

K Means++

Measuring Cluster Quality

Supervised method

Homogeneity: Each cluster contains only members of a single class.

Completeness: All members of a given class are assigned to the same cluster.

Unsupervised method

Silhouette Coefficient: Evaluate how well the **compactness** and the **separation** of the clusters are. (Note that the notation below is consistent with the above content.) Using *Silhouette Coefficient*, we can choose an optimal value for number of clusters.

$a(x_i)$ denotes the **mean intra-cluster distance**. Evaluate the compactness of the cluster to which x_i belongs. (The smaller the more compact)

$$a(x_i) = \frac{\sum_{x_k \in C_j, k \neq i} D(x_i, x_k)}{|C_j| - 1}$$

For the data point x_i , calculate its average distance to all the other data points in its cluster. (Minusing one in denominator part is to leave out the current data point x_i)

$b(x_i)$ denotes the **mean nearest-cluster distance**. Evaluate how x_i is separated from other clusters. (The larger the more separated)

$$b(x_i) = \min_{C_j: 1 \leq j \leq k, x_i \notin C_j} \left\{ \frac{\sum_{x_k \in C_j} D(x_i, x_k)}{|C_j|} \right\}$$

For the data point x_i and all the other clusters not containing x_i , calculate its average distance to all the other data points in the given clusters. Find the minimum distance value with respect to the given clusters.

Finally, *Silhouette Coefficient*: $s(x_i) = \frac{b(x_i) - a(x_i)}{\max\{a(x_i), b(x_i)\}}$, $-1 \leq s(x_i) \leq 1$. Want $a(x_i) < b(x_i)$ and $a(x_i) \rightarrow 0$ so as to $s(x_i) \rightarrow 1$.

KMeans groups all data points to each one of the 'K' clusters. These clusters have similar variance and they are derived by minimizing a specific cost function: sum of squares distance (Euclidean) within the cluster. K-Means can be seen as a special case of Gaussian mixture model (discussed later) with equal covariance per component.

1. Number of clusters are chosen
2. Randomly guess K cluster center locations
3. Each data point finds out which center it is closest to
4. Each center finds the centroid of the points in owns
5. K cluster center jumps to the new centroid and repeats steps 3 and 4
6. Step 5 is repeated until it is terminated

The k-means algorithm makes all-or-nothing assignments of data points to clusters, and these hard decisions can often lead to poor solutions corresponding to local minima. Also it is very sensitive to initialization therefore prone to local minima. It responds poorly to elongated clusters, or manifolds with irregular shapes. In very high-dimensional spaces, Euclidean distances tend to become inflated (this is an instance of the so-called "curse of dimensionality"). Running a dimensionality reduction algorithm such as PCA (discussed later) prior to K-means clustering can alleviate this problem and speed up the computations.

K-Means++ is the default setting. It is a variant of K-means, where the algorithm randomly chooses one centroid from data points using weighted probability distribution proportional to the distance square. This initializes the centroids to be (generally) distant from each other, leading to provably better results than random initialization. Speeds up convergence.

The Algorithm

1. Randomly choose k centroids $C = \{c_1, c_2, \dots, c_k\}$ from the data points
 $X = \{x_1, x_2, \dots, x_n\} \in \mathbb{R}^D$.
2. For each data point x_i , find the nearest centroid c_j as its corresponding cluster using *sum of squared distance* $D(x_i, c_j) = \sum_{i=1}^n \|x_i - c_j\|^2$.
3. For each cluster, update its centroid by computing means value along the dimension of data points in the cluster.
4. Compute the displacement between the old and the new centroids and repeat steps 2 and 3 if the displacement is less than a threshold (converged).

```
In [1]: from sklearn import datasets
from sklearn import preprocessing
from sklearn.model_selection import train_test_split

from sklearn.cluster import KMeans
from sklearn.ensemble import IsolationForest
from sklearn.neighbors import LocalOutlierFactor
from sklearn import svm, neighbors
from sklearn.neighbors import NearestNeighbors

from sklearn.metrics import classification_report
from sklearn.metrics import confusion_matrix
from sklearn.metrics import recall_score
from sklearn.metrics import roc_auc_score
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import make_scorer
from sklearn.metrics import accuracy_score

import pandas as pd
import numpy as np
import itertools
import matplotlib.pyplot as plt
import datetime

%matplotlib inline
```

```
In [2]: train_split = 0.80
nrows = 250_000
path = 'c:/users/ugy1/abs/'
df=pd.read_csv(path+'datasets/processed_abs_loan_'+str(nrows)+'.csv',
               #usecols=use_list,
               #sep='\t',
               #compression=bz2,
               nrows=nrows,
               low_memory=False,
               index_col=0,
               parse_dates=True
               )

df.shape
```

```
Out[2]: (237024, 58)
```

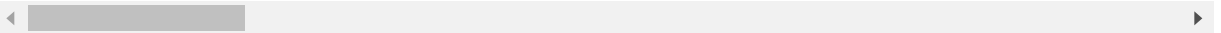
```
In [3]: column_list=df.columns.tolist()
```

In [4]: `df.head()`

Out[4]:

	originalloanamount	originalloanterm	originalinterestratepercentage	graceperiodnuml
0	66711.84	60	3.29	1
1	16258.45	60	0.90	0
2	31930.41	72	2.90	1
3	26065.02	65	0.90	0
4	42091.00	72	3.90	0

5 rows × 58 columns



In [5]: `# prepare label for scikit-learn`
`Y=df.label.values`
`Y.shape`

Out[5]: (237024,)

In [6]: `# prepare input data for scikit-learn`
`input=df.values`
`input.shape`

Out[6]: (237024, 58)

In [7]: `# calculate train/test split`
`len_train = int(len(input)*train_split)`
`print(len_train)`

189619

In [8]: `# apply train/test split to labels`
`y_train = Y[0:len_train]`
`y_test = Y[len_train:]`
`x_train = input[0:len_train]`
`x_test = input[len_train:]`
`x_train.shape`

Out[8]: (189619, 58)

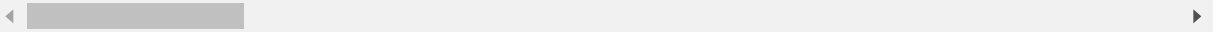
In [9]: `export_x_test = pd.DataFrame(data=x_test)`

```
In [10]: export_x_test.columns=column_list
export_x_test.rename(columns={'label':'True Label'}, inplace=True)
export_x_test.head()
```

Out[10]:

	originalloanamount	originalloanterm	originalinterestratepercentage	graceperiodnuml
0	36863.24	72.0	1.00	1.0
1	23811.32	60.0	1.90	0.0
2	30669.00	48.0	1.00	1.0
3	54083.21	72.0	1.00	0.0
4	31557.75	72.0	3.89	1.0

5 rows × 58 columns



```
In [11]: #from sklearn.preprocessing import MinMaxScaler
# from sklearn.preprocessing import minmax_scale
# from sklearn.preprocessing import MaxAbsScaler
from sklearn.preprocessing import StandardScaler
# from sklearn.preprocessing import RobustScaler
# from sklearn.preprocessing import Normalizer
# from sklearn.preprocessing import QuantileTransformer
# from sklearn.preprocessing import PowerTransformer
```

```
In [12]: x_scaler=StandardScaler()
x_train = x_scaler.fit_transform(x_train)
x_test = x_scaler.fit_transform(x_test)
```

```
In [13]: # Perform K-means++ on our data.
kmeans_plus_plus = KMeans(n_clusters=2,
                           n_init=100,
                           init='k-means++',
                           tol=1e-4,
                           random_state=54,
                           verbose=1).fit(x_train)
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Initialization complete
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Iteration 8, inertia 9188532.87357
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Iteration 9, inertia 9186846.80212
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Iteration 10, inertia 9185249.06219
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Iteration 11, inertia 9183624.18989
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Iteration 12, inertia 9181771.81145
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Iteration 13, inertia 9179597.61337
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Iteration 14, inertia 9176597.83305
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Iteration 15, inertia 9172464.13392
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Iteration 16, inertia 9166402.52443
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Iteration 17, inertia 9157038.54834
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Iteration 18, inertia 9141939.27642
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end inner loop
Iteration 19, inertia 9118878.81943
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done sorting
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Iteration 21, inertia 9076841.96925
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Iteration 22, inertia 9063857.75961
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Iteration 23, inertia 9048904.52577
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Iteration 24, inertia 9028809.55925
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Iteration 25, inertia 9005017.99208
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Iteration 26, inertia 8984728.3707
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end inner loop
Iteration 27, inertia 8972964.42482
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end inner loop
Iteration 28, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 29, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9324340.60834
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done sorting
end inner loop
Iteration 1, inertia 9124845.80453
start iteration
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end inner loop
Iteration 2, inertia 9073845.3502
start iteration
done sorting
end inner loop
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Iteration 3, inertia 9029672.03891
start iteration
done sorting
end inner loop
Iteration 4, inertia 8978636.39947
start iteration
done sorting
end inner loop
Iteration 5, inertia 8963627.55337
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done sorting
end inner loop
Iteration 6, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 7, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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end inner loop
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Iteration 2, inertia 9429309.796
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Iteration 3, inertia 9275035.62893
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Iteration 4, inertia 9148348.2677
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Iteration 5, inertia 9063022.9922
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Iteration 6, inertia 9004694.5033
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Iteration 7, inertia 8972172.24804
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end inner loop
Iteration 8, inertia 8963386.43122
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end inner loop
Iteration 9, inertia 8963188.48259
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end inner loop
Iteration 10, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
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Iteration 3, inertia 9001582.4229
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Iteration 4, inertia 8975302.44382
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end inner loop
Iteration 5, inertia 8971527.64063
start iteration
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end inner loop
Iteration 6, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
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Iteration 2, inertia 9105254.56768
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Iteration 3, inertia 8973449.16285
start iteration
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Iteration 4, inertia 8971527.64063
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end inner loop
Iteration 5, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
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Iteration 9, inertia 9194946.53513
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Iteration 10, inertia 9193207.22365
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end inner loop
Iteration 11, inertia 9191372.76983
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Iteration 31, inertia 8971527.64063
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Iteration 7, inertia 9309384.69137
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Iteration 37, inertia 8976300.25019
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Iteration 38, inertia 8971573.67526
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end inner loop
Iteration 39, inertia 8971527.64063
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Initialization complete
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Iteration 28, inertia 9041310.99515
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Iteration 33, inertia 8971527.64063
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Iteration 34, inertia 8971527.64063
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Initialization complete
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Iteration 3, inertia 8963188.48259
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Iteration 4, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
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Iteration 2, inertia 9076519.25577
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Iteration 7, inertia 8971586.72279
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Iteration 8, inertia 8971527.64063
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Iteration 3, inertia 8963223.01706
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Iteration 4, inertia 8963188.48259
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Iteration 9, inertia 9207355.86118
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Iteration 23, inertia 9120792.5459
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Initialization complete
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Iteration 3, inertia 9064230.10221
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Iteration 7, inertia 8976663.18754
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Iteration 8, inertia 8971573.67526
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end inner loop
Iteration 9, inertia 8971527.64063
center shift 7.020093e-03 within tolerance 8.965517e-05
Initialization complete
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Iteration 4, inertia 8963264.61441
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Iteration 5, inertia 8963188.48259
center shift 5.879008e-03 within tolerance 8.965517e-05
Initialization complete
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Iteration 10, inertia 9186539.019
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Iteration 24, inertia 9012967.68194
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end inner loop
Iteration 28, inertia 8971527.64063
center shift 7.020093e-03 within tolerance 8.965517e-05
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done sorting
end inner loop
Iteration 7, inertia 8971813.28013
start iteration
done sorting
end inner loop
Iteration 8, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 9, inertia 8971527.64063
```

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center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9640809.4872
start iteration
done sorting
end inner loop
Iteration 1, inertia 9554947.80623
start iteration
done sorting
end inner loop
Iteration 2, inertia 9478177.8462
start iteration
done sorting
end inner loop
Iteration 3, inertia 9359441.79139
start iteration
done sorting
end inner loop
Iteration 4, inertia 9197846.25722
start iteration
done sorting
end inner loop
Iteration 5, inertia 8966282.27826
start iteration
done sorting
end inner loop
Iteration 6, inertia 8963244.63736
start iteration
done sorting
end inner loop
Iteration 7, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 8, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9366672.87859
start iteration
done sorting
end inner loop
Iteration 1, inertia 9100329.75063
start iteration
done sorting
end inner loop
Iteration 2, inertia 8989083.1505
start iteration
done sorting
end inner loop
Iteration 3, inertia 8964696.68893
start iteration
```

```
done sorting
end inner loop
Iteration 4, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 5, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9397469.78212
start iteration
done sorting
end inner loop
Iteration 1, inertia 9210595.39511
start iteration
done sorting
end inner loop
Iteration 2, inertia 8973383.1486
start iteration
done sorting
end inner loop
Iteration 3, inertia 8963259.71033
start iteration
done sorting
end inner loop
Iteration 4, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 5, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9066521.21343
start iteration
done sorting
end inner loop
Iteration 1, inertia 9059979.63521
start iteration
done sorting
end inner loop
Iteration 2, inertia 9059930.46387
start iteration
done sorting
end inner loop
Iteration 3, inertia 9059930.34134
center shift 2.777544e-03 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9368971.30667
```

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start iteration
done sorting
end inner loop
Iteration 1, inertia 9139989.4931
start iteration
done sorting
end inner loop
Iteration 2, inertia 8966379.78674
start iteration
done sorting
end inner loop
Iteration 3, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 4, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9368311.63146
start iteration
done sorting
end inner loop
Iteration 1, inertia 9233471.13591
start iteration
done sorting
end inner loop
Iteration 2, inertia 9153491.50062
start iteration
done sorting
end inner loop
Iteration 3, inertia 9043627.40974
start iteration
done sorting
end inner loop
Iteration 4, inertia 8989919.76343
start iteration
done sorting
end inner loop
Iteration 5, inertia 8965610.00274
start iteration
done sorting
end inner loop
Iteration 6, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 7, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9499302.21613
start iteration
```

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done sorting
end inner loop
Iteration 1, inertia 9248476.86357
start iteration
done sorting
end inner loop
Iteration 2, inertia 9226508.79827
start iteration
done sorting
end inner loop
Iteration 3, inertia 9220468.17944
start iteration
done sorting
end inner loop
Iteration 4, inertia 9215781.84196
start iteration
done sorting
end inner loop
Iteration 5, inertia 9212625.19956
start iteration
done sorting
end inner loop
Iteration 6, inertia 9210478.89412
start iteration
done sorting
end inner loop
Iteration 7, inertia 9208789.20265
start iteration
done sorting
end inner loop
Iteration 8, inertia 9207301.11046
start iteration
done sorting
end inner loop
Iteration 9, inertia 9205977.5733
start iteration
done sorting
end inner loop
Iteration 10, inertia 9204733.39805
start iteration
done sorting
end inner loop
Iteration 11, inertia 9203609.40887
start iteration
done sorting
end inner loop
Iteration 12, inertia 9202579.22474
start iteration
done sorting
end inner loop
Iteration 13, inertia 9201631.2085
start iteration
done sorting
end inner loop
Iteration 14, inertia 9200675.53995
start iteration
done sorting
```

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end inner loop
Iteration 15, inertia 9199662.00868
start iteration
done sorting
end inner loop
Iteration 16, inertia 9198545.32037
start iteration
done sorting
end inner loop
Iteration 17, inertia 9197268.97024
start iteration
done sorting
end inner loop
Iteration 18, inertia 9195869.30635
start iteration
done sorting
end inner loop
Iteration 19, inertia 9194268.55915
start iteration
done sorting
end inner loop
Iteration 20, inertia 9192394.69719
start iteration
done sorting
end inner loop
Iteration 21, inertia 9190197.19529
start iteration
done sorting
end inner loop
Iteration 22, inertia 9187684.78742
start iteration
done sorting
end inner loop
Iteration 23, inertia 9184776.4163
start iteration
done sorting
end inner loop
Iteration 24, inertia 9181312.12198
start iteration
done sorting
end inner loop
Iteration 25, inertia 9176805.44624
start iteration
done sorting
end inner loop
Iteration 26, inertia 9170833.84412
start iteration
done sorting
end inner loop
Iteration 27, inertia 9162543.17828
start iteration
done sorting
end inner loop
Iteration 28, inertia 9150122.19618
start iteration
done sorting
end inner loop
```

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Iteration 29, inertia 9129993.231
start iteration
done sorting
end inner loop
Iteration 30, inertia 9103927.73478
start iteration
done sorting
end inner loop
Iteration 31, inertia 9083104.85814
start iteration
done sorting
end inner loop
Iteration 32, inertia 9069176.57728
start iteration
done sorting
end inner loop
Iteration 33, inertia 9055462.90308
start iteration
done sorting
end inner loop
Iteration 34, inertia 9037869.94252
start iteration
done sorting
end inner loop
Iteration 35, inertia 9015013.26626
start iteration
done sorting
end inner loop
Iteration 36, inertia 8992731.15237
start iteration
done sorting
end inner loop
Iteration 37, inertia 8976947.98761
start iteration
done sorting
end inner loop
Iteration 38, inertia 8971609.81691
start iteration
done sorting
end inner loop
Iteration 39, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 40, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9439586.61998
start iteration
done sorting
end inner loop
Iteration 1, inertia 9362485.15592
start iteration
done sorting
```

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end inner loop
Iteration 2, inertia 9339067.58552
start iteration
done sorting
end inner loop
Iteration 3, inertia 9320603.05921
start iteration
done sorting
end inner loop
Iteration 4, inertia 9298863.45629
start iteration
done sorting
end inner loop
Iteration 5, inertia 9275116.53107
start iteration
done sorting
end inner loop
Iteration 6, inertia 9251758.8283
start iteration
done sorting
end inner loop
Iteration 7, inertia 9230855.87487
start iteration
done sorting
end inner loop
Iteration 8, inertia 9214092.52393
start iteration
done sorting
end inner loop
Iteration 9, inertia 9201389.67215
start iteration
done sorting
end inner loop
Iteration 10, inertia 9192418.33634
start iteration
done sorting
end inner loop
Iteration 11, inertia 9185951.32778
start iteration
done sorting
end inner loop
Iteration 12, inertia 9180832.87565
start iteration
done sorting
end inner loop
Iteration 13, inertia 9175823.08429
start iteration
done sorting
end inner loop
Iteration 14, inertia 9170240.32521
start iteration
done sorting
end inner loop
Iteration 15, inertia 9162522.86828
start iteration
done sorting
end inner loop
```



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Iteration 16, inertia 9151107.41889
start iteration
done sorting
end inner loop
Iteration 17, inertia 9132742.3115
start iteration
done sorting
end inner loop
Iteration 18, inertia 9107991.34036
start iteration
done sorting
end inner loop
Iteration 19, inertia 9087256.02344
start iteration
done sorting
end inner loop
Iteration 20, inertia 9073353.27425
start iteration
done sorting
end inner loop
Iteration 21, inertia 9061154.05151
start iteration
done sorting
end inner loop
Iteration 22, inertia 9045464.67968
start iteration
done sorting
end inner loop
Iteration 23, inertia 9024331.03669
start iteration
done sorting
end inner loop
Iteration 24, inertia 9000330.0098
start iteration
done sorting
end inner loop
Iteration 25, inertia 8981077.07836
start iteration
done sorting
end inner loop
Iteration 26, inertia 8971980.5458
start iteration
done sorting
end inner loop
Iteration 27, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 28, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9368498.01817
start iteration
done sorting
```

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end inner loop
Iteration 1, inertia 9299360.15222
start iteration
done sorting
end inner loop
Iteration 2, inertia 9280645.87443
start iteration
done sorting
end inner loop
Iteration 3, inertia 9269388.91199
start iteration
done sorting
end inner loop
Iteration 4, inertia 9247107.29239
start iteration
done sorting
end inner loop
Iteration 5, inertia 9169506.72385
start iteration
done sorting
end inner loop
Iteration 6, inertia 9007389.93741
start iteration
done sorting
end inner loop
Iteration 7, inertia 8963649.60673
start iteration
done sorting
end inner loop
Iteration 8, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 9, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9472771.33605
start iteration
done sorting
end inner loop
Iteration 1, inertia 9334454.20738
start iteration
done sorting
end inner loop
Iteration 2, inertia 9287755.81493
start iteration
done sorting
end inner loop
Iteration 3, inertia 9259626.31809
start iteration
done sorting
end inner loop
Iteration 4, inertia 9239425.8547
start iteration
```

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done sorting
end inner loop
Iteration 5, inertia 9224568.59807
start iteration
done sorting
end inner loop
Iteration 6, inertia 9213754.88417
start iteration
done sorting
end inner loop
Iteration 7, inertia 9206679.05162
start iteration
done sorting
end inner loop
Iteration 8, inertia 9202326.01988
start iteration
done sorting
end inner loop
Iteration 9, inertia 9199502.89675
start iteration
done sorting
end inner loop
Iteration 10, inertia 9197366.87614
start iteration
done sorting
end inner loop
Iteration 11, inertia 9195476.42408
start iteration
done sorting
end inner loop
Iteration 12, inertia 9193582.09067
start iteration
done sorting
end inner loop
Iteration 13, inertia 9191700.85085
start iteration
done sorting
end inner loop
Iteration 14, inertia 9189883.07855
start iteration
done sorting
end inner loop
Iteration 15, inertia 9187902.94372
start iteration
done sorting
end inner loop
Iteration 16, inertia 9185613.51129
start iteration
done sorting
end inner loop
Iteration 17, inertia 9183098.90151
start iteration
done sorting
end inner loop
Iteration 18, inertia 9180165.11765
start iteration
done sorting
```

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end inner loop
Iteration 19, inertia 9176322.75635
start iteration
done sorting
end inner loop
Iteration 20, inertia 9171000.61111
start iteration
done sorting
end inner loop
Iteration 21, inertia 9163541.6924
start iteration
done sorting
end inner loop
Iteration 22, inertia 9152261.1144
start iteration
done sorting
end inner loop
Iteration 23, inertia 9133896.38165
start iteration
done sorting
end inner loop
Iteration 24, inertia 9108219.46006
start iteration
done sorting
end inner loop
Iteration 25, inertia 9086154.04281
start iteration
done sorting
end inner loop
Iteration 26, inertia 9071452.89046
start iteration
done sorting
end inner loop
Iteration 27, inertia 9058256.49849
start iteration
done sorting
end inner loop
Iteration 28, inertia 9041421.14209
start iteration
done sorting
end inner loop
Iteration 29, inertia 9019390.88519
start iteration
done sorting
end inner loop
Iteration 30, inertia 8996309.22561
start iteration
done sorting
end inner loop
Iteration 31, inertia 8978937.83407
start iteration
done sorting
end inner loop
Iteration 32, inertia 8971797.16485
start iteration
done sorting
end inner loop
```

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Iteration 33, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 34, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9368658.0282
start iteration
done sorting
end inner loop
Iteration 1, inertia 9061338.50218
start iteration
done sorting
end inner loop
Iteration 2, inertia 9059944.33941
start iteration
done sorting
end inner loop
Iteration 3, inertia 9059929.13501
start iteration
done sorting
end inner loop
Iteration 4, inertia 9059929.13501
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9635896.69653
start iteration
done sorting
end inner loop
Iteration 1, inertia 9252324.72252
start iteration
done sorting
end inner loop
Iteration 2, inertia 9063754.48252
start iteration
done sorting
end inner loop
Iteration 3, inertia 8992031.31364
start iteration
done sorting
end inner loop
Iteration 4, inertia 8965413.91725
start iteration
done sorting
end inner loop
Iteration 5, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 6, inertia 8963188.48259
```

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center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9580983.32132
start iteration
done sorting
end inner loop
Iteration 1, inertia 9438007.36216
start iteration
done sorting
end inner loop
Iteration 2, inertia 9331486.38859
start iteration
done sorting
end inner loop
Iteration 3, inertia 9275335.6356
start iteration
done sorting
end inner loop
Iteration 4, inertia 9248782.13347
start iteration
done sorting
end inner loop
Iteration 5, inertia 9231569.34345
start iteration
done sorting
end inner loop
Iteration 6, inertia 9217906.03368
start iteration
done sorting
end inner loop
Iteration 7, inertia 9207033.80347
start iteration
done sorting
end inner loop
Iteration 8, inertia 9198649.47282
start iteration
done sorting
end inner loop
Iteration 9, inertia 9192584.88564
start iteration
done sorting
end inner loop
Iteration 10, inertia 9188473.33739
start iteration
done sorting
end inner loop
Iteration 11, inertia 9185332.45139
start iteration
done sorting
end inner loop
Iteration 12, inertia 9182472.69868
start iteration
done sorting
end inner loop
```

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Iteration 13, inertia 9179506.04733
start iteration
done sorting
end inner loop
Iteration 14, inertia 9175962.62734
start iteration
done sorting
end inner loop
Iteration 15, inertia 9171230.40348
start iteration
done sorting
end inner loop
Iteration 16, inertia 9164185.25086
start iteration
done sorting
end inner loop
Iteration 17, inertia 9153328.18042
start iteration
done sorting
end inner loop
Iteration 18, inertia 9136007.23875
start iteration
done sorting
end inner loop
Iteration 19, inertia 9111081.66143
start iteration
done sorting
end inner loop
Iteration 20, inertia 9088415.91799
start iteration
done sorting
end inner loop
Iteration 21, inertia 9073295.49395
start iteration
done sorting
end inner loop
Iteration 22, inertia 9060380.1879
start iteration
done sorting
end inner loop
Iteration 23, inertia 9044251.4964
start iteration
done sorting
end inner loop
Iteration 24, inertia 9022778.25997
start iteration
done sorting
end inner loop
Iteration 25, inertia 8999022.68818
start iteration
done sorting
end inner loop
Iteration 26, inertia 8980423.40613
start iteration
done sorting
end inner loop
Iteration 27, inertia 8971924.34737
```

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start iteration
done sorting
end inner loop
Iteration 28, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 29, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9444783.46841
start iteration
done sorting
end inner loop
Iteration 1, inertia 9349998.67921
start iteration
done sorting
end inner loop
Iteration 2, inertia 9241146.00915
start iteration
done sorting
end inner loop
Iteration 3, inertia 8999108.97433
start iteration
done sorting
end inner loop
Iteration 4, inertia 8963389.10551
start iteration
done sorting
end inner loop
Iteration 5, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 6, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9437167.01753
start iteration
done sorting
end inner loop
Iteration 1, inertia 9275077.2383
start iteration
done sorting
end inner loop
Iteration 2, inertia 9237422.42312
start iteration
done sorting
end inner loop
Iteration 3, inertia 9219250.62506
start iteration
```



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done sorting
end inner loop
Iteration 4, inertia 9207731.28326
start iteration
done sorting
end inner loop
Iteration 5, inertia 9200325.73697
start iteration
done sorting
end inner loop
Iteration 6, inertia 9195591.1339
start iteration
done sorting
end inner loop
Iteration 7, inertia 9192574.90395
start iteration
done sorting
end inner loop
Iteration 8, inertia 9190517.56316
start iteration
done sorting
end inner loop
Iteration 9, inertia 9188959.97424
start iteration
done sorting
end inner loop
Iteration 10, inertia 9187554.944
start iteration
done sorting
end inner loop
Iteration 11, inertia 9186226.77247
start iteration
done sorting
end inner loop
Iteration 12, inertia 9184945.07166
start iteration
done sorting
end inner loop
Iteration 13, inertia 9183525.72792
start iteration
done sorting
end inner loop
Iteration 14, inertia 9181905.20171
start iteration
done sorting
end inner loop
Iteration 15, inertia 9179921.12828
start iteration
done sorting
end inner loop
Iteration 16, inertia 9177114.05967
start iteration
done sorting
end inner loop
Iteration 17, inertia 9173118.54183
start iteration
done sorting
```

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end inner loop
Iteration 18, inertia 9167334.14774
start iteration
done sorting
end inner loop
Iteration 19, inertia 9158546.06522
start iteration
done sorting
end inner loop
Iteration 20, inertia 9144521.8934
start iteration
done sorting
end inner loop
Iteration 21, inertia 9122694.68194
start iteration
done sorting
end inner loop
Iteration 22, inertia 9096981.31406
start iteration
done sorting
end inner loop
Iteration 23, inertia 9078645.7448
start iteration
done sorting
end inner loop
Iteration 24, inertia 9065335.24361
start iteration
done sorting
end inner loop
Iteration 25, inertia 9050750.91621
start iteration
done sorting
end inner loop
Iteration 26, inertia 9031361.56315
start iteration
done sorting
end inner loop
Iteration 27, inertia 9007723.08363
start iteration
done sorting
end inner loop
Iteration 28, inertia 8986696.95406
start iteration
done sorting
end inner loop
Iteration 29, inertia 8973774.33101
start iteration
done sorting
end inner loop
Iteration 30, inertia 8971545.71577
start iteration
done sorting
end inner loop
Iteration 31, inertia 8971527.64063
center shift 3.172246e-03 within tolerance 8.965517e-05
Initialization complete
start iteration
```

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done sorting
end inner loop
Iteration 0, inertia 9319917.43689
start iteration
done sorting
end inner loop
Iteration 1, inertia 9310423.55318
start iteration
done sorting
end inner loop
Iteration 2, inertia 9309384.69137
start iteration
done sorting
end inner loop
Iteration 3, inertia 9309384.69137
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9668256.04074
start iteration
done sorting
end inner loop
Iteration 1, inertia 9668256.04074
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9314659.52034
start iteration
done sorting
end inner loop
Iteration 1, inertia 9309972.51689
start iteration
done sorting
end inner loop
Iteration 2, inertia 9309402.32442
start iteration
done sorting
end inner loop
Iteration 3, inertia 9309384.69137
start iteration
done sorting
end inner loop
Iteration 4, inertia 9309384.69137
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9334111.02918
start iteration
done sorting
end inner loop
Iteration 1, inertia 9226001.0326
```

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start iteration
done sorting
end inner loop
Iteration 2, inertia 9199146.03628
start iteration
done sorting
end inner loop
Iteration 3, inertia 9186512.70043
start iteration
done sorting
end inner loop
Iteration 4, inertia 9177983.57586
start iteration
done sorting
end inner loop
Iteration 5, inertia 9170025.22254
start iteration
done sorting
end inner loop
Iteration 6, inertia 9160234.98227
start iteration
done sorting
end inner loop
Iteration 7, inertia 9146171.1129
start iteration
done sorting
end inner loop
Iteration 8, inertia 9124862.49919
start iteration
done sorting
end inner loop
Iteration 9, inertia 9100196.29852
start iteration
done sorting
end inner loop
Iteration 10, inertia 9082461.0906
start iteration
done sorting
end inner loop
Iteration 11, inertia 9070254.398
start iteration
done sorting
end inner loop
Iteration 12, inertia 9057892.50463
start iteration
done sorting
end inner loop
Iteration 13, inertia 9040979.15766
start iteration
done sorting
end inner loop
Iteration 14, inertia 9018541.24363
start iteration
done sorting
end inner loop
Iteration 15, inertia 8995062.34782
start iteration
```

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done sorting
end inner loop
Iteration 16, inertia 8977805.50493
start iteration
done sorting
end inner loop
Iteration 17, inertia 8971644.34685
start iteration
done sorting
end inner loop
Iteration 18, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 19, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9233807.51
start iteration
done sorting
end inner loop
Iteration 1, inertia 9086027.20118
start iteration
done sorting
end inner loop
Iteration 2, inertia 8997595.20504
start iteration
done sorting
end inner loop
Iteration 3, inertia 8963403.17188
start iteration
done sorting
end inner loop
Iteration 4, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 5, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9338118.95127
start iteration
done sorting
end inner loop
Iteration 1, inertia 9258606.97966
start iteration
done sorting
end inner loop
Iteration 2, inertia 9222652.2655
start iteration
done sorting
```

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end inner loop
Iteration 3, inertia 9205484.42637
start iteration
done sorting
end inner loop
Iteration 4, inertia 9199215.98038
start iteration
done sorting
end inner loop
Iteration 5, inertia 9196212.36467
start iteration
done sorting
end inner loop
Iteration 6, inertia 9194005.39358
start iteration
done sorting
end inner loop
Iteration 7, inertia 9192182.80908
start iteration
done sorting
end inner loop
Iteration 8, inertia 9190667.62316
start iteration
done sorting
end inner loop
Iteration 9, inertia 9189340.10234
start iteration
done sorting
end inner loop
Iteration 10, inertia 9188043.98661
start iteration
done sorting
end inner loop
Iteration 11, inertia 9186721.33757
start iteration
done sorting
end inner loop
Iteration 12, inertia 9185374.64825
start iteration
done sorting
end inner loop
Iteration 13, inertia 9183920.78085
start iteration
done sorting
end inner loop
Iteration 14, inertia 9182290.80614
start iteration
done sorting
end inner loop
Iteration 15, inertia 9180266.36964
start iteration
done sorting
end inner loop
Iteration 16, inertia 9177564.41951
start iteration
done sorting
end inner loop
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Iteration 17, inertia 9173684.09892
start iteration
done sorting
end inner loop
Iteration 18, inertia 9168152.06837
start iteration
done sorting
end inner loop
Iteration 19, inertia 9159789.5621
start iteration
done sorting
end inner loop
Iteration 20, inertia 9146678.78389
start iteration
done sorting
end inner loop
Iteration 21, inertia 9125596.05102
start iteration
done sorting
end inner loop
Iteration 22, inertia 9099884.95221
start iteration
done sorting
end inner loop
Iteration 23, inertia 9080480.14729
start iteration
done sorting
end inner loop
Iteration 24, inertia 9066992.70933
start iteration
done sorting
end inner loop
Iteration 25, inertia 9052821.91346
start iteration
done sorting
end inner loop
Iteration 26, inertia 9034293.84092
start iteration
done sorting
end inner loop
Iteration 27, inertia 9011028.68106
start iteration
done sorting
end inner loop
Iteration 28, inertia 8989398.90856
start iteration
done sorting
end inner loop
Iteration 29, inertia 8975228.92212
start iteration
done sorting
end inner loop
Iteration 30, inertia 8971573.67526
start iteration
done sorting
end inner loop
Iteration 31, inertia 8971527.64063
```

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center shift 7.020093e-03 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9128651.7334
start iteration
done sorting
end inner loop
Iteration 1, inertia 9060114.9971
start iteration
done sorting
end inner loop
Iteration 2, inertia 9059952.87644
start iteration
done sorting
end inner loop
Iteration 3, inertia 9059929.13934
start iteration
done sorting
end inner loop
Iteration 4, inertia 9059929.13934
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9398248.49676
start iteration
done sorting
end inner loop
Iteration 1, inertia 9253189.41629
start iteration
done sorting
end inner loop
Iteration 2, inertia 9224898.7965
start iteration
done sorting
end inner loop
Iteration 3, inertia 9215478.2505
start iteration
done sorting
end inner loop
Iteration 4, inertia 9210910.71985
start iteration
done sorting
end inner loop
Iteration 5, inertia 9208343.21284
start iteration
done sorting
end inner loop
Iteration 6, inertia 9206558.54613
start iteration
done sorting
end inner loop
Iteration 7, inertia 9205138.33466
start iteration
```



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done sorting
end inner loop
Iteration 8, inertia 9203911.54349
start iteration
done sorting
end inner loop
Iteration 9, inertia 9202853.7048
start iteration
done sorting
end inner loop
Iteration 10, inertia 9201875.57887
start iteration
done sorting
end inner loop
Iteration 11, inertia 9200940.86683
start iteration
done sorting
end inner loop
Iteration 12, inertia 9199955.48982
start iteration
done sorting
end inner loop
Iteration 13, inertia 9198851.84098
start iteration
done sorting
end inner loop
Iteration 14, inertia 9197625.21952
start iteration
done sorting
end inner loop
Iteration 15, inertia 9196255.49389
start iteration
done sorting
end inner loop
Iteration 16, inertia 9194733.9303
start iteration
done sorting
end inner loop
Iteration 17, inertia 9192929.798
start iteration
done sorting
end inner loop
Iteration 18, inertia 9190854.53315
start iteration
done sorting
end inner loop
Iteration 19, inertia 9188493.23298
start iteration
done sorting
end inner loop
Iteration 20, inertia 9185728.55982
start iteration
done sorting
end inner loop
Iteration 21, inertia 9182487.41852
start iteration
done sorting
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end inner loop
Iteration 22, inertia 9178456.24209
start iteration
done sorting
end inner loop
Iteration 23, inertia 9173059.08937
start iteration
done sorting
end inner loop
Iteration 24, inertia 9165714.81858
start iteration
done sorting
end inner loop
Iteration 25, inertia 9155062.06993
start iteration
done sorting
end inner loop
Iteration 26, inertia 9138093.99586
start iteration
done sorting
end inner loop
Iteration 27, inertia 9113118.43322
start iteration
done sorting
end inner loop
Iteration 28, inertia 9089520.21078
start iteration
done sorting
end inner loop
Iteration 29, inertia 9073900.1919
start iteration
done sorting
end inner loop
Iteration 30, inertia 9061012.1388
start iteration
done sorting
end inner loop
Iteration 31, inertia 9045006.36407
start iteration
done sorting
end inner loop
Iteration 32, inertia 9023890.81441
start iteration
done sorting
end inner loop
Iteration 33, inertia 9000535.7888
start iteration
done sorting
end inner loop
Iteration 34, inertia 8981966.23897
start iteration
done sorting
end inner loop
Iteration 35, inertia 8972210.11296
start iteration
done sorting
end inner loop
```

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Iteration 36, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 37, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9072684.19001
start iteration
done sorting
end inner loop
Iteration 1, inertia 8976623.41721
start iteration
done sorting
end inner loop
Iteration 2, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 3, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9327365.80309
start iteration
done sorting
end inner loop
Iteration 1, inertia 9222430.73875
start iteration
done sorting
end inner loop
Iteration 2, inertia 9203801.51062
start iteration
done sorting
end inner loop
Iteration 3, inertia 9196900.50713
start iteration
done sorting
end inner loop
Iteration 4, inertia 9192559.12385
start iteration
done sorting
end inner loop
Iteration 5, inertia 9188712.86352
start iteration
done sorting
end inner loop
Iteration 6, inertia 9184960.51623
start iteration
done sorting
end inner loop
Iteration 7, inertia 9180877.73647
```

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start iteration
done sorting
end inner loop
Iteration 8, inertia 9175852.77726
start iteration
done sorting
end inner loop
Iteration 9, inertia 9169311.13295
start iteration
done sorting
end inner loop
Iteration 10, inertia 9160161.45221
start iteration
done sorting
end inner loop
Iteration 11, inertia 9146235.60712
start iteration
done sorting
end inner loop
Iteration 12, inertia 9124581.51705
start iteration
done sorting
end inner loop
Iteration 13, inertia 9098947.77515
start iteration
done sorting
end inner loop
Iteration 14, inertia 9080318.6626
start iteration
done sorting
end inner loop
Iteration 15, inertia 9067350.85948
start iteration
done sorting
end inner loop
Iteration 16, inertia 9053429.01128
start iteration
done sorting
end inner loop
Iteration 17, inertia 9035169.14376
start iteration
done sorting
end inner loop
Iteration 18, inertia 9011936.42559
start iteration
done sorting
end inner loop
Iteration 19, inertia 8990109.69852
start iteration
done sorting
end inner loop
Iteration 20, inertia 8975490.02518
start iteration
done sorting
end inner loop
Iteration 21, inertia 8971573.67526
start iteration
```

```
done sorting
end inner loop
Iteration 22, inertia 8971527.64063
center shift 7.020093e-03 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9165563.79678
start iteration
done sorting
end inner loop
Iteration 1, inertia 9082331.05151
start iteration
done sorting
end inner loop
Iteration 2, inertia 9067572.60462
start iteration
done sorting
end inner loop
Iteration 3, inertia 9053452.04122
start iteration
done sorting
end inner loop
Iteration 4, inertia 9033310.7821
start iteration
done sorting
end inner loop
Iteration 5, inertia 9005537.11232
start iteration
done sorting
end inner loop
Iteration 6, inertia 8978840.70457
start iteration
done sorting
end inner loop
Iteration 7, inertia 8971586.72279
start iteration
done sorting
end inner loop
Iteration 8, inertia 8971527.64063
center shift 8.482500e-03 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9388865.05987
start iteration
done sorting
end inner loop
Iteration 1, inertia 9309922.58873
start iteration
done sorting
end inner loop
Iteration 2, inertia 9309384.69137
start iteration
done sorting
```

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end inner loop
Iteration 3, inertia 9309384.69137
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9344640.64218
start iteration
done sorting
end inner loop
Iteration 1, inertia 9251943.57122
start iteration
done sorting
end inner loop
Iteration 2, inertia 9218202.8968
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done sorting
end inner loop
Iteration 3, inertia 9200112.58304
start iteration
done sorting
end inner loop
Iteration 4, inertia 9189929.99878
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done sorting
end inner loop
Iteration 5, inertia 9183766.54604
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done sorting
end inner loop
Iteration 6, inertia 9178929.65193
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done sorting
end inner loop
Iteration 7, inertia 9174203.77174
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done sorting
end inner loop
Iteration 8, inertia 9168258.9834
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end inner loop
Iteration 9, inertia 9159713.16934
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done sorting
end inner loop
Iteration 10, inertia 9146493.36652
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done sorting
end inner loop
Iteration 11, inertia 9125907.79309
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done sorting
end inner loop
Iteration 12, inertia 9101251.8457
start iteration
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done sorting
end inner loop
Iteration 14, inertia 9069580.56676
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end inner loop
Iteration 15, inertia 9056575.73491
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end inner loop
Iteration 16, inertia 9039344.83693
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end inner loop
Iteration 17, inertia 9016485.64778
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end inner loop
Iteration 18, inertia 8993261.70239
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end inner loop
Iteration 19, inertia 8976619.8794
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done sorting
end inner loop
Iteration 20, inertia 8971591.31299
start iteration
done sorting
end inner loop
Iteration 21, inertia 8971527.64063
center shift 8.384720e-03 within tolerance 8.965517e-05
Initialization complete
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end inner loop
Iteration 0, inertia 9475824.94269
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done sorting
end inner loop
Iteration 1, inertia 9352744.13908
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end inner loop
Iteration 2, inertia 9280925.42473
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done sorting
end inner loop
Iteration 3, inertia 9240174.94163
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done sorting
end inner loop
Iteration 4, inertia 9220235.62822
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start iteration
done sorting
end inner loop
Iteration 5, inertia 9211198.63151
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done sorting
end inner loop
Iteration 6, inertia 9206340.00127
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Iteration 7, inertia 9203153.16198
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end inner loop
Iteration 8, inertia 9200928.52804
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Iteration 9, inertia 9198940.74879
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Iteration 10, inertia 9196903.8132
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Iteration 11, inertia 9194761.47128
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Iteration 12, inertia 9192322.14464
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Iteration 13, inertia 9189339.11126
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Iteration 14, inertia 9185656.34994
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end inner loop
Iteration 15, inertia 9181177.40973
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Iteration 16, inertia 9175439.04547
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end inner loop
Iteration 17, inertia 9167844.07286
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end inner loop
Iteration 18, inertia 9156947.77621
start iteration
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end inner loop
Iteration 20, inertia 9115691.88511
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Iteration 21, inertia 9091412.5028
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Iteration 22, inertia 9075248.01643
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end inner loop
Iteration 23, inertia 9062409.27992
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Iteration 24, inertia 9046927.55705
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end inner loop
Iteration 25, inertia 9026497.56429
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end inner loop
Iteration 26, inertia 9002961.6998
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end inner loop
Iteration 27, inertia 8983670.14143
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Iteration 28, inertia 8972738.1873
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done sorting
end inner loop
Iteration 29, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 30, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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done sorting
end inner loop
Iteration 0, inertia 9453745.64115
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done sorting
end inner loop
Iteration 1, inertia 9314995.18938
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done sorting
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Iteration 2, inertia 9258745.47695
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Iteration 3, inertia 9230437.66224
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Iteration 4, inertia 9213746.02551
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end inner loop
Iteration 5, inertia 9203368.2441
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Iteration 6, inertia 9196951.54188
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end inner loop
Iteration 7, inertia 9193211.87048
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Iteration 8, inertia 9190875.76715
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Iteration 9, inertia 9189134.83264
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Iteration 10, inertia 9187775.48846
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Iteration 11, inertia 9186523.18572
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Iteration 12, inertia 9185300.4524
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end inner loop
Iteration 13, inertia 9183996.70363
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end inner loop
Iteration 14, inertia 9182459.87553
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done sorting
end inner loop
Iteration 15, inertia 9180680.98927
start iteration
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done sorting
end inner loop
Iteration 16, inertia 9178325.17996
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done sorting
end inner loop
Iteration 17, inertia 9174866.50485
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Iteration 18, inertia 9169976.19309
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Iteration 19, inertia 9162648.89134
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end inner loop
Iteration 20, inertia 9151277.58779
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Iteration 21, inertia 9132723.37169
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Iteration 22, inertia 9107219.82201
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Iteration 23, inertia 9085605.26244
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Iteration 24, inertia 9071077.14031
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Iteration 25, inertia 9057772.99098
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Iteration 26, inertia 9040806.78411
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Iteration 27, inertia 9018590.15376
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end inner loop
Iteration 28, inertia 8995355.00083
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end inner loop
Iteration 29, inertia 8978211.21669
start iteration
done sorting
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end inner loop
Iteration 30, inertia 8971644.34685
start iteration
done sorting
end inner loop
Iteration 31, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 32, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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end inner loop
Iteration 0, inertia 9551474.46058
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end inner loop
Iteration 1, inertia 9264080.17961
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Iteration 2, inertia 8980656.80419
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end inner loop
Iteration 3, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 4, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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done sorting
end inner loop
Iteration 0, inertia 9738799.96643
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end inner loop
Iteration 1, inertia 9481302.50953
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Iteration 2, inertia 9304655.90522
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Iteration 3, inertia 9246791.78825
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end inner loop
Iteration 4, inertia 9222531.49978
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end inner loop
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Iteration 5, inertia 9212428.18409
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Iteration 7, inertia 9205292.21749
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Iteration 8, inertia 9203644.44135
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Iteration 9, inertia 9202355.57345
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Iteration 10, inertia 9201332.12147
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end inner loop
Iteration 11, inertia 9200382.2174
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end inner loop
Iteration 12, inertia 9199347.40167
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Iteration 13, inertia 9198216.78727
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Iteration 14, inertia 9196958.80885
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end inner loop
Iteration 15, inertia 9195530.16718
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done sorting
end inner loop
Iteration 16, inertia 9193898.10115
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done sorting
end inner loop
Iteration 17, inertia 9192020.96183
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done sorting
end inner loop
Iteration 18, inertia 9189975.0614
start iteration
done sorting
end inner loop
Iteration 19, inertia 9187607.80242
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start iteration
done sorting
end inner loop
Iteration 20, inertia 9184825.65026
start iteration
done sorting
end inner loop
Iteration 21, inertia 9181650.59695
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end inner loop
Iteration 22, inertia 9177553.90292
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end inner loop
Iteration 23, inertia 9172054.61059
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end inner loop
Iteration 24, inertia 9164492.7049
start iteration
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Iteration 25, inertia 9153341.54206
start iteration
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end inner loop
Iteration 26, inertia 9135424.27806
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done sorting
end inner loop
Iteration 27, inertia 9109874.10772
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done sorting
end inner loop
Iteration 28, inertia 9087254.44146
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done sorting
end inner loop
Iteration 29, inertia 9072225.02569
start iteration
done sorting
end inner loop
Iteration 30, inertia 9059158.78574
start iteration
done sorting
end inner loop
Iteration 31, inertia 9042553.86912
start iteration
done sorting
end inner loop
Iteration 32, inertia 9020743.84431
start iteration
done sorting
end inner loop
Iteration 33, inertia 8997613.63296
start iteration
```

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done sorting
end inner loop
Iteration 34, inertia 8980128.82545
start iteration
done sorting
end inner loop
Iteration 35, inertia 8971924.34737
start iteration
done sorting
end inner loop
Iteration 36, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 37, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9267335.0772
start iteration
done sorting
end inner loop
Iteration 1, inertia 9095199.61656
start iteration
done sorting
end inner loop
Iteration 2, inertia 9077044.50249
start iteration
done sorting
end inner loop
Iteration 3, inertia 9073462.08896
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done sorting
end inner loop
Iteration 4, inertia 9072090.99772
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done sorting
end inner loop
Iteration 5, inertia 9071404.54789
start iteration
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end inner loop
Iteration 6, inertia 9070828.10655
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end inner loop
Iteration 7, inertia 9069424.32968
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done sorting
end inner loop
Iteration 8, inertia 9062774.74467
start iteration
done sorting
end inner loop
Iteration 9, inertia 9029928.63757
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start iteration
done sorting
end inner loop
Iteration 10, inertia 8970737.32425
start iteration
done sorting
end inner loop
Iteration 11, inertia 8963200.65684
start iteration
done sorting
end inner loop
Iteration 12, inertia 8963188.48259
center shift 4.800312e-03 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9350488.75287
start iteration
done sorting
end inner loop
Iteration 1, inertia 9095793.41487
start iteration
done sorting
end inner loop
Iteration 2, inertia 8970259.04474
start iteration
done sorting
end inner loop
Iteration 3, inertia 8963192.23603
start iteration
done sorting
end inner loop
Iteration 4, inertia 8963188.48259
center shift 3.094304e-03 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9321071.57614
start iteration
done sorting
end inner loop
Iteration 1, inertia 9133650.21027
start iteration
done sorting
end inner loop
Iteration 2, inertia 8986560.4124
start iteration
done sorting
end inner loop
Iteration 3, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 4, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
```



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Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9238529.88804
start iteration
done sorting
end inner loop
Iteration 1, inertia 8971539.98638
start iteration
done sorting
end inner loop
Iteration 2, inertia 8963216.5294
start iteration
done sorting
end inner loop
Iteration 3, inertia 8963188.48259
center shift 5.759913e-03 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9452883.47685
start iteration
done sorting
end inner loop
Iteration 1, inertia 9336500.65527
start iteration
done sorting
end inner loop
Iteration 2, inertia 9270675.58345
start iteration
done sorting
end inner loop
Iteration 3, inertia 9222282.42328
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done sorting
end inner loop
Iteration 4, inertia 9185477.00415
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done sorting
end inner loop
Iteration 5, inertia 9152212.5217
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done sorting
end inner loop
Iteration 6, inertia 9120239.92866
start iteration
done sorting
end inner loop
Iteration 7, inertia 9097343.45395
start iteration
done sorting
end inner loop
Iteration 8, inertia 9084250.20404
start iteration
done sorting
```

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end inner loop
Iteration 9, inertia 9077393.0118
start iteration
done sorting
end inner loop
Iteration 10, inertia 9073788.07277
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end inner loop
Iteration 11, inertia 9071296.0142
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end inner loop
Iteration 12, inertia 9067525.59848
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end inner loop
Iteration 13, inertia 9058499.41601
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end inner loop
Iteration 14, inertia 9039264.45901
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end inner loop
Iteration 15, inertia 9009883.94421
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end inner loop
Iteration 16, inertia 8980762.06424
start iteration
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end inner loop
Iteration 17, inertia 8971626.6607
start iteration
done sorting
end inner loop
Iteration 18, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 19, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9377159.98263
start iteration
done sorting
end inner loop
Iteration 1, inertia 9266672.42174
start iteration
done sorting
end inner loop
Iteration 2, inertia 9225543.92
start iteration
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done sorting
end inner loop
Iteration 3, inertia 9212370.13218
start iteration
done sorting
end inner loop
Iteration 4, inertia 9207610.41341
start iteration
done sorting
end inner loop
Iteration 5, inertia 9205655.69275
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Iteration 6, inertia 9204372.11802
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Iteration 7, inertia 9203272.40585
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Iteration 8, inertia 9202228.80044
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Iteration 9, inertia 9201302.32828
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Iteration 10, inertia 9200327.30572
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Iteration 11, inertia 9199266.74249
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Iteration 12, inertia 9198077.96187
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Iteration 13, inertia 9196716.25686
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Iteration 14, inertia 9195217.84232
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end inner loop
Iteration 15, inertia 9193494.00866
start iteration
done sorting
end inner loop
Iteration 16, inertia 9191448.13375
start iteration
done sorting
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end inner loop
Iteration 17, inertia 9189085.11338
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done sorting
end inner loop
Iteration 18, inertia 9186394.87313
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Iteration 19, inertia 9183219.90532
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end inner loop
Iteration 20, inertia 9179242.4582
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end inner loop
Iteration 21, inertia 9174187.46448
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Iteration 22, inertia 9167245.49386
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Iteration 23, inertia 9157208.74274
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Iteration 24, inertia 9141546.39061
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Iteration 25, inertia 9117880.95503
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Iteration 26, inertia 9092961.38669
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Iteration 27, inertia 9076177.73781
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Iteration 28, inertia 9063214.64029
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Iteration 29, inertia 9048053.41995
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end inner loop
Iteration 30, inertia 9027863.70476
start iteration
done sorting
end inner loop
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Iteration 31, inertia 9004280.7594
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end inner loop
Iteration 32, inertia 8984721.90034
start iteration
done sorting
end inner loop
Iteration 33, inertia 8973112.78849
start iteration
done sorting
end inner loop
Iteration 34, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 35, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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end inner loop
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done sorting
end inner loop
Iteration 1, inertia 9345436.01786
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end inner loop
Iteration 2, inertia 9314798.03519
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done sorting
end inner loop
Iteration 3, inertia 9286638.0763
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end inner loop
Iteration 4, inertia 9259062.45524
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end inner loop
Iteration 5, inertia 9235286.22914
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end inner loop
Iteration 6, inertia 9216921.90675
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end inner loop
Iteration 7, inertia 9203826.26517
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end inner loop
Iteration 8, inertia 9195190.10279
start iteration
done sorting
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end inner loop
Iteration 10, inertia 9184778.00868
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end inner loop
Iteration 11, inertia 9180981.24015
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end inner loop
Iteration 13, inertia 9172151.27743
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Iteration 14, inertia 9165397.00801
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end inner loop
Iteration 15, inertia 9155442.87468
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Iteration 16, inertia 9139631.87867
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Iteration 17, inertia 9115927.09926
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Iteration 18, inertia 9092268.87379
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end inner loop
Iteration 19, inertia 9076345.06907
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done sorting
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Iteration 20, inertia 9063797.44226
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end inner loop
Iteration 21, inertia 9049075.26
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done sorting
end inner loop
Iteration 22, inertia 9029030.74589
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done sorting
end inner loop
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end inner loop
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done sorting
end inner loop
Iteration 26, inertia 8971527.64063
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done sorting
end inner loop
Iteration 27, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
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end inner loop
Iteration 7, inertia 9150647.04979
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end inner loop
Iteration 8, inertia 9130914.9429
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done sorting
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Iteration 12, inertia 9068581.2678
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Iteration 13, inertia 9057099.86133
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done sorting
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Iteration 14, inertia 9039896.47053
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done sorting
end inner loop
Iteration 15, inertia 9016466.07359
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Iteration 16, inertia 8992006.78817
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end inner loop
Iteration 17, inertia 8975177.37646
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done sorting
end inner loop
Iteration 18, inertia 8971573.67526
start iteration
done sorting
end inner loop
Iteration 19, inertia 8971527.64063
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Initialization complete
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end inner loop
Iteration 1, inertia 9331533.7035
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done sorting
end inner loop
Iteration 2, inertia 9252379.78981
start iteration
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end inner loop
Iteration 3, inertia 9218992.75217
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done sorting
end inner loop
Iteration 4, inertia 9208128.55609
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done sorting
end inner loop
Iteration 5, inertia 9203722.07331
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done sorting
end inner loop
Iteration 6, inertia 9200962.23471
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done sorting
end inner loop
Iteration 7, inertia 9198767.46492
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end inner loop
Iteration 8, inertia 9196720.28281
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end inner loop
Iteration 9, inertia 9194821.46364
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end inner loop
Iteration 10, inertia 9193004.47533
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end inner loop
Iteration 11, inertia 9191244.2078
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end inner loop
Iteration 12, inertia 9189427.53893
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end inner loop
Iteration 13, inertia 9187452.39515
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end inner loop
Iteration 14, inertia 9185226.01748
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done sorting
end inner loop
Iteration 15, inertia 9182790.39161
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done sorting
end inner loop
Iteration 16, inertia 9179936.95916
start iteration
done sorting
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end inner loop
Iteration 18, inertia 9170920.38045
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done sorting
end inner loop
Iteration 19, inertia 9163487.43123
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done sorting
end inner loop
Iteration 20, inertia 9152231.97412
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done sorting
end inner loop
Iteration 21, inertia 9133929.31457
start iteration
done sorting
end inner loop
Iteration 22, inertia 9108201.91069
start iteration
done sorting
end inner loop
Iteration 23, inertia 9086049.44176
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done sorting
end inner loop
Iteration 24, inertia 9071363.83933
start iteration
done sorting
end inner loop
Iteration 25, inertia 9058082.68428
start iteration
done sorting
end inner loop
Iteration 26, inertia 9041239.73906
start iteration
done sorting
end inner loop
Iteration 27, inertia 9019185.82568
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end inner loop
Iteration 28, inertia 8996048.0151
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done sorting
end inner loop
Iteration 29, inertia 8978785.63106
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done sorting
end inner loop
Iteration 30, inertia 8971797.16485
start iteration
done sorting
end inner loop
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Iteration 31, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 32, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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end inner loop
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end inner loop
Iteration 1, inertia 9059991.55498
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end inner loop
Iteration 2, inertia 9059932.9307
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end inner loop
Iteration 3, inertia 9059930.51657
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Initialization complete
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Iteration 2, inertia 9153502.38007
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Iteration 3, inertia 9116418.61715
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Iteration 4, inertia 9082646.42023
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Iteration 5, inertia 9063102.7346
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end inner loop
Iteration 6, inertia 9046069.09498
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end inner loop
Iteration 7, inertia 9025132.81359
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start iteration
done sorting
end inner loop
Iteration 8, inertia 9000803.74245
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done sorting
end inner loop
Iteration 9, inertia 8980759.26298
start iteration
done sorting
end inner loop
Iteration 10, inertia 8971924.34737
start iteration
done sorting
end inner loop
Iteration 11, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 12, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9668256.04074
start iteration
done sorting
end inner loop
Iteration 1, inertia 9668256.04074
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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end inner loop
Iteration 0, inertia 9390164.87284
start iteration
done sorting
end inner loop
Iteration 1, inertia 9254372.70162
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end inner loop
Iteration 2, inertia 9218296.4583
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done sorting
end inner loop
Iteration 3, inertia 9201743.02166
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end inner loop
Iteration 4, inertia 9191843.88363
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end inner loop
Iteration 5, inertia 9185342.87115
start iteration
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end inner loop
Iteration 7, inertia 9174350.34894
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Iteration 8, inertia 9167467.38557
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Iteration 9, inertia 9157729.36992
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Iteration 10, inertia 9142505.81466
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Iteration 11, inertia 9119994.35632
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end inner loop
Iteration 12, inertia 9095827.21791
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end inner loop
Iteration 13, inertia 9078985.17331
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Iteration 14, inertia 9066503.86306
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Iteration 15, inertia 9052671.58391
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Iteration 16, inertia 9034045.77834
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Iteration 17, inertia 9010278.19699
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end inner loop
Iteration 18, inertia 8987689.01132
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end inner loop
Iteration 19, inertia 8973929.02444
start iteration
done sorting
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end inner loop
Iteration 20, inertia 8971545.71577
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done sorting
end inner loop
Iteration 21, inertia 8971527.64063
center shift 3.172246e-03 within tolerance 8.965517e-05
Initialization complete
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done sorting
end inner loop
Iteration 0, inertia 9106515.64728
start iteration
done sorting
end inner loop
Iteration 1, inertia 8971770.90327
start iteration
done sorting
end inner loop
Iteration 2, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 3, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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done sorting
end inner loop
Iteration 0, inertia 9576003.21881
start iteration
done sorting
end inner loop
Iteration 1, inertia 9435380.09748
start iteration
done sorting
end inner loop
Iteration 2, inertia 9360032.39842
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done sorting
end inner loop
Iteration 3, inertia 9325446.8403
start iteration
done sorting
end inner loop
Iteration 4, inertia 9308892.30365
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done sorting
end inner loop
Iteration 5, inertia 9299249.83847
start iteration
done sorting
end inner loop
Iteration 6, inertia 9292379.16758
start iteration
done sorting
end inner loop
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Iteration 7, inertia 9286552.76893
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end inner loop
Iteration 8, inertia 9279029.06667
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end inner loop
Iteration 9, inertia 9262948.69314
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end inner loop
Iteration 10, inertia 9210428.85051
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done sorting
end inner loop
Iteration 11, inertia 9054705.16937
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end inner loop
Iteration 12, inertia 8966265.48743
start iteration
done sorting
end inner loop
Iteration 13, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 14, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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done sorting
end inner loop
Iteration 0, inertia 9010256.99402
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done sorting
end inner loop
Iteration 1, inertia 8964626.06515
start iteration
done sorting
end inner loop
Iteration 2, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 3, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9313275.90825
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done sorting
end inner loop
Iteration 1, inertia 9157135.72673
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done sorting
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Iteration 2, inertia 9068983.40147
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done sorting
end inner loop
Iteration 3, inertia 9035696.76847
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end inner loop
Iteration 4, inertia 9004097.90578
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done sorting
end inner loop
Iteration 5, inertia 8976328.27448
start iteration
done sorting
end inner loop
Iteration 6, inertia 8971540.86655
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done sorting
end inner loop
Iteration 7, inertia 8971527.64063
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Initialization complete
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Iteration 0, inertia 9297768.40396
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end inner loop
Iteration 2, inertia 8971772.48706
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end inner loop
Iteration 3, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 4, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
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end inner loop
Iteration 0, inertia 9068260.95727
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done sorting
end inner loop
Iteration 1, inertia 9060126.63533
start iteration
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done sorting
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done sorting
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Iteration 3, inertia 9059930.33842
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end inner loop
Iteration 4, inertia 9059929.13934
start iteration
done sorting
end inner loop
Iteration 5, inertia 9059929.13934
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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Iteration 3, inertia 9196002.85983
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Iteration 4, inertia 9182090.71455
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Iteration 7, inertia 9139397.27497
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end inner loop
Iteration 8, inertia 9115768.80836
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end inner loop
Iteration 9, inertia 9094176.40297
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Iteration 10, inertia 9079790.8856
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end inner loop
Iteration 11, inertia 9069003.79659
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end inner loop
Iteration 12, inertia 9056912.74127
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Iteration 13, inertia 9039730.30015
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end inner loop
Iteration 14, inertia 9016248.99337
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Iteration 15, inertia 8991601.86775
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end inner loop
Iteration 16, inertia 8974911.94244
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done sorting
end inner loop
Iteration 17, inertia 8971573.67526
start iteration
done sorting
end inner loop
Iteration 18, inertia 8971527.64063
center shift 7.020093e-03 within tolerance 8.965517e-05
Initialization complete
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done sorting
end inner loop
Iteration 0, inertia 9186454.4402
start iteration
done sorting
end inner loop
Iteration 1, inertia 9072339.19848
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done sorting
end inner loop
Iteration 2, inertia 9048466.86491
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done sorting
end inner loop
Iteration 3, inertia 9023483.05692
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done sorting
end inner loop
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Iteration 4, inertia 8992153.27788
start iteration
done sorting
end inner loop
Iteration 5, inertia 8972645.59937
start iteration
done sorting
end inner loop
Iteration 6, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 7, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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end inner loop
Iteration 0, inertia 9389078.05763
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end inner loop
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end inner loop
Iteration 2, inertia 9053221.952
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end inner loop
Iteration 3, inertia 8963345.95289
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done sorting
end inner loop
Iteration 4, inertia 8963188.48259
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done sorting
end inner loop
Iteration 5, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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end inner loop
Iteration 1, inertia 9477166.12919
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
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Iteration 0, inertia 9369243.55702
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done sorting
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end inner loop
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Iteration 3, inertia 9309384.69137
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done sorting
end inner loop
Iteration 4, inertia 9309384.69137
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Initialization complete
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Iteration 4, inertia 9019831.91598
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Iteration 5, inertia 8978499.06652
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end inner loop
Iteration 6, inertia 8963732.66562
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done sorting
end inner loop
Iteration 7, inertia 8963188.48259
start iteration
done sorting
end inner loop
Iteration 8, inertia 8963188.48259
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
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Iteration 2, inertia 9355684.57323
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Iteration 4, inertia 9182110.80156
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Iteration 7, inertia 9049629.81274
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Iteration 8, inertia 9000161.53017
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Iteration 9, inertia 8969032.98503
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end inner loop
Iteration 10, inertia 8963241.98711
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done sorting
end inner loop
Iteration 11, inertia 8963188.48259
center shift 6.478059e-03 within tolerance 8.965517e-05
Initialization complete
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end inner loop
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end inner loop
Iteration 1, inertia 9226639.71141
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done sorting
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end inner loop
Iteration 3, inertia 9202916.147
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Iteration 4, inertia 9200503.49099
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Iteration 6, inertia 9197850.86781
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Iteration 7, inertia 9196487.86369
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Iteration 8, inertia 9194935.42466
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Iteration 9, inertia 9193204.72743
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Iteration 10, inertia 9191348.42844
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Iteration 11, inertia 9189440.29362
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Iteration 12, inertia 9187192.51633
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end inner loop
Iteration 13, inertia 9184623.41677
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Iteration 14, inertia 9181693.35039
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done sorting
end inner loop
Iteration 15, inertia 9178043.33547
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end inner loop
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Iteration 17, inertia 9166299.41477
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Iteration 18, inertia 9156308.78485
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Iteration 19, inertia 9140407.05523
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end inner loop
Iteration 20, inertia 9116408.67209
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Iteration 21, inertia 9091919.89363
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end inner loop
Iteration 22, inertia 9075470.7668
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end inner loop
Iteration 23, inertia 9062520.13073
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Iteration 24, inertia 9047096.67153
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Iteration 25, inertia 9026614.35785
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Iteration 26, inertia 9002924.83186
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end inner loop
Iteration 27, inertia 8983511.02097
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done sorting
end inner loop
Iteration 28, inertia 8972633.54527
start iteration
done sorting
end inner loop
Iteration 29, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 30, inertia 8971527.64063
```

```
center shift 0.000000e+00 within tolerance 8.965517e-05
Initialization complete
start iteration
done sorting
end inner loop
Iteration 0, inertia 9336476.10026
start iteration
done sorting
end inner loop
Iteration 1, inertia 9255443.45748
start iteration
done sorting
end inner loop
Iteration 2, inertia 9230265.25966
start iteration
done sorting
end inner loop
Iteration 3, inertia 9215044.42281
start iteration
done sorting
end inner loop
Iteration 4, inertia 9204725.45625
start iteration
done sorting
end inner loop
Iteration 5, inertia 9197729.10359
start iteration
done sorting
end inner loop
Iteration 6, inertia 9193250.64072
start iteration
done sorting
end inner loop
Iteration 7, inertia 9190375.99265
start iteration
done sorting
end inner loop
Iteration 8, inertia 9188310.89982
start iteration
done sorting
end inner loop
Iteration 9, inertia 9186557.28205
start iteration
done sorting
end inner loop
Iteration 10, inertia 9184860.41786
start iteration
done sorting
end inner loop
Iteration 11, inertia 9183119.027
start iteration
done sorting
end inner loop
Iteration 12, inertia 9181207.58301
start iteration
done sorting
end inner loop
```



```
Iteration 13, inertia 9178848.41022
start iteration
done sorting
end inner loop
Iteration 14, inertia 9175594.28271
start iteration
done sorting
end inner loop
Iteration 15, inertia 9170997.7154
start iteration
done sorting
end inner loop
Iteration 16, inertia 9164083.6449
start iteration
done sorting
end inner loop
Iteration 17, inertia 9153480.39172
start iteration
done sorting
end inner loop
Iteration 18, inertia 9136338.48724
start iteration
done sorting
end inner loop
Iteration 19, inertia 9111391.02433
start iteration
done sorting
end inner loop
Iteration 20, inertia 9088522.10748
start iteration
done sorting
end inner loop
Iteration 21, inertia 9073249.6465
start iteration
done sorting
end inner loop
Iteration 22, inertia 9060241.08279
start iteration
done sorting
end inner loop
Iteration 23, inertia 9044040.61392
start iteration
done sorting
end inner loop
Iteration 24, inertia 9022561.99728
start iteration
done sorting
end inner loop
Iteration 25, inertia 8998924.0123
start iteration
done sorting
end inner loop
Iteration 26, inertia 8980524.31728
start iteration
done sorting
end inner loop
Iteration 27, inertia 8971924.34737
```

```

start iteration
done sorting
end inner loop
Iteration 28, inertia 8971527.64063
start iteration
done sorting
end inner loop
Iteration 29, inertia 8971527.64063
center shift 0.000000e+00 within tolerance 8.965517e-05

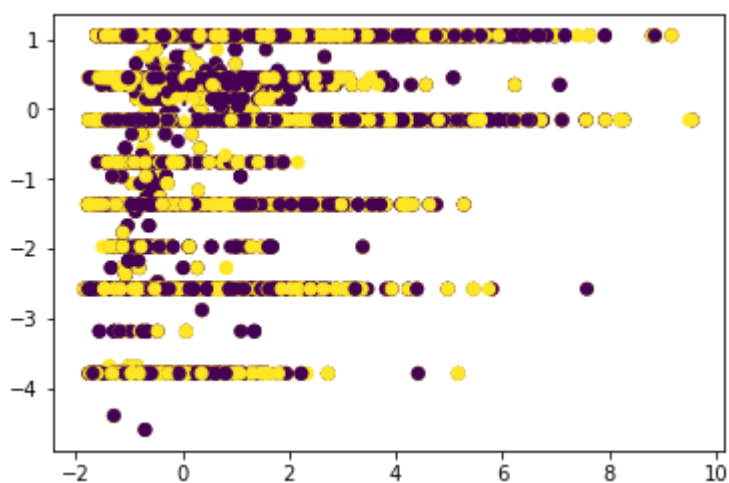
```

```

In [15]: # Plot the predictions.
plt.scatter(x_train[:,0], x_train[:,1], c=kmeans_plus_plus.labels_)
plt.scatter(kmeans_plus_plus.cluster_centers_[0,0],
            kmeans_plus_plus.cluster_centers_[0,1],
            c='w', marker='x', linewidths=2)

```

Out[15]: <matplotlib.collections.PathCollection at 0x27507e84320>



```

In [16]: x_pred = x_test

```

```

In [17]: prediction_kmeans = kmeans_plus_plus.predict(x_pred)

```

```

In [18]: # We can get distances from data point to every centroid

        """ The below code is equivalent to:
        from sklearn.metrics.pairwise import euclidean_distances
        euclidean_distances(X_new, kmeans.cluster_centers_)
        """

        kmeans_plus_plus.transform(x_pred)

```

```

Out[18]: array([[ 6.90332456,  4.88619027],
                [ 5.22709478,  6.84721214],
                [ 5.96850221,  4.70894271],
                ...,
                [ 7.39753009,  6.22157909],
                [ 9.98620461, 10.66605437],
                [ 3.86455657,  5.44512669]])

```

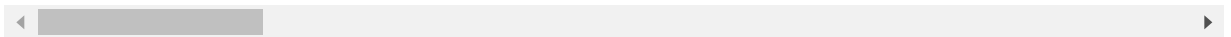
```
In [19]: export_x_test['Predicted Label']=prediction_kmeans
```

```
In [20]: export_x_test.head()
```

```
Out[20]:
```

	originalloanamount	originalloanterm	originalinterestratepercentage	graceperiodnuml
0	36863.24	72.0	1.00	1.0
1	23811.32	60.0	1.90	0.0
2	30669.00	48.0	1.00	1.0
3	54083.21	72.0	1.00	0.0
4	31557.75	72.0	3.89	1.0

5 rows × 59 columns



```
In [21]: export_x_test.shape
```

```
Out[21]: (47405, 59)
```

```
In [22]: export_x_test.to_csv(path+"prediction/kmeans/predicated_kmeans_plus_unsupervis  
ed_abs_loans_"+str(nrows)+".csv", chunksize=10000)
```

```
In [23]: def plot_confusion_matrix(cm, title, classes=['Non-Current', 'Current'],
                                     cmap=plt.cm.Blues, save=False, saveas="MyFigure.png"):

    # print Confusion matrix with blue gradient colours

    cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]

    plt.imshow(cm, interpolation='nearest', cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=90)
    plt.yticks(tick_marks, classes)

    fmt = '.1%'
    thresh = cm.max() / 2.
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
        plt.text(j, i, format(cm[i, j], fmt),
                 horizontalalignment="center",
                 color="white" if cm[i, j] > thresh else "black")

    plt.tight_layout()
    plt.ylabel('True label')
    plt.xlabel('Predicted label')

    if save:
        plt.savefig(saveas, dpi=100)
```

```

In [24]: def plot_gridsearch_cv(results, estimator, x_min, x_max, y_min, y_max, save=False,
saveas="MyFigure.png"):

    # print GridSearch cross-validation for parameters

    plt.figure(figsize=(10,8))
    plt.title("GridSearchCV for "+estimator, fontsize=24)

    plt.xlabel(estimator)
    plt.ylabel("Score")
    plt.grid()

    ax = plt.axes()
    ax.set_xlim(x_min, x_max)
    ax.set_ylim(y_min, y_max)

    pad = 0.005
    X_axis = np.array(results["param_"+estimator].data, dtype=float)

    for scorer, color in zip(sorted(scoring), ['b', 'k']):
        for sample, style in (('train', '--'), ('test', '-')):
            sample_score_mean = results['mean_%s_%s' % (sample, scorer)]
            sample_score_std = results['std_%s_%s' % (sample, scorer)]
            ax.fill_between(X_axis, sample_score_mean - sample_score_std,
                            sample_score_mean + sample_score_std,
                            alpha=0.1 if sample == 'test' else 0, color=color)
            ax.plot(X_axis, sample_score_mean, style, color=color,
                    alpha=1 if sample == 'test' else 0.7,
                    label="%s (%s)" % (scorer, sample))

            best_index = np.nonzero(results['rank_test_%s' % scorer] == 1)[0][0]
            best_score = results['mean_test_%s' % scorer][best_index]

            # Plot a dotted vertical line at the best score for that scorer marked
by x
            ax.plot([X_axis[best_index], ] * 2, [0, best_score],
                    linestyle='-.', color=color, marker='x', markeredgewidth=3, ms=8)

            # Annotate the best score for that scorer
            ax.annotate("%0.2f" % best_score,
                        (X_axis[best_index], best_score+pad))

    plt.legend(loc="best")
    plt.grid('off')
    plt.tight_layout()
    if save:
        plt.savefig(saveas, dpi=100)

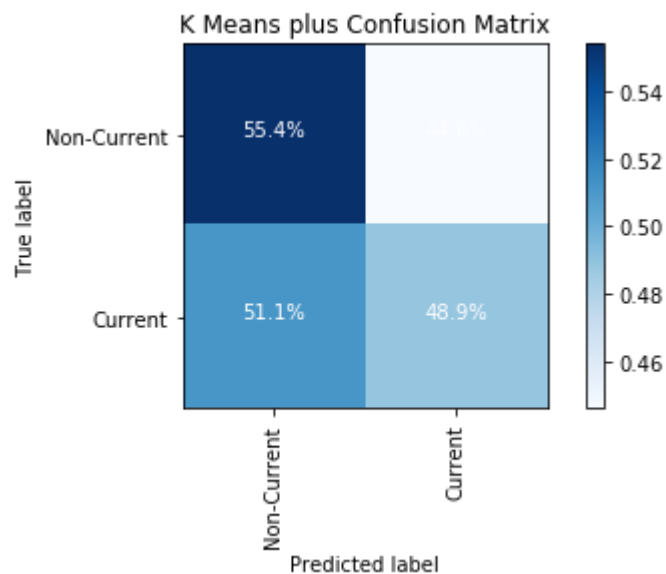
    plt.show()

```

```
In [25]: print(classification_report(y_test, prediction_kmeans, target_names=['Non-Cu
rrent', 'Current']))
print ("AUC: ", "{:.1%}".format(roc_auc_score(y_test, prediction_kmeans)))
cm = confusion_matrix(y_test, prediction_kmeans)
plot_confusion_matrix(cm, title="K Means plus Confusion Matrix",save=True,
                      saveas='prediction/kmeans/cm'+str(' K_Means plus Unsup
ervised Accuracy-')+str(nrows)+' .jpg')
```

	precision	recall	f1-score	support
Non-Current	0.97	0.55	0.71	45938
Current	0.03	0.49	0.06	1467
avg / total	0.94	0.55	0.69	47405

AUC: 52.1%



```

In [26]: class_names = ['Current', 'Non-Current']

def plot_confusion_matrix(cm, classes,
                          normalize=False,
                          title='Confusion matrix',
                          cmap=plt.cm.Blues):
    """
    This function prints and plots the confusion matrix.
    Normalization can be applied by setting `normalize=True`.
    """
    if normalize:
        cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
        print("Normalized confusion matrix")
    else:
        print('Confusion matrix, without normalization')

    print(cm)

    plt.imshow(cm, interpolation='nearest', cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=45)
    plt.yticks(tick_marks, classes)

    fmt = '.2f' if normalize else 'd'
    thresh = cm.max() / 2.
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
        plt.text(j, i, format(cm[i, j], fmt),
                 horizontalalignment="center",
                 color="white" if cm[i, j] > thresh else "black")

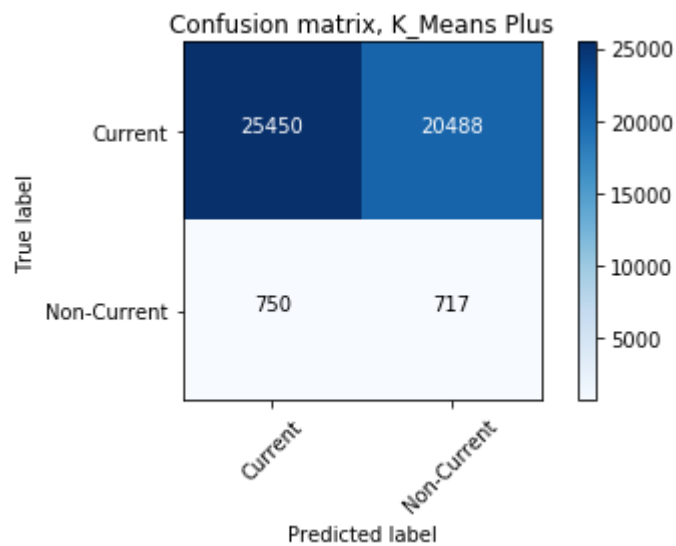
    plt.ylabel('True label')
    plt.xlabel('Predicted label')
    plt.tight_layout()

print('ROC_AUC_SCORE ; ', roc_auc_score(y_test, prediction_kmeans))
# Compute confusion matrix
cnf_matrix = confusion_matrix(y_test, prediction_kmeans)
np.set_printoptions(precision=2)

# Plot non-normalized confusion matrix
plt.figure()
plot_confusion_matrix(cnf_matrix, classes=class_names, title= 'Confusion matrix, K_Means Plus')
plt.savefig('prediction/kmeans/cm'+str(' K_Means plus Prediction-')+str(nrows)
+'.jpg')
plt.show()

```

```
ROC_AUC_SCORE ; 0.521380065832  
Confusion matrix, without normalization  
[[25450 20488]  
 [ 750 717]]
```



Silhoutte Analysis Various cluster Sizes


```

In [30]: from sklearn import metrics
import matplotlib.cm as cm

# List of number of clusters
range_n_clusters = [2, 3, 4, 5, 6]

# For each number of clusters, perform Silhouette analysis and visualize the
results.
for n_clusters in range_n_clusters:

    # Perform k-means.
    kmeans = KMeans(n_clusters=n_clusters, random_state=10)
    y_pred = kmeans.fit_predict(x_test)

    # Compute the cluster homogeneity and completeness.
    homogeneity = metrics.homogeneity_score(y_test, y_pred)
    completeness = metrics.completeness_score(y_test, y_pred)

    # Compute the Silhouette Coefficient for each sample.
    s = metrics.silhouette_samples(x_test, y_pred)

    # Compute the mean Silhouette Coefficient of all data points.
    s_mean = metrics.silhouette_score(x_test, y_pred)

    # For plot configuration -----
    -----
    fig, (ax1, ax2) = plt.subplots(1, 2)
    fig.set_size_inches(18, 7)

    # Configure plot.
    plt.suptitle('Silhouette analysis for K-Means clustering with n_cluster
s: {}'.format(n_clusters),
                fontsize=14, fontweight='bold')

    # Configure 1st subplot.
    ax1.set_title('Silhouette Coefficient for each sample')
    ax1.set_xlabel("The silhouette coefficient values")
    ax1.set_ylabel("Cluster label")
    ax1.set_xlim([-1, 1])
    ax1.set_ylim([0, len(x_train) + (n_clusters + 1) * 10])

    # Configure 2nd subplot.
    ax2.set_title('Homogeneity: {}, Completeness: {}, Mean Silhouette score:
{}'.format(homogeneity,
            completeness,
            s_mean))
    ax2.set_xlabel("Feature space for the 1st feature")
    ax2.set_ylabel("Feature space for the 2nd feature")

    # For 1st subplot -----
    -----

    # Plot Silhouette Coefficient for each sample
    y_lower = 10

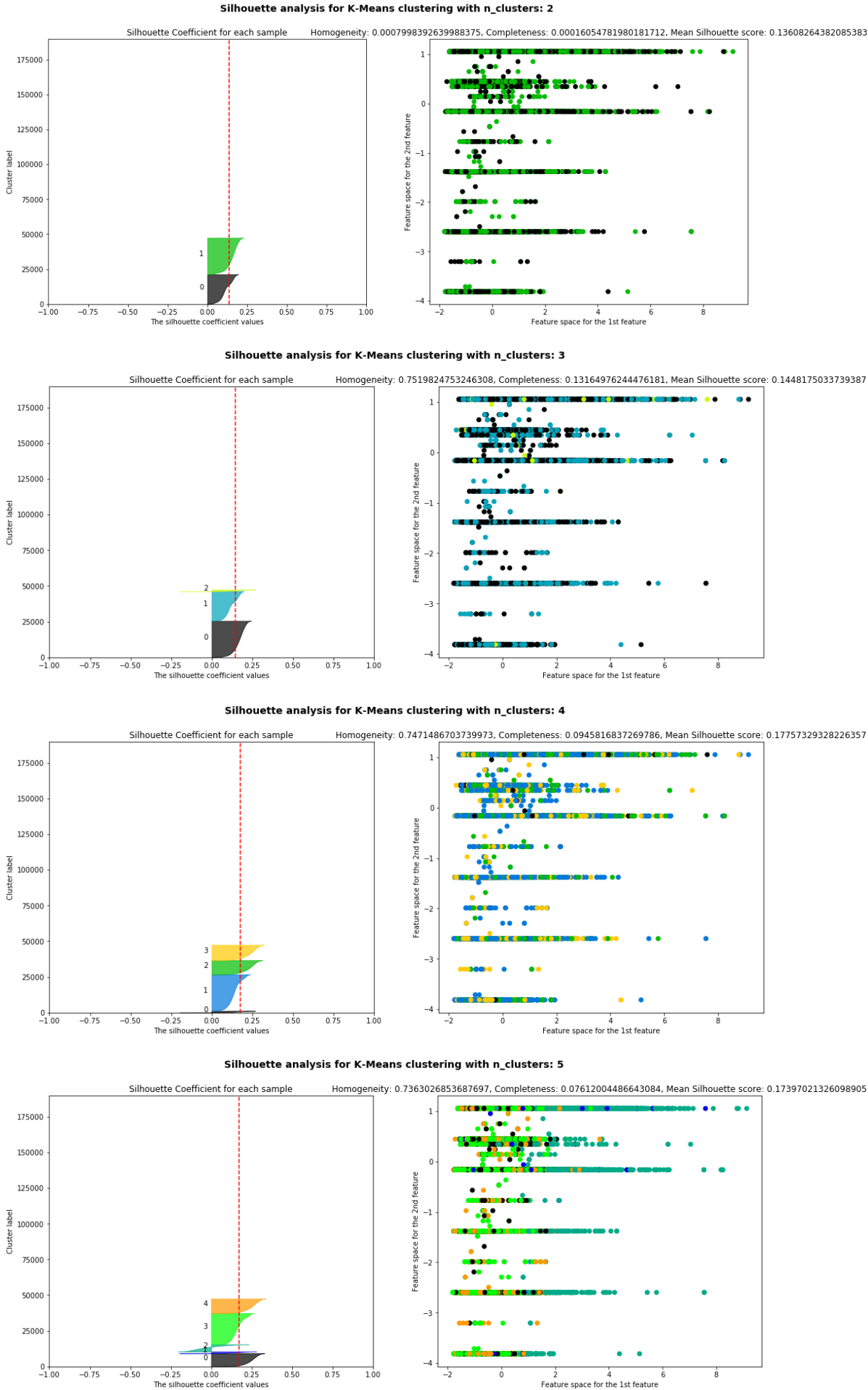
```

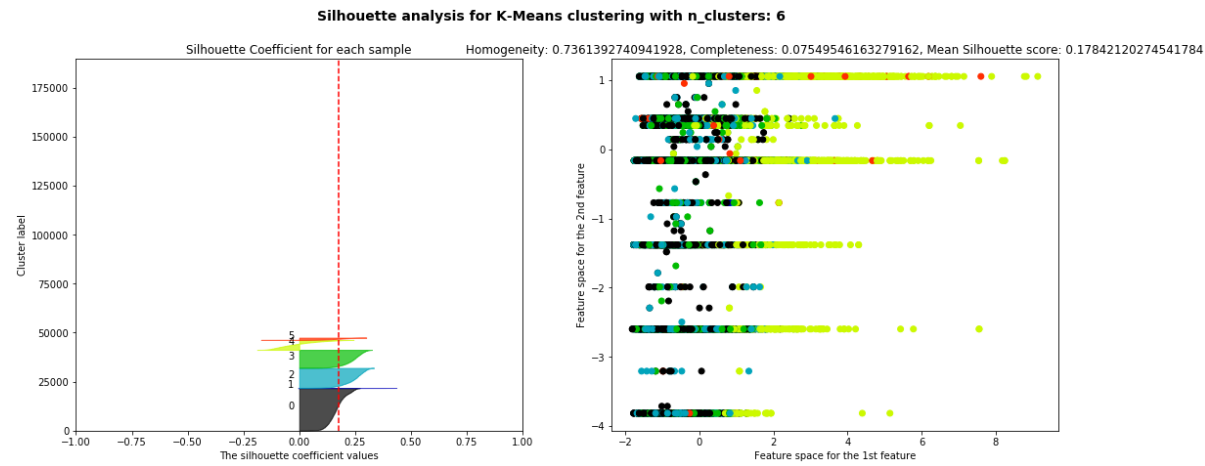
```
for i in range(n_clusters):
    ith_s = s[y_pred == i]
    ith_s.sort()
    size_cluster_i = ith_s.shape[0]
    y_upper = y_lower + size_cluster_i
    color = cm.nipy_spectral(float(i) / n_clusters)
    ax1.fill_betweenx(np.arange(y_lower, y_upper), 0, ith_s,
                      facecolor=color, edgecolor=color, alpha=0.7)
    ax1.text(-0.05, y_lower + 0.5 * size_cluster_i, str(i))
    y_lower = y_upper + 10

# Plot the mean Silhouette Coefficient using red vertical dash line.
ax1.axvline(x=s_mean, color="red", linestyle="--")

# For 2st subplot -----
-----

# Plot the predictions
colors = cm.nipy_spectral(y_pred.astype(float) / n_clusters)
ax2.scatter(x_test[:,0], x_test[:,1], c=colors)
```





In []: