Import the libraries

In [1]:
```
#importing the libraries
import tensorflow as tf
from tensorflow import keras
import numpy as np
import pandas as pd
from sklearn.metrics import mean_absolute_error
import matplotlib.pyplot as plt
```

```
WARNING:tensorflow:From C:\Users\Teo Boon Kean\AppData\Local\Programs\Python\Python311\Lib\site-packages\keras\src\losses.py:2976: The name tf.losses.sparse_softmax_cross_entropy is deprecated. Please use tf.compat.v1.losses.sparse_softmax_cross_entropy instead.
```

Load the data and data pre-processing

In [2]:
```
#load the extracted features
baseline_df = pd.read_excel('extracted_features_baseline.xlsx')
toolwear_df = pd.read_excel('extracted_features_toolwear.xlsx')
```

In [3]:
```
good_features = baseline_df.values
bad_features = toolwear_df.values
```

train test split

from sklearn.model_selection import train_test_split good_train, good_test = train_test_split(good_features, test_size=0.2, random_state=5)

bad_train, bad_test = train_test_split(bad_features, test_size=0.2, random_state=5)

In [5]:
```
#data scalling
from sklearn.preprocessing import StandardScaler

sc = StandardScaler()
good_train = sc.fit_transform(good_train)
good_test = sc.transform(good_test)
bad_train = sc.fit_transform(bad_train)
bad_test = sc.transform(bad_test)
```

Specifying the number of encoded features to be investigated

In [6]:
```
feature_size = [5, 10, 20, 40, 60]
```

Train and Evaluate Autoencoders with different hidden layer size (encoded features)

In [7]:
```
result = []

# The number of encoded feature of autoencoder is varied in each iteration of the for loop
for size in feature_size:

    condensed_f = size

    #constructing the good autoencoder model

    #input layer which number of neurons equals the number of original features
    l_in_good = keras.Input(good_features.shape[1])

    #hidden layer which condenses the feature into the specified number of condensed features
    l_condensed_good = keras.layers.Dense(condensed_f)(l_in_good)

    #output layer which is the same as the input
    l_out_good = keras.layers.Dense(good_features.shape[1])(l_condensed_good)


    #defining the good autoencoder
    autoencoder_good = keras.Model(l_in_good, l_out_good)

    #compile the model
    autoencoder_good.compile(optimizer='adam', loss='mse')
    #train the model
```

```
    autoencoder_good.fit(good_train, good_train, epochs = 50, batch_size = 8, validation_split = 0.1)



    #The autoencoders are asked to predict both classes of test data
    GAE_pred_good = autoencoder_good.predict(good_test)
    GAE_pred_bad = autoencoder_good.predict(bad_test)

    #The MSE of each entry in the entire dataset is stored in a temporary array
    #The 2 temporary arrays will be used to determine the margin between 2 classes (it needs all the values to
    GAE_MSE_bad = []
    GAE_MSE_good = []

    #The MSE of each entry in the test datasets are computed and stored in the temporary array
    for i in range(len(bad_test)):
        GAE_MSE_good.append(mean_absolute_error(good_test[i],GAE_pred_good[i]))
        GAE_MSE_bad.append(mean_absolute_error(bad_test[i],GAE_pred_bad[i]))

    #For each variation of window size, the margin between 2 classes will be stored in 'difference' array
    difference = []

    for x in range(1,20):
        window = x
        GAE_average_good = []
        GAE_average_bad = []

        for ind in range(len(GAE_MSE_good) - window + 1):
            GAE_average_good.append(np.mean(GAE_MSE_good[ind:ind+window]))
            GAE_average_bad.append(np.mean(GAE_MSE_bad[ind:ind+window]))

        #calculates the minimum difference in MSE between 2 classes and stores in the array
        difference.append(min(GAE_average_bad) - max(GAE_average_good))

    #The array 'difference' is obtained for each autoencoder with different number of encoded features. The ent
    result.append(difference)
```

```
WARNING:tensorflow:From C:\Users\Teo Boon Kean\AppData\Local\Programs\Python\Python311\Lib\site-packages\keras\s
rc\backend.py:1398: The name tf.executing_eagerly_outside_functions is deprecated. Please use tf.compat.v1.execu
ting_eagerly_outside_functions instead.

WARNING:tensorflow:From C:\Users\Teo Boon Kean\AppData\Local\Programs\Python\Python311\Lib\site-packages\keras\s
rc\optimizers\__init__.py:309: The name tf.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimize
r instead.

Epoch 1/50
WARNING:tensorflow:From C:\Users\Teo Boon Kean\AppData\Local\Programs\Python\Python311\Lib\site-packages\keras\s
rc\utils\tf_utils.py:492: The name tf.ragged.RaggedTensorValue is deprecated. Please use tf.compat.v1.ragged.Rag
gedTensorValue instead.

38/38 [==============================] - 1s 7ms/step - loss: 1.1079 - val_loss: 1.0250
Epoch 2/50
38/38 [==============================] - 0s 3ms/step - loss: 0.9638 - val_loss: 0.9201
Epoch 3/50
38/38 [==============================] - 0s 3ms/step - loss: 0.8571 - val_loss: 0.8201
Epoch 4/50
38/38 [==============================] - 0s 3ms/step - loss: 0.7590 - val_loss: 0.7267
Epoch 5/50
38/38 [==============================] - 0s 3ms/step - loss: 0.6751 - val_loss: 0.6529
Epoch 6/50
38/38 [==============================] - 0s 2ms/step - loss: 0.6129 - val_loss: 0.6019
Epoch 7/50
38/38 [==============================] - 0s 2ms/step - loss: 0.5667 - val_loss: 0.5653
Epoch 8/50
38/38 [==============================] - 0s 2ms/step - loss: 0.5319 - val_loss: 0.5359
Epoch 9/50
38/38 [==============================] - 0s 2ms/step - loss: 0.5034 - val_loss: 0.5106
Epoch 10/50
38/38 [==============================] - 0s 2ms/step - loss: 0.4796 - val_loss: 0.4895
Epoch 11/50
38/38 [==============================] - 0s 2ms/step - loss: 0.4601 - val_loss: 0.4722
Epoch 12/50
38/38 [==============================] - 0s 2ms/step - loss: 0.4440 - val_loss: 0.4556
Epoch 13/50
38/38 [==============================] - 0s 2ms/step - loss: 0.4301 - val_loss: 0.4432
Epoch 14/50
38/38 [==============================] - 0s 2ms/step - loss: 0.4183 - val_loss: 0.4311
Epoch 15/50
38/38 [==============================] - 0s 2ms/step - loss: 0.4082 - val_loss: 0.4216
Epoch 16/50
38/38 [==============================] - 0s 3ms/step - loss: 0.3984 - val_loss: 0.4130
Epoch 17/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3899 - val_loss: 0.4088
Epoch 18/50
38/38 [==============================] - 0s 3ms/step - loss: 0.3819 - val_loss: 0.4019
```

```
Epoch 19/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3751 - val_loss: 0.3961
Epoch 20/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3689 - val_loss: 0.3930
Epoch 21/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3636 - val_loss: 0.3909
Epoch 22/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3594 - val_loss: 0.3879
Epoch 23/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3559 - val_loss: 0.3860
Epoch 24/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3525 - val_loss: 0.3840
Epoch 25/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3501 - val_loss: 0.3842
Epoch 26/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3477 - val_loss: 0.3831
Epoch 27/50
38/38 [==============================] - 0s 3ms/step - loss: 0.3462 - val_loss: 0.3814
Epoch 28/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3446 - val_loss: 0.3809
Epoch 29/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3430 - val_loss: 0.3814
Epoch 30/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3424 - val_loss: 0.3806
Epoch 31/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3413 - val_loss: 0.3797
Epoch 32/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3408 - val_loss: 0.3782
Epoch 33/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3403 - val_loss: 0.3791
Epoch 34/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3389 - val_loss: 0.3785
Epoch 35/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3385 - val_loss: 0.3770
Epoch 36/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3376 - val_loss: 0.3792
Epoch 37/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3374 - val_loss: 0.3775
Epoch 38/50
38/38 [==============================] - 0s 3ms/step - loss: 0.3367 - val_loss: 0.3784
Epoch 39/50
38/38 [==============================] - 0s 3ms/step - loss: 0.3364 - val_loss: 0.3778
Epoch 40/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3363 - val_loss: 0.3784
Epoch 41/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3359 - val_loss: 0.3784
Epoch 42/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3358 - val_loss: 0.3769
Epoch 43/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3356 - val_loss: 0.3760
Epoch 44/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3353 - val_loss: 0.3777
Epoch 45/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3354 - val_loss: 0.3765
Epoch 46/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3351 - val_loss: 0.3757
Epoch 47/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3350 - val_loss: 0.3768
Epoch 48/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3345 - val_loss: 0.3775
Epoch 49/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3347 - val_loss: 0.3769
Epoch 50/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3343 - val_loss: 0.3758
3/3 [==============================] - 0s 2ms/step
3/3 [==============================] - 0s 2ms/step
Epoch 1/50
38/38 [==============================] - 1s 6ms/step - loss: 1.2304 - val_loss: 1.1386
Epoch 2/50
38/38 [==============================] - 0s 2ms/step - loss: 0.9853 - val_loss: 0.9347
Epoch 3/50
38/38 [==============================] - 0s 2ms/step - loss: 0.8218 - val_loss: 0.7735
Epoch 4/50
38/38 [==============================] - 0s 2ms/step - loss: 0.6823 - val_loss: 0.6496
Epoch 5/50
38/38 [==============================] - 0s 2ms/step - loss: 0.5812 - val_loss: 0.5661
Epoch 6/50
38/38 [==============================] - 0s 2ms/step - loss: 0.5140 - val_loss: 0.5152
Epoch 7/50
38/38 [==============================] - 0s 2ms/step - loss: 0.4671 - val_loss: 0.4758
Epoch 8/50
38/38 [==============================] - 0s 2ms/step - loss: 0.4297 - val_loss: 0.4445
Epoch 9/50
```

```
38/38 [==============================] - 0s 3ms/step - loss: 0.3997 - val_loss: 0.4182
Epoch 10/50
38/38 [==============================] - 0s 3ms/step - loss: 0.3723 - val_loss: 0.3951
Epoch 11/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3494 - val_loss: 0.3758
Epoch 12/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3288 - val_loss: 0.3577
Epoch 13/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3107 - val_loss: 0.3437
Epoch 14/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2962 - val_loss: 0.3309
Epoch 15/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2839 - val_loss: 0.3195
Epoch 16/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2729 - val_loss: 0.3095
Epoch 17/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2638 - val_loss: 0.3005
Epoch 18/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2550 - val_loss: 0.2947
Epoch 19/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2483 - val_loss: 0.2891
Epoch 20/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2410 - val_loss: 0.2825
Epoch 21/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2352 - val_loss: 0.2774
Epoch 22/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2294 - val_loss: 0.2723
Epoch 23/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2237 - val_loss: 0.2666
Epoch 24/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2185 - val_loss: 0.2623
Epoch 25/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2146 - val_loss: 0.2597
Epoch 26/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2088 - val_loss: 0.2548
Epoch 27/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2043 - val_loss: 0.2522
Epoch 28/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2003 - val_loss: 0.2485
Epoch 29/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1969 - val_loss: 0.2431
Epoch 30/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1923 - val_loss: 0.2437
Epoch 31/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1886 - val_loss: 0.2393
Epoch 32/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1857 - val_loss: 0.2363
Epoch 33/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1829 - val_loss: 0.2333
Epoch 34/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1800 - val_loss: 0.2325
Epoch 35/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1771 - val_loss: 0.2300
Epoch 36/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1745 - val_loss: 0.2277
Epoch 37/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1726 - val_loss: 0.2263
Epoch 38/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1704 - val_loss: 0.2240
Epoch 39/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1688 - val_loss: 0.2226
Epoch 40/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1672 - val_loss: 0.2203
Epoch 41/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1653 - val_loss: 0.2190
Epoch 42/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1644 - val_loss: 0.2188
Epoch 43/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1634 - val_loss: 0.2152
Epoch 44/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1612 - val_loss: 0.2145
Epoch 45/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1603 - val_loss: 0.2134
Epoch 46/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1597 - val_loss: 0.2129
Epoch 47/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1585 - val_loss: 0.2118
Epoch 48/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1577 - val_loss: 0.2102
Epoch 49/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1569 - val_loss: 0.2097
Epoch 50/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1561 - val_loss: 0.2086
```

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3/3 [==============================] - 0s 1ms/step
3/3 [==============================] - 0s 2ms/step
Epoch 1/50
38/38 [==============================] - 1s 6ms/step - loss: 1.2672 - val_loss: 1.0769
Epoch 2/50
38/38 [==============================] - 0s 2ms/step - loss: 0.8833 - val_loss: 0.8370
Epoch 3/50
38/38 [==============================] - 0s 2ms/step - loss: 0.6856 - val_loss: 0.6660
Epoch 4/50
38/38 [==============================] - 0s 3ms/step - loss: 0.5456 - val_loss: 0.5524
Epoch 5/50
38/38 [==============================] - 0s 2ms/step - loss: 0.4578 - val_loss: 0.4751
Epoch 6/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3950 - val_loss: 0.4179
Epoch 7/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3448 - val_loss: 0.3734
Epoch 8/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3030 - val_loss: 0.3312
Epoch 9/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2687 - val_loss: 0.3001
Epoch 10/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2392 - val_loss: 0.2726
Epoch 11/50
38/38 [==============================] - 0s 2ms/step - loss: 0.2155 - val_loss: 0.2510
Epoch 12/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1954 - val_loss: 0.2349
Epoch 13/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1793 - val_loss: 0.2213
Epoch 14/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1663 - val_loss: 0.2091
Epoch 15/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1542 - val_loss: 0.1983
Epoch 16/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1447 - val_loss: 0.1911
Epoch 17/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1361 - val_loss: 0.1839
Epoch 18/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1289 - val_loss: 0.1753
Epoch 19/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1217 - val_loss: 0.1707
Epoch 20/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1157 - val_loss: 0.1640
Epoch 21/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1101 - val_loss: 0.1594
Epoch 22/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1052 - val_loss: 0.1562
Epoch 23/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1006 - val_loss: 0.1513
Epoch 24/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0965 - val_loss: 0.1485
Epoch 25/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0924 - val_loss: 0.1426
Epoch 26/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0889 - val_loss: 0.1394
Epoch 27/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0857 - val_loss: 0.1356
Epoch 28/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0831 - val_loss: 0.1337
Epoch 29/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0802 - val_loss: 0.1308
Epoch 30/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0779 - val_loss: 0.1278
Epoch 31/50
38/38 [==============================] - 0s 5ms/step - loss: 0.0755 - val_loss: 0.1254
Epoch 32/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0735 - val_loss: 0.1233
Epoch 33/50
38/38 [==============================] - 0s 6ms/step - loss: 0.0714 - val_loss: 0.1196
Epoch 34/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0698 - val_loss: 0.1184
Epoch 35/50
38/38 [==============================] - 0s 6ms/step - loss: 0.0680 - val_loss: 0.1171
Epoch 36/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0661 - val_loss: 0.1138
Epoch 37/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0645 - val_loss: 0.1117
Epoch 38/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0629 - val_loss: 0.1093
Epoch 39/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0614 - val_loss: 0.1070
Epoch 40/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0600 - val_loss: 0.1047
Epoch 41/50
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38/38 [==============================] - 0s 2ms/step - loss: 0.0588 - val_loss: 0.1033
Epoch 42/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0575 - val_loss: 0.1015
Epoch 43/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0565 - val_loss: 0.0993
Epoch 44/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0550 - val_loss: 0.0978
Epoch 45/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0542 - val_loss: 0.0952
Epoch 46/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0530 - val_loss: 0.0932
Epoch 47/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0519 - val_loss: 0.0922
Epoch 48/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0509 - val_loss: 0.0898
Epoch 49/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0499 - val_loss: 0.0885
Epoch 50/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0490 - val_loss: 0.0869
3/3 [==============================] - 0s 2ms/step
3/3 [==============================] - 0s 2ms/step
Epoch 1/50
38/38 [==============================] - 1s 8ms/step - loss: 1.2969 - val_loss: 0.9010
Epoch 2/50
38/38 [==============================] - 0s 3ms/step - loss: 0.6980 - val_loss: 0.5774
Epoch 3/50
38/38 [==============================] - 0s 2ms/step - loss: 0.4643 - val_loss: 0.4341
Epoch 4/50
38/38 [==============================] - 0s 2ms/step - loss: 0.3505 - val_loss: 0.3510
Epoch 5/50
38/38 [==============================] - 0s 3ms/step - loss: 0.2783 - val_loss: 0.2898
Epoch 6/50
38/38 [==============================] - 0s 3ms/step - loss: 0.2282 - val_loss: 0.2473
Epoch 7/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1912 - val_loss: 0.2148
Epoch 8/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1634 - val_loss: 0.1897
Epoch 9/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1418 - val_loss: 0.1706
Epoch 10/50
38/38 [==============================] - 0s 3ms/step - loss: 0.1251 - val_loss: 0.1530
Epoch 11/50
38/38 [==============================] - 0s 5ms/step - loss: 0.1115 - val_loss: 0.1420
Epoch 12/50
38/38 [==============================] - 0s 2ms/step - loss: 0.1007 - val_loss: 0.1298
Epoch 13/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0914 - val_loss: 0.1218
Epoch 14/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0834 - val_loss: 0.1127
Epoch 15/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0767 - val_loss: 0.1065
Epoch 16/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0708 - val_loss: 0.0998
Epoch 17/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0659 - val_loss: 0.0940
Epoch 18/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0605 - val_loss: 0.0913
Epoch 19/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0567 - val_loss: 0.0851
Epoch 20/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0534 - val_loss: 0.0818
Epoch 21/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0500 - val_loss: 0.0776
Epoch 22/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0473 - val_loss: 0.0744
Epoch 23/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0447 - val_loss: 0.0721
Epoch 24/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0425 - val_loss: 0.0681
Epoch 25/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0401 - val_loss: 0.0654
Epoch 26/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0383 - val_loss: 0.0635
Epoch 27/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0364 - val_loss: 0.0608
Epoch 28/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0347 - val_loss: 0.0583
Epoch 29/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0333 - val_loss: 0.0560
Epoch 30/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0317 - val_loss: 0.0535
Epoch 31/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0301 - val_loss: 0.0513
```

```
Epoch 32/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0289 - val_loss: 0.0488
Epoch 33/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0278 - val_loss: 0.0472
Epoch 34/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0264 - val_loss: 0.0444
Epoch 35/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0255 - val_loss: 0.0428
Epoch 36/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0242 - val_loss: 0.0411
Epoch 37/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0232 - val_loss: 0.0395
Epoch 38/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0224 - val_loss: 0.0378
Epoch 39/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0215 - val_loss: 0.0370
Epoch 40/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0208 - val_loss: 0.0351
Epoch 41/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0200 - val_loss: 0.0340
Epoch 42/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0192 - val_loss: 0.0324
Epoch 43/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0186 - val_loss: 0.0311
Epoch 44/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0180 - val_loss: 0.0304
Epoch 45/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0174 - val_loss: 0.0293
Epoch 46/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0170 - val_loss: 0.0279
Epoch 47/50
38/38 [==============================] - 0s 6ms/step - loss: 0.0164 - val_loss: 0.0277
Epoch 48/50
38/38 [==============================] - 0s 6ms/step - loss: 0.0159 - val_loss: 0.0266
Epoch 49/50
38/38 [==============================] - 0s 4ms/step - loss: 0.0156 - val_loss: 0.0259
Epoch 50/50
38/38 [==============================] - 0s 4ms/step - loss: 0.0150 - val_loss: 0.0256
3/3 [==============================] - 0s 2ms/step
3/3 [==============================] - 0s 2ms/step
Epoch 1/50
38/38 [==============================] - 1s 5ms/step - loss: 1.2152 - val_loss: 0.8030
Epoch 2/50
38/38 [==============================] - 0s 3ms/step - loss: 0.5520 - val_loss: 0.4916
Epoch 3/50
38/38 [==============================] - 0s 3ms/step - loss: 0.3475 - val_loss: 0.3527
Epoch 4/50
38/38 [==============================] - 0s 4ms/step - loss: 0.2430 - val_loss: 0.2673
Epoch 5/50
38/38 [==============================] - 0s 4ms/step - loss: 0.1822 - val_loss: 0.2160
Epoch 6/50
38/38 [==============================] - 0s 4ms/step - loss: 0.1436 - val_loss: 0.1786
Epoch 7/50
38/38 [==============================] - 0s 5ms/step - loss: 0.1171 - val_loss: 0.1524
Epoch 8/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0979 - val_loss: 0.1350
Epoch 9/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0846 - val_loss: 0.1192
Epoch 10/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0746 - val_loss: 0.1067
Epoch 11/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0662 - val_loss: 0.0969
Epoch 12/50
38/38 [==============================] - 0s 4ms/step - loss: 0.0599 - val_loss: 0.0893
Epoch 13/50
38/38 [==============================] - 0s 4ms/step - loss: 0.0540 - val_loss: 0.0816
Epoch 14/50
38/38 [==============================] - 0s 4ms/step - loss: 0.0493 - val_loss: 0.0756
Epoch 15/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0453 - val_loss: 0.0692
Epoch 16/50
38/38 [==============================] - 0s 4ms/step - loss: 0.0417 - val_loss: 0.0647
Epoch 17/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0386 - val_loss: 0.0608
Epoch 18/50
38/38 [==============================] - 0s 4ms/step - loss: 0.0360 - val_loss: 0.0564
Epoch 19/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0332 - val_loss: 0.0533
Epoch 20/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0308 - val_loss: 0.0498
Epoch 21/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0290 - val_loss: 0.0461
Epoch 22/50
```

```
38/38 [==============================] - 0s 2ms/step - loss: 0.0270 - val_loss: 0.0443
Epoch 23/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0254 - val_loss: 0.0418
Epoch 24/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0240 - val_loss: 0.0384
Epoch 25/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0227 - val_loss: 0.0368
Epoch 26/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0216 - val_loss: 0.0351
Epoch 27/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0207 - val_loss: 0.0334
Epoch 28/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0194 - val_loss: 0.0315
Epoch 29/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0186 - val_loss: 0.0307
Epoch 30/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0175 - val_loss: 0.0289
Epoch 31/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0167 - val_loss: 0.0278
Epoch 32/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0160 - val_loss: 0.0269
Epoch 33/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0154 - val_loss: 0.0253
Epoch 34/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0146 - val_loss: 0.0239
Epoch 35/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0140 - val_loss: 0.0231
Epoch 36/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0133 - val_loss: 0.0227
Epoch 37/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0128 - val_loss: 0.0210
Epoch 38/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0121 - val_loss: 0.0205
Epoch 39/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0117 - val_loss: 0.0195
Epoch 40/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0112 - val_loss: 0.0183
Epoch 41/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0110 - val_loss: 0.0181
Epoch 42/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0104 - val_loss: 0.0170
Epoch 43/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0100 - val_loss: 0.0164
Epoch 44/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0096 - val_loss: 0.0159
Epoch 45/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0093 - val_loss: 0.0149
Epoch 46/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0088 - val_loss: 0.0149
Epoch 47/50
38/38 [==============================] - 0s 2ms/step - loss: 0.0085 - val_loss: 0.0143
Epoch 48/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0083 - val_loss: 0.0136
Epoch 49/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0080 - val_loss: 0.0137
Epoch 50/50
38/38 [==============================] - 0s 3ms/step - loss: 0.0076 - val_loss: 0.0125
3/3 [==============================] - 0s 2ms/step
3/3 [==============================] - 0s 1ms/step
```

In [8]:

```
#plotting the result
window_sizes = list(range(1,len(result[0])+1))
plt.plot(window_sizes, result[0], label = "5 features")
plt.plot(window_sizes, result[1], label = "10 features")
plt.plot(window_sizes, result[2], label = "20 features")
plt.plot(window_sizes, result[3], label = "40 features")
plt.plot(window_sizes, result[4], label = "60 features")
plt.xlabel("Window Size")
plt.ylabel("Margin")
plt.legend(loc='lower right')
plt.xticks([2, 4, 6, 8, 10, 12, 14, 16, 18, 20])
```

Out[8]:
```
([<matplotlib.axis.XTick at 0x22d091f3b90>,
  <matplotlib.axis.XTick at 0x22d0e3e7110>,
  <matplotlib.axis.XTick at 0x22d0e615010>,
  <matplotlib.axis.XTick at 0x22d0f76a210>,
  <matplotlib.axis.XTick at 0x22d0f770690>,
  <matplotlib.axis.XTick at 0x22d0cfa38d0>,
  <matplotlib.axis.XTick at 0x22d0f773dd0>,
  <matplotlib.axis.XTick at 0x22d0f77e190>,
  <matplotlib.axis.XTick at 0x22d0f7845d0>,
  <matplotlib.axis.XTick at 0x22d0f786910>],
 [Text(2, 0, '2'),
  Text(4, 0, '4'),
  Text(6, 0, '6'),
  Text(8, 0, '8'),
  Text(10, 0, '10'),
  Text(12, 0, '12'),
  Text(14, 0, '14'),
  Text(16, 0, '16'),
  Text(18, 0, '18'),
  Text(20, 0, '20')])
```