.527086  2449.833914
25611  25612  128.080615          4  680.518029  1547.352429  2993.827143
25612  25613  128.085615          4  661.291971  1514.037086  2888.433857
25613  25614  128.090615          4  618.659429  1501.347057  2881.246086

         F4(Hz)        F5(Hz)       F1n       F2n
216    4071.770  --undefined--  0.077447  0.379579
217    4045.339  --undefined--  0.071033  0.400028
218    4048.476  --undefined--  0.068056  0.432224
219    4077.945  --undefined--  0.059189  0.458027
220    4093.573  --undefined--  0.037936  0.467884
```

```
…      …            …         …         …
25609  2834.477       3897.068  0.197998 -0.086330
25610  3816.326  --undefined--  0.399208 -0.043544
25611  3812.763  --undefined--  0.517514 -0.051011
25612  3904.840  --undefined--  0.474641 -0.071443
25613  3920.092  --undefined--  0.379573 -0.079226

[14156 rows x 10 columns]
```

[8]:

```
formants2["F1n"], formants2["F2n"] = normalize(formants2["F1(Hz)"]),␣
↪normalize(formants2["F2(Hz)"])
formants2
```

[8]:

```
         row      time(s)  nformants      F1(Hz)       F2(Hz)       F3(Hz)  \
36        37     0.206125          5  259.619971  1608.766943  2736.520571
37        38     0.211125          5  284.714943  1654.981657  2744.307114
38        39     0.216125          5  315.448429  1781.165886  2793.104571
39        40     0.221125          4  354.112657  1802.510000  2778.130629
40        41     0.226125          4  383.846600  1639.902429  2685.364143
…        …          …          …         …            …            …
25543  25544  127.741125          5  413.804057  1635.534429  2721.144400
25544  25545  127.746125          4  415.984057  1551.674286  2828.643457
25545  25546  127.751125          5  421.675314  1035.278457  2704.662286
25546  25547  127.756125          5  434.122143  1078.263800  2643.685000
25547  25548  127.761125          4  443.209486  2120.264171  3103.293886

         F4(Hz)         F5(Hz)       F1n       F2n
36     3544.549       4661.790 -0.433176  0.007371
37     3568.744       4463.170 -0.378386  0.036310
38     2928.488       4334.039 -0.311286  0.115323
39     4198.303  --undefined-- -0.226871  0.128688
40     3959.942  --undefined-- -0.161954  0.026867
…      …            …         …         …
25543  3358.220       3935.011 -0.096548  0.024132
25544  3930.549  --undefined-- -0.091788 -0.028379
25545  3368.003       3920.753 -0.079363 -0.351734
25546  3395.524       3912.248 -0.052188 -0.324817
25547  3851.776  --undefined-- -0.032347  0.327658

[14260 rows x 10 columns]
```

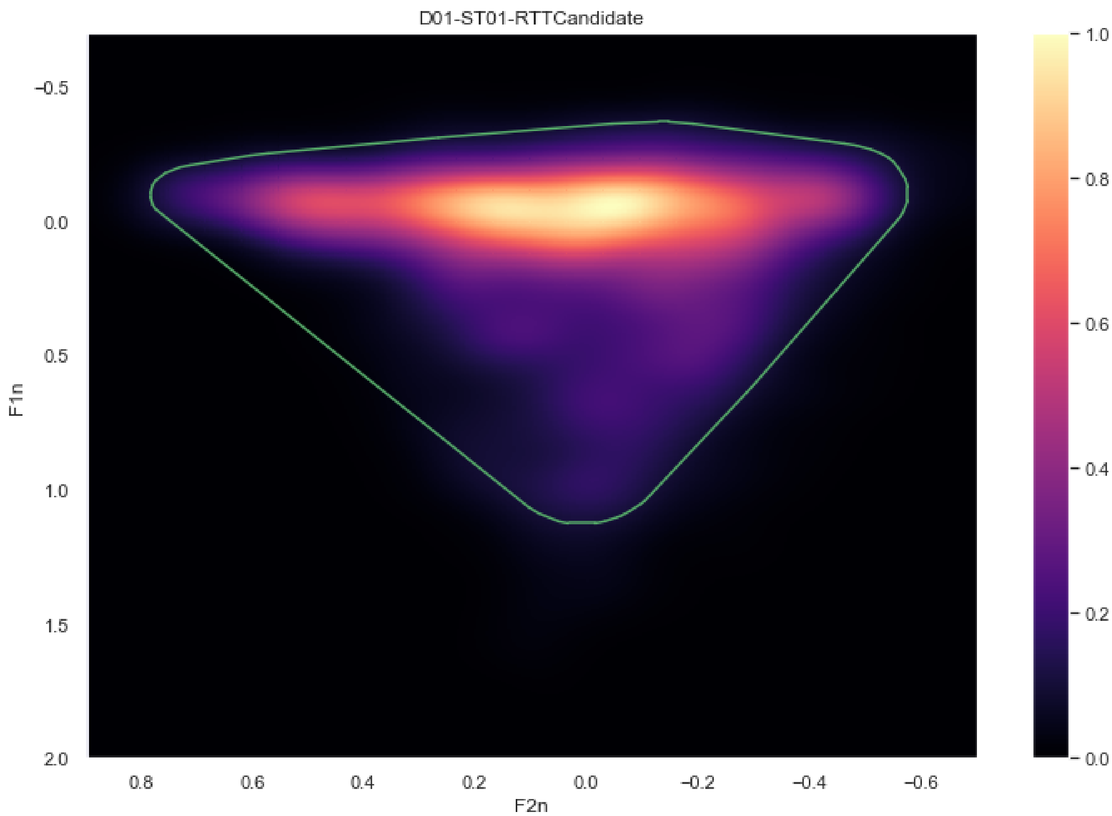
Displaying and comparing

Let's plot the vowel space density for both samples. Is there a difference that is visible on inspection? If inspection shows no difference, is there a better way to calculate how much difference there might be?

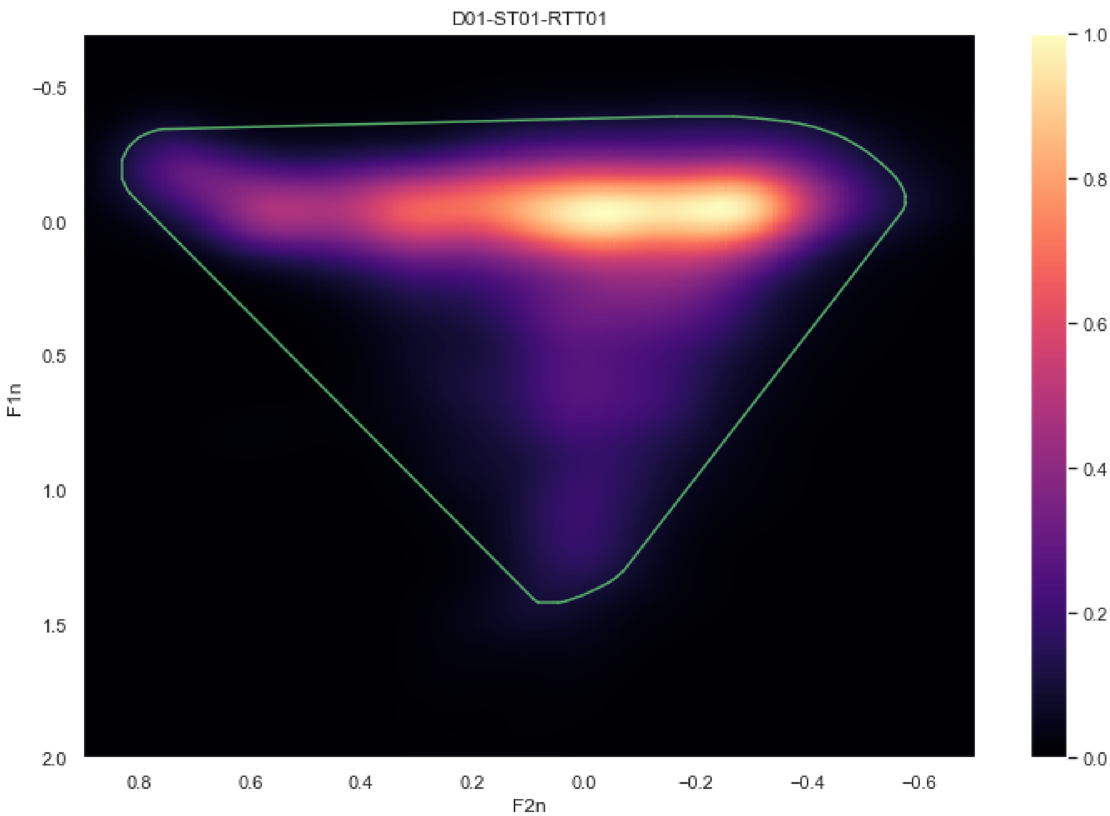
[9]:
```python
def plot_vsd(F1n_frame, F2n_frame, plot_title,
             show_hull = True, cutoff = 0.2, iso_3d = False, save_fig = False):
    """Create a plot for a vowel space density and convex hull

    Note that this function assumes the F1 and F2 frames are already normalized.
    The axis limits work fine for most data encountered so far, but there is
    no guarantee that all data will fit these limits.

    show_hull is a logical flag to toggle whether the convex hull is plotted.
    cutoff is the value at which to draw the hull.
    iso_3d is a logical flag to toggle whether a 2d or 3d plot is made.
    save_fig is a logical flag to toggle whether the image is saved.
    """

    # TODO: check that incoming arguments are correct.

    fig, ax = plt.subplots()
    ax.grid()

    # Evaluate a gaussian kde on a regular grid of nbins x nbins over data extents
    nbins=400
    k = kde.gaussian_kde([F2n_frame,F1n_frame])
    xi, yi = np.mgrid[F2n_frame.min():F2n_frame.max():nbins*1j,
                      F1n_frame.min():F1n_frame.max():nbins*1j]
    zi = k(np.vstack([xi.flatten(), yi.flatten()]))
    znorm = zi / zi.max()

    # Make the basic plot
    if iso_3d:
        ax = plt.axes(projection='3d')
        ax.plot_surface(xi, yi, znorm.reshape(xi.shape), rstride=1, cstride=1,
                        cmap=plt.cm.magma, edgecolor='none')
    else:
        plt.pcolormesh(xi, yi, znorm.reshape(xi.shape), cmap=plt.cm.magma)
        plt.colorbar()

    ax.set_ylim(2.0, -0.7)  # decreasing F1
    ax.set_xlim(0.9, -0.7)  # decreasing F2
    ax.set(xlabel='F2n', ylabel='F1n', title=plot_title)

    plt.rcParams['figure.figsize'] = [12, 8]

    # Calculate and plot the convex hull
    if show_hull:
        vsd = pd.DataFrame(list(zip(xi.flatten(), yi.flatten(), znorm)),
                           columns=['x', 'y', 'value'])
        vsd_filtered = vsd[vsd['value']>=cutoff]
```

```
        hull = ConvexHull(vsd_filtered[["x","y"]])
        for simplex in hull.simplices:
            plt.plot(vsd_filtered["x"].iloc[simplex], vsd_filtered["y"].
↪iloc[simplex], 'g-')

    if save_fig:
        if iso_3d:
            fig.savefig("{}-iso.png".format(plot_title))
        else:
            fig.savefig("{}.png".format(plot_title))
    plt.show()
```

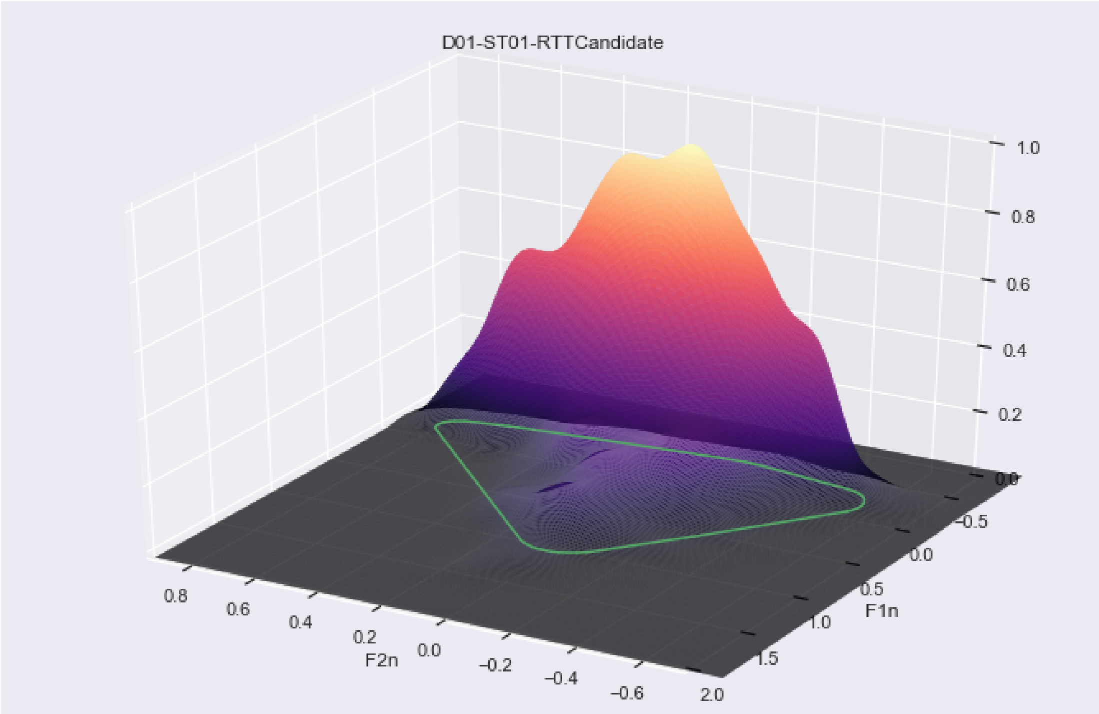
[15]:
```
plot_vsd(formants1["F1n"], formants1["F2n"], file1_title, True, 0.1, False, True)
```



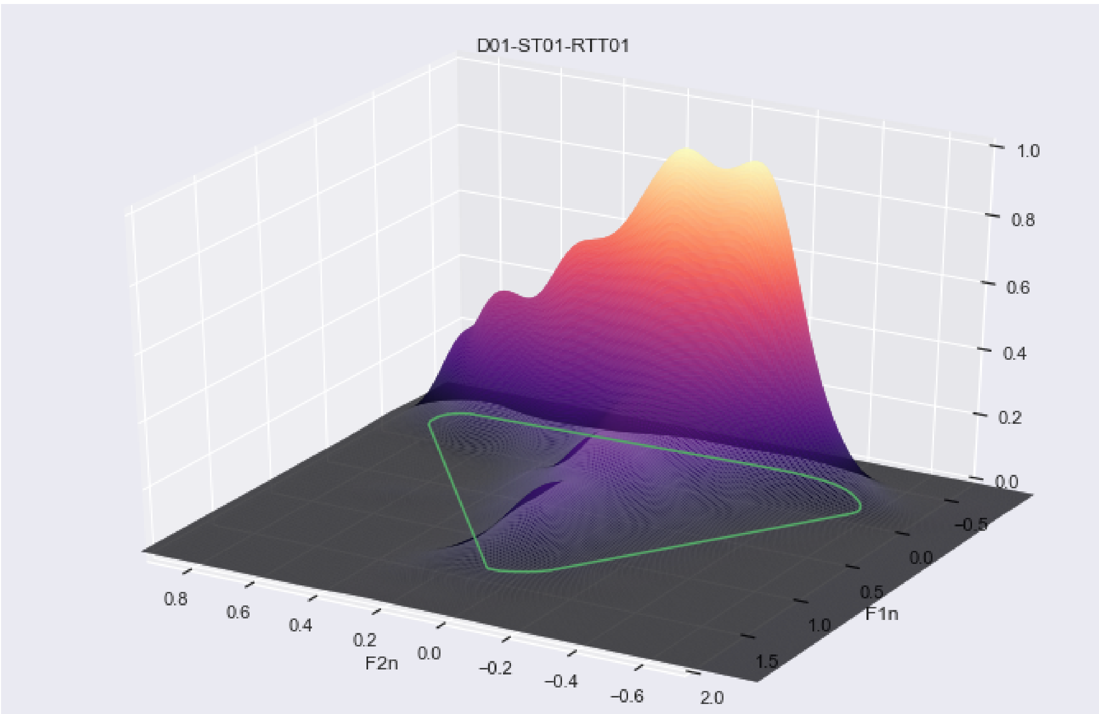
[16]:
```
plot_vsd(formants2["F1n"], formants2["F2n"], file2_title, True, 0.1, False, True)
```



[17]:
```
plot_vsd(formants1["F1n"], formants1["F2n"], file1_title, True, 0.1, True, True)
```




```
[18]: plot_vsd(formants2["F1n"], formants2["F2n"], file2_title, True, 0.1, True, True)
```



This is interesting! The overall area that gets used seems to be very similar based just on a visual comparison, but the peaks are certainly different. It would be good to actually calculate the hull area for these two samples, or find a way to show more clearly that the peaks are at different positions in the formant space, or even plot the two hulls and compare their shape.

Convex hull

Lastly, this just documents the procedure I worked through to get the hull calculation to be at P=0.2 (or any arbitrary value), rather than including all data points. Start by looking at what these nparrays actually are:

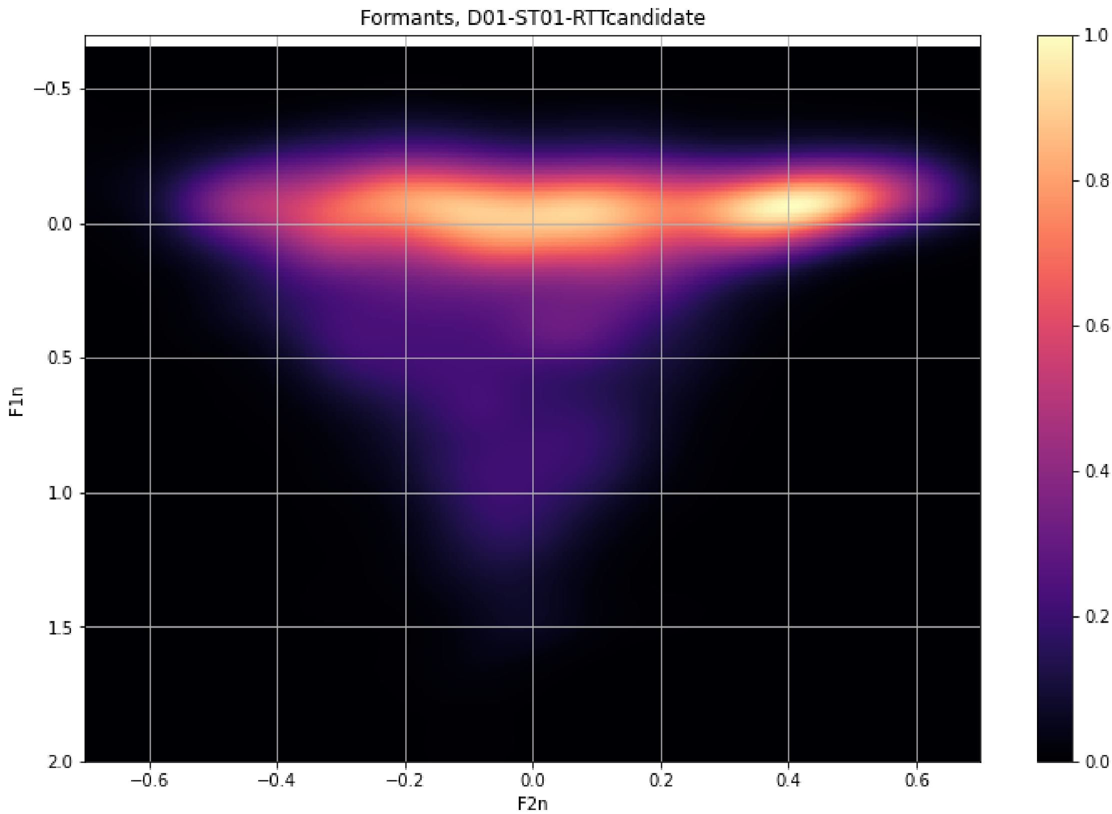
[12]:
```
#xi
xi.shape
#yi
#zi
#zi.min()
#zi.max()
```

[12]:
```
(400, 400)
```

The use of mgrid to generate xi and yi is a way to get the effect of a loop over all x and y points in a grid, without actually running a loop. The nparray xi goes through the x values of an nbins * nbins grid, and yi goes through the y values of an nbins * nbins grid. The nparray zi is a one-domensional array which, when you shape it like xi (not yi, because it's linearly flattened by x-row, not by y-column), gives you all the z values (ie, the values of the probability density function generated from the kernel density estimation)at those points.

[13]:
```
# formants["F2n", "F1n"].plot.kde
fig, ax = plt.subplots()

# Evaluate a gaussian kde on a regular grid of nbins x nbins over data extents
nbins=400
k = kde.gaussian_kde([story1_formants["F2n"],story1_formants["F1n"]])
xi, yi = np.mgrid[story1_formants["F2n"].min():story1_formants["F2n"].max():
 ↪nbins*1j,
                  story1_formants["F1n"].min():story1_formants["F1n"].max():
 ↪nbins*1j]
zi = k(np.vstack([xi.flatten(), yi.flatten()]))
znorm = zi / zi.max()

# Make the plot
plt.pcolormesh(xi, yi, znorm.reshape(xi.shape), cmap=plt.cm.magma)
plt.colorbar()
ax.set_ylim(2.0, -0.7)  # decreasing F1
ax.set_xlim(-0.7, 0.7)
ax.set(xlabel='F2n', ylabel='F1n',
       title='Formants, D01-ST01-RTTcandidate')
```

```
ax.grid()

plt.rcParams['figure.figsize'] = [12, 8]


#fig.savefig("D01-ST01-RTTcandidate.png")
plt.show()
```



[14]:
```
vsd = pd.DataFrame(list(zip(xi.flatten(), yi.flatten(), znorm)),
                   columns=['x', 'y', 'value'])
vsd
```

[14]:

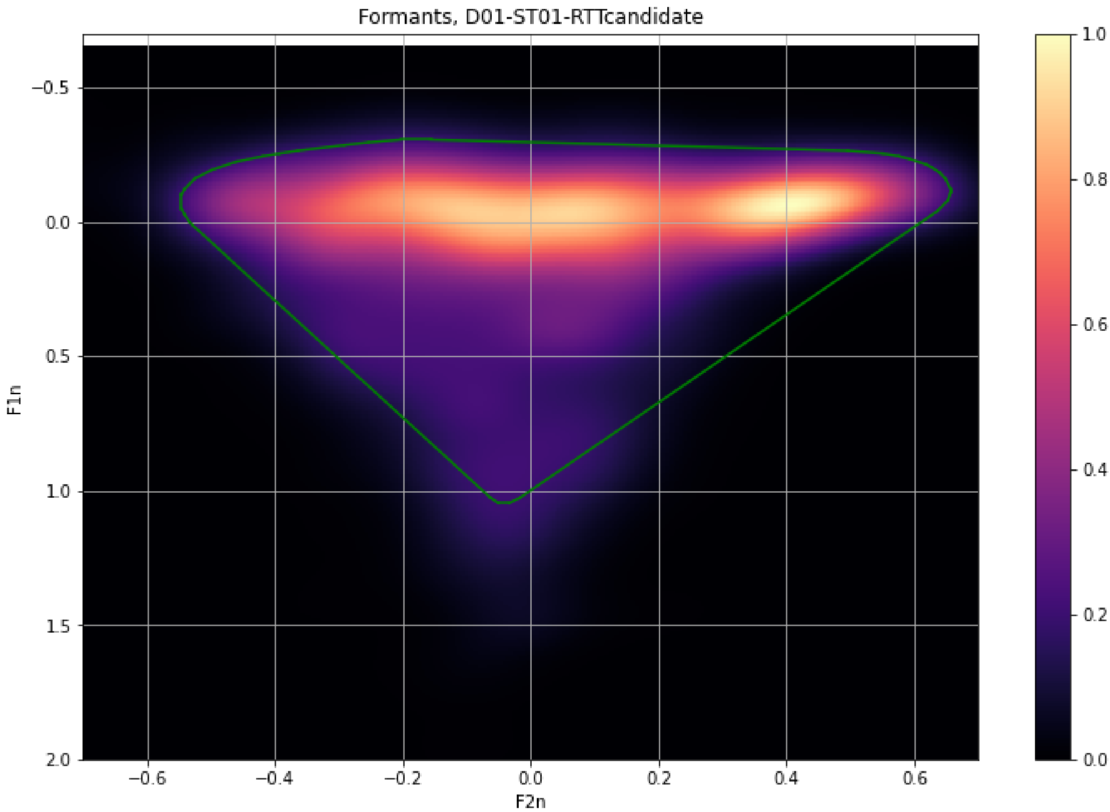
	x	y	value
0	-0.800007	-0.654034	0.000899
1	-0.800007	-0.643788	0.000984
2	-0.800007	-0.633543	0.001073
3	-0.800007	-0.623298	0.001166
4	-0.800007	-0.613053	0.001266
…	…	…	…
159995	0.889830	3.392812	0.000091
159996	0.889830	3.403058	0.000089

```
159997  0.889830  3.413303  0.000086
159998  0.889830  3.423548  0.000081
159999  0.889830  3.433793  0.000076

[160000 rows x 3 columns]
```

[15]:
```python
filter = vsd['value']>=0.20
vsd_filtered = vsd[filter]
```

[16]:
```python
hull = ConvexHull(vsd_filtered[["x","y"]])
```

[17]:
```python
fig, ax = plt.subplots()
plt.pcolormesh(xi, yi, znorm.reshape(xi.shape), cmap=plt.cm.magma)
plt.colorbar()
ax.set_ylim(2.0, -0.7)  # decreasing F1
ax.set_xlim(-0.7, 0.7)
ax.set(xlabel='F2n', ylabel='F1n',
       title='Formants, D01-ST01-RTTcandidate')
ax.grid()
plt.rcParams['figure.figsize'] = [12, 8]

for simplex in hull.simplices:
    plt.plot(vsd_filtered["x"].iloc[simplex], vsd_filtered["y"].iloc[simplex],␣
 ↪'g-')

plt.show()
```


Formants, D01-ST01-RTTcandidate
F1n
F2n
−0.5
0.0
0.5
1.0
1.5
2.0
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
1.0
0.8
0.6
0.4
0.2
0.0

```
[ ]:
```