```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import scipy.cluster.hierarchy as shc
from scipy.spatial.distance import squareform, pdist
```

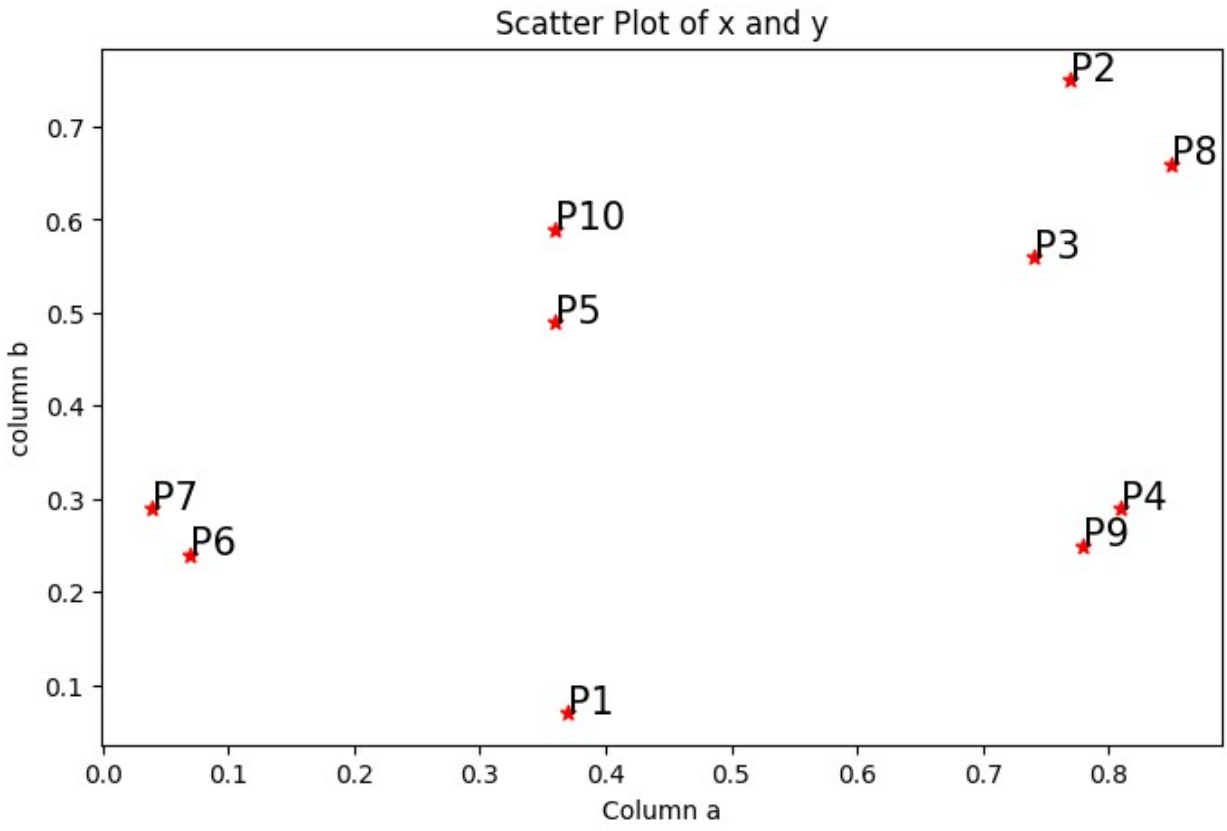
Creating a random dataset with 2 features, a real time dataset is not used because, in hierarchial clustering we need to create n clusters for n points in the start (divisive) or in the end (agglomerative), so the plotting will be very difficult for large no of points. so for learning purpose ive used a random data with 10 points and 2 features

```
a = np.random.random_sample(size = 10)
b = np.random.random_sample(size = 10)

point = ['P1','P2','P3','P4','P5','P6','P7','P8','P9','P10']
data = pd.DataFrame({'Point':point, 'a':np.round(a,2),
'b':np.round(b,2)})
data = data.set_index('Point')
data
```

Point	a	b
P1	0.37	0.07
P2	0.77	0.75
P3	0.74	0.56
P4	0.81	0.29
P5	0.36	0.49
P6	0.07	0.24
P7	0.04	0.29
P8	0.85	0.66
P9	0.78	0.25
P10	0.36	0.59

Plotting the points

```
plt.figure(figsize=(8,5))
plt.scatter(data['a'], data['b'], c='r', marker='*')
plt.xlabel('Column a')
plt.ylabel('column b')
plt.title('Scatter Plot of x and y')
for j in data.itertuples():
    plt.annotate(j.Index, (j.a, j.b), fontsize=15)
```



Calculating the distance matrix

```
dist = pd.DataFrame(squareform(pdist(data[['a', 'b']]), 'euclidean'),
columns=data.index.values, index=data.index.values)
dist
```

```
           P1        P2        P3        P4        P5        P6
P7  \
P1   0.000000  0.788923  0.614003  0.491935  0.420119  0.344819
0.396611
P2   0.788923  0.000000  0.192354  0.461736  0.485489  0.866083
0.862844
P3   0.614003  0.192354  0.000000  0.278927  0.386394  0.742496
0.750267
P4   0.491935  0.461736  0.278927  0.000000  0.492443  0.741687
0.770000
P5   0.420119  0.485489  0.386394  0.492443  0.000000  0.382884
0.377359
P6   0.344819  0.866083  0.742496  0.741687  0.382884  0.000000
0.058310
P7   0.396611  0.862844  0.750267  0.770000  0.377359  0.058310
0.000000
P8   0.760592  0.120416  0.148661  0.372156  0.518652  0.885889
0.890505
```

```
P9   0.447772  0.500100  0.312570  0.050000  0.483735  0.710070
0.741080
P10  0.520096  0.440114  0.381182  0.540833  0.100000  0.454533
0.438634

           P8        P9       P10
P1   0.760592  0.447772  0.520096
P2   0.120416  0.500100  0.440114
P3   0.148661  0.312570  0.381182
P4   0.372156  0.050000  0.540833
P5   0.518652  0.483735  0.100000
P6   0.885889  0.710070  0.454533
P7   0.890505  0.741080  0.438634
P8   0.000000  0.415933  0.494975
P9   0.415933  0.000000  0.540370
P10  0.494975  0.540370  0.000000
```

perform single link clustering method, the shortest distance between 2 clusters is considered when one or both the clusters have 2 or more points

```
def single_linkage(dist_matrix):
    n = len(dist_matrix)
    while n > 1:
        min_val = float('inf')
        min_index = None
        for i in range(n):
            for j in range(i+1, n):
                if dist_matrix.iloc[i, j] < min_val and
dist_matrix.index[i] != dist_matrix.columns[j]:
                    min_val = dist_matrix.iloc[i, j]
                    min_index = (i, j)

        if min_val == float('inf'):
            break

        i, j = min_index
        cluster1, cluster2 = dist_matrix.index[i],
dist_matrix.columns[j]

        print(f'Merging clusters {cluster1} and {cluster2} with
distance {min_val}')
        new_cluster = f'({cluster1},{cluster2})'
        dist_matrix[new_cluster] = dist_matrix[[cluster1,
cluster2]].min(axis=1)
        dist_matrix.loc[new_cluster] = dist_matrix.loc[[cluster1,
cluster2]].min(axis=0)
        dist_matrix = dist_matrix.drop([cluster1, cluster2], axis=0)
        dist_matrix = dist_matrix.drop([cluster1, cluster2], axis=1)
```

```
        n -= 1

        print(dist_matrix)
        print("")

# Perform single linkage clustering
print("Single Linkage Clustering:")
single_linkage(dist.copy())
```

```
Single Linkage Clustering:
Merging clusters P4 and P9 with distance 0.05
               P1        P2        P3        P5        P6        P7
P8  \
P1       0.000000  0.788923  0.614003  0.420119  0.344819  0.396611
0.760592
P2       0.788923  0.000000  0.192354  0.485489  0.866083  0.862844
0.120416
P3       0.614003  0.192354  0.000000  0.386394  0.742496  0.750267
0.148661
P5       0.420119  0.485489  0.386394  0.000000  0.382884  0.377359
0.518652
P6       0.344819  0.866083  0.742496  0.382884  0.000000  0.058310
0.885889
P7       0.396611  0.862844  0.750267  0.377359  0.058310  0.000000
0.890505
P8       0.760592  0.120416  0.148661  0.518652  0.885889  0.890505
0.000000
P10      0.520096  0.440114  0.381182  0.100000  0.454533  0.438634
0.494975
(P4,P9)  0.447772  0.461736  0.278927  0.483735  0.710070  0.741080
0.372156

              P10   (P4,P9)
P1       0.520096  0.447772
P2       0.440114  0.461736
P3       0.381182  0.278927
P5       0.100000  0.483735
P6       0.454533  0.710070
P7       0.438634  0.741080
P8       0.494975  0.372156
P10      0.000000  0.540370
(P4,P9)  0.540370  0.000000

Merging clusters P6 and P7 with distance 0.058309518948452994
               P1        P2        P3        P5        P8       P10
(P4,P9)  \
P1       0.000000  0.788923  0.614003  0.420119  0.760592  0.520096
0.447772
P2       0.788923  0.000000  0.192354  0.485489  0.120416  0.440114
```

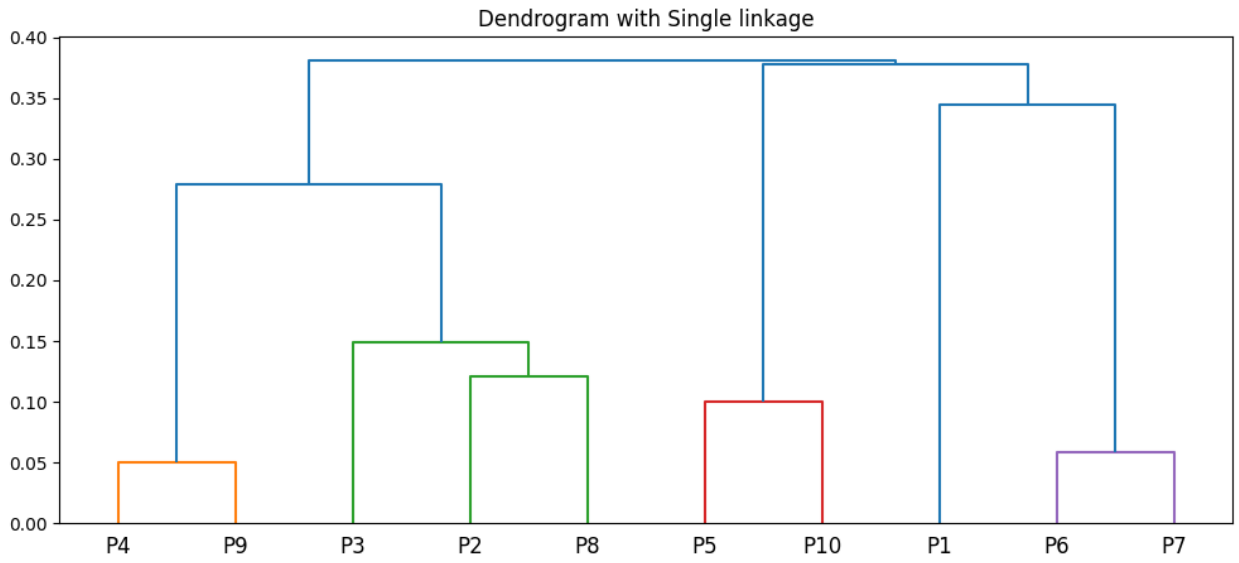
```
0.461736
P3       0.614003  0.192354  0.000000  0.386394  0.148661  0.381182
0.278927
P5       0.420119  0.485489  0.386394  0.000000  0.518652  0.100000
0.483735
P8       0.760592  0.120416  0.148661  0.518652  0.000000  0.494975
0.372156
P10      0.520096  0.440114  0.381182  0.100000  0.494975  0.000000
0.540370
(P4,P9)  0.447772  0.461736  0.278927  0.483735  0.372156  0.540370
0.000000
(P6,P7)  0.344819  0.862844  0.742496  0.377359  0.885889  0.438634
0.710070

          (P6,P7)
P1       0.344819
P2       0.862844
P3       0.742496
P5       0.377359
P8       0.885889
P10      0.438634
(P4,P9)  0.710070
(P6,P7)  0.000000

Merging clusters P5 and P10 with distance 0.09999999999999998
                P1        P2        P3        P8   (P4,P9)   (P6,P7)
(P5,P10)
P1        0.000000  0.788923  0.614003  0.760592  0.447772  0.344819
0.420119
P2        0.788923  0.000000  0.192354  0.120416  0.461736  0.862844
0.440114
P3        0.614003  0.192354  0.000000  0.148661  0.278927  0.742496
0.381182
P8        0.760592  0.120416  0.148661  0.000000  0.372156  0.885889
0.494975
(P4,P9)   0.447772  0.461736  0.278927  0.372156  0.000000  0.710070
0.483735
(P6,P7)   0.344819  0.862844  0.742496  0.885889  0.710070  0.000000
0.377359
(P5,P10)  0.420119  0.440114  0.381182  0.494975  0.483735  0.377359
0.000000

Merging clusters P2 and P8 with distance 0.1204159457879229
                P1        P3   (P4,P9)   (P6,P7)  (P5,P10)   (P2,P8)
P1        0.000000  0.614003  0.447772  0.344819  0.420119  0.760592
P3        0.614003  0.000000  0.278927  0.742496  0.381182  0.148661
(P4,P9)   0.447772  0.278927  0.000000  0.710070  0.483735  0.372156
(P6,P7)   0.344819  0.742496  0.710070  0.000000  0.377359  0.862844
(P5,P10)  0.420119  0.381182  0.483735  0.377359  0.000000  0.440114
(P2,P8)   0.760592  0.148661  0.372156  0.862844  0.440114  0.000000
```

```
Merging clusters P3 and (P2,P8) with distance 0.14866068747318503
                    P1   (P4,P9)   (P6,P7)  (P5,P10)  (P3,(P2,P8))
P1            0.000000  0.447772  0.344819  0.420119      0.614003
(P4,P9)       0.447772  0.000000  0.710070  0.483735      0.278927
(P6,P7)       0.344819  0.710070  0.000000  0.377359      0.742496
(P5,P10)      0.420119  0.483735  0.377359  0.000000      0.381182
(P3,(P2,P8))  0.614003  0.278927  0.742496  0.381182      0.000000

Merging clusters (P4,P9) and (P3,(P2,P8)) with distance
0.2789265136196271
                              P1   (P6,P7)  (P5,P10)  ((P4,P9),(P3,
(P2,P8)))
P1                        0.000000  0.344819  0.420119
0.447772
(P6,P7)                   0.344819  0.000000  0.377359
0.710070
(P5,P10)                  0.420119  0.377359  0.000000
0.381182
((P4,P9),(P3,(P2,P8)))  0.447772  0.710070  0.381182
0.000000

Merging clusters P1 and (P6,P7) with distance 0.34481879299133333
                        (P5,P10)  ((P4,P9),(P3,(P2,P8)))  (P1,(P6,P7))
(P5,P10)                0.000000               0.381182      0.377359
((P4,P9),(P3,(P2,P8)))  0.381182               0.000000      0.447772
(P1,(P6,P7))            0.377359               0.447772      0.000000

Merging clusters (P5,P10) and (P1,(P6,P7)) with distance
0.37735924528226417
                         ((P4,P9),(P3,(P2,P8)))  ((P5,P10),(P1,
(P6,P7)))
((P4,P9),(P3,(P2,P8)))                0.000000
0.381182
((P5,P10),(P1,(P6,P7)))               0.381182
0.000000

Merging clusters ((P4,P9),(P3,(P2,P8))) and ((P5,P10),(P1,(P6,P7)))
with distance 0.38118237105091834
                                                    (((P4,P9),(P3,
(P2,P8))),((P5,P10),(P1,(P6,P7))))
(((P4,P9),(P3,(P2,P8))),((P5,P10),(P1,(P6,P7))))
0.0
```

Visualising the dendogram for single link clustering

```
plt.figure(figsize=(12,5))
plt.title("Dendrogram with Single linkage")
```

```
dend = shc.dendrogram(shc.linkage(data[['a', 'b']], method='single'),
labels=data.index)
```




```
perform complete link clustering method, the longest distance between
2 clusters is considered when one or both the clusters have 2 or more
points

def complete_linkage(dist_matrix):
    n = len(dist_matrix)
    while n > 1:
        min_val = float('inf')
        min_index = None
        for i in range(n):
            for j in range(i+1, n):
                if dist_matrix.iloc[i, j] < min_val and
dist_matrix.index[i] != dist_matrix.columns[j]:
                    min_val = dist_matrix.iloc[i, j]
                    min_index = (i, j)

        if min_val == float('inf'):
            break

        i, j = min_index
        cluster1, cluster2 = dist_matrix.index[i],
dist_matrix.columns[j]

        print(f'Merging clusters {cluster1} and {cluster2} with
distance {min_val}')
        new_cluster = f'({cluster1},{cluster2})'
        dist_matrix[new_cluster] = dist_matrix[[cluster1,
cluster2]].max(axis=1)
```

```
        dist_matrix.loc[new_cluster] = dist_matrix.loc[[cluster1,
cluster2]].max(axis=0)
        dist_matrix = dist_matrix.drop([cluster1, cluster2], axis=0)
        dist_matrix = dist_matrix.drop([cluster1, cluster2], axis=1)

        n -= 1

        print(dist_matrix)
        print("")

# Perform complete linkage clustering
print("Complete Linkage Clustering:")
complete_linkage(dist.copy())
```

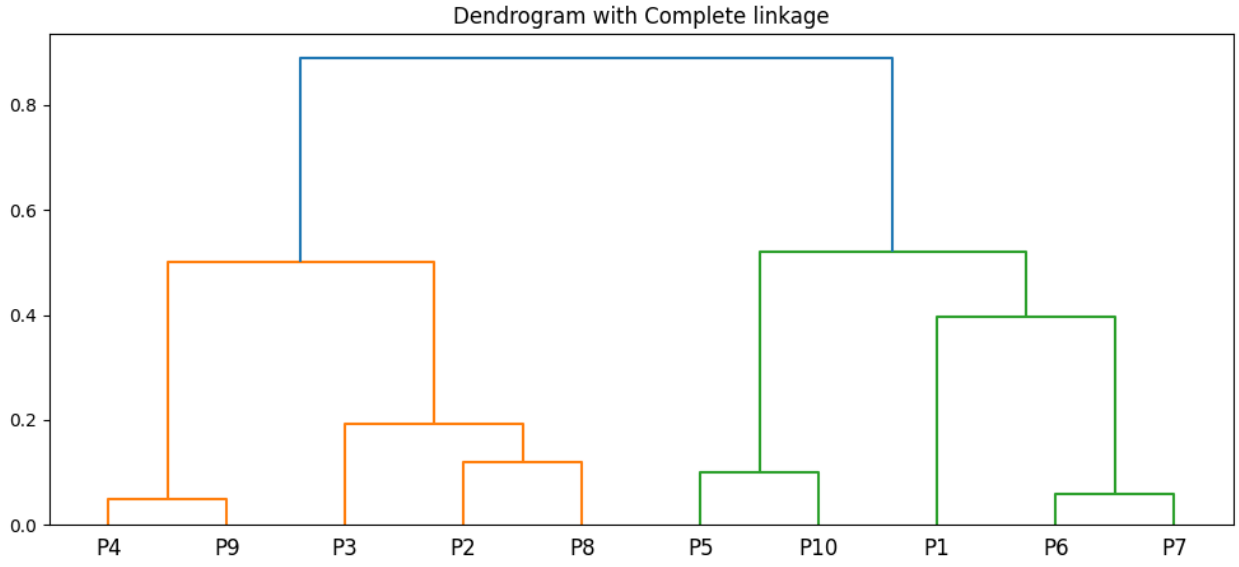
```
Complete Linkage Clustering:
Merging clusters P4 and P9 with distance 0.05
               P1        P2        P3        P5        P6        P7
P8  \
P1       0.000000  0.788923  0.614003  0.420119  0.344819  0.396611
0.760592
P2       0.788923  0.000000  0.192354  0.485489  0.866083  0.862844
0.120416
P3       0.614003  0.192354  0.000000  0.386394  0.742496  0.750267
0.148661
P5       0.420119  0.485489  0.386394  0.000000  0.382884  0.377359
0.518652
P6       0.344819  0.866083  0.742496  0.382884  0.000000  0.058310
0.885889
P7       0.396611  0.862844  0.750267  0.377359  0.058310  0.000000
0.890505
P8       0.760592  0.120416  0.148661  0.518652  0.885889  0.890505
0.000000
P10      0.520096  0.440114  0.381182  0.100000  0.454533  0.438634
0.494975
(P4,P9)  0.491935  0.500100  0.312570  0.492443  0.741687  0.770000
0.415933

              P10   (P4,P9)
P1       0.520096  0.491935
P2       0.440114  0.500100
P3       0.381182  0.312570
P5       0.100000  0.492443
P6       0.454533  0.741687
P7       0.438634  0.770000
P8       0.494975  0.415933
P10      0.000000  0.540833
(P4,P9)  0.540833  0.050000

Merging clusters P6 and P7 with distance 0.058309518948452994
               P1        P2        P3        P5        P8       P10
```

```
(P4,P9)  \
P1       0.000000  0.788923  0.614003  0.420119  0.760592  0.520096
0.491935
P2       0.788923  0.000000  0.192354  0.485489  0.120416  0.440114
0.500100
P3       0.614003  0.192354  0.000000  0.386394  0.148661  0.381182
0.312570
P5       0.420119  0.485489  0.386394  0.000000  0.518652  0.100000
0.492443
P8       0.760592  0.120416  0.148661  0.518652  0.000000  0.494975
0.415933
P10      0.520096  0.440114  0.381182  0.100000  0.494975  0.000000
0.540833
(P4,P9)  0.491935  0.500100  0.312570  0.492443  0.415933  0.540833
0.050000
(P6,P7)  0.396611  0.866083  0.750267  0.382884  0.890505  0.454533
0.770000

          (P6,P7)
P1       0.396611
P2       0.866083
P3       0.750267
P5       0.382884
P8       0.890505
P10      0.454533
(P4,P9)  0.770000
(P6,P7)  0.058310

Merging clusters P5 and P10 with distance 0.09999999999999998
                P1        P2        P3        P8   (P4,P9)   (P6,P7)
(P5,P10)
P1        0.000000  0.788923  0.614003  0.760592  0.491935  0.396611
0.520096
P2        0.788923  0.000000  0.192354  0.120416  0.500100  0.866083
0.485489
P3        0.614003  0.192354  0.000000  0.148661  0.312570  0.750267
0.386394
P8        0.760592  0.120416  0.148661  0.000000  0.415933  0.890505
0.518652
(P4,P9)   0.491935  0.500100  0.312570  0.415933  0.050000  0.770000
0.540833
(P6,P7)   0.396611  0.866083  0.750267  0.890505  0.770000  0.058310
0.454533
(P5,P10)  0.520096  0.485489  0.386394  0.518652  0.540833  0.454533
0.100000

Merging clusters P2 and P8 with distance 0.1204159457879229
                P1        P3   (P4,P9)   (P6,P7)  (P5,P10)   (P2,P8)
P1        0.000000  0.614003  0.491935  0.396611  0.520096  0.788923
P3        0.614003  0.000000  0.312570  0.750267  0.386394  0.192354
```

```
(P4,P9)   0.491935  0.312570  0.050000  0.770000  0.540833  0.500100
(P6,P7)   0.396611  0.750267  0.770000  0.058310  0.454533  0.890505
(P5,P10)  0.520096  0.386394  0.540833  0.454533  0.100000  0.518652
(P2,P8)   0.788923  0.192354  0.500100  0.890505  0.518652  0.120416

Merging clusters P3 and (P2,P8) with distance 0.1923538406167134
                    P1   (P4,P9)   (P6,P7)  (P5,P10)  (P3,(P2,P8))
P1            0.000000  0.491935  0.396611  0.520096      0.788923
(P4,P9)       0.491935  0.050000  0.770000  0.540833      0.500100
(P6,P7)       0.396611  0.770000  0.058310  0.454533      0.890505
(P5,P10)      0.520096  0.540833  0.454533  0.100000      0.518652
(P3,(P2,P8))  0.788923  0.500100  0.890505  0.518652      0.192354

Merging clusters P1 and (P6,P7) with distance 0.3966106403010388
                (P4,P9)  (P5,P10)  (P3,(P2,P8))  (P1,(P6,P7))
(P4,P9)       0.050000  0.540833      0.500100      0.770000
(P5,P10)      0.540833  0.100000      0.518652      0.520096
(P3,(P2,P8))  0.500100  0.518652      0.192354      0.890505
(P1,(P6,P7))  0.770000  0.520096      0.890505      0.396611

Merging clusters (P4,P9) and (P3,(P2,P8)) with distance
0.5000999900019995
                        (P5,P10)  (P1,(P6,P7))  ((P4,P9),(P3,(P2,P8)))
(P5,P10)                0.100000      0.520096                0.540833
(P1,(P6,P7))            0.520096      0.396611                0.890505
((P4,P9),(P3,(P2,P8)))  0.540833      0.890505                0.500100

Merging clusters (P5,P10) and (P1,(P6,P7)) with distance
0.5200961449578337
                         ((P4,P9),(P3,(P2,P8)))  ((P5,P10),(P1,
(P6,P7)))
((P4,P9),(P3,(P2,P8)))                 0.500100
0.890505
((P5,P10),(P1,(P6,P7)))                0.890505
0.520096

Merging clusters ((P4,P9),(P3,(P2,P8))) and ((P5,P10),(P1,(P6,P7)))
with distance 0.8905054744357274
                                                  (((P4,P9),(P3,
(P2,P8))),((P5,P10),(P1,(P6,P7))))
(((P4,P9),(P3,(P2,P8))),((P5,P10),(P1,(P6,P7))))
0.890505
```

Dendogram for complete link clustering

```
plt.figure(figsize=(12,5))
plt.title("Dendrogram with Complete linkage")
dend = shc.dendrogram(shc.linkage(data[['a', 'b']],
method='complete'), labels=data.index)
```


Dendrogram with Complete linkage
0.8
0.6
0.4
0.2
0.0
P4
P9
P3
P2
P8
P5
P10
P1
P6
P7