#

به نام خدا

#

تمرین درس پردازش گفتار

##

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##

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##

تابستان 1400

این پروژه با استفاده از $jupyter \neg eb\infty k$ در زبان برنامه نویسی پایتون پیاده سازی شده است . ### شرح پروژه : در این پروژه با بکار گرفتن از ابزار DTW میزان تفاوت دو سیگنال صدا به صورت خام و بصورت برداری از ویژگی ها مورد بررسی قرار گرفته است . ابتدا کتابخانه ها و ماژول های لازم را فراخوانی میکنیم.

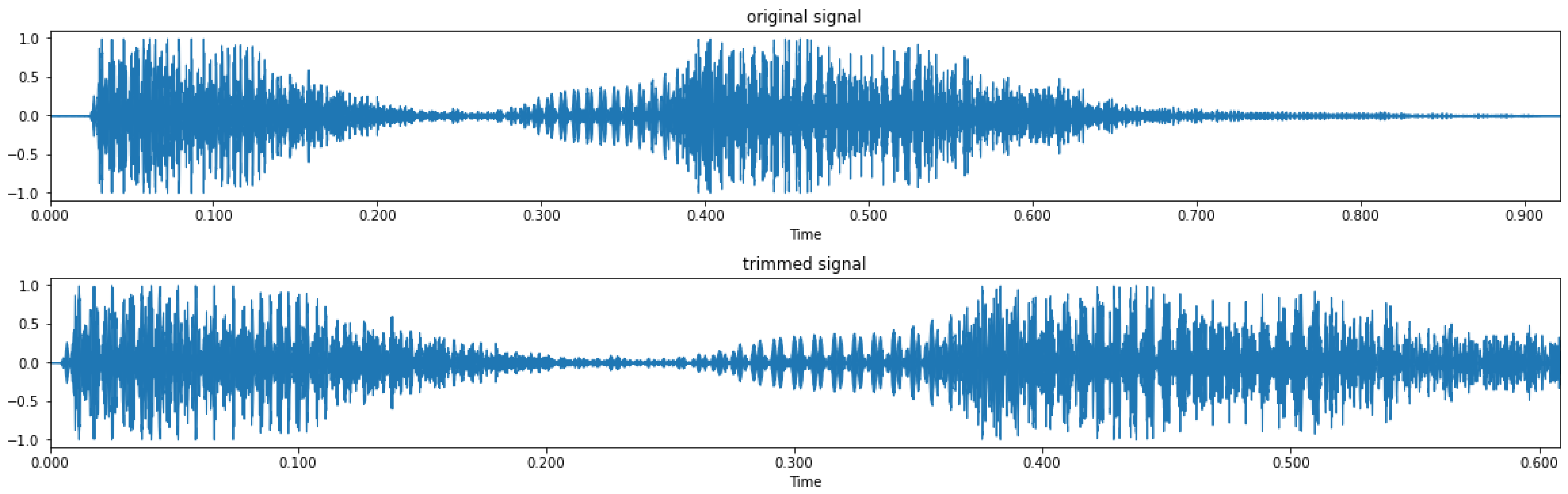
```
In [ ]:
import numpy as np
import librosa
import glob
import matplotlib.pyplot as plt
import librosa.display as display
import pandas as pd
import xlsxwriter
import xlrd
import openpyxl
import sklearn.preprocessing

%matplotlib inline
```

ابتدا قبل از اماده سازی داده به یکی از مراحل ان توجه میکنیم که در ان سکوت هایی که باعث افزایش طول صوت و همچنین افزایش میزان پردازش میشود جلوگیری میکنیم که برای ان از ابزار $trim$ استفاده شده است . در قسمت پایین صوتی اصلی را با حالت صوت بدون سکوت مقایسه شده است که نشان میدهد طول کاهش پیدا کرده است. همچنین با استفاده از یک پنجره به طول $30ms$ این بررسی وجود سکوت انجام گرفته شده است و تمامی اصواتی که با قدرت زیر $10db$ وجود داشته اند حذف شده است

```
In [ ]:
# trimming analysis
signal,samplerate = librosa.load('data/last_name_by_myself/lastname_001.wav',sr=22050,mono=True)

fig, ax = plt.subplots(2,1,constrained_layout=True)
```

```python
fig.set_size_inches(16,5)

display.waveplot(signal,sr=22050,ax=ax[0])
ax[0].set(title="original signal")

print("duration : ",round(librosa.get_duration(signal),4))

# frame length : The number of samples per analysis frame (30ms = 661 samples) ~= N
# hop length : The number of samples between analysis frames (10ms = 220 samples) ~= M
# top_db : The threshold (in decibels) below reference to consider as silence

signal_trimmed,index = librosa.effects.trim(signal,top_db=10,frame_length=int(30e-3*samplerate),hop_length=int(10e-3*samp

display.waveplot(signal_trimmed,sr=22050,ax=ax[1])
ax[1].set(title="trimmed signal")

print("trimmed duration : ",round(librosa.get_duration(signal_trimmed),4))

print("the interval of original signal corresponding to the non-silent region would start at : ",index[0]," and end at :
```

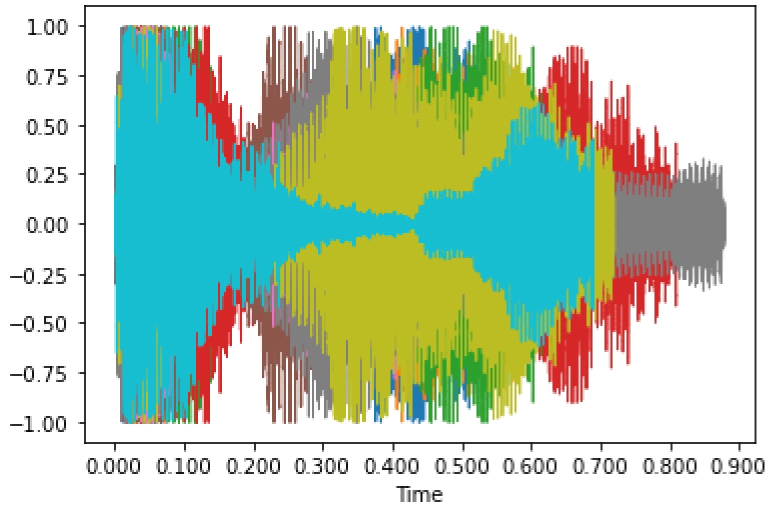
```
duration :  0.9218
trimmed duration :  0.6086
the interval of original signal corresponding to the non-silent region would start at :  440  and end at :  13860
```



<p dir="rtl">#### توصیف داده : دادهایی که در این پروژه استفاده شده اند به قسمت کلی شامل صدا ا ن ی س و صدا م ا ن ه ب تشکیل شده است که توسط دوشخص متفاوت ادا شده اند هر یک از اشخاص ده بار صدا ا ن ی س ضبط شده است و ده بار م ا ن ه ب و هر کدام دو به دو تحلیل شده اند و در نهایت میزان تفاوت ان با یک دیگر مقایسه شده است.</p>

In [ ]:
```
data = 'data/'
lastname_bymyself_folder = data + 'last_name_by_myself/'
lastname_bymyself_file = glob.glob(lastname_bymyself_folder+'*.wav')

lastname_bymyself = []
for lastname_path in lastname_bymyself_file:
    signal,samplerate = librosa.load(lastname_path,sr=22050,mono=True)
    signal,index = librosa.effects.trim(signal,top_db=10,frame_length=int(30e-3*samplerate),hop_length=int(10e-3*samplera
    display.waveshow(signal)
    lastname_bymyself.append([signal,samplerate])

print("record number : ",len(lastname_bymyself))
```

```
record number :  10
```



تابع زیر میزان DTW بین دو فایل صوتی را تشخیص میدهد و در نهایت بهترین فاصله را به صورت یک مجموعه در قالب جدول نمایش میدهد

In [ ]:
```
def signal_dtw_calculation(y1,y2,is_equal=False,dtw_weight_path=None):

    if(dtw_weight_path):
        return pd.read_excel(dtw_weight_path,index_col=0)

    record_number_y1 = len(y1)
    record_number_y2 = len(y2)

    if(is_equal):

        distances = np.zeros((record_number_y1, record_number_y2))
        for i in range(record_number_y1):
            for j in range(i+1, record_number_y2):
                x_1, fs = y1[i]
                x_2, fs = y2[j]
                D, wp = librosa.sequence.dtw(x_1, x_2)
                best_cost = D[-1, -1]
                distances[i][j] = round(best_cost, 3)

        distances = pd.DataFrame(distances)

        return distances


    distances = np.zeros((record_number_y1, record_number_y2))
    for i in range(record_number_y1):
        for j in range(record_number_y2):
            x_1, fs = y1[i]
            x_2, fs = y2[j]
            D, wp = librosa.sequence.dtw(x_1, x_2)
            best_cost = D[-1, -1]
            distances[i][j] = round(best_cost, 3)

    distances = pd.DataFrame(distances)

    return distances
```

میزان شباهت ادای صوت خام م ا ن ه ب توسط خودم همان طور که مشاهده میشود میزان DTW سیگنال زیاد میباشد و به خوبی قابل تفکیک نمیباشند

In [ ]:

```
signal_distances_lastname_lastname_bymyself = signal_dtw_calculation(lastname_bymyself,lastname_bymyself,is_equal=True,dt
signal_distances_lastname_lastname_bymyself
```

Out[ ]:

	0	1	2	3	4	5	6	7	8	9
0	0	848.716	1008.144	1240.776	1305.755	1243.724	1040.890	1315.072	1480.996	1329.427
1	0	0.000	1014.244	1213.117	1212.691	1220.273	964.352	1273.261	1392.649	1297.726
2	0	0.000	0.000	1320.593	1439.262	1394.256	1158.300	1369.722	1490.365	1436.390
3	0	0.000	0.000	0.000	1125.506	1352.069	1253.510	1393.819	1424.594	1107.705
4	0	0.000	0.000	0.000	0.000	874.804	908.985	1336.700	1556.205	846.317
5	0	0.000	0.000	0.000	0.000	0.000	933.461	1653.566	1768.868	1143.542

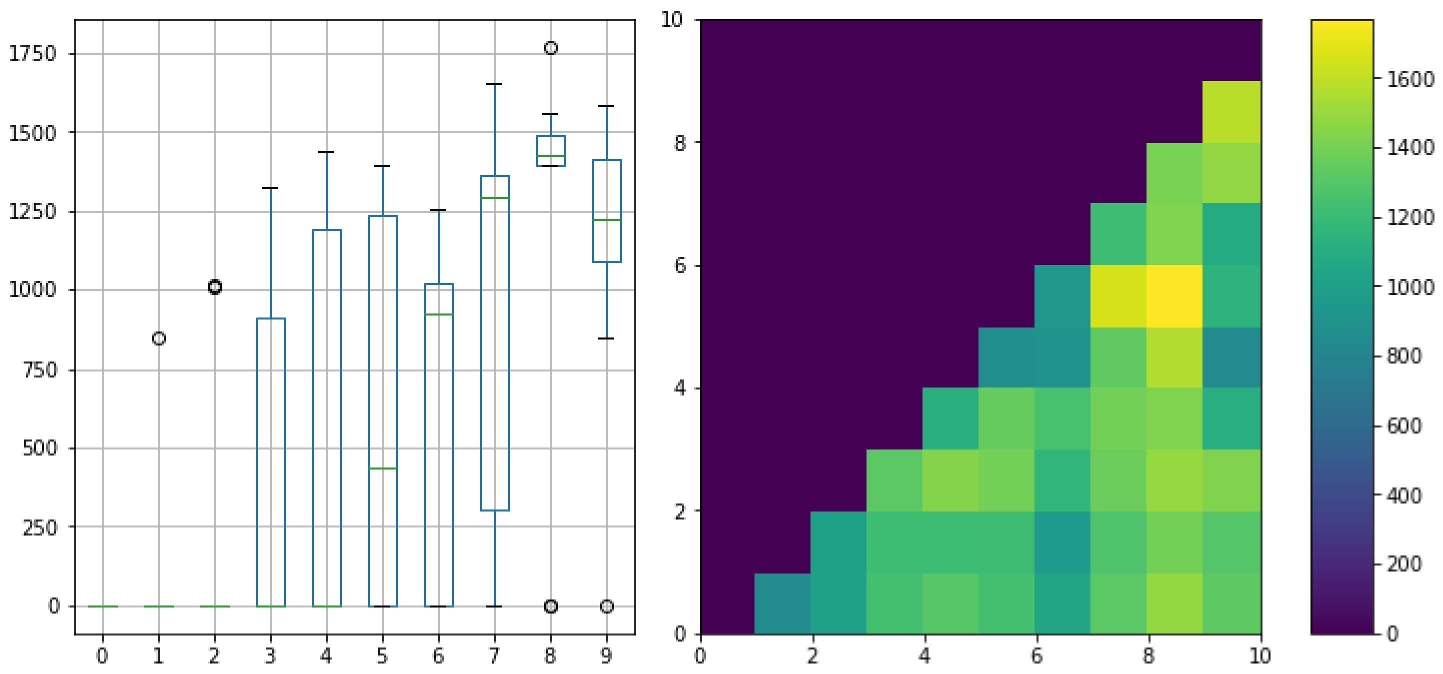
	0	1	2	3	4	5	6	7	8	9
6	0	0.000	0.000	0.000	0.000	0.000	0.000	1218.390	1429.339	1082.597
7	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1408.016	1472.040
8	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1580.603
9	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

در شکل زیر سعی شده است تا اطلاعاتی از نمای کلی از مقدار تفاوت بین سیگنال نمونه نشان میدهد و در نمودار اول به صورت جبعی و در نمودار دوم به صورت نمایش رنگدار که هر نمونه نسبت به دیگر با چه شدتی با هم متشابه هستند و هر چه این مقدار کمتر باشد میزان شباهت بین نمونه ها بیشتر است .

```
In [ ]:
fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Signal DTW intuition illustration of Lastname to Lastname by myself", fontsize=14)

signal_distances_lastname_lastname_bymyself.boxplot(ax=ax[0])

img = ax[1].pcolormesh(signal_distances_lastname_lastname_bymyself.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

```
Out[ ]: <matplotlib.colorbar.Colorbar at 0x2a7ddf98d90>
```

Signal DTW intuition illustration of Lastname to Lastname by myself



به علت حجم بالای محاسبات سیگنال خام نتیجه ان یک خروجی $exel$ گرفته میشود تا در دفعات بعد نیاز به اجرا الگوریتم نباشد .

In [ ]:
```python
# repoting out of dwt
signal_distances_lastname_lastname_bymyself.to_excel(lastname_bymyself_folder+'output/signal_distances_lastname_lastname_
```

همان طور که مشاهده شد میزان شباهت به شکل صحیح و قابل تفکیکی انجام نشده و لذا نیاز است با استفاده از استخراج بعضی از ویژگی های صوت انرا قابل تشخیص تر برای سیستم کنیم ## ویژگی های استفاده شده : 1. MFCC 2. مشتق اول **MFCC** 3. مشتق دوم **MFCC** 4. عبور از صفر (ZCR) 5. انرژی سیگنال (RMS) ### نکته : برای انجام استخراج ویژگی نیاز به انجام دو مرحله پیشنیاز **frame** بندی و پنجره گذاری نیاز میاشد که برای فریم بندی مانند بخش ایجاد سکوت از دو پارامتر زیر استفاده میشود : 1. frame_length = 30ms <- که معرف 661 نمونه 2. hop_length = 10ms <- که معرف 220 نمونه میباشد ### نکته : تعداد نمونه های بالا از طریق ضرب طول زمانی در فرکانس نمونه برداری انجام میشود

In [ ]:
```python
# feature extraction
frame_length = int(30e-3*samplerate) # 30ms
hop_length = int(10e-3*samplerate) # 10ms

lastname_bymyself_features = []

for signal,samplerate in lastname_bymyself:
    mfcc = librosa.feature.mfcc(signal,samplerate,n_mfcc=13,hop_length=hop_length,n_fft=frame_length,window=np.hamming(fr
    mfcc_delta = librosa.feature.delta(mfcc)
    mfcc_delta2 = librosa.feature.delta(mfcc,order=2)
    zcr = librosa.feature.zero_crossing_rate(signal,frame_length=frame_length,hop_length=hop_length)
    rms = librosa.feature.rms(signal,frame_length=frame_length,hop_length=hop_length)
    feature = np.concatenate([mfcc,mfcc_delta,mfcc_delta2,zcr,rms])
    lastname_bymyself_features.append(feature)

lastname_bymyself_features[0].shape
```

Out[ ]:
```
(41, 61)
```

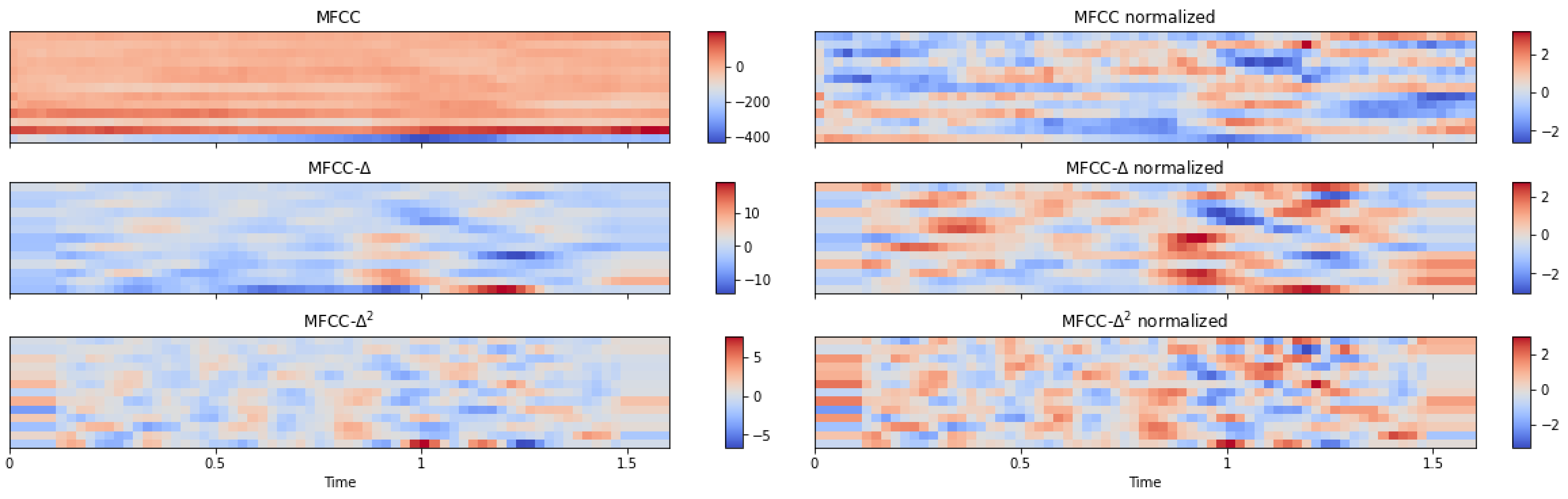
به طور کلی برای دریافت نمونه بهتر قبل از پردازش و کاهش حجم محاسبات میتوان از نرمال سازی داده بهره گرفت که در تابع زیر به بررسی تاثیر نرمال توجه شده است . نرمال سازی زیر به صورت **Standard Score** انجام شده است اما مدل های دیگر نرمال سازی نیز میباشد که برخی از انها در لیست زیر اماده است و فقط نیاز به تغییر پارامتر $r \leq sca$ توسط کتابخانه $arn \leq \ - sikit$ دارد . 1. RobustScaler 3. MaxAbsScaler 2. MinMaxScaler برای اطلاعات بیشتر میتوان به داکیومنت sklearn مراجعه بفرمایید [اینجا](https://scikit-learn.org/stable/modules/classes.html#module-sklearn.preprocessing) ### فرمول ریاضی Standard Score به گونه زیر است : !\[\Large x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}](https://latex.codecogs.com/svg.latex?\Large&space;x^{norm}=\frac{x-mean}{stdev})

In [ ]:
```
def mfcc_scaler(features,n_mfcc,scaler=sklearn.preprocessing.StandardScaler()):
    features_s = scaler.fit_transform(features.T).T
    mfcc_s = features_s[:n_mfcc,:]
    mfcc_delta_s = features_s[n_mfcc:2*n_mfcc,:]
    mfcc_delta2_s = features_s[2*n_mfcc:3*n_mfcc,:]

    return features_s,mfcc_s,mfcc_delta_s,mfcc_delta2_s
```

In [ ]:
```
features_s,mfcc_s,mfcc_delta_s,mfcc_delta2_s = mfcc_scaler(feature,13,sklearn.preprocessing.StandardScaler())

fig, ax = plt.subplots(3,2,constrained_layout=True, sharex=True, sharey=True)

fig.set_size_inches(16,5)

img1 = display.specshow(mfcc, ax=ax[0][0], x_axis='time')
ax[0][0].set(title='MFCC')
ax[0][0].label_outer()
img2 = display.specshow(mfcc_delta, ax=ax[1][0], x_axis='time')
ax[1][0].set(title=r'MFCC-$\Delta$')
ax[1][0].label_outer()
img3 = display.specshow(mfcc_delta2, ax=ax[2][0], x_axis='time')
ax[2][0].set(title=r'MFCC-$\Delta^2$')
ax[2][0].label_outer()
```

```
fig.colorbar(img1, ax=[ax[0][0]])
fig.colorbar(img2, ax=[ax[1][0]])
fig.colorbar(img3, ax=[ax[2][0]])

img1 = display.specshow(mfcc_s, ax=ax[0][1], x_axis='time')
ax[0][1].set(title='MFCC normalized')
ax[0][1].label_outer()
img2 = display.specshow(mfcc_delta_s, ax=ax[1][1], x_axis='time')
ax[1][1].set(title=r'MFCC-$\Delta$ normalized')
ax[1][1].label_outer()
img3 = display.specshow(mfcc_delta2_s, ax=ax[2][1], x_axis='time')
ax[2][1].set(title=r'MFCC-$\Delta^2$ normalized')
ax[2][1].label_outer()
fig.colorbar(img1, ax=[ax[0][1]])
fig.colorbar(img2, ax=[ax[1][1]])
fig.colorbar(img3, ax=[ax[2][1]])
```

Out[ ]:
```
<matplotlib.colorbar.Colorbar at 0x2a7def53e80>
```



In [ ]:
```
lastname_bymyself_features_normalized = []
for feature in lastname_bymyself_features:
    lastname_bymyself_features_normalized.append(mfcc_scaler(feature,13)[0])
```

اجرا DTW بروی بردار های ویژگی صوت *بهنام*

In [ ]:

```
def features_dtw_calculation(y1,y2,is_equal=False,dtw_weight_path=None):

    if(dtw_weight_path):
        return pd.read_excel(dtw_weight_path,index_col=0)

    record_number_y1 = len(y1)
    record_number_y2 = len(y2)

    if(is_equal):

        distances = np.zeros((record_number_y1, record_number_y2))
        for i in range(record_number_y1):
            for j in range(i+1, record_number_y2):

                D, wp = librosa.sequence.dtw(y1[i], y2[j])
                best_cost = D[-1, -1]
                distances[i][j] = round(best_cost, 3)

        distances = pd.DataFrame(distances)

        return distances

    distances = np.zeros((record_number_y1, record_number_y2))
    for i in range(record_number_y1):
        for j in range(record_number_y2):
            D, wp = librosa.sequence.dtw(y1[i], y2[j])
            best_cost = D[-1, -1]
            distances[i][j] = round(best_cost, 3)

    distances = pd.DataFrame(distances)

    return distances
```

همان طور که مشاهده میشود میزان مقادیر خروجی الگوریتم کاهش پیدا کرده قابل تفکیک پذیر تر شده است و همچنین از حجم پردازش به شکل قابل توجه کم شده است.

In [ ]:

```
features_distances_lastname_lastname_bymyself = features_dtw_calculation(lastname_bymyself_features_normalized,lastname_b
features_distances_lastname_lastname_bymyself
```

Out[ ]:

	0	1	2	3	4	5	6	7	8	9
0	0	331.926	362.141	480.141	377.399	382.911	375.612	639.533	436.869	425.664
1	0	0.000	369.588	466.638	429.371	428.425	429.445	641.180	443.073	498.624

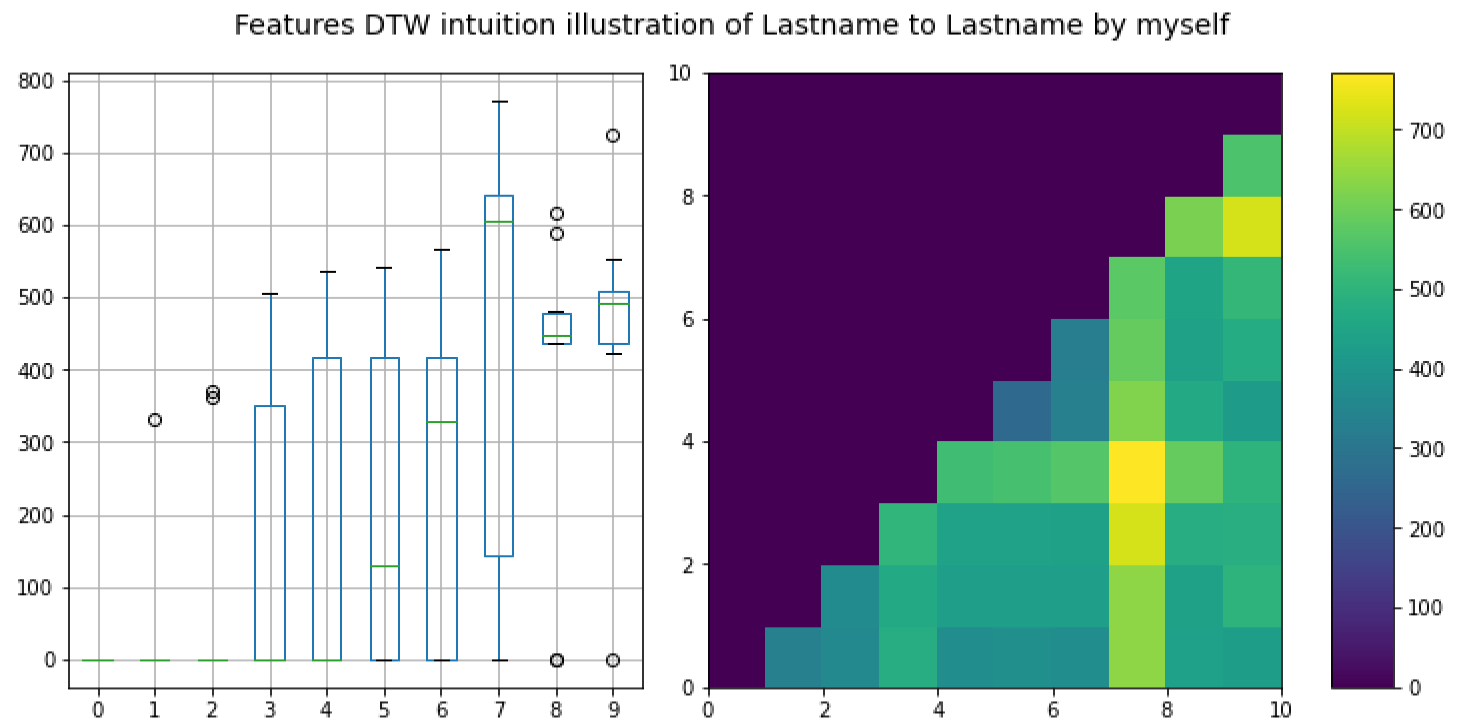
	0	1	2	3	4	5	6	7	8	9
2	0	0.000	0.000	504.535	443.913	443.711	437.591	720.702	480.701	484.635
3	0	0.000	0.000	0.000	535.273	542.801	566.456	771.841	589.041	499.466
4	0	0.000	0.000	0.000	0.000	261.122	332.673	624.341	466.935	422.429
5	0	0.000	0.000	0.000	0.000	0.000	325.496	588.321	438.715	473.469
6	0	0.000	0.000	0.000	0.000	0.000	0.000	574.382	451.596	510.216
7	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	615.293	722.774
8	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	552.971
9	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

In [ ]:

```
fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Features DTW intuition illustration of Lastname to Lastname by myself", fontsize=14)

features_distances_lastname_lastname_bymyself.boxplot(ax=ax[0])

img = ax[1].pcolormesh(features_distances_lastname_lastname_bymyself.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

Out[ ]:

```
<matplotlib.colorbar.Colorbar at 0x2a7d9d2a430>
```

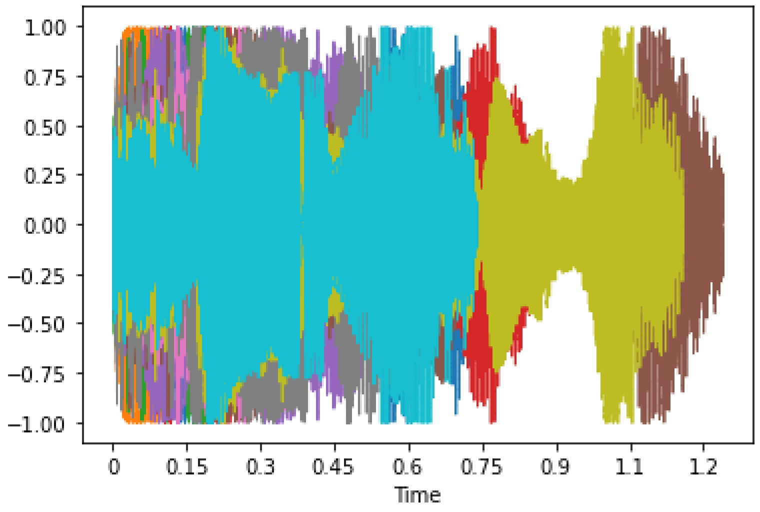


```
In [ ]:
# repoting out of dwt
features_distances_lastname_lastname_bymyself.to_excel(lastname_bymyself_folder+'output/features_distances_lastname_lastr
```

دریافت صوت ا ن ی س توسط خودم

```
In [ ]:
firstname_bymyself_folder = data + 'first_name_by_myself/'
firstname_bymyself_file = glob.glob(firstname_bymyself_folder+'*.wav')

firstname_bymyself = []
for firstname_path in firstname_bymyself_file:
    signal,samplerate = librosa.load(firstname_path,sr=22050,mono=True)
    signal,index = librosa.effects.trim(signal,top_db=10,frame_length=int(30e-3*samplerate),hop_length=int(10e-3*samplera
    display.waveshow(signal)
    firstname_bymyself.append([signal,samplerate])

print("record number : ",len(firstname_bymyself))
```

```
record number :  10
```



میزان شباهت صدا خام ا ن ی س با خودش

In [ ]:
```
signal_distances_firstname_bymyself = signal_dtw_calculation(firstname_bymyself,
firstname_bymyself,
dtw_weight_path=firstname_bymyself_folder+'output/signal_distances_firstname_firstname_bymyself.xlsx')

signal_distances_firstname_bymyself
```

Out[ ]:

	0	1	2	3	4	5	6	7	8	9
0	0	2109.323	2007.944	1789.689	1555.662	1807.638	1941.926	1999.109	2307.285	1444.116
1	0	0.000	1161.119	2069.439	1577.083	2522.635	1036.808	1915.698	2735.544	1709.328
2	0	0.000	0.000	1886.670	1644.274	2414.100	1107.257	1892.337	2539.966	1867.726
3	0	0.000	0.000	0.000	1860.474	1791.070	1989.821	1916.957	2010.343	1687.440
4	0	0.000	0.000	0.000	0.000	1886.188	1573.933	1647.217	2476.379	1481.490
5	0	0.000	0.000	0.000	0.000	0.000	2196.674	2131.059	2272.796	1739.960
6	0	0.000	0.000	0.000	0.000	0.000	0.000	1731.418	2512.765	1717.441
7	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2685.835	1654.975
8	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2270.118
9	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

In [ ]:

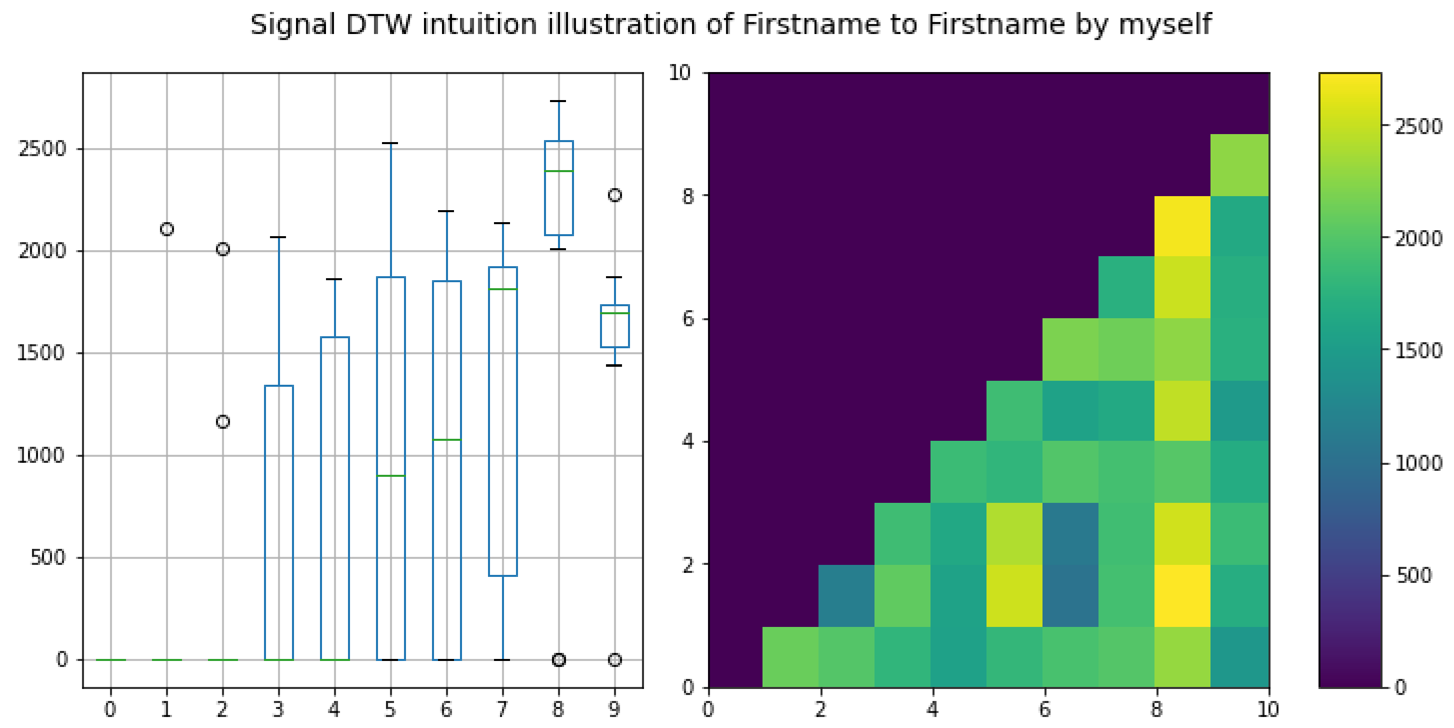
```
# reporting dtw of firstname signal
signal_distances_firstname_bymyself.to_excel(firstname_bymyself_folder+'output/signal_distances_firstname_firstname_bymys
```

In [ ]:

```

fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Signal DTW intuition illustration of Firstname to Firstname by myself", fontsize=14)

signal_distances_firstname_bymyself.boxplot(ax=ax[0])

img = ax[1].pcolormesh(signal_distances_firstname_bymyself.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

Out[ ]:

```
<matplotlib.colorbar.Colorbar at 0x2a7db7bfd90>
```



میزان شباهت صدای خامی که از دو صوت ا ن ی س , م ا ن ه ب در یافت شده است که توسط خودم ادا شده اند

In [ ]:

```
signal_distances_firstname_lastname_bymyself = signal_dtw_calculation(lastname_bymyself,firstname_bymyself,is_equal=False
signal_distances_firstname_lastname_bymyself
```

Out[ ]:

	0	1	2	3	4	5	6	7	8	9
0	1683.990	1331.745	1446.639	2050.028	1445.512	2174.044	1433.124	1905.469	2408.824	1680.526
1	1667.015	1308.934	1411.346	2006.050	1463.842	2095.592	1368.548	1922.697	2410.367	1683.062
2	1767.681	1580.044	1539.985	2067.451	1539.071	2194.348	1585.854	1954.776	2465.376	1764.881
3	1864.580	1490.942	1442.202	2083.256	1677.484	2312.780	1451.244	2068.739	2480.803	1799.243
4	2146.921	880.820	1011.370	1961.151	1782.383	2686.503	1286.858	2128.173	2696.408	1941.140
5	2080.034	803.135	1203.037	2091.851	1620.318	2489.756	1279.260	1883.683	2696.833	1761.284
6	1806.885	1029.213	1296.860	1868.596	1454.998	2270.966	1342.774	2035.771	2449.069	1690.393
7	1976.403	1827.527	1684.776	2121.449	1748.571	2461.990	1771.982	2140.691	2766.273	1933.806
8	1930.396	1820.877	1673.176	2139.787	1655.915	2267.704	1658.031	2036.491	2605.619	1874.651
9	2106.205	1205.405	1336.449	2030.222	1763.672	2621.877	1621.840	2261.873	2434.738	1916.569

In [ ]:

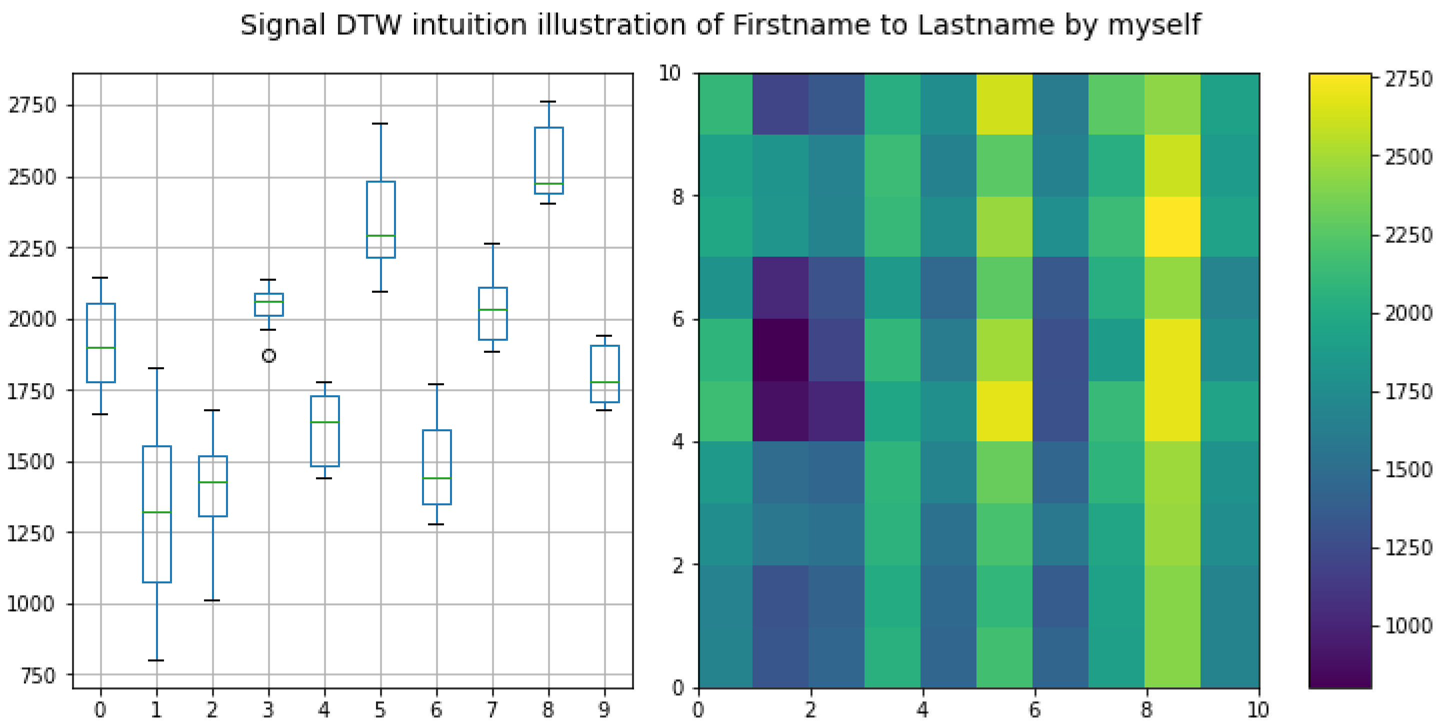
```
# reporting dtw of firstname to lastname signal
signal_distances_firstname_lastname_bymyself.to_excel(data+'/signal_distances_firstname_lastname_bymyself.xlsx', engine='
```

In [ ]:

```
fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Signal DTW intuition illustration of Firstname to Lastname by myself", fontsize=14)

signal_distances_firstname_lastname_bymyself.boxplot(ax=ax[0])

img = ax[1].pcolormesh(signal_distances_firstname_lastname_bymyself.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

Out[ ]:

```
<matplotlib.colorbar.Colorbar at 0x2a7dcc08ca0>
```



استخراج ویژگی ها از صوت ا ن ی س که توسط خودم گفته شده است

In [ ]:

```
# feature extraction
frame_length = int(30e-3*samplerate) # 30ms
hop_length = int(10e-3*samplerate) # 10ms

firstname_bymyself_features = []

for signal,samplerate in firstname_bymyself:
    mfcc = librosa.feature.mfcc(signal,samplerate,n_mfcc=13,hop_length=hop_length,n_fft=frame_length,window=np.hamming(fr
    mfcc_delta = librosa.feature.delta(mfcc)
    mfcc_delta2 = librosa.feature.delta(mfcc,order=2)
    zcr = librosa.feature.zero_crossing_rate(signal,frame_length=frame_length,hop_length=hop_length)
    rms = librosa.feature.rms(signal,frame_length=frame_length,hop_length=hop_length)
    feature = np.concatenate([mfcc,mfcc_delta,mfcc_delta2,zcr,rms])
    firstname_bymyself_features.append(feature)

firstname_bymyself_features[0].shape
```

Out[ ]:

```
(41, 81)
```

In [ ]:
```
firstname_bymyself_features_normalized = []
for feature in firstname_bymyself_features:
    firstname_bymyself_features_normalized.append(mfcc_scaler(feature,13)[0])
```

میزان شباهت ویژگی ها صوت ا ن ی س با خود در حالتی که خودم ان را گفته ام

In [ ]:
```
features_distances_firstname_bymyself = features_dtw_calculation(firstname_bymyself_features_normalized,
firstname_bymyself_features_normalized,
is_equal=True
)

features_distances_firstname_bymyself
```

Out[ ]:

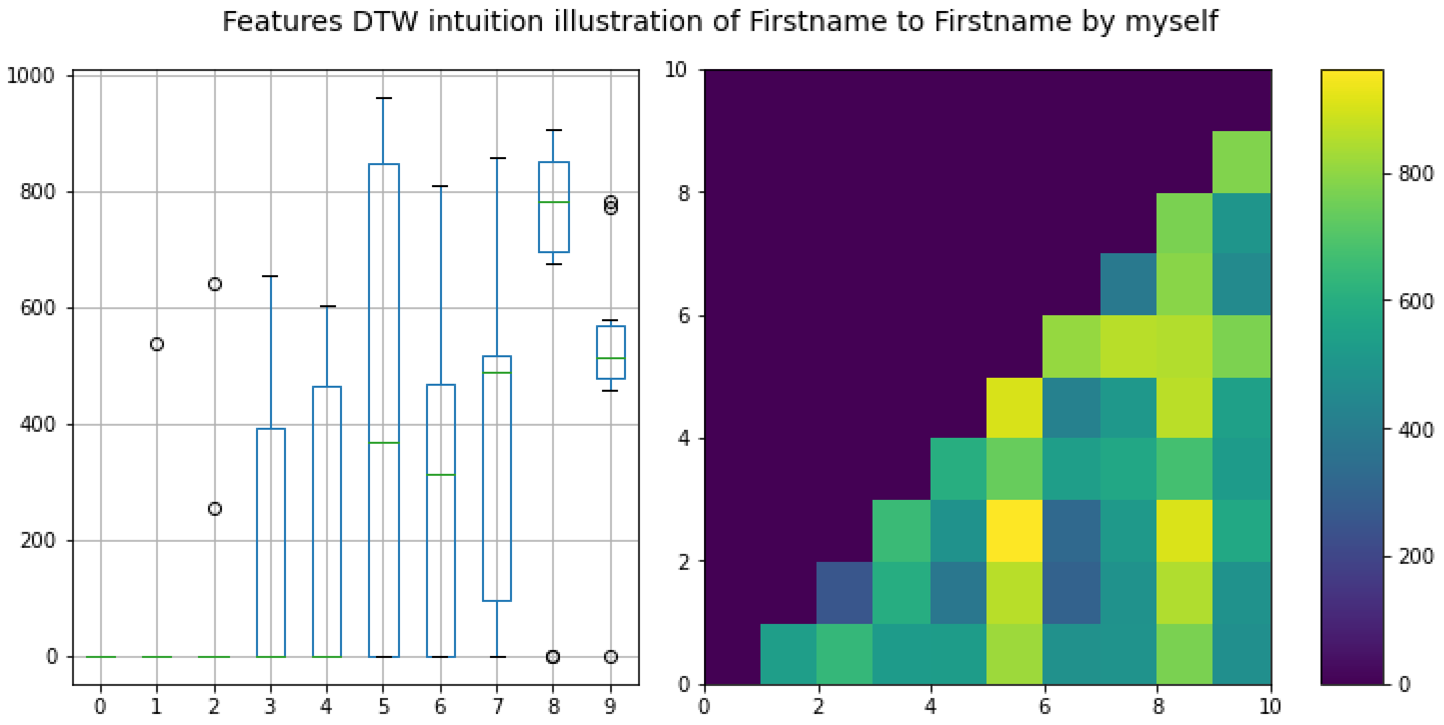
	0	1	2	3	4	5	6	7	8	9
0	0.0	537.074	641.425	523.154	528.998	822.325	483.612	494.564	769.856	475.264
1	0.0	0.000	255.625	597.700	379.863	857.386	298.925	485.870	846.072	488.977
2	0.0	0.000	0.000	652.942	491.404	962.001	326.042	515.695	906.861	577.674
3	0.0	0.000	0.000	0.000	603.441	737.380	534.645	574.544	673.785	524.614
4	0.0	0.000	0.000	0.000	0.000	904.086	419.197	514.153	863.559	544.792
5	0.0	0.000	0.000	0.000	0.000	0.000	810.724	859.058	851.378	770.800
6	0.0	0.000	0.000	0.000	0.000	0.000	0.000	389.564	792.192	457.669
7	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	767.179	499.891
8	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	780.611
9	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

In [ ]:
```
# reporting dtw features of firstname
features_distances_firstname_bymyself.to_excel(firstname_bymyself_folder+'output/features_distances_firstname_firstname_b
```

In [ ]:
```
fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Features DTW intuition illustration of Firstname to Firstname by myself", fontsize=14)
```

```
features_distances_firstname_bymyself.boxplot(ax=ax[0])

img = ax[1].pcolormesh(features_distances_firstname_bymyself.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

Out[ ]:
```
<matplotlib.colorbar.Colorbar at 0x2a7de1e4b20>
```



میزان شباهت ویژگی های دو صوت ا ن ی س , م ا ن ه ب توسط خودم

In [ ]:
```
features_distances_firstname_lastname_bymyself = features_dtw_calculation(firstname_bymyself_features_normalized,
lastname_bymyself_features_normalized,
is_equal=False,
)

features_distances_firstname_lastname_bymyself
```

Out[ ]:

	0	1	2	3	4	5	6	7	8	9
0	573.708	587.288	586.202	628.375	610.116	580.514	640.521	778.305	681.801	624.250
1	409.907	464.811	484.947	588.269	248.228	273.103	382.165	640.759	518.260	496.348

	0	1	2	3	4	5	6	7	8	9
2	502.635	531.510	558.181	641.016	300.282	339.459	436.104	728.520	591.045	545.732
3	695.310	715.048	713.209	721.083	671.635	665.952	695.776	757.583	708.281	699.372
4	499.246	487.400	505.216	634.670	460.445	422.831	455.434	661.933	508.308	605.500
5	934.651	962.004	938.641	944.313	909.255	916.215	956.999	938.953	965.198	906.021
6	441.475	475.089	509.989	630.806	338.976	332.576	416.862	701.207	552.711	529.449
7	531.370	560.476	577.187	661.232	534.838	520.248	544.806	737.326	594.522	596.658
8	915.752	923.223	908.835	938.404	906.432	896.392	878.446	909.446	899.625	901.717
9	548.807	575.685	559.487	627.083	552.553	515.694	599.128	737.851	630.126	582.386

In [ ]:

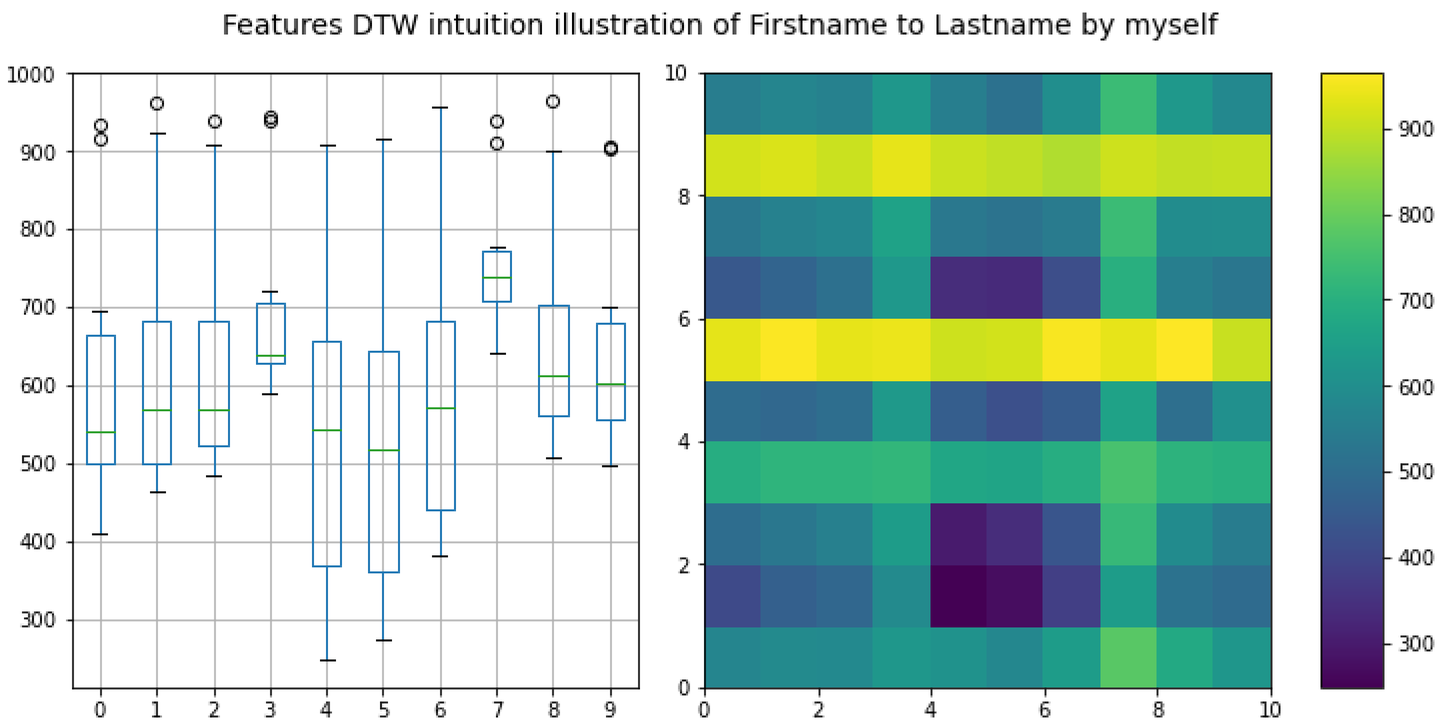
```
# reporting dtw features of firstname to lastname
features_distances_firstname_lastname_bymyself.to_excel(data+'/features_distances_firstname_lastname_bymyself.xlsx', engi
```

In [ ]:

```
fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Features DTW intuition illustration of Firstname to Lastname by myself", fontsize=14)

features_distances_firstname_lastname_bymyself.boxplot(ax=ax[0])

img = ax[1].pcolormesh(features_distances_firstname_lastname_bymyself.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

Out[ ]:

```
<matplotlib.colorbar.Colorbar at 0x2a7dec78130>
```

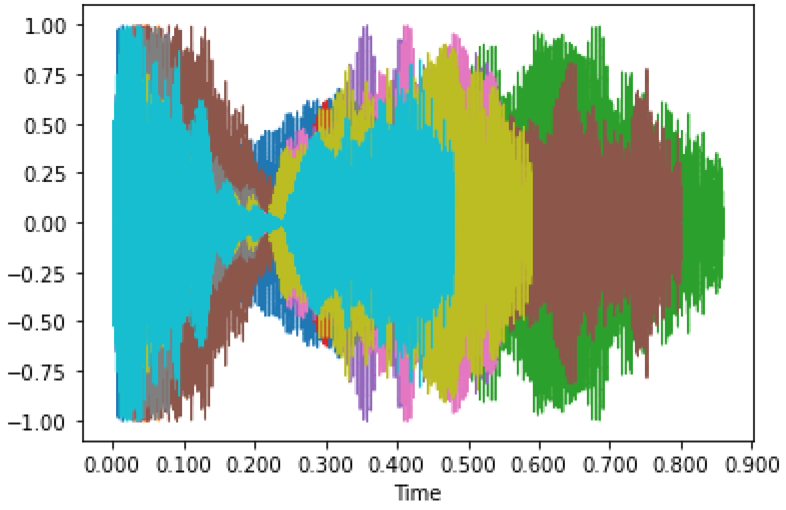


دریافت اصوات ضبط شده توسط شخص دیگری برای صوت ا ن ی س

In [ ]:

```
data = 'data/'
lastname_byperson1_folder = data + 'last_name_by_person1/'
lastname_byperson1_file = glob.glob(lastname_byperson1_folder+'*.wav')

lastname_byperson1 = []
for lastname_path in lastname_byperson1_file:
    signal,samplerate = librosa.load(lastname_path,sr=22050,mono=True)
    signal,index = librosa.effects.trim(signal,top_db=10,frame_length=int(30e-3*samplerate),hop_length=int(10e-3*samplera
    display.waveshow(signal)
    lastname_byperson1.append([signal,samplerate])

print("record number : ",len(lastname_byperson1))
```

```
record number :  10
```



میزان شباهت صوت خام م ا ن ه ب در دو حالت ضبط شده توسط خودم و شخص دیگر

In [ ]:
```
signal_distances_lastname_lastname_byperson1_bymyself = signal_dtw_calculation(lastname_bymyself,
lastname_byperson1,
is_equal=False,
dtw_weight_path=data+'/signal_distances_lastname_lastname_bymyself_byperson1.xlsx',
)
signal_distances_lastname_lastname_byperson1_bymyself
```

Out[ ]:

	0	1	2	3	4	5	6	7	8	9
0	1093.370	1139.166	1431.301	1163.656	1149.364	1399.139	1286.686	1104.962	1239.657	1093.258
1	1011.884	1070.055	1363.176	1154.460	1136.845	1298.516	1183.857	1061.030	1164.003	1061.337
2	1199.646	1174.955	1433.299	1250.444	1176.793	1382.044	1336.931	1188.058	1329.753	1185.190
3	1250.232	1063.758	1565.835	1180.865	1290.616	1290.309	1456.031	1120.716	1373.393	1141.362
4	926.373	726.830	1527.580	964.799	1167.794	1276.690	1350.904	868.757	1181.328	774.128
5	979.292	930.708	1528.458	1047.452	1240.147	1458.596	1380.820	940.220	1283.803	912.148
6	858.966	881.287	1385.085	982.661	1082.064	1326.055	1209.281	893.420	1070.829	870.111
7	1280.243	1434.201	1538.592	1391.899	1346.179	1598.893	1473.042	1433.264	1410.567	1393.865
8	1361.012	1553.341	1511.239	1435.769	1462.340	1567.427	1365.234	1485.671	1354.899	1432.656

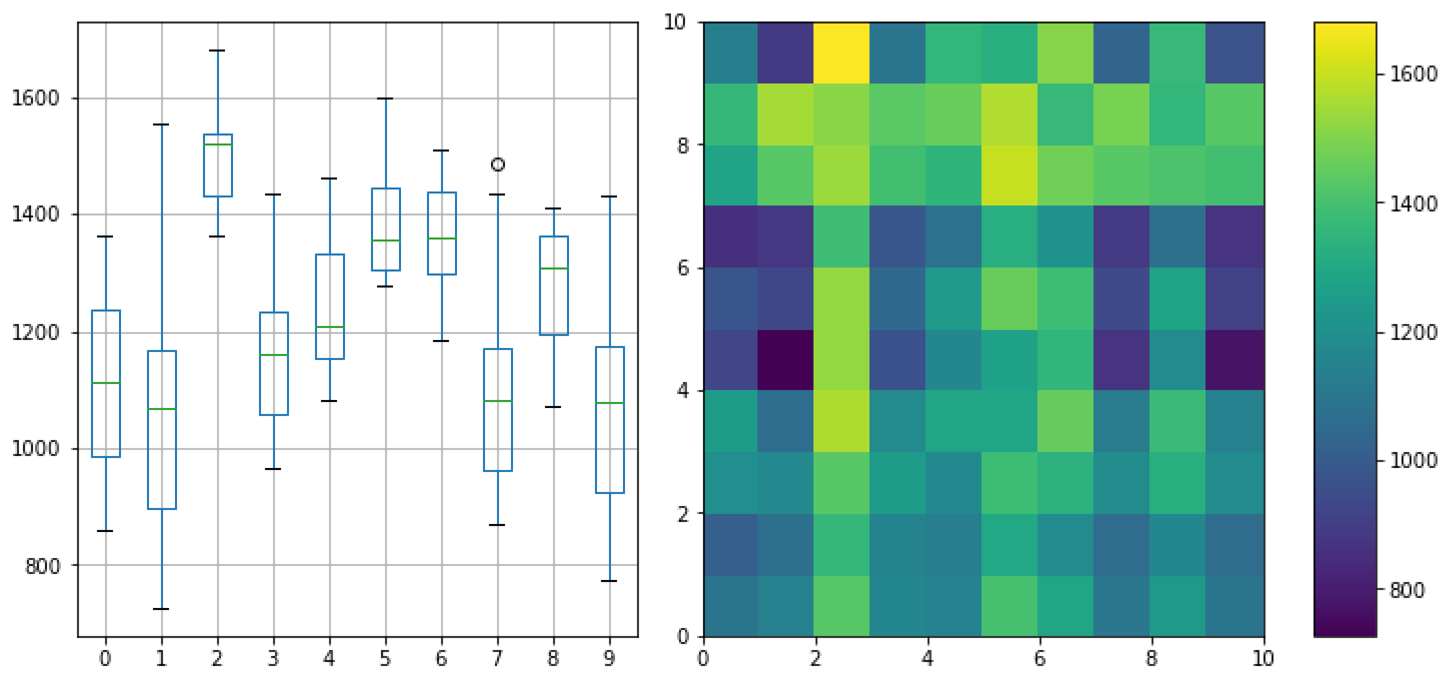
	0	1	2	3	4	5	6	7	8	9
9	1134.591	887.228	1681.518	1094.907	1356.428	1328.916	1509.857	1033.947	1364.764	969.023

In [ ]:
```
# reporting dtw signal of lastname to lastname by myself and person 1
signal_distances_lastname_lastname_byperson1_bymyself.to_excel(data+'/signal_distances_lastname_lastname_bymyself_bypersc
```

In [ ]:
```
fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Signal DTW intuition illustration of Lastname to Lastname by myself and by person1", fontsize=14)

signal_distances_lastname_lastname_byperson1_bymyself.boxplot(ax=ax[0])

img = ax[1].pcolormesh(signal_distances_lastname_lastname_byperson1_bymyself.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

Out[ ]:
```
<matplotlib.colorbar.Colorbar at 0x2a7e102bbb0>
```

Signal DTW intuition illustration of Lastname to Lastname by myself and by person1



استخراج ویژگی صوت م ا ن ه ب توسط گوینده دیگر

In [ ]:
```
# feature extraction
frame_length = int(30e-3*samplerate) # 30ms
hop_length = int(10e-3*samplerate) # 10ms

lastname_byperson1_features = []

for signal,samplerate in lastname_byperson1:
    mfcc = librosa.feature.mfcc(signal,samplerate,n_mfcc=13,hop_length=hop_length,n_fft=frame_length,window=np.hamming(fr
    mfcc_delta = librosa.feature.delta(mfcc)
    mfcc_delta2 = librosa.feature.delta(mfcc,order=2)
    zcr = librosa.feature.zero_crossing_rate(signal,frame_length=frame_length,hop_length=hop_length)
    rms = librosa.feature.rms(signal,frame_length=frame_length,hop_length=hop_length)
    feature = np.concatenate([mfcc,mfcc_delta,mfcc_delta2,zcr,rms])
    lastname_byperson1_features.append(feature)

lastname_byperson1_features[0].shape
```

Out[ ]:
```
(41, 52)
```

In [ ]:
```
# normalization
lastname_byperson1_features_normalized = []
for feature in lastname_byperson1_features:
    lastname_byperson1_features_normalized.append(mfcc_scaler(feature,13)[0])
```

و همچنین میزان شباهت صوت م ا ن ه ب توسط شخص دوم

In [ ]:
```
features_distances_lastname_byperson1 = features_dtw_calculation(lastname_byperson1_features_normalized,
lastname_byperson1_features_normalized,
is_equal=True
)

features_distances_lastname_byperson1
```

Out[ ]:

	0	1	2	3	4	5	6	7	8	9
0	0.0	361.979	553.126	381.567	383.506	487.364	351.316	379.463	365.847	365.409
1	0.0	0.000	519.807	372.560	357.820	444.006	358.456	355.566	382.465	296.196
2	0.0	0.000	0.000	601.458	563.903	521.682	536.223	588.476	546.648	583.558

	0	1	2	3	4	5	6	7	8	9
3	0.0	0.000	0.000	0.000	384.534	485.216	380.221	284.650	365.044	325.325
4	0.0	0.000	0.000	0.000	0.000	489.014	368.309	381.572	349.584	355.470
5	0.0	0.000	0.000	0.000	0.000	0.000	453.365	484.309	491.412	481.490
6	0.0	0.000	0.000	0.000	0.000	0.000	0.000	356.420	346.793	351.303
7	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	362.006	289.004
8	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	338.740
9	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

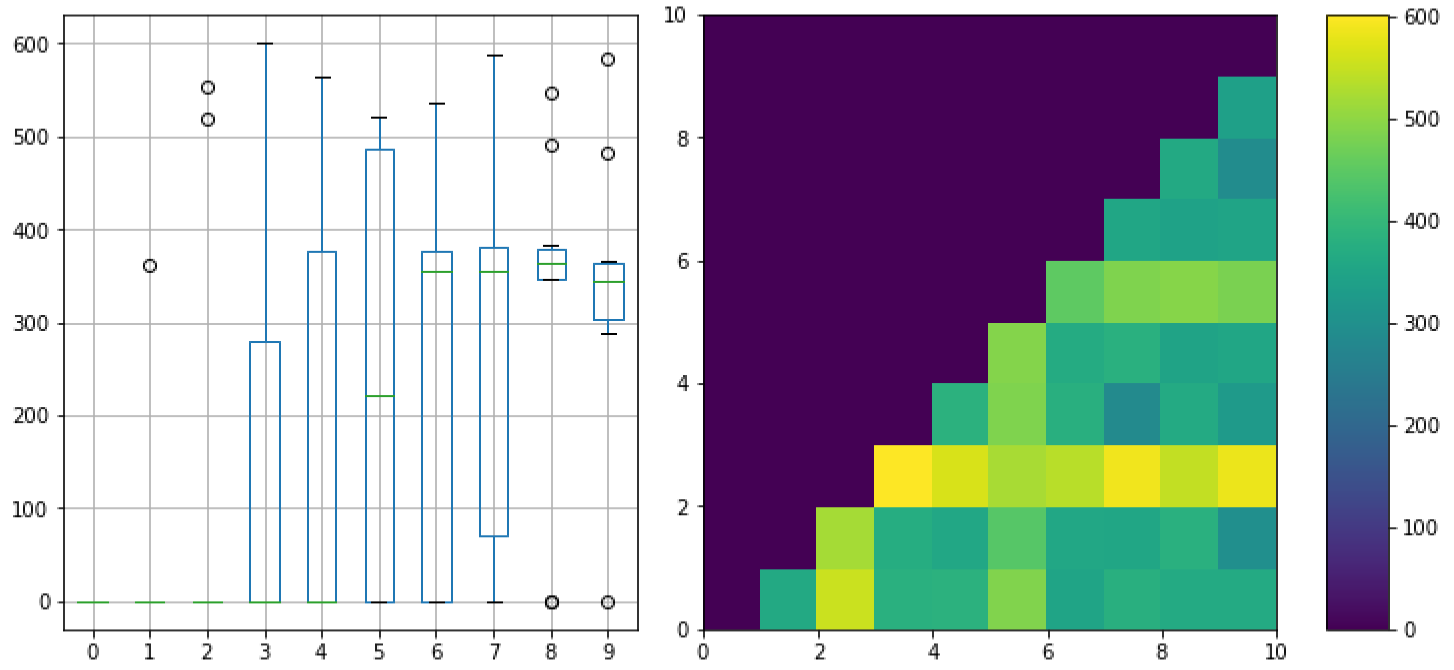
In [ ]:

```
fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Features DTW intuition illustration of Lastname to Lastname by Person1", fontsize=14)

features_distances_lastname_byperson1.boxplot(ax=ax[0])

img = ax[1].pcolormesh(features_distances_lastname_byperson1.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

Out[ ]:

```
<matplotlib.colorbar.Colorbar at 0x2a7df040cd0>
```

Features DTW intuition illustration of Lastname to Lastname by Person1



میزان شباهت ادای صوت م ا ن ه ب توسط هر دو شخص

In [ ]:
```
features_distances_lastname_byperson1_bymyself = features_dtw_calculation(lastname_bymyself_features_normalized,
lastname_byperson1_features_normalized,
is_equal=False
)

features_distances_lastname_byperson1_bymyself
```

Out[ ]:

	0	1	2	3	4	5	6	7	8	9
0	495.603	437.192	643.938	482.514	469.302	561.863	503.229	477.590	502.693	457.723
1	507.705	450.154	599.821	513.439	480.763	566.613	514.475	499.728	517.546	490.662
2	530.578	478.909	649.235	512.726	506.521	562.879	528.538	523.243	527.206	496.087
3	646.523	546.884	657.732	614.926	603.307	634.625	613.869	599.593	639.400	583.213
4	388.989	368.103	635.636	390.590	436.949	589.091	452.763	389.652	428.114	333.584
5	387.249	380.508	645.922	419.289	433.776	592.530	441.563	408.155	441.075	359.972

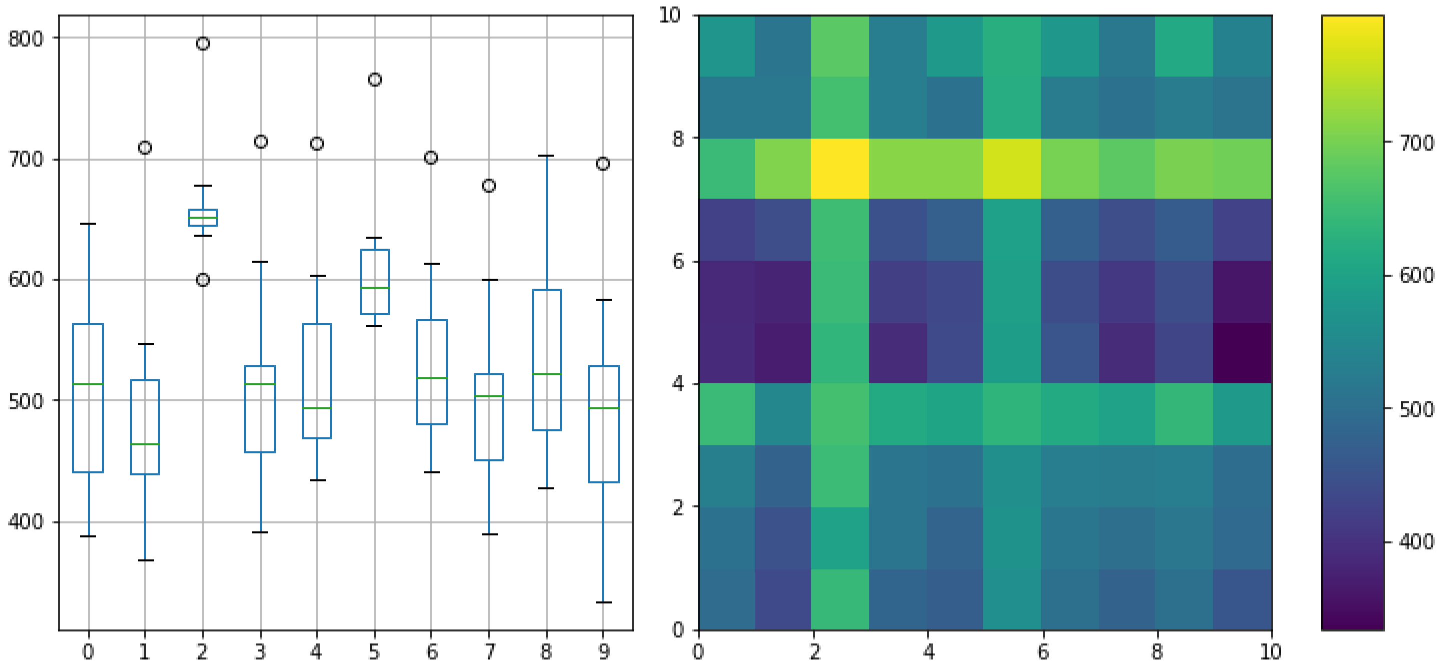
	0	1	2	3	4	5	6	7	8	9
6	422.004	443.514	653.092	448.484	471.089	595.142	473.213	442.394	466.446	424.639
7	646.324	708.605	795.756	713.529	713.011	765.004	701.329	678.536	702.835	696.256
8	519.009	518.418	658.447	527.902	506.481	622.292	523.533	508.633	525.598	509.291
9	574.911	512.519	677.926	528.418	583.076	625.049	580.394	519.274	612.405	535.608

In [ ]:
```
# reporting dtw features of lastname to lastname by myself and by person 1
features_distances_lastname_byperson1_bymyself.to_excel(data+'/features_distances_lastname_lastname_bymyself_byperson1.xl
```

In [ ]:
```
fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Features DTW intuition illustration of Lastname to Lastname by Person1 and by Myself", fontsize=14)

features_distances_lastname_byperson1_bymyself.boxplot(ax=ax[0])

img = ax[1].pcolormesh(features_distances_lastname_byperson1_bymyself.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

Out[ ]:
```
<matplotlib.colorbar.Colorbar at 0x2a7dcdf0b20>
```

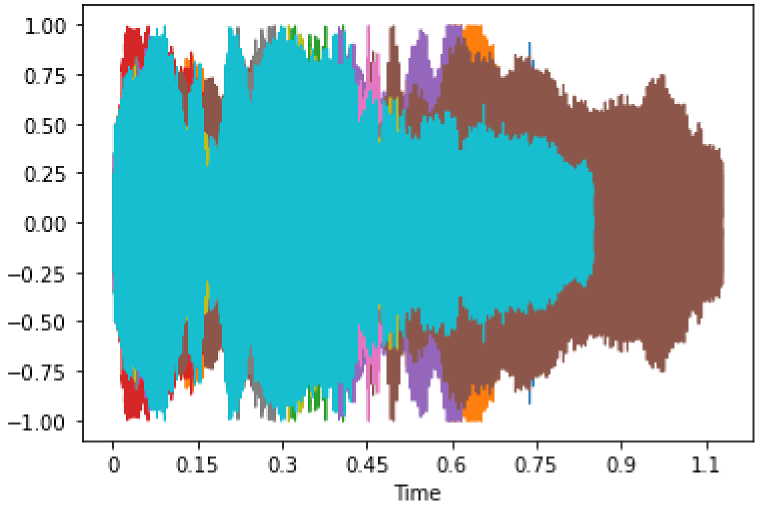
Features DTW intuition illustration of Lastname to Lastname by Person1 and by Myself



دریافت اصوات ا ن ی س توسط شخص دوم

```
In [ ]:
data = 'data/'
firstname_byperson1_folder = data + 'first_name_by_person1/'
firstname_byperson1_file = glob.glob(firstname_byperson1_folder+'*.wav')

firstname_byperson1 = []
for firstname_path in firstname_byperson1_file:
    signal,samplerate = librosa.load(firstname_path,sr=22050,mono=True)
    signal,index = librosa.effects.trim(signal,top_db=10,frame_length=int(30e-3*samplerate),hop_length=int(10e-3*samplera
    display.waveshow(signal)
    firstname_byperson1.append([signal,samplerate])

print("record number : ",len(firstname_byperson1))
```

```
record number :  10
```



میزان شباهت صوت خام ا ن ی س توسط هر دو شخص با هم دیگر

In [ ]:

```
signal_distances_firstname_byperson1_bymyself = signal_dtw_calculation(firstname_bymyself,
firstname_byperson1,
is_equal=False,
dtw_weight_path=data+'/signal_distances_firstname_firstname_bymyself_byperson1.xlsx'
)
signal_distances_firstname_byperson1_bymyself
```

Out[ ]:

	0	1	2	3	4	5	6	7	8	9
0	2086.716	1903.531	1836.868	1760.762	1999.369	2436.289	1861.004	1922.193	1882.522	2121.177
1	1944.021	2116.721	1408.345	1256.753	2095.928	3848.010	1426.785	1322.640	1521.934	2348.935
2	1488.350	1808.980	1294.491	1492.111	1902.677	2832.330	1316.425	1294.384	1272.669	2177.299
3	2069.212	2113.530	1932.345	1770.957	2178.733	2735.479	1790.839	1868.809	1904.998	2151.490
4	1957.748	1665.229	1541.668	1500.131	1728.332	2230.331	1518.032	1545.600	1642.536	1766.049
5	2470.835	2237.613	2234.690	2078.468	2288.502	2703.441	2134.180	2352.086	2222.278	2449.408
6	1649.815	1773.992	1283.922	1566.821	1799.548	2806.806	1299.612	1363.392	1379.790	2169.014
7	2262.891	2228.416	1846.044	1935.144	2102.608	2617.360	1788.277	1868.235	1888.037	2108.149
8	2542.441	2444.097	2604.420	2262.996	2681.021	2923.246	2483.563	2509.345	2454.167	2637.705

	0	1	2	3	4	5	6	7	8	9
9	2012.308	1945.717	1701.372	1714.913	1889.358	2609.226	1677.776	1765.544	1731.351	2094.376

In [ ]:

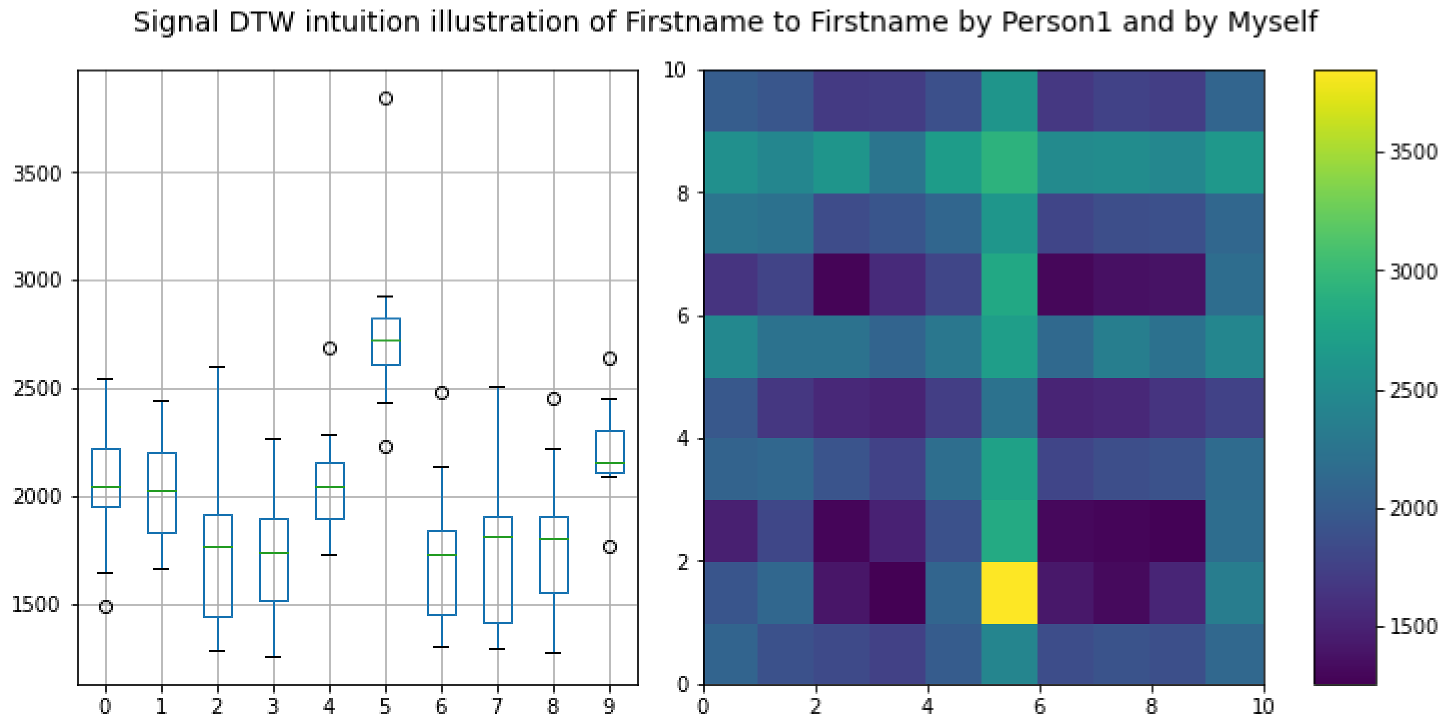
```
# reporting dtw signal of firstname to firstname by myself and by person 1
signal_distances_firstname_byperson1_bymyself.to_excel(data+'/signal_distances_firstname_firstname_bymyself_byperson1.xls
```

In [ ]:

```
fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Signal DTW intuition illustration of Firstname to Firstname by Person1 and by Myself", fontsize=14)

signal_distances_firstname_byperson1_bymyself.boxplot(ax=ax[0])

img = ax[1].pcolormesh(signal_distances_firstname_byperson1_bymyself.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

Out[ ]:

```
<matplotlib.colorbar.Colorbar at 0x2a7de7ace80>
```



استخراج ویژگی های صوت ا ن ی س توسط شخص دوم

In [ ]:
```
# feature extraction
frame_length = int(30e-3*samplerate) # 30ms
hop_length = int(10e-3*samplerate) # 10ms

firstname_byperson1_features = []

for signal,samplerate in firstname_byperson1:
    mfcc = librosa.feature.mfcc(signal,samplerate,n_mfcc=13,hop_length=hop_length,n_fft=frame_length,window=np.hamming(fr
    mfcc_delta = librosa.feature.delta(mfcc)
    mfcc_delta2 = librosa.feature.delta(mfcc,order=2)
    zcr = librosa.feature.zero_crossing_rate(signal,frame_length=frame_length,hop_length=hop_length)
    rms = librosa.feature.rms(signal,frame_length=frame_length,hop_length=hop_length)
    feature = np.concatenate([mfcc,mfcc_delta,mfcc_delta2,zcr,rms])
    firstname_byperson1_features.append(feature)

firstname_byperson1_features[0].shape
```

Out[ ]:
```
(41, 86)
```

In [ ]:
```
# normalization
firstname_byperson1_features_normalized = []
for feature in firstname_byperson1_features:
    firstname_byperson1_features_normalized.append(mfcc_scaler(feature,13)[0])
```

میزان شباهت ادای صوت ا ن ی س توسط هر دو شخص

In [ ]:
```
features_distances_firstname_byperson1_bymyself = features_dtw_calculation(firstname_bymyself_features_normalized,
firstname_byperson1_features_normalized,
is_equal=False
)

features_distances_firstname_byperson1_bymyself
```

Out[ ]:

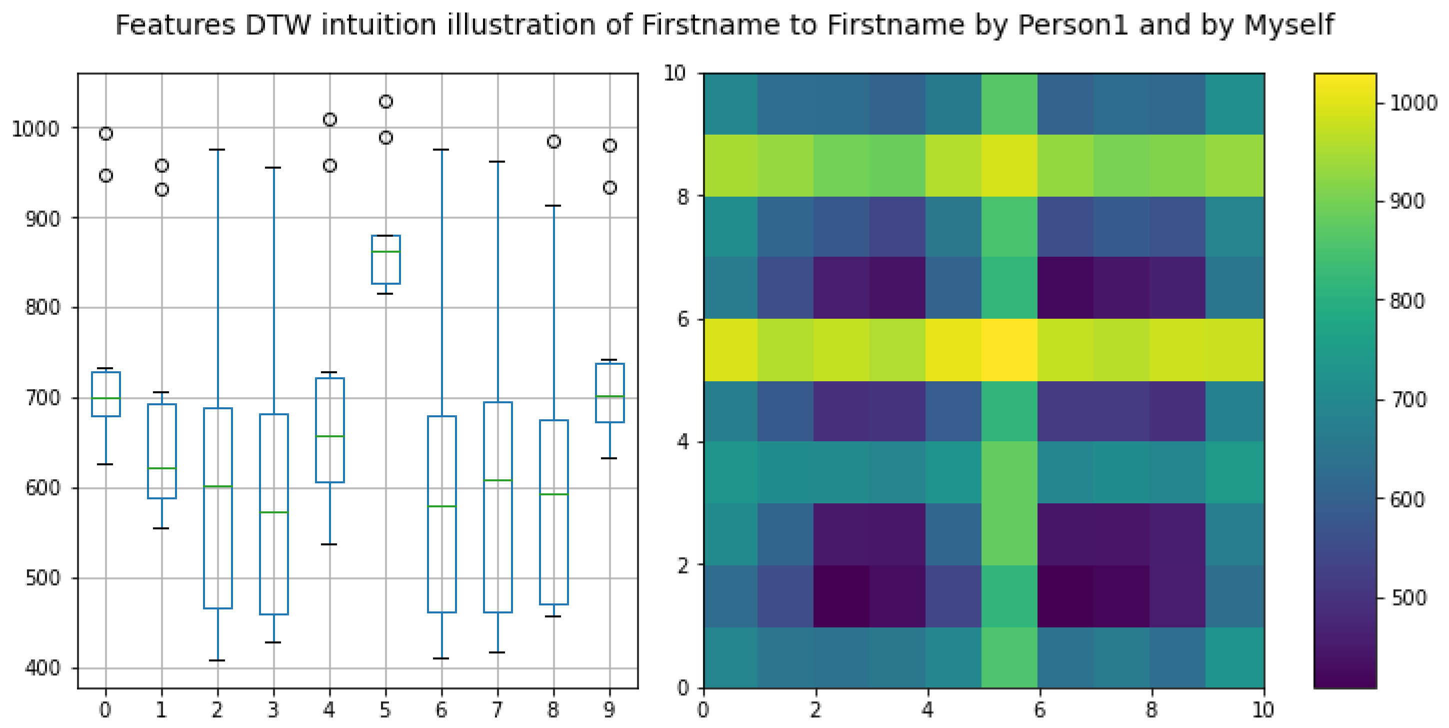
	0	1	2	3	4	5	6	7	8	9
0	691.643	651.401	644.120	655.798	696.972	856.438	641.247	664.289	630.673	730.985
1	625.786	555.321	409.242	428.652	537.843	815.357	411.053	417.969	458.266	634.005
2	703.593	608.476	448.362	446.951	611.089	880.349	443.935	441.757	460.429	670.811

	0	1	2	3	4	5	6	7	8	9
3	734.479	707.000	703.419	690.131	730.057	879.445	692.011	704.998	691.752	741.728
4	675.378	582.362	494.799	499.172	589.268	815.195	514.419	516.805	494.077	678.677
5	993.833	958.457	974.738	954.798	1010.243	1029.713	975.407	962.587	983.659	980.393
6	665.717	557.793	456.222	440.747	606.036	818.167	423.489	444.974	464.657	653.743
7	714.323	613.453	576.531	539.181	654.556	850.633	557.150	587.898	567.900	687.185
8	947.437	930.492	897.327	887.988	957.331	989.153	927.989	901.986	912.686	932.683
9	695.983	630.091	629.294	605.666	659.101	867.118	601.090	628.188	620.026	716.639

In [ ]:
```
# reporting dtw features of firstname to firstname by myself and person 1
features_distances_firstname_byperson1_bymyself.to_excel(data+'/features_distances_firstname_firstname_bymyself_byperson1
```

In [ ]:
```
fig, ax = plt.subplots(1,2,constrained_layout=True)

fig.set_size_inches(10,5)
fig.suptitle("Features DTW intuition illustration of Firstname to Firstname by Person1 and by Myself", fontsize=14)

features_distances_firstname_byperson1_bymyself.boxplot(ax=ax[0])

img = ax[1].pcolormesh(features_distances_firstname_byperson1_bymyself.to_numpy())
fig.colorbar(img, ax=[ax[1]])
```

Out[ ]:
```
<matplotlib.colorbar.Colorbar at 0x2a7df29be50>
```



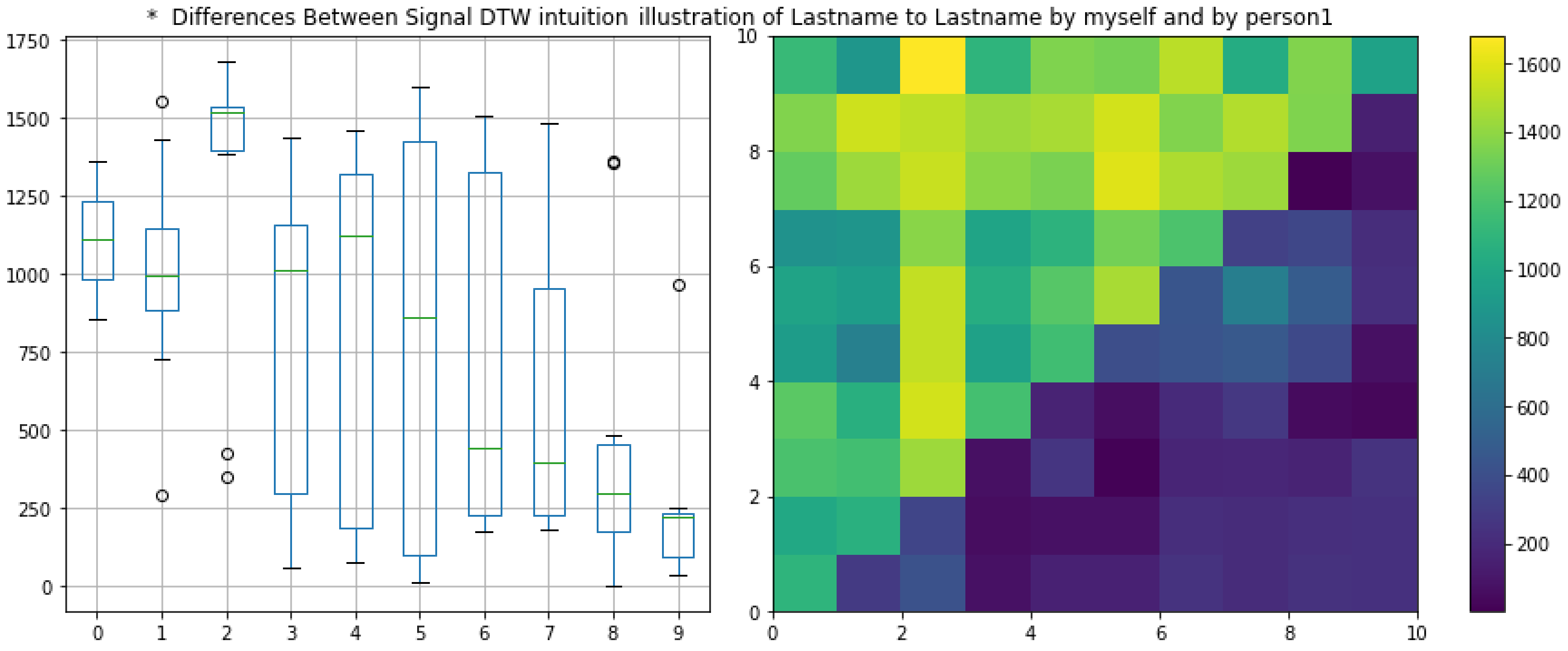
میزان تفاوت شباهت های اصوات م ا ن ه ب در زمانی که خودم ان را نسبت به خودم ادا کرده ام و حالتی که گوینده دوم نسبت به خودم انرا دوباره ادا کرده است و در دو حالت سیگنال خام و بردار ویژگی ها که نشان از میزان متفاوت بودن هر یک از اصوات با ادای متفاوت توسط دو شخص را نمایش میدهد و همچنین میزان تفاوت در حالتی که با استفاده از بردار ویژگی و صوت خام صورت گرفته است را نشان میدهد

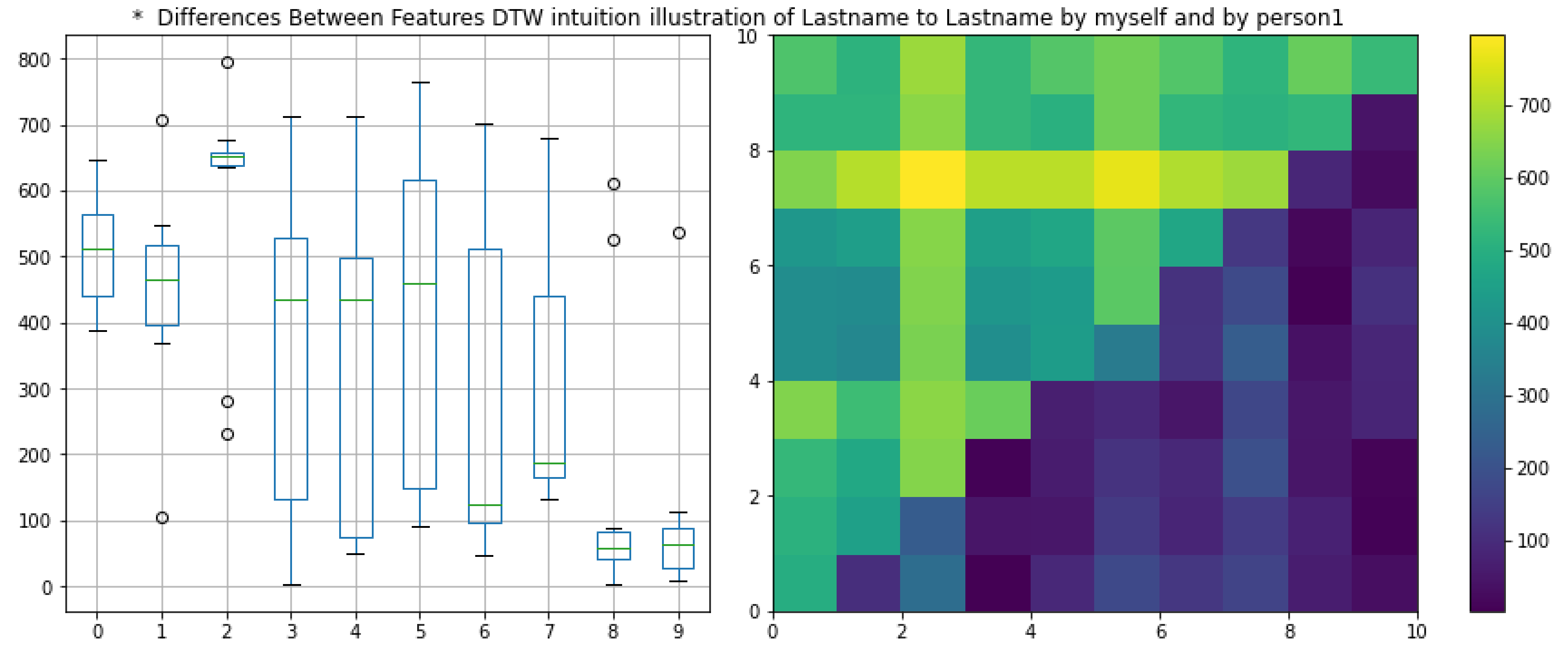
In [ ]:

```
signal_lastname_difference = pd.DataFrame.abs(signal_distances_lastname_lastname_bymyself - signal_distances_lastname_las

fig, ax = plt.subplots(2,2,constrained_layout=True)

fig.set_size_inches(12,10)
# fig.suptitle("Differences Between Signal DTW intuition illustration of Lastname to Lastname by myself and by person1",

ax[0][0].set(title="*  Differences Between Signal DTW intuition")
ax[0][1].set(title="illustration of Lastname to Lastname by myself and by person1                              ")

signal_lastname_difference.boxplot(ax=ax[0][0])

img = ax[0][1].pcolormesh(signal_lastname_difference.to_numpy())
fig.colorbar(img, ax=[ax[0][1]])

features_lastname_difference = pd.DataFrame.abs(features_distances_lastname_lastname_bymyself - features_distances_lastna
ax[1][0].set(title="*  Differences Between Features DTW intuition")
ax[1][1].set(title="illustration of Lastname to Lastname by myself and by person1                            ")

features_lastname_difference.boxplot(ax=ax[1][0])

img = ax[1][1].pcolormesh(features_lastname_difference.to_numpy())
fig.colorbar(img, ax=[ax[1][1]])
```

Out[ ]:

```
<matplotlib.colorbar.Colorbar at 0x2a7e0e18c40>
```

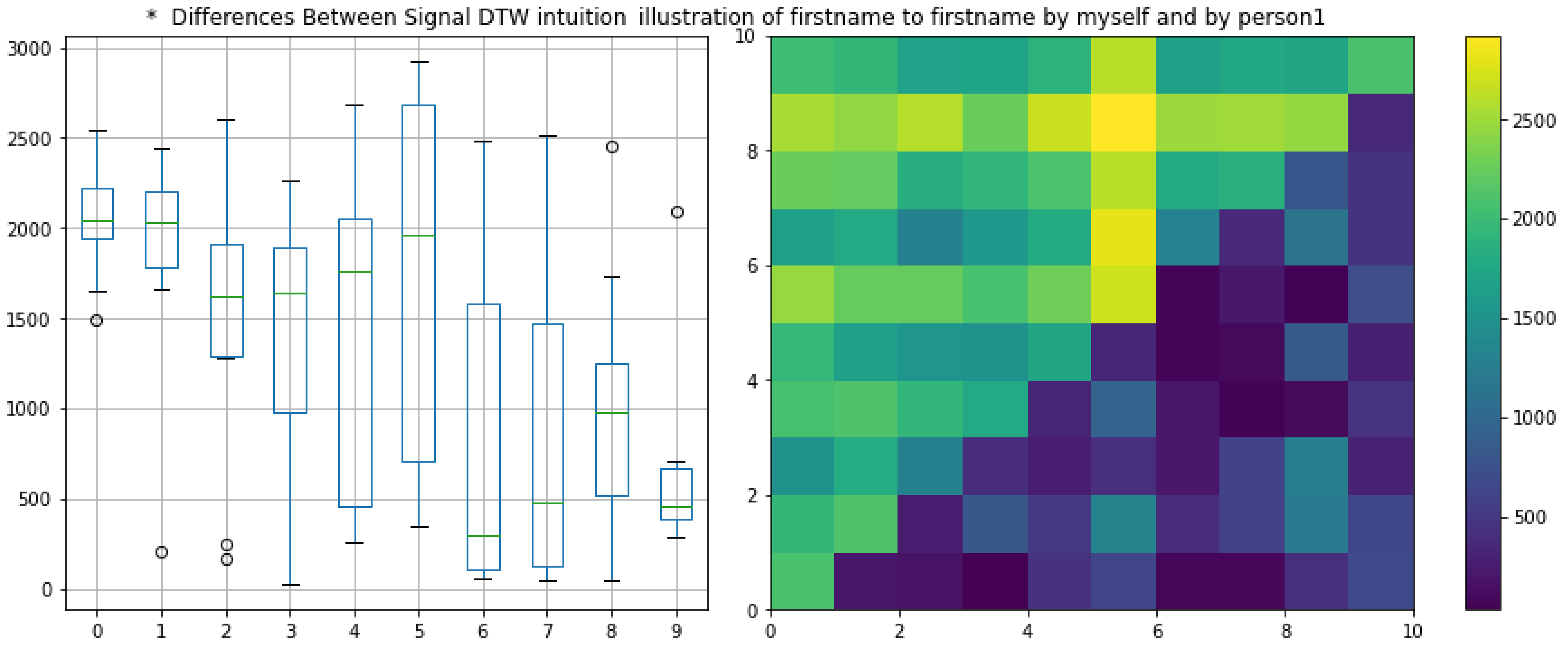

* Differences Between Signal DTW intuition illustration of Lastname to Lastname by myself and by person1
1750
1500
1250
1000
750
500
250
0
0 1 2 3 4 5 6 7 8 9
0 2 4 6 8 10
1600
1400
1200
1000
800
600
400
200

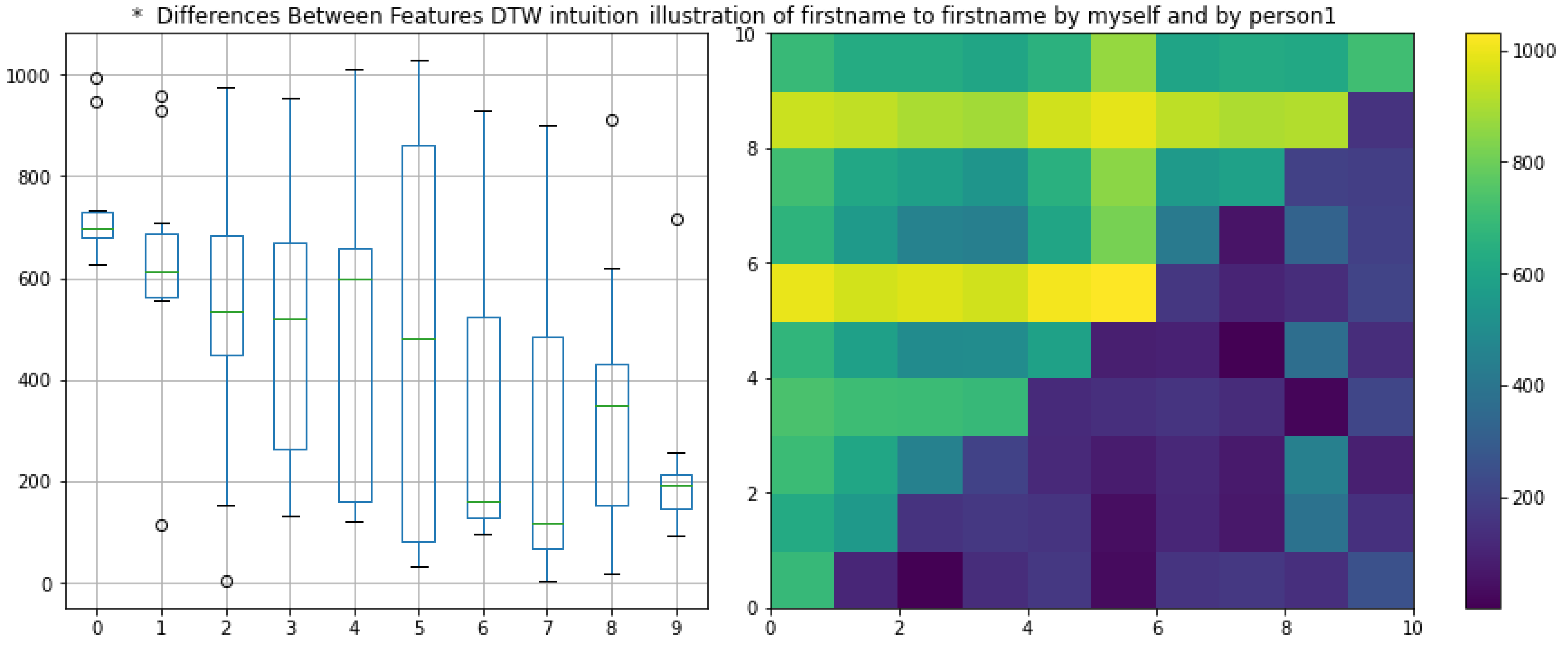

* Differences Between Features DTW intuition illustration of Lastname to Lastname by myself and by person1
800
700
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9
0 2 4 6 8 10
700
600
500
400
300
200
100

مانند بالا برای ادای صوت ا ن ی س

In [ ]:
```
signal_firstname_difference = pd.DataFrame.abs(signal_distances_firstname_bymyself - signal_distances_firstname_byperson1

fig, ax = plt.subplots(2,2,constrained_layout=True)

fig.set_size_inches(12,10)
# fig.suptitle("Differences Between Signal DTW intuition illustration of firstname to firstname by myself and by person1"

ax[0][0].set(title="*  Differences Between Signal DTW intuition")
ax[0][1].set(title="illustration of firstname to firstname by myself and by person1                               ")

signal_firstname_difference.boxplot(ax=ax[0][0])

img = ax[0][1].pcolormesh(signal_firstname_difference.to_numpy())
fig.colorbar(img, ax=[ax[0][1]])

features_firstname_difference = pd.DataFrame.abs(features_distances_firstname_bymyself - features_distances_firstname_byp

ax[1][0].set(title="*  Differences Between Features DTW intuition")
ax[1][1].set(title="illustration of firstname to firstname by myself and by person1                            ")

features_firstname_difference.boxplot(ax=ax[1][0])

img = ax[1][1].pcolormesh(features_firstname_difference.to_numpy())
fig.colorbar(img, ax=[ax[1][1]])
```

Out[ ]:
```
<matplotlib.colorbar.Colorbar at 0x2a7e17ffe20>
```


* Differences Between Signal DTW intuition illustration of firstname to firstname by myself and by person1
3000
2500
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
8
9
10
8
6
4
2
0
0
2
4
6
8
10
2500
2000
1500
1000
500


* Differences Between Features DTW intuition illustration of firstname to firstname by myself and by person1
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
8
9
10
8
6
4
2
0
0
2
4
6
8
10
1000
800
600
400
200