Clustering_electric_meters

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1 Cluster electric meters based on interval average voltages

This is a prototype of electric meters clustering using their voltage data. Here I will present snippets of code and plots with some explaination. I cannot expose datasets due to privacy concerns.

Data analysis process: 1. Preprocess input data 2. Perform PCA to reduce dimensionality 3. I have GIS information, so I considered local points computing Equirectangular distance 4. Run fuzzy c-means with custom distance measure (Voltage correlation) 5. Plot the clusters

In addition, I am adding analysis using different data set with DBSCAN algorithm. 1. Find eps value using nearest neighbor search 2. Apply DBSCAN

```
In [640]: import pandas as pd
          import numpy as np
          from sklearn.cluster import KMeans
          from sklearn.cluster import DBSCAN
          import skfuzzy as fuzz
          import matplotlib.pyplot as plt
          import seaborn as sns
          from scipy.stats.stats import pearsonr
          from sklearn.cluster import DBSCAN
          from sklearn.cluster import AffinityPropagation
          from sklearn.decomposition import PCA
          import datetime
          import skfuzzy as fuzz
          from sklearn.neighbors import NearestNeighbors
          from mpl_toolkits.mplot3d import Axes3D
          from scipy.spatial.distance import pdist, squareform
          import math
          from scipy import fftpack
          from statsmodels.tsa.seasonal import seasonal_decompose
          from sklearn.cluster import AffinityPropagation

          from sklearn.preprocessing import MinMaxScaler
          %matplotlib inline
```

```
In [ ]: ### Preprocess data
```

```
In [ ]: df_latlong, df_voltPoints, df_trMapping = processInputData()
        df_voltPoints.shape
```

```
        df_voltPoints = normalizeVoltages(df_voltPoints)
        df_voltPoints = df_voltPoints[df_voltPoints>0.95]
        df_voltPoints = averagepoints(numAvg, df_voltPoints)
```

```
In [642]: def processIds(df):
              df['_id'] = df['_id'].apply(lambda x: x.split('_', 1)[0])
              return df
```

```
In [643]: def createPoints(df, nDays):
              dfvp = pd.DataFrame()
              for i in range(0,len(df), nDays):
                  df1 = df.iloc[i:i+nDays,1:]
                  dfvp[str(df.iloc[i,0])] = df1.stack().values
              return dfvp
```

```
In [644]: def readVoltageData(vFile):
              df_voltages = pd.read_csv(path+vFile)
              return df_voltages
```

```
In [645]: def processInputData():
              #Read meter coordinates
              df_latlong = pd.read_csv(path+MeterCoordinatesFile)
              df_latlong = processIds(df_latlong)
              #create volt points
              vp1 = createPoints(readVoltageData(VoltageFile1), 3)
              print(vp1.shape)
              vp2 = createPoints(readVoltageData(VoltageFile2), 4)
              vp2.columns = list(map(lambda x:x.split('_',1)[0], vp2.columns))
              print(vp2.shape)
              df_voltPoints = vp1.append(vp2, ignore_index = True)
              print(df_voltPoints.shape)
              return df_latlong, df_voltPoints, df_trMapping
```

```
In [646]: #select sparse points
          #df_voltPoints = df_voltPoints[df_voltPoints.index%4==0].reset_index(drop=True)
```

```
In [647]: #compute deltas
          #df_voltPoints = (df_voltPoints.shift(-1)-df_voltPoints).dropna()
```

```
In [648]: def imputeVals(dfx):
              dfx = dfx.dropna().reset_index(drop=True)
              for col in dfx.columns:
                  dfx[col] = dfx[col].replace(to_replace=0, method='ffill')
              return dfx
```

```
In [649]: #Compute average of specified number of points
          def averagepoints(numOfAvg, dfx):
              dfx = imputeVals(dfx)
              dfxav = pd.DataFrame()
```

```
        for col in dfx.columns:
            dfxav[col] = np.mean(dfx[col][:].values.reshape(-1, numOfAvg), axis=1)
        return dfxav
    #df_voltPoints = averagepoints(numAvg, df_voltPoints)
    #df_voltPoints.shape
```

In [652]:
```
def computeDelta(dfvp):
    return (dfvp.shift(-1)-dfvp).dropna()
#df_voltPoints = computeDelta(df_voltPoints)
```

1.0.1 PCA

In [653]:
```
#Perform Principal Component Analysis. n--> number of components
def performPca(dfp, n, plot=False):
    pca = PCA(n_components=n)
    pc = pca.fit_transform(dfp.values)
    cols = []
    print("Performing PCA")
    print("Explained variance ratio with PCA:",pca.explained_variance_ratio_)
    for i in range(n):
        cols.append("pc"+str(i+1))
    dfpc = pd.DataFrame(data =pc, columns=cols)
   # print("PCA:", dfpc)
    if plot==True:
        plt.figure(figsize=(8, 6))
        plt.bar(dfpc.columns, pca.explained_variance_ratio_)
    return dfpc
```

In [655]:
```
#Visualize 3d
# Visualize the test data
def plotClusters3D(dfvp, labels, *args):
    pcInp = performPca(dfvp.T, 3, False)
    pcInp['labels'] = labels
    plt.figure(figsize=(14, 10))
    x = pcInp.iloc[:,0]
    y = pcInp.iloc[:,1]
    z = pcInp.iloc[:,2]
    fig = plt.figure(figsize=(10,8))
    ax = fig.add_subplot(111, projection='3d')
    ax.scatter(x, y, z)
    ax.set_xlabel('X Label')
    ax.set_ylabel('Y Label')
    ax.set_zlabel('Z Label')
    if args:
        for ar in args:
            pcntr = ar
            break
        plt.scatter(pcntr[:, 0], pcntr[:, 1], c='red', s=200, alpha=0.5);
```

```
    x = pcInp['pc1']
    y = pcInp['pc2']
    z = pcInp['pc3']
plt.show()
```

1.1 Clustering

1.2 Fuzzy c-means clustering

```
In [656]: ### Run fuzzy C means
          def runFuzzyCMeans(dfvp, c, fuzzy):
              #Running fuzzy with 2 pc fails. Use min of 3.
              pcInp = performPca(dfvp.T, 3, True)

              #print("Input data points",pcInp)
              cntr, u, u0, d, jm, p, fpc = fuzz.cluster.cmeans(
                pcInp.T, c, fuzzy, error=0.005,metric=voltCorr, maxiter=1000, init=None, seed =1
              labels_fuzzy = np.argmax(u, axis=0)
              #print(cntr)
              print("Cluster labels:",labels_fuzzy)
              print("strength:", fpc)
              return labels_fuzzy, cntr
          #labels_fuzzy, cntr_fuzzy = runFuzzyCMeans(df_voltPoints, 3, 2)
```

1.2.1 Verify clusters with result set

```
In [658]: def printClusters(dfvp, labels):
              pcInp = performPca(dfvp.T, 2, False)
             # for i in np.unique(labels):
                 # print("cluster:",i)
                #  print(dfvp.columns[labels==i].values)
          #printClusters(df_voltPoints, labels_fuzzy)

In [659]: # Visualize the test data
          def plotClusters(dfvp, labels, annotate, *args):
              pcInp = performPca(dfvp.T, 2, False)
              pcInp['labels'] = labels
              plt.figure(figsize=(14, 10))
              sns.scatterplot(x='pc1', y='pc2', hue='labels', data=pcInp)
              if args:
                  for ar in args:
                      pcntr = ar
                      break
                  plt.scatter(pcntr[:, 0], pcntr[:, 1], c='red', s=200, alpha=0.5);
              x = pcInp['pc1']
              y = pcInp['pc2']
              if annotate:
                  for i, txt in enumerate(dfvp.T.index):
```

```
                plt.annotate(txt, (x[i], y[i]))
    #plotClusters(df_voltPoints, labels_fuzzy, cntr_fuzzy)
```

```
In [660]: # Visualize the test data

          def showClustersFuzzy(dfvp, pc,labels, cntr):
              pc_copy = pc.copy()
              pc_copy['labels'] = labels

              pcntr = pc.fit_transform(cntr)
              print("Center after pca",pcntr)
              dfvp['labels'] = labels
              #for i in np.unique(labels):
                 # print("cluster:",i)
                  #print(dfvp.columns[labels==i].values)
              plt.figure(figsize=(10, 8))
              sns.scatterplot(x='pc1', y='pc2', hue='labels', data=dfvp)
              plt.scatter(pcntr[:, 0], pcntr[:, 1], c='red', s=200, alpha=0.5);
```

1.3 Compute distances from meter coordinates - Euclidean/Equirectangular

```
In [661]: ## Equirectangular distance calculation
          def equirectangular(p1, p2):
              lat1 = math.radians(p1[0] )
              lat2 = math.radians(p2[0])
              lon1 = math.radians(p1[1])
              lon2 = math.radians(p2[1])
              R = 6371 * 1000
              x = (lat2 - lat1) * math.cos(0.5*(lon2+lon1))
              y = lon2 - lon1
              d = R*math.sqrt(x*x + y*y)
              return d
```

```
In [662]: def computePairWiseDistMat(dflatlong):
              dflatlongR = dflatlong.iloc[:,1:3]
              distances = pdist(dflatlongR.values, metric=equirectangular)
              dist_matrix = squareform(distances)
              return dist_matrix
```

```
In [663]: #Get nearest meters based on radius
          def getNearestMeters(meterId, radius, df_coord):
              #Select a meter and get neibors within the specified radius
              idx = df_coord.index[df_coord['_id']==meterId][0]
              print("Index:",idx)
              dist_matrix = computePairWiseDistMat(df_coord)
              df_meterDist = pd.DataFrame(list(zip(df_coord['_id'], dist_matrix[idx])), columns=
              df_meterDistSorted = df_meterDist.sort_values(by='distances').reset_index(drop=Tru
              df_filtered = df_meterDistSorted[df_meterDistSorted['distances']<=radius]
```

```
        return df_filtered

    #ref_meterId = '301048685'
    #df_filteredMeters = getNearestMeters(ref_meterId, radius, df_latlong)
```

```
In [664]: def getVoltagePointsFiltered(df_filteredMeters, dfvp):
              df_filteredVp = dfvp.T.merge(df_filteredMeters, left_index=True, right_on='_id').d
              df_filteredVp.head()
              del df_filteredVp.index.name
              return df_filteredVp.T
```

```
In [665]: def getExpectedClusters(dfMeters, dfTrMap):
              dfTrMap['Name'] = dfTrMap['Name'].astype(str)
              #print(dfTrMap.head()), print(dfMeters)
              dfr = dfTrMap.merge(dfMeters, left_on='Name', right_on='_id',how='inner' )
              return len(dfr.groupby(by='Current Phase'))
          #getExpectedClusters(df_filteredMeters, df_trMapping)
```

```
In [666]: def getFftAbs(dfvp):
              df_fft = pd.DataFrame()
              for i in dfvp.columns:
                  f=fftpack.fft(dfvp[i])
                  df_fft[i] = abs(f)
              return df_fft
```

```
In [669]: def getProcessedData(dfvp, analysisType):
              if analysisType is AnalysisType.TIME_SERIES:
                  print("performing time series decomposition")
                  return getTimeSeriesTrend(dfvp, 8, False, 1).dropna().reset_index(drop=True)
              elif analysisType is AnalysisType.FOURIER:
                  print("performing fourier transformation")
                  return getFFT(dfvp)
```

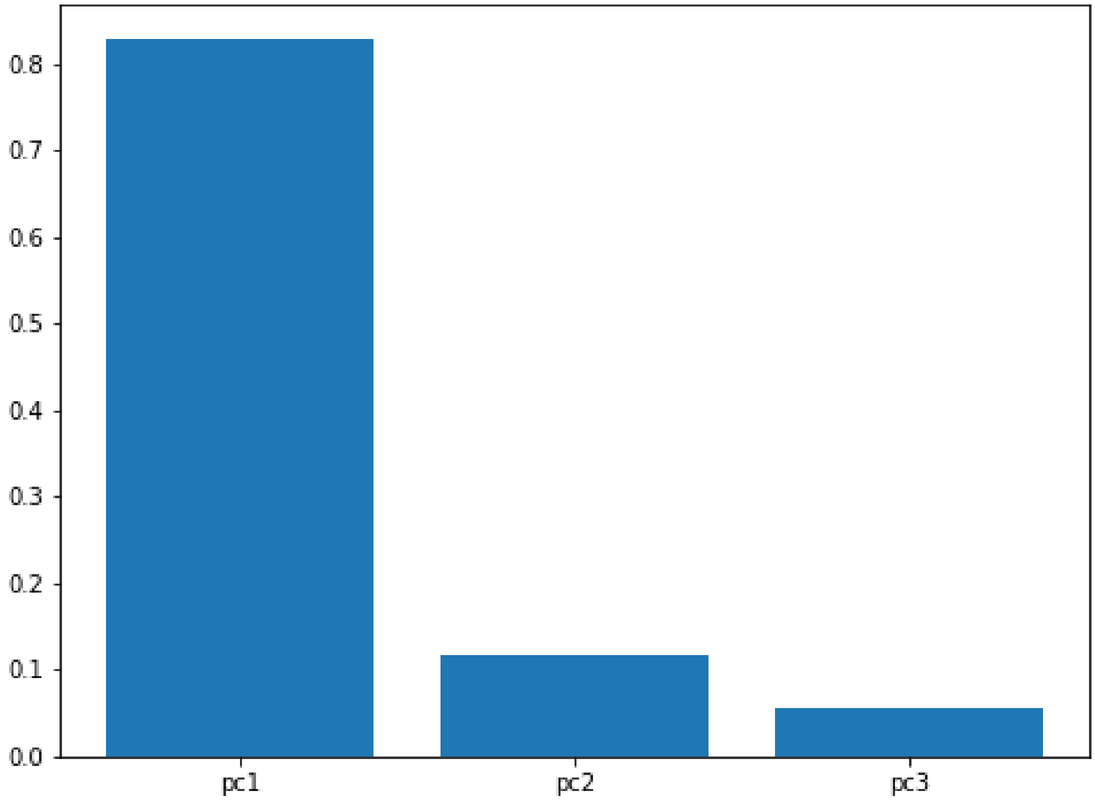
```
In [670]: from enum import Enum, auto
          class AnalysisType(Enum):
              TIME_SERIES = auto()
              FOURIER = auto()
```

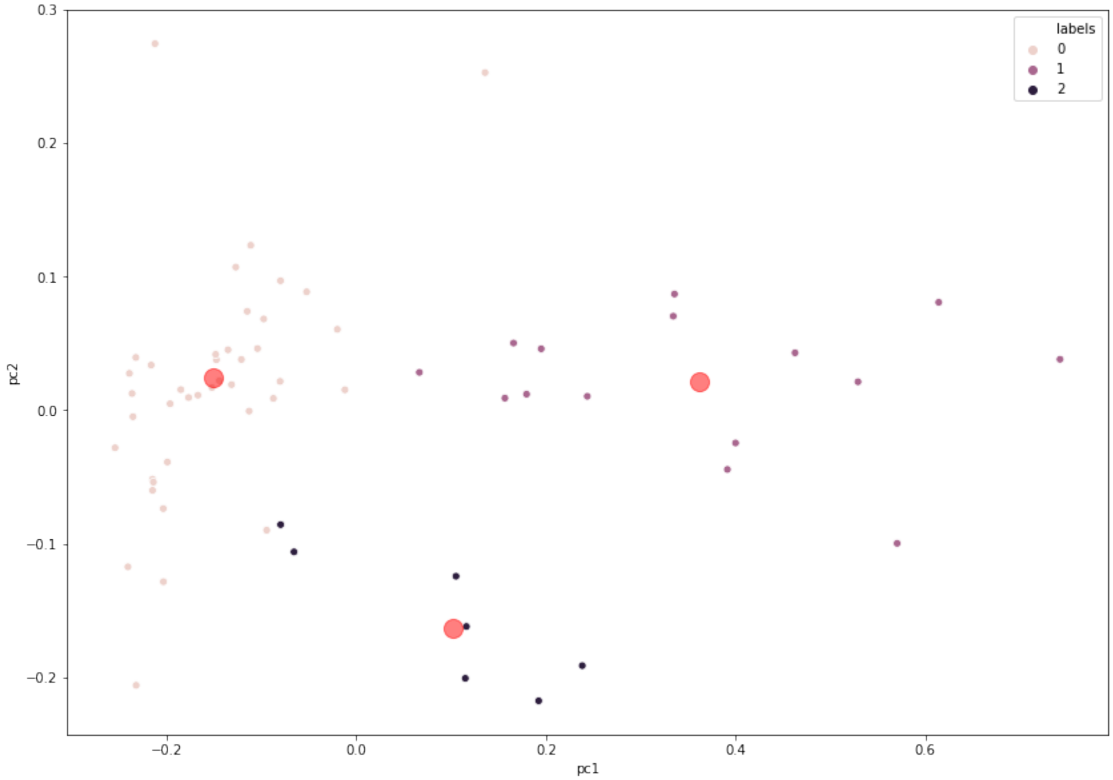
```
In [671]: ##plot percentage of variance vs pcs
          def plotPercentVariance(dfvp):
              pcInpt = performPca(dfvp.T, 10, False)
              pcInpt.apply(perVar, axis=1)

          def perVar(df_var):
              df_var = abs(df_var)
              print("abs",df_var)
              sum = df_var.sum()
              res = [x*100/sum for x in df_var]
              dfPlot = pd.DataFrame(data=pd.DataFrame(list(zip(df_var.index, res)), columns = ['
```

```
        sns.barplot(x='pc', y = 'perVariance', data=dfPlot)
        plt.show()
    #plotPercentVariance(df_filteredVp)
```

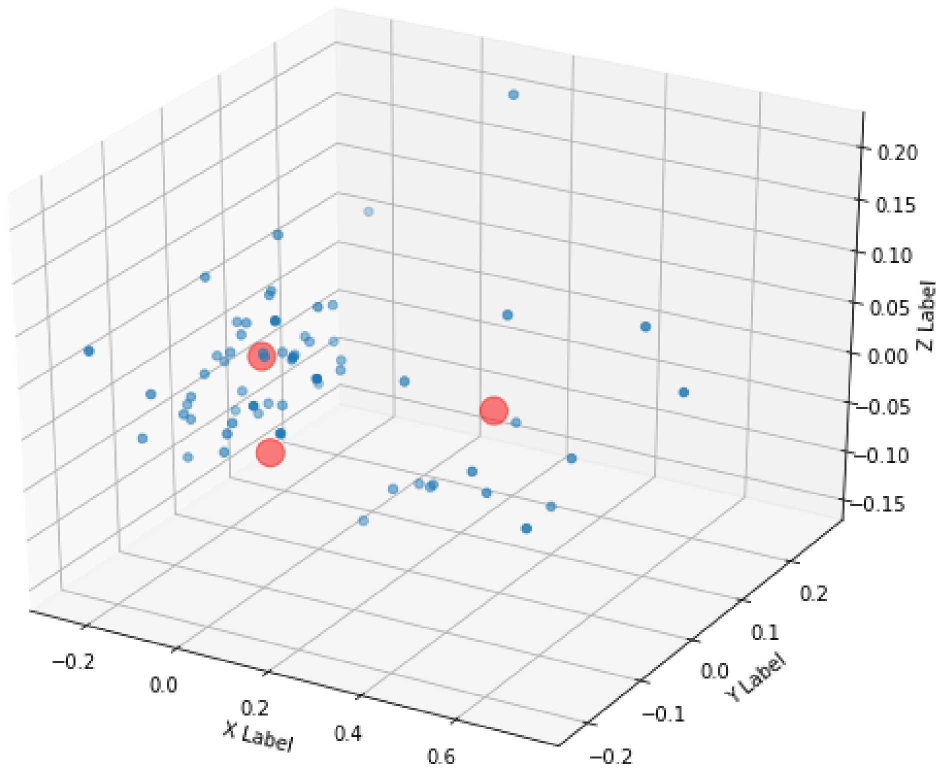
In [673]:

```
Radius in m 600
(288, 204)
(384, 204)
(672, 204)
Index: 49
Dimension points (629, 62)
performing fourier transformation
Performing PCA
Explained variance ratio with PCA: [ 0.82766017  0.11786175  0.05447807]
Cluster labels: [1 0 0 0 0 1 1 1 0 0 0 0 0 0 1 0 1 1 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0
 2 2 0 0 0 0 0 2 0 0 0 2 0 1 2 1 1 2 0 1 0 2 0 0 0]
strength: 0.956076071291
Performing PCA
Explained variance ratio with PCA: [ 0.82766017  0.11786175]
Performing PCA
Explained variance ratio with PCA: [ 0.82766017  0.11786175]
cluster: 0
----------------------------------------------------------------------------------
Number of meters in each cluster: A:1 B:30 C:9
----------------------------------------------------------------------------------
cluster: 1
----------------------------------------------------------------------------------
Number of meters in each cluster: A:0 B:0 C:15
----------------------------------------------------------------------------------
cluster: 2
----------------------------------------------------------------------------------
Number of meters in each cluster: A:0 B:5 C:2
----------------------------------------------------------------------------------
Overall accuracy: 0.806451612903
----------------------------------------------------------------------------------
Performing PCA
Explained variance ratio with PCA: [ 0.82766017  0.11786175  0.05447807]
```


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
pc1
pc2
pc3




```
<matplotlib.figure.Figure at 0x7f0e518e7ef0>
```



In [674]:
```
from scipy.spatial.distance import pdist, squareform
df_latlong, df_voltPoints, df_trMapping = processInputData()

distances = pdist(df_latlong.iloc[:,1:3].values, metric='euclidean')
#print(len(distances))
dist_matrix = squareform(distances)
print(dist_matrix)
```

```
(288, 204)
(384, 204)
(672, 204)
[[ 0.          0.00234874  0.00234874 ...,  0.00234874  0.00234874
   0.01240292]
 [ 0.00234874  0.          0.         ...,  0.          0.          0.0104154 ]
 [ 0.00234874  0.          0.         ...,  0.          0.          0.0104154 ]
 ...,
 [ 0.00234874  0.          0.         ...,  0.          0.          0.0104154 ]
 [ 0.00234874  0.          0.         ...,  0.          0.          0.0104154 ]
 [ 0.01240292  0.0104154   0.0104154  ...,  0.0104154   0.0104154   0.        ]]
```

```
In [676]: df_meterDist = pd.DataFrame(list(zip(df_latlong['_id'], dist_matrix[idx])), columns=['
          df_meterDistSorted = df_meterDist.sort_values(by='distances').reset_index(drop=True)
```

1.4 DBSCAN analysis

```
In [ ]: nbrs = NearestNeighbors(n_neighbors=3).fit(dfxt.values)
        distances, indices = nbrs.kneighbors(dfxt)
        dists = np.sort(distances.flatten())
        plt.plot(dists)
```

```
In [ ]: #DBSCAN Clustering

        dfInp = performPca(dfxt)
        clustering_dbscan = DBSCAN(eps=0.005, min_samples=2, metric=voltCorr).fit(dfxt)
        labels_dbscan = clustering_dbscan.labels_
        showClusters(dfInp, labels_dbscan)
```

2 Results:

cluster: 0 ['Meter 2' 'Meter 14' 'Meter 15' 'Meter 24'] cluster: 1 ['Meter 6' 'Meter 7' 'Meter 10' 'Meter 17' 'Meter 20' 'Meter 27'] cluster: 2 ['Meter 9' 'Meter 11']