IBM Developer
SKILLS NETWORK

Hierarchical Clustering

Estimated time needed: **25** minutes

Objectives

After completing this lab you will be able to:

- Use scikit-learn to do Hierarchical clustering
- Create dendograms to visualize the clustering

Table of contents

Hierarchical Clustering - Agglomerative

We will be looking at a clustering technique, which is **Agglomerative Hierarchical Clustering**. Remember that agglomerative is the bottom up approach.

In this lab, we will be looking at Agglomerative clustering, which is more popular than Divisive clustering.

We will also be using Complete Linkage as the Linkage Criteria.
NOTE: You can also try using Average Linkage wherever Complete Linkage would be used to see the difference!

In [1]:

```
import numpy as np
import pandas as pd
from scipy import ndimage
from scipy.cluster import hierarchy
from scipy.spatial import distance_matrix
from matplotlib import pyplot as plt
from sklearn import manifold, datasets
from sklearn.cluster import AgglomerativeClustering
from sklearn.datasets.samples_generator import make_blobs
%matplotlib inline
```

```
/opt/conda/envs/Python-3.8-main/lib/python3.8/site-packages/sklearn/utils/deprecatio
n.py:143: FutureWarning: The sklearn.datasets.samples_generator module is  deprecate
d in version 0.22 and will be removed in version 0.24. The corresponding classes / f
unctions should instead be imported from sklearn.datasets. Anything that cannot be i
mported from sklearn.datasets is now part of the private API.
  warnings.warn(message, FutureWarning)
```

Generating Random Data

We will be generating a set of data using the **make_blobs** class.

Input these parameters into make_blobs:

- **n_samples**: The total number of points equally divided among clusters.
  - Choose a number from 10-1500
- **centers**: The number of centers to generate, or the fixed center locations.
  - Choose arrays of x,y coordinates for generating the centers. Have 1-10 centers (ex. centers=[[1,1], [2,5]])
- **cluster_std**: The standard deviation of the clusters. The larger the number, the further apart the clusters
  - Choose a number between 0.5-1.5

  Save the result to **X1** and **y1**.

In [2]:

```
X1, y1 = make_blobs(n_samples=50, centers=[[4,4], [-2, -1], [1, 1], [10,4]], cluster
```

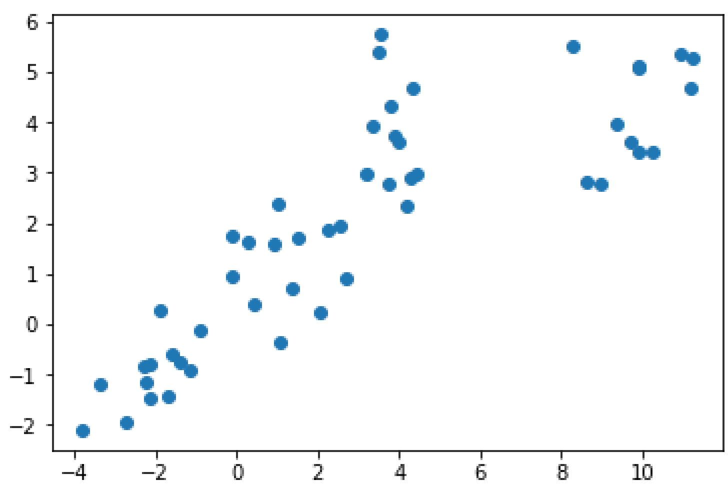
Plot the scatter plot of the randomly generated data.

In [3]:

```
plt.scatter(X1[:, 0], X1[:, 1], marker='o')
```

Out[3]:

```
<matplotlib.collections.PathCollection at 0x7f70cd3af3a0>
```



Agglomerative Clustering

We will start by clustering the random data points we just created.

The **Agglomerative Clustering** class will require two inputs:

- **n_clusters**: The number of clusters to form as well as the number of centroids to generate.
    - Value will be: 4
- **linkage**: Which linkage criterion to use. The linkage criterion determines which distance to use between sets of observation. The algorithm will merge the pairs of cluster that minimize this criterion.
    - Value will be: 'complete'
    - **Note**: It is recommended you try everything with 'average' as well

  Save the result to a variable called **agglom** .

In [4]:

```
agglom = AgglomerativeClustering(n_clusters = 4, linkage = 'average')
```

Fit the model with **X2** and **y2** from the generated data above.

In [5]:

```
agglom.fit(X1,y1)
```

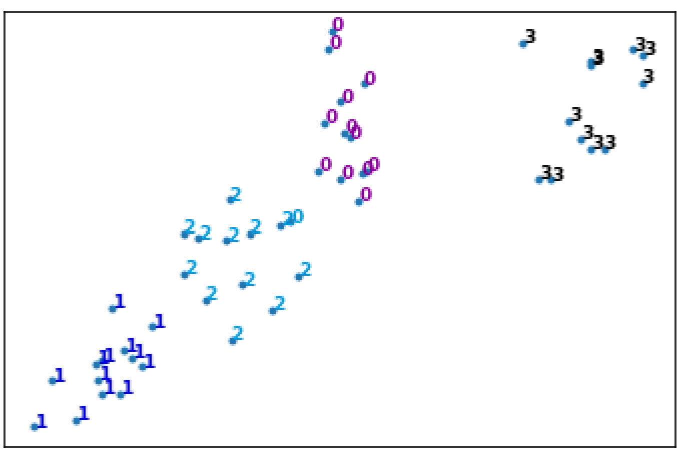
Out[5]:

```
AgglomerativeClustering(linkage='average', n_clusters=4)
```

Run the following code to show the clustering!
Remember to read the code and comments to gain more understanding on how the plotting works.

In [6]:

```
# Create a figure of size 6 inches by 4 inches.
plt.figure(figsize=(6,4))

# These two lines of code are used to scale the data points down,
# Or else the data points will be scattered very far apart.

# Create a minimum and maximum range of X1.
x_min, x_max = np.min(X1, axis=0), np.max(X1, axis=0)

# Get the average distance for X1.
X1 = (X1 - x_min) / (x_max - x_min)

# This loop displays all of the datapoints.
for i in range(X1.shape[0]):
    # Replace the data points with their respective cluster value
    # (ex. 0) and is color coded with a colormap (plt.cm.spectral)
    plt.text(X1[i, 0], X1[i, 1], str(y1[i]),
             color=plt.cm.nipy_spectral(agglom.labels_[i] / 10.),
             fontdict={'weight': 'bold', 'size': 9})

# Remove the x ticks, y ticks, x and y axis
plt.xticks([])
plt.yticks([])
#plt.axis('off')



# Display the plot of the original data before clustering
plt.scatter(X1[:, 0], X1[:, 1], marker='.')
# Display the plot
plt.show()
```



Dendrogram Associated for the Agglomerative Hierarchical Clustering

Remember that a **distance matrix** contains the **distance from each point to every other point of a dataset** .

Use the function **distance_matrix,** which requires **two inputs**. Use the Feature Matrix, **X1** as both inputs and save the distance matrix to a variable called **dist_matrix**

Remember that the distance values are symmetric, with a diagonal of 0's. This is one way of making sure your matrix is correct.
(print out dist_matrix to make sure it's correct)

In [7]:
```
dist_matrix = distance_matrix(X1,X1)
print(dist_matrix)
```

```
[[0.         0.13450397 0.52467482 ... 0.53342106 0.34858045 0.36802513]
 [0.13450397 0.         0.57492033 ... 0.44046402 0.27340766 0.49366278]
 [0.52467482 0.57492033 0.         ... 1.01204481 0.84751451 0.40533959]
 ...
 [0.53342106 0.44046402 1.01204481 ... 0.         0.18932398 0.89252419]
 [0.34858045 0.27340766 0.84751451 ... 0.18932398 0.         0.70361519]
 [0.36802513 0.49366278 0.40533959 ... 0.89252419 0.70361519 0.        ]]
```

Using the **linkage** class from hierarchy, pass in the parameters:

- The distance matrix
- 'complete' for complete linkage

Save the result to a variable called **Z** .

In [8]:
```
Z = hierarchy.linkage(dist_matrix, 'complete')
```

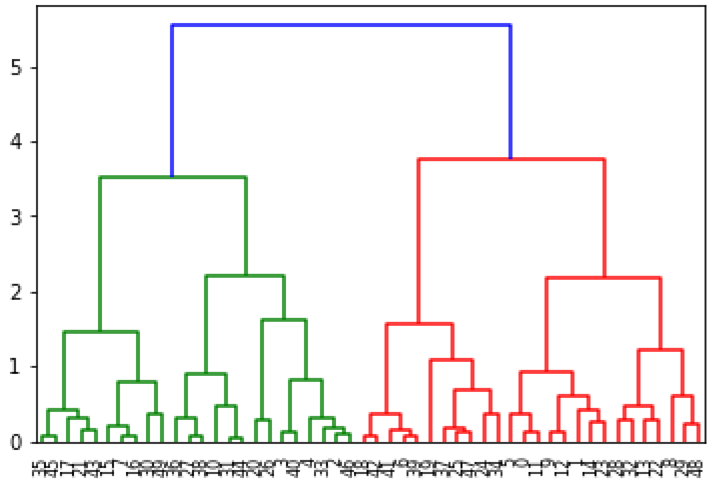
```
<ipython-input-8-3814b774a052>:1: ClusterWarning: scipy.cluster: The symmetric non-n
egative hollow observation matrix looks suspiciously like an uncondensed distance ma
trix
  Z = hierarchy.linkage(dist_matrix, 'complete')
```

A Hierarchical clustering is typically visualized as a dendrogram as shown in the following cell. Each merge is represented by a horizontal line. The y-coordinate of the horizontal line is the similarity of the two clusters that were merged, where cities are viewed as singleton clusters. By moving up from the bottom layer to the top node, a dendrogram allows us to reconstruct the history of merges that resulted in the depicted clustering.

Next, we will save the dendrogram to a variable called **dendro**. In doing this, the dendrogram will also be displayed. Using the **dendrogram** class from hierarchy, pass in the parameter:

- Z

In [9]:
```
dendro = hierarchy.dendrogram(Z)
```



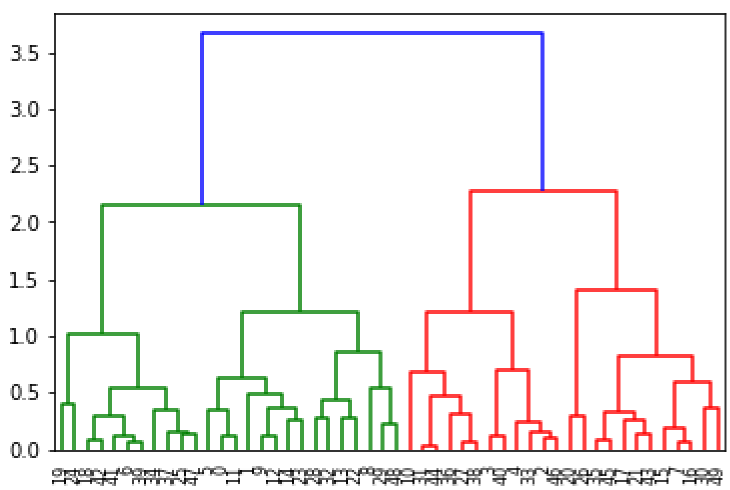
Practice

We used **complete** linkage for our case, change it to **average** linkage to see how the dendogram changes.

In [10]:

```
Z = hierarchy.linkage(dist_matrix, 'average')
dendro = hierarchy.dendrogram(Z)
```

```
<ipython-input-10-90bcb3750f27>:1: ClusterWarning: scipy.cluster: The symmetric non-
negative hollow observation matrix looks suspiciously like an uncondensed distance m
atrix
  Z = hierarchy.linkage(dist_matrix, 'average')
```



Clustering on Vehicle dataset

Imagine that an automobile manufacturer has developed prototypes for a new vehicle. Before introducing the new model into its range, the manufacturer wants to determine which existing vehicles on the market are most like the prototypes--that is, how vehicles can be grouped, which group is the most similar with the model, and therefore which models they will be competing against.

Our objective here, is to use clustering methods, to find the most distinctive clusters of vehicles. It will summarize the existing vehicles and help manufacturers to make decision about the supply of new models.

Download data

To download the data, we will use `!wget` to download it from IBM Object Storage.\ **Did you know?** When it comes to Machine Learning, you will likely be working with large datasets. As a business, where can you host your data? IBM is offering a unique opportunity for businesses, with 10 Tb of IBM Cloud Object Storage: Sign up now for free

In [11]:

```
!wget -O cars_clus.csv https://cf-courses-data.s3.us.cloud-object-storage.appdomain.
```

```
--2021-11-07 02:13:54--  https://cf-courses-data.s3.us.cloud-object-storage.appdomai
n.cloud/IBMDeveloperSkillsNetwork-ML0101EN-SkillsNetwork/labs/Module%204/data/cars_c
lus.csv
Resolving cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud (cf-courses-dat
a.s3.us.cloud-object-storage.appdomain.cloud)... 198.23.119.245
Connecting to cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud (cf-courses
-data.s3.us.cloud-object-storage.appdomain.cloud)|198.23.119.245|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 17774 (17K) [text/csv]
Saving to: 'cars_clus.csv'

cars_clus.csv       100%[===================>]  17.36K  --.-KB/s    in 0s

2021-11-07 02:13:54 (119 MB/s) - 'cars_clus.csv' saved [17774/17774]
```

Read data

Let's read dataset to see what features the manufacturer has collected about the existing models.

In [12]:

```
filename = 'cars_clus.csv'

#Read csv
pdf = pd.read_csv(filename)
print ("Shape of dataset: ", pdf.shape)

pdf.head(5)
```

```
Shape of dataset:  (159, 16)
```

Out[12]:

	manufact	model	sales	resale	type	price	engine_s	horsepow	wheelbas	width	length
0	Acura	Integra	16.919	16.360	0.000	21.500	1.800	140.000	101.200	67.300	172.400
1	Acura	TL	39.384	19.875	0.000	28.400	3.200	225.000	108.100	70.300	192.900

	manufact	model	sales	resale	type	price	engine_s	horsepow	wheelbas	width	length
2	Acura	CL	14.114	18.225	0.000	*null*	3.200	225.000	106.900	70.600	192.000
3	Acura	RL	8.588	29.725	0.000	42.000	3.500	210.000	114.600	71.400	196.600
4	Audi	A4	20.397	22.255	0.000	23.990	1.800	150.000	102.600	68.200	178.000

The feature sets include price in thousands (price), engine size (engine_s), horsepower (horsepow), wheelbase (wheelbas), width (width), length (length), curb weight (curb_wgt), fuel capacity (fuel_cap) and fuel efficiency (mpg).

Data Cleaning

Let's clean the dataset by dropping the rows that have null value:

In [13]:

```
print ("Shape of dataset before cleaning: ", pdf.size)
pdf[[ 'sales', 'resale', 'type', 'price', 'engine_s',
       'horsepow', 'wheelbas', 'width', 'length', 'curb_wgt', 'fuel_cap',
       'mpg', 'lnsales']] = pdf[['sales', 'resale', 'type', 'price', 'engine_s',
       'horsepow', 'wheelbas', 'width', 'length', 'curb_wgt', 'fuel_cap',
       'mpg', 'lnsales']].apply(pd.to_numeric, errors='coerce')
pdf = pdf.dropna()
pdf = pdf.reset_index(drop=True)
print ("Shape of dataset after cleaning: ", pdf.size)
pdf.head(5)
```

```
Shape of dataset before cleaning:  2544
Shape of dataset after cleaning:  1872
```

Out[13]:

	manufact	model	sales	resale	type	price	engine_s	horsepow	wheelbas	width	length	cu
0	Acura	Integra	16.919	16.360	0.0	21.50	1.8	140.0	101.2	67.3	172.4	
1	Acura	TL	39.384	19.875	0.0	28.40	3.2	225.0	108.1	70.3	192.9	
2	Acura	RL	8.588	29.725	0.0	42.00	3.5	210.0	114.6	71.4	196.6	
3	Audi	A4	20.397	22.255	0.0	23.99	1.8	150.0	102.6	68.2	178.0	
4	Audi	A6	18.780	23.555	0.0	33.95	2.8	200.0	108.7	76.1	192.0	

Feature selection

Let's select our feature set:

In [14]:

```
featureset = pdf[['engine_s',  'horsepow', 'wheelbas', 'width', 'length', 'curb_wgt'
```

Normalization

Now we can normalize the feature set. **MinMaxScaler** transforms features by scaling each feature to a given range. It is by default (0, 1). That is, this estimator scales and translates each feature individually such that it is between zero and one.

In [15]:

```
from sklearn.preprocessing import MinMaxScaler
x = featureset.values #returns a numpy array
min_max_scaler = MinMaxScaler()
feature_mtx = min_max_scaler.fit_transform(x)
feature_mtx [0:5]
```

Out[15]:

```
array([[0.11428571, 0.21518987, 0.18655098, 0.28143713, 0.30625832,
        0.2310559 , 0.13364055, 0.43333333],
       [0.31428571, 0.43037975, 0.3362256 , 0.46107784, 0.5792277 ,
        0.50372671, 0.31797235, 0.33333333],
       [0.35714286, 0.39240506, 0.47722343, 0.52694611, 0.62849534,
        0.60714286, 0.35483871, 0.23333333],
       [0.11428571, 0.24050633, 0.21691974, 0.33532934, 0.38082557,
        0.34254658, 0.28110599, 0.4       ],
       [0.25714286, 0.36708861, 0.34924078, 0.80838323, 0.56724368,
        0.5173913 , 0.37788018, 0.23333333]])
```

Clustering using Scipy

In this part we use Scipy package to cluster the dataset.

First, we calculate the distance matrix.

In [16]:

```
import scipy
leng = feature_mtx.shape[0]
D = scipy.zeros([leng,leng])
for i in range(leng):
    for j in range(leng):
        D[i,j] = scipy.spatial.distance.euclidean(feature_mtx[i], feature_mtx[j])
D
```

```
<ipython-input-16-2630f2af58dc>:3: DeprecationWarning: scipy.zeros is deprecated and
will be removed in SciPy 2.0.0, use numpy.zeros instead
  D = scipy.zeros([leng,leng])
```

Out[16]:

```
array([[0.        , 0.57777143, 0.75455727, ..., 0.28530295, 0.24917241,
        0.18879995],
       [0.57777143, 0.        , 0.22798938, ..., 0.36087756, 0.66346677,
        0.62201282],
       [0.75455727, 0.22798938, 0.        , ..., 0.51727787, 0.81786095,
        0.77930119],
       ...,
       [0.28530295, 0.36087756, 0.51727787, ..., 0.        , 0.41797928,
        0.35720492],
       [0.24917241, 0.66346677, 0.81786095, ..., 0.41797928, 0.        ,
        0.15212198],
       [0.18879995, 0.62201282, 0.77930119, ..., 0.35720492, 0.15212198,
        0.        ]])
```

In agglomerative clustering, at each iteration, the algorithm must update the distance matrix to reflect the distance of the newly formed cluster with the remaining clusters in the forest.

The following methods are supported in Scipy for calculating the distance between the newly formed cluster and each: - single - complete - average - weighted - centroid

We use **complete** for our case, but feel free to change it to see how the results change.

In [17]:

```
import pylab
import scipy.cluster.hierarchy
Z = hierarchy.linkage(D, 'complete')
```

```
<ipython-input-17-8655000d21de>:3: ClusterWarning: scipy.cluster: The symmetric non-negative hollow observation matrix looks suspiciously like an uncondensed distance m
atrix
  Z = hierarchy.linkage(D, 'complete')
```

Essentially, Hierarchical clustering does not require a pre-specified number of clusters. However, in some applications we want a partition of disjoint clusters just as in flat clustering. So you can use a cutting line:

In [18]:

```
from scipy.cluster.hierarchy import fcluster
max_d = 3
clusters = fcluster(Z, max_d, criterion='distance')
clusters
```

Out[18]:

```
array([ 1,  5,  5,  6,  5,  4,  6,  5,  5,  5,  5,  5,  4,  4,  5,  1,  6,
        5,  5,  5,  4,  2, 11,  6,  6,  5,  6,  5,  1,  6,  6, 10,  9,  8,
        9,  3,  5,  1,  7,  6,  5,  3,  5,  3,  8,  7,  9,  2,  6,  6,  5,
        4,  2,  1,  6,  5,  2,  7,  5,  5,  5,  4,  4,  3,  2,  6,  6,  5,
        7,  4,  7,  6,  6,  5,  3,  5,  5,  6,  5,  4,  4,  1,  6,  5,  5,
        5,  6,  4,  5,  4,  1,  6,  5,  6,  6,  5,  5,  5,  7,  7,  7,  2,
        2,  1,  2,  6,  5,  1,  1,  1,  7,  8,  1,  1,  6,  1,  1],
      dtype=int32)
```

Also, you can determine the number of clusters directly:

In [19]:

```
from scipy.cluster.hierarchy import fcluster
k = 5
clusters = fcluster(Z, k, criterion='maxclust')
clusters
```

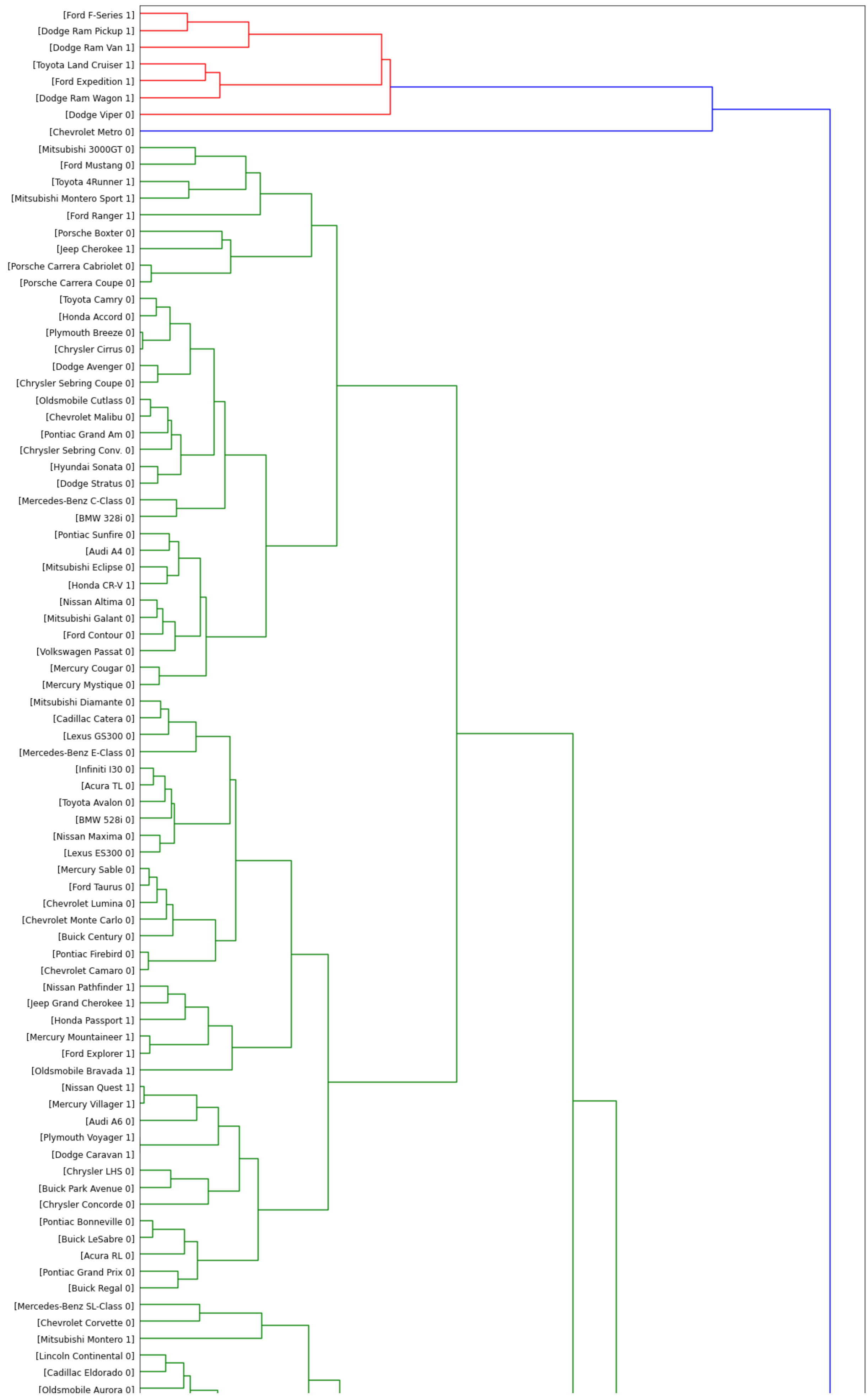
Out[19]:

```
array([1, 3, 3, 3, 3, 2, 3, 3, 3, 3, 3, 3, 2, 2, 3, 1, 3, 3, 3, 3, 2, 1,
       5, 3, 3, 3, 3, 3, 1, 3, 3, 4, 4, 4, 4, 2, 3, 1, 3, 3, 3, 2, 3, 2,
       4, 3, 4, 1, 3, 3, 3, 2, 1, 1, 3, 3, 1, 3, 3, 3, 3, 2, 2, 2, 1, 3,
       3, 3, 3, 2, 3, 3, 3, 3, 2, 3, 3, 3, 3, 2, 2, 1, 3, 3, 3, 3, 3, 2,
       3, 2, 1, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 1, 1, 1, 1, 3, 3, 1, 1, 1,
       3, 4, 1, 1, 3, 1, 1], dtype=int32)
```

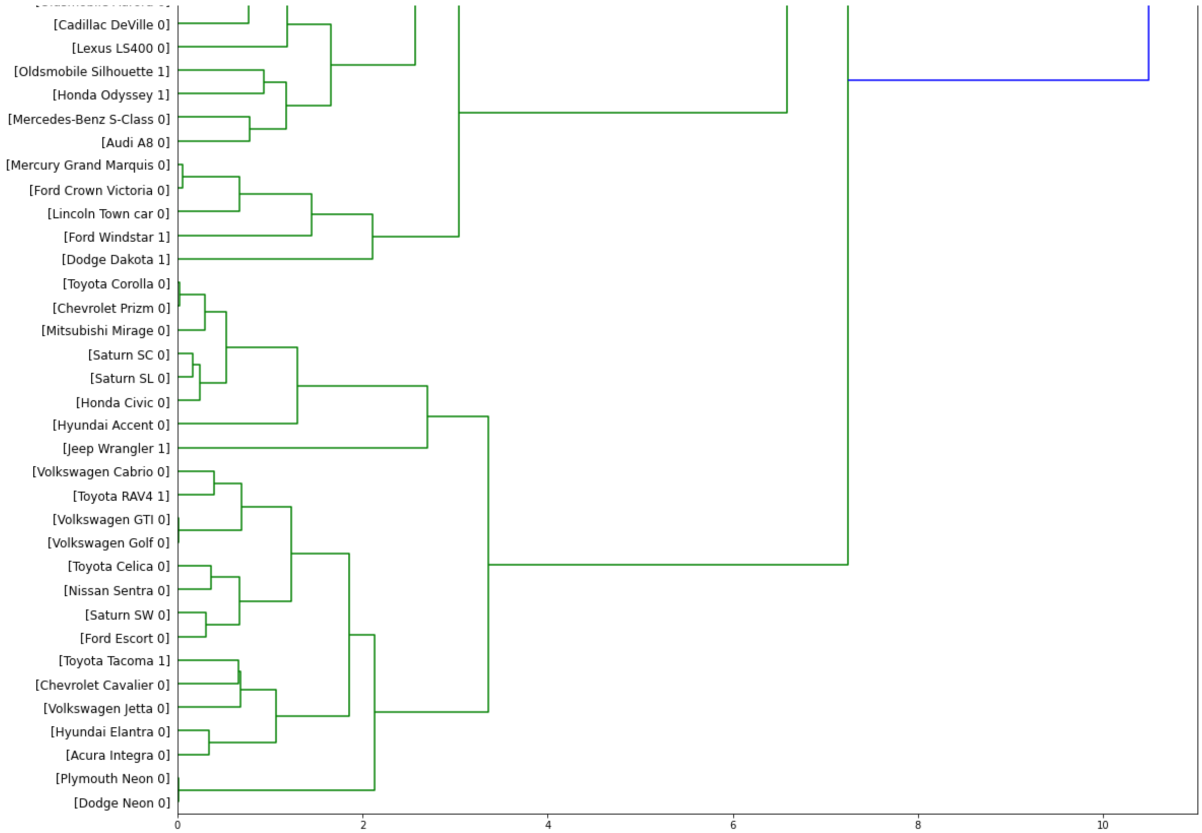
Now, plot the dendrogram:

In [20]:

```
fig = pylab.figure(figsize=(18,50))
def llf(id):
    return '[%s %s %s]' % (pdf['manufact'][id], pdf['model'][id], int(float(pdf['typ

dendro = hierarchy.dendrogram(Z,  leaf_label_func=llf, leaf_rotation=0, leaf_font_si
```



[Ford F-Series 1]
[Dodge Ram Pickup 1]
[Dodge Ram Van 1]
[Toyota Land Cruiser 1]
[Ford Expedition 1]
[Dodge Ram Wagon 1]
[Dodge Viper 0]
[Chevrolet Metro 0]
[Mitsubishi 3000GT 0]
[Ford Mustang 0]
[Toyota 4Runner 1]
[Mitsubishi Montero Sport 1]
[Ford Ranger 1]
[Porsche Boxter 0]
[Jeep Cherokee 1]
[Porsche Carrera Cabriolet 0]
[Porsche Carrera Coupe 0]
[Toyota Camry 0]
[Honda Accord 0]
[Plymouth Breeze 0]
[Chrysler Cirrus 0]
[Dodge Avenger 0]
[Chrysler Sebring Coupe 0]
[Oldsmobile Cutlass 0]
[Chevrolet Malibu 0]
[Pontiac Grand Am 0]
[Chrysler Sebring Conv. 0]
[Hyundai Sonata 0]
[Dodge Stratus 0]
[Mercedes-Benz C-Class 0]
[BMW 328i 0]
[Pontiac Sunfire 0]
[Audi A4 0]
[Mitsubishi Eclipse 0]
[Honda CR-V 1]
[Nissan Altima 0]
[Mitsubishi Galant 0]
[Ford Contour 0]
[Volkswagen Passat 0]
[Mercury Cougar 0]
[Mercury Mystique 0]
[Mitsubishi Diamante 0]
[Cadillac Catera 0]
[Lexus GS300 0]
[Mercedes-Benz E-Class 0]
[Infiniti I30 0]
[Acura TL 0]
[Toyota Avalon 0]
[BMW 528i 0]
[Nissan Maxima 0]
[Lexus ES300 0]
[Mercury Sable 0]
[Ford Taurus 0]
[Chevrolet Lumina 0]
[Chevrolet Monte Carlo 0]
[Buick Century 0]
[Pontiac Firebird 0]
[Chevrolet Camaro 0]
[Nissan Pathfinder 1]
[Jeep Grand Cherokee 1]
[Honda Passport 1]
[Mercury Mountaineer 1]
[Ford Explorer 1]
[Oldsmobile Bravada 1]
[Nissan Quest 1]
[Mercury Villager 1]
[Audi A6 0]
[Plymouth Voyager 1]
[Dodge Caravan 1]
[Chrysler LHS 0]
[Buick Park Avenue 0]
[Chrysler Concorde 0]
[Pontiac Bonneville 0]
[Buick LeSabre 0]
[Acura RL 0]
[Pontiac Grand Prix 0]
[Buick Regal 0]
[Mercedes-Benz SL-Class 0]
[Chevrolet Corvette 0]
[Mitsubishi Montero 1]
[Lincoln Continental 0]
[Cadillac Eldorado 0]
[Oldsmobile Aurora 0]



Clustering using scikit-learn

Let's redo it again, but this time using the scikit-learn package:

In [21]:

```
from sklearn.metrics.pairwise import euclidean_distances
dist_matrix = euclidean_distances(feature_mtx,feature_mtx)
print(dist_matrix)
```

```
[[0.         0.57777143 0.75455727 ... 0.28530295 0.24917241 0.18879995]
 [0.57777143 0.         0.22798938 ... 0.36087756 0.66346677 0.62201282]
 [0.75455727 0.22798938 0.         ... 0.51727787 0.81786095 0.77930119]
 ...
 [0.28530295 0.36087756 0.51727787 ... 0.         0.41797928 0.35720492]
 [0.24917241 0.66346677 0.81786095 ... 0.41797928 0.         0.15212198]
 [0.18879995 0.62201282 0.77930119 ... 0.35720492 0.15212198 0.        ]]
```

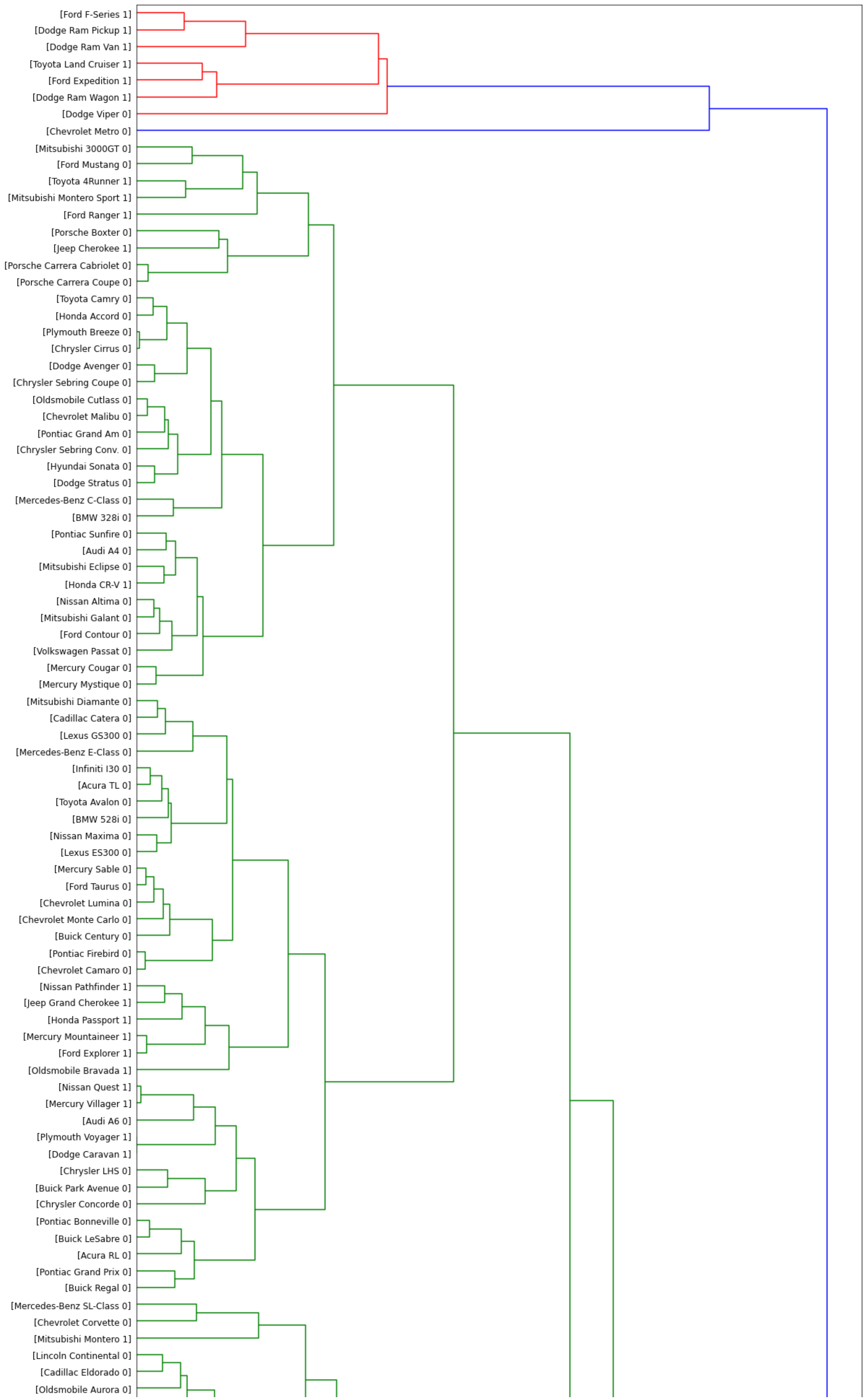
In [22]:

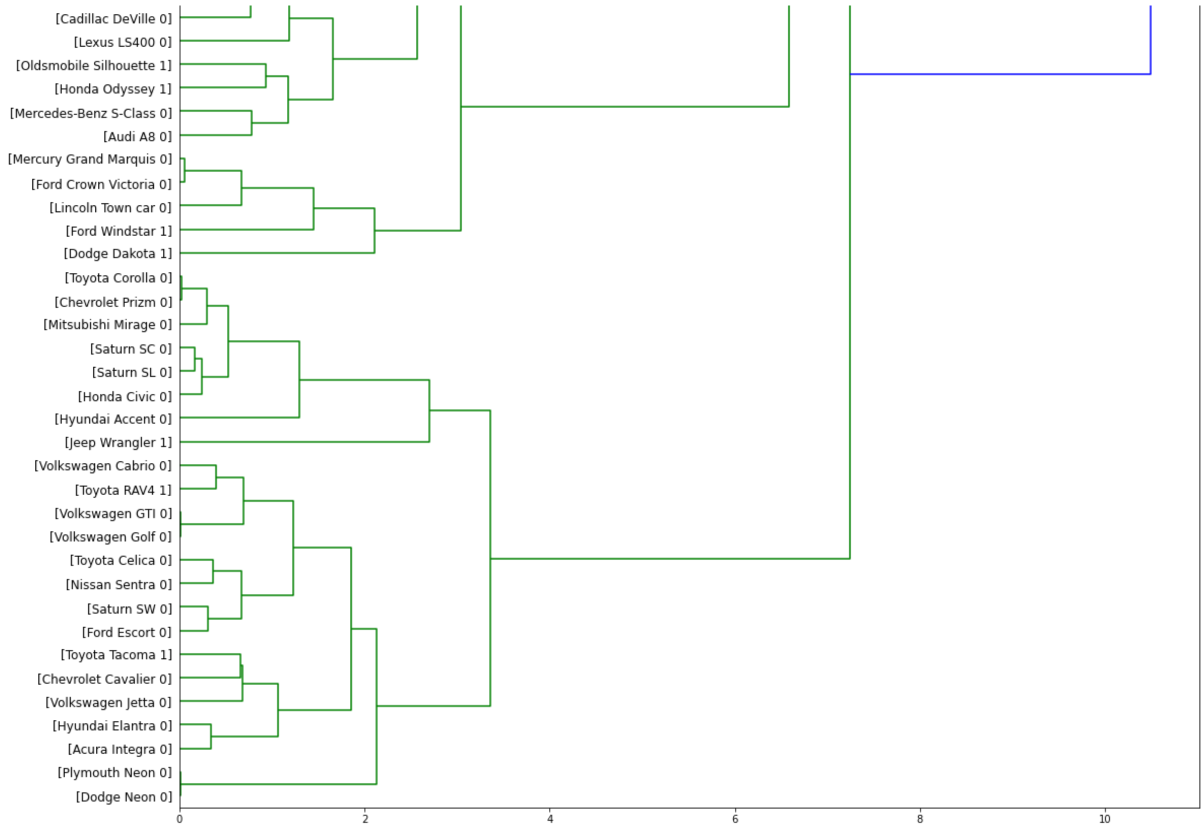
```
Z_using_dist_matrix = hierarchy.linkage(dist_matrix, 'complete')
```

```
<ipython-input-22-bf9ca02f569b>:1: ClusterWarning: scipy.cluster: The symmetric non-
negative hollow observation matrix looks suspiciously like an uncondensed distance m
atrix
  Z_using_dist_matrix = hierarchy.linkage(dist_matrix, 'complete')
```

In [23]:

```
fig = pylab.figure(figsize=(18,50))
def llf(id):
    return '[%s %s %s]' % (pdf['manufact'][id], pdf['model'][id], int(float(pdf['typ

dendro = hierarchy.dendrogram(Z_using_dist_matrix,  leaf_label_func=llf, leaf_rotati
```


[Ford F-Series 1]
[Dodge Ram Pickup 1]
[Dodge Ram Van 1]
[Toyota Land Cruiser 1]
[Ford Expedition 1]
[Dodge Ram Wagon 1]
[Dodge Viper 0]
[Chevrolet Metro 0]
[Mitsubishi 3000GT 0]
[Ford Mustang 0]
[Toyota 4Runner 1]
[Mitsubishi Montero Sport 1]
[Ford Ranger 1]
[Porsche Boxter 0]
[Jeep Cherokee 1]
[Porsche Carrera Cabriolet 0]
[Porsche Carrera Coupe 0]
[Toyota Camry 0]
[Honda Accord 0]
[Plymouth Breeze 0]
[Chrysler Cirrus 0]
[Dodge Avenger 0]
[Chrysler Sebring Coupe 0]
[Oldsmobile Cutlass 0]
[Chevrolet Malibu 0]
[Pontiac Grand Am 0]
[Chrysler Sebring Conv. 0]
[Hyundai Sonata 0]
[Dodge Stratus 0]
[Mercedes-Benz C-Class 0]
[BMW 328i 0]
[Pontiac Sunfire 0]
[Audi A4 0]
[Mitsubishi Eclipse 0]
[Honda CR-V 1]
[Nissan Altima 0]
[Mitsubishi Galant 0]
[Ford Contour 0]
[Volkswagen Passat 0]
[Mercury Cougar 0]
[Mercury Mystique 0]
[Mitsubishi Diamante 0]
[Cadillac Catera 0]
[Lexus GS300 0]
[Mercedes-Benz E-Class 0]
[Infiniti I30 0]
[Acura TL 0]
[Toyota Avalon 0]
[BMW 528i 0]
[Nissan Maxima 0]
[Lexus ES300 0]
[Mercury Sable 0]
[Ford Taurus 0]
[Chevrolet Lumina 0]
[Chevrolet Monte Carlo 0]
[Buick Century 0]
[Pontiac Firebird 0]
[Chevrolet Camaro 0]
[Nissan Pathfinder 1]
[Jeep Grand Cherokee 1]
[Honda Passport 1]
[Mercury Mountaineer 1]
[Ford Explorer 1]
[Oldsmobile Bravada 1]
[Nissan Quest 1]
[Mercury Villager 1]
[Audi A6 0]
[Plymouth Voyager 1]
[Dodge Caravan 1]
[Chrysler LHS 0]
[Buick Park Avenue 0]
[Chrysler Concorde 0]
[Pontiac Bonneville 0]
[Buick LeSabre 0]
[Acura RL 0]
[Pontiac Grand Prix 0]
[Buick Regal 0]
[Mercedes-Benz SL-Class 0]
[Chevrolet Corvette 0]
[Mitsubishi Montero 1]
[Lincoln Continental 0]
[Cadillac Eldorado 0]
[Oldsmobile Aurora 0]



Now, we can use the 'AgglomerativeClustering' function from scikit-learn library to cluster the dataset. The AgglomerativeClustering performs a hierarchical clustering using a bottom up approach. The linkage criteria determines the metric used for the merge strategy:

- Ward minimizes the sum of squared differences within all clusters. It is a variance-minimizing approach and in this sense is similar to the k-means objective function but tackled with an agglomerative hierarchical approach.
- Maximum or complete linkage minimizes the maximum distance between observations of pairs of clusters.
- Average linkage minimizes the average of the distances between all observations of pairs of clusters.

In [24]:

```
agglom = AgglomerativeClustering(n_clusters = 6, linkage = 'complete')
agglom.fit(dist_matrix)

agglom.labels_
```

```
/opt/conda/envs/Python-3.8-main/lib/python3.8/site-packages/sklearn/cluster/_agglome
rative.py:492: ClusterWarning: scipy.cluster: The symmetric non-negative hollow obse
rvation matrix looks suspiciously like an uncondensed distance matrix
  out = hierarchy.linkage(X, method=linkage, metric=affinity)
```

Out[24]:

```
array([1, 2, 2, 3, 2, 4, 3, 2, 2, 2, 2, 2, 4, 4, 2, 1, 3, 2, 2, 2, 4, 1,
       5, 3, 3, 2, 3, 2, 1, 3, 3, 0, 0, 0, 0, 4, 2, 1, 3, 3, 2, 4, 2, 4,
       0, 3, 0, 1, 3, 3, 2, 4, 1, 1, 3, 2, 1, 3, 2, 2, 2, 4, 4, 4, 1, 3,
       3, 2, 3, 4, 3, 3, 3, 2, 4, 2, 2, 3, 2, 4, 4, 1, 3, 2, 2, 2, 3, 4,
       2, 4, 1, 3, 2, 3, 3, 2, 2, 2, 3, 3, 3, 1, 1, 1, 1, 3, 2, 1, 1, 1,
       3, 0, 1, 1, 3, 1, 1])
```

We can add a new field to our dataframe to show the cluster of each row:

In [25]:

```
pdf['cluster_'] = agglom.labels_
pdf.head()
```

Out[25]:

	manufact	model	sales	resale	type	price	engine_s	horsepow	wheelbas	width	length	cu
0	Acura	Integra	16.919	16.360	0.0	21.50	1.8	140.0	101.2	67.3	172.4	
1	Acura	TL	39.384	19.875	0.0	28.40	3.2	225.0	108.1	70.3	192.9	
2	Acura	RL	8.588	29.725	0.0	42.00	3.5	210.0	114.6	71.4	196.6	
3	Audi	A4	20.397	22.255	0.0	23.99	1.8	150.0	102.6	68.2	178.0	
4	Audi	A6	18.780	23.555	0.0	33.95	2.8	200.0	108.7	76.1	192.0	

In [26]:

```
import matplotlib.cm as cm
n_clusters = max(agglom.labels_)+1
colors = cm.rainbow(np.linspace(0, 1, n_clusters))
cluster_labels = list(range(0, n_clusters))

# Create a figure of size 6 inches by 4 inches.
plt.figure(figsize=(16,14))

for color, label in zip(colors, cluster_labels):
    subset = pdf[pdf.cluster_ == label]
    for i in subset.index:
            plt.text(subset.horsepow[i], subset.mpg[i],str(subset['model'][i]), rota
    plt.scatter(subset.horsepow, subset.mpg, s= subset.price*10, c=color, label='clu
#    plt.scatter(subset.horsepow, subset.mpg)
plt.legend()
plt.title('Clusters')
plt.xlabel('horsepow')
plt.ylabel('mpg')
```

```
*c* argument looks like a single numeric RGB or RGBA sequence, which should be avoid
ed as value-mapping will have precedence in case its length matches with *x* & *y*.
Please use the *color* keyword-argument or provide a 2-D array with a single row if
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```
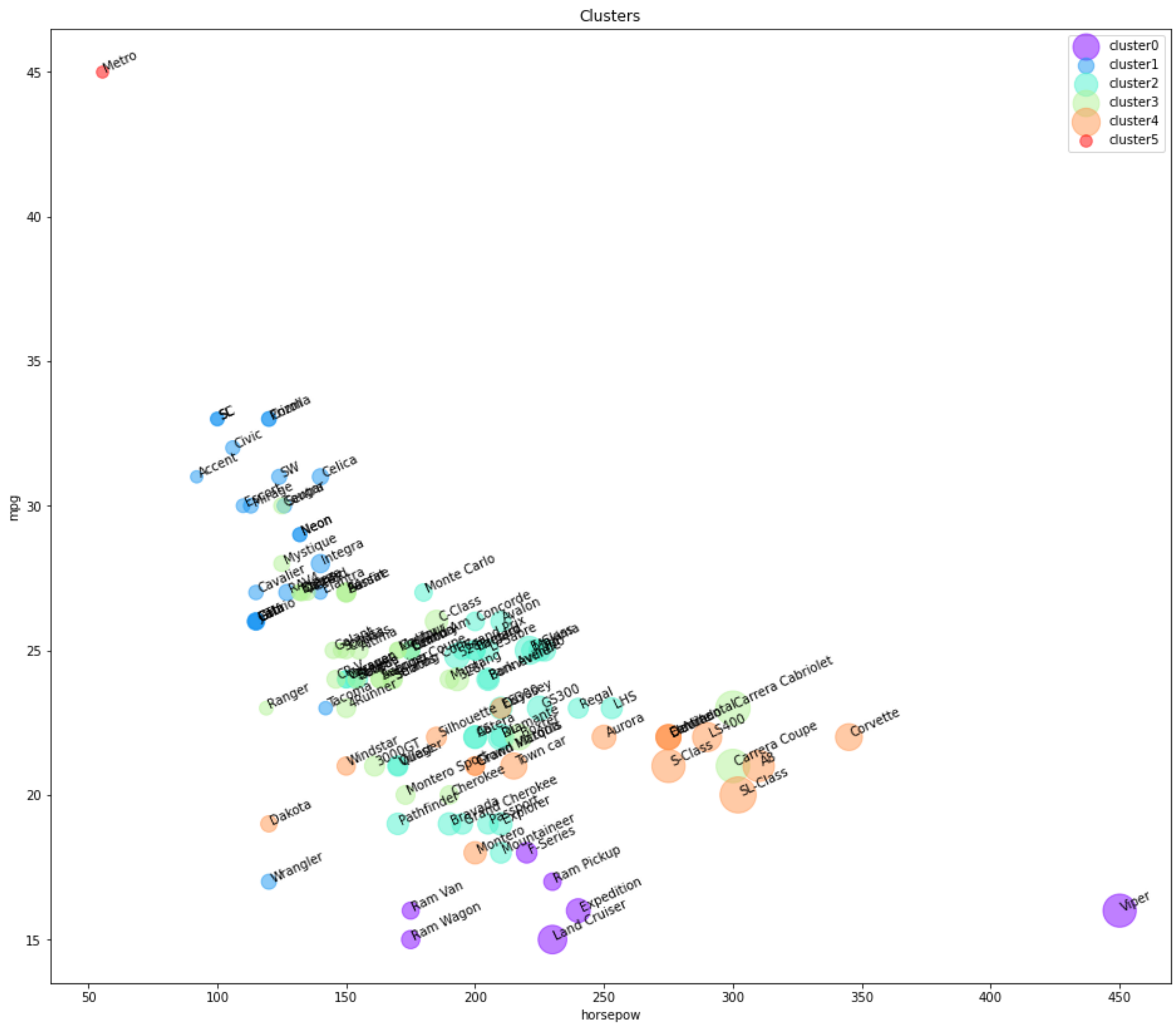

```
Please use the *color* keyword-argument or provide a 2-D array with a single row if
you intend to specify the same RGB or RGBA value for all points.
```

Out[26]:

```
Text(0, 0.5, 'mpg')
```



As you can see, we are seeing the distribution of each cluster using the scatter plot, but it is not very clear where is the centroid of each cluster. Moreover, there are 2 types of vehicles in our dataset, "truck" (value of 1 in the type column) and "car" (value of 0 in the type column). So, we use them to distinguish the classes, and summarize the cluster. First we count the number of cases in each group:

In [27]:

```python
pdf.groupby(['cluster_','type'])['cluster_'].count()
```

Out[27]:

```
cluster_  type
0         0.0      1
          1.0      6
1         0.0     20
          1.0      3
2         0.0     26
          1.0     10
3         0.0     28
          1.0      5
4         0.0     12
          1.0      5
```

```
5          0.0       1
Name: cluster_, dtype: int64
```

Now we can look at the characteristics of each cluster:

In [28]:

```
agg_cars = pdf.groupby(['cluster_','type'])['horsepow','engine_s','mpg','price'].mea
agg_cars
```

```
<ipython-input-28-fb63ecec89ff>:1: FutureWarning: Indexing with multiple keys (impli
citly converted to a tuple of keys) will be deprecated, use a list instead.
  agg_cars = pdf.groupby(['cluster_','type'])['horsepow','engine_s','mpg','price'].m
ean()
```

Out[28]:

cluster_	type	horsepow	engine_s	mpg	price
0	0.0	450.000000	8.000000	16.000000	69.725000
	1.0	211.666667	4.483333	16.166667	29.024667
1	0.0	118.500000	1.890000	29.550000	14.226100
	1.0	129.666667	2.300000	22.333333	14.292000
2	0.0	203.615385	3.284615	24.223077	27.988692
	1.0	182.000000	3.420000	20.300000	26.120600
3	0.0	168.107143	2.557143	25.107143	24.693786
	1.0	155.600000	2.840000	22.000000	19.807000
4	0.0	267.666667	4.566667	21.416667	46.417417
	1.0	173.000000	3.180000	20.600000	24.308400
5	0.0	55.000000	1.000000	45.000000	9.235000

It is obvious that we have 3 main clusters with the majority of vehicles in those.

Cars:

- Cluster 1: with almost high mpg, and low in horsepower.
- Cluster 2: with good mpg and horsepower, but higher price than average.
- Cluster 3: with low mpg, high horsepower, highest price.

Trucks:

- Cluster 1: with almost highest mpg among trucks, and lowest in horsepower and price.
- Cluster 2: with almost low mpg and medium horsepower, but higher price than average.
- Cluster 3: with good mpg and horsepower, low price.

Please notice that we did not use **type** and **price** of cars in the clustering process, but Hierarchical clustering could forge the clusters and discriminate them with quite a high accuracy.

In [29]:

```
plt.figure(figsize=(16,10))
for color, label in zip(colors, cluster_labels):
    subset = agg_cars.loc[(label,),]
    for i in subset.index:
        plt.text(subset.loc[i][0]+5, subset.loc[i][2], 'type='+str(int(i)) + ', pric
    plt.scatter(subset.horsepow, subset.mpg, s=subset.price*20, c=color, label='clus
plt.legend()
plt.title('Clusters')
plt.xlabel('horsepow')
plt.ylabel('mpg')
```

```
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Please use the *color* keyword-argument or provide a 2-D array with a single row if
you intend to specify the same RGB or RGBA value for all points.
```
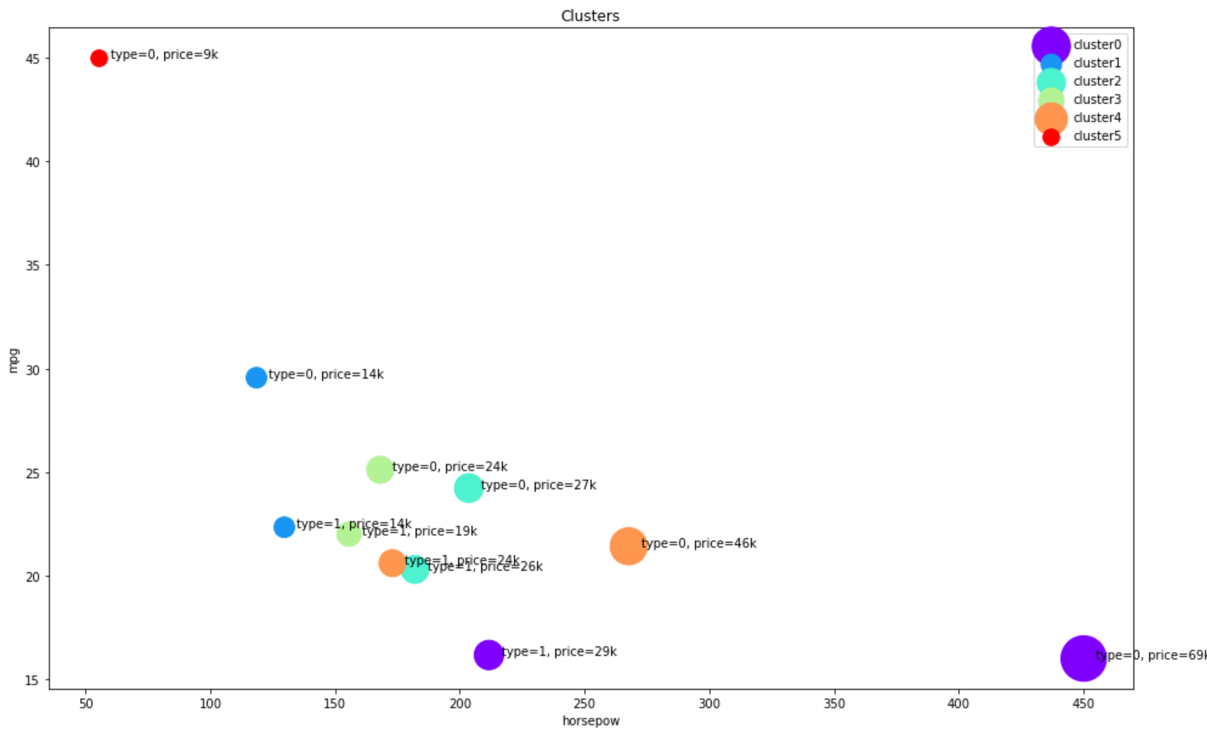

Out[29]:

```
Text(0, 0.5, 'mpg')
```



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Thank you for completing this lab!

Author

Saeed Aghabozorgi

Other Contributors

Joseph Santarcangelo

Change Log

Date (YYYY-MM-DD)	Version	Changed By	Change Description
2021-01-11	2.2	Lakshmi	Changed distance matrix in agglomerative clustering
2020-11-03	2.1	Lakshmi	Updated URL
2020-08-27	2.0	Lavanya	Moved lab to course repo in GitLab