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MATH6350
HW4 part 2
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Question 1
The original classification task for this dataset was Human Activity Recognition. The dataset contained 5 original classes (sitting-down, standing-up, standing, walking, and sitting) collected on 8 hours of activities from 4 healthy subjects. The data were gathered from accelerometer devices (which measure acceleration) that were mounted on each subject's waist, left thigh, right arm, and right ankle. There were no discrete features. The twelve (continuous) features that I kept and used for classification are as follows:

- x1 (contains the read value of the axis 'x' of the 1st accelerometer, mounted on waist)
- y1 (contains the read value of the axis 'y' of the 1st accelerometer, mounted on waist)
- z1 (contains the read value of the axis 'z' of the 1st accelerometer, mounted on waist)
- x2 (contains the read value of the axis 'x' of the 2nd accelerometer, mounted on the left thigh)
- y2 (contains the read value of the axis 'y' of the 2nd accelerometer, mounted on the left thigh)
- z2 (contains the read value of the axis 'z' of the 2nd accelerometer, mounted on the left thigh)
- x3 (contains the read value of the axis 'x' of the 3rd accelerometer, mounted on the right ankle)
- y3 (contains the read value of the axis 'y' of the 3rd accelerometer, mounted on the right ankle)
- z3 (contains the read value of the axis 'z' of the 3rd accelerometer, mounted on the right ankle)
- x4 (contains the read value of the axis 'x' of the 4th accelerometer, mounted on the right upper-arm)
- y4 (contains the read value of the axis 'y' of the 4th accelerometer, mounted on the right upper-arm)
- z4 (contains the read value of the axis 'z' of the 4th accelerometer, mounted on the right upper-arm)

The features that I omitted from analysis (because I evaluated them as not useful for classification task) are as follows:

- subject name (text)
- subject gender (text)
- subject age (integer)
- subject height in meters (real number)
- subject weight (integer)
- subject BMI (real number)

The dataset has 165,632 cases and 5 classes, thus proportioned:

sitting	50631
standing	47370
walking	43390
standing-up	12415
sitting-down	11827

These classes refer to the position/activity of the human body. For the purposes of this assignment, I retained only the three largest classes: [CL1 (sitting): 50631 cases, CL2 (standing): 47370 cases, CL3 (walking): 43390 cases]

This gave me a total of 141,391 cases, all of which I kept for my analysis. Though this dataset is considerably larger than the size required, I wanted the experience and challenge of working with a large dataset.

Feature Statistics:

feature	CL1 mean	CL1 std	CL2 mean	CL2 std	CL3 mean	CL3 std
x1	-7.14	12.75	-6.49	4.78	-7.91	14.2
y1	65.99	25.3	97.75	5.06	100.89	20.99
z1	-49.53	25.04	-106.78	21.04	-115.45	19.97
x2	-58.92	90.53	-18.57	108.41	-191.4	231.27
y2	-55.17	116.25	53.83	128.36	-153.77	285.42
z2	-87.2	134.36	-144.93	106.41	-311.59	239.26
x3	23.4	42.22	23	20.45	13.81	62.84
y3	88.48	23.42	108.12	27.01	132.44	51.78
z3	-95.39	21.21	-87.98	23.96	-96.48	48.86
x4	-131.73	32.12	-178.18	17.63	-185.84	24.56
y4	-109.84	18.01	-85.32	10.84	-79.63	17.64
z4	-161.98	12.01	-157.32	7.11	-166.26	11.82

I centered and scaled the data, then split into test and training sets:
- Size of training set: 113112
- Size of test set: 28279
- Class ratios in test set: CL1(sitting): 0.36, CL2(standing): 0.33, CL3(walking): 0.31

Please Note: In all of the confusion matrices shown below with class 0 and class 1, class 0 is the first class referenced in the bold section title, and class 1 is the second class referenced.

Question 2: SVM classification by radial kernel: CL1 vs CL2
See code document for all code. Output displayed below.

```
Best parameters from list of options: {'SVM__C': 25, 'SVM__gamma': 0.01}
Number of support vectors in training set: 91
Ratio of support vectors in training set = 0.001
Test set accuracy = 1.000
Training set accuracy = 1.000
Test Set Confusion Matrix:
       0     1
0  10115     1
1      0  9485
Training Set Confusion Matrix:
       0      1
0  40516      0
1      0  37884
Test Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Training Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Test Set Confusion Matrix by 95% CI:
            0           1
0  (1.0, 1.0)  (0.0, 0.0)
1  (0.0, 0.0)  (1.0, 1.0)
Training Set Confusion Matrix by 95% CI:
            0           1
0  (1.0, 1.0)  (0.0, 0.0)
1  (0.0, 0.0)  (1.0, 1.0)
95 percent CI for test set performance: 1.000, 1.000
95 percent CI for training set performance: 1.000, 1.000

Time: 779.404 seconds.
```

Interpretation:
This SVM performed incredibly well on both test and training set! The 95% confidence interval of these performances is shown above. There were only 91 support vectors in the training set, which represents about .001% of the training set. Performance accuracy is 100% for the training set, while performance accuracy for the test set is also virtually 100%, with only 1 erroneous classification out of the entire test set of 28,279 cases. There is only a minuscule difference in performance between test and training sets. It is evident that CL1 and CL2 are very well separated by this SVM. While such high accuracy may arouse skepticism, we must note the distinction between the classes 'sitting' and 'standing.' We can surmise that these activities are indeed distinct enough to be truly well-separable.

Parameter tuning: Out of the list of cost parameters: [.1,1,5,25], this SVM found best cost of 25. And out of the list of gamma parameters: [.01,.1,.5,1], this SVM found the best gamma to be .01.

Re-evaluation of tuning, CL1 vs CL3:
See code document for all code. Output displayed below:

```
Best parameters from list of options: {'SVM__C': 5, 'SVM__gamma': 0.1}
Number of support vectors in training set: 550
Ratio of support vectors in training set = 0.007
Test set accuracy = 1.000
Training set accuracy = 1.000
Test Set Confusion Matrix:
       0     1
0  10152     1
1      2  8650
Training Set Confusion Matrix:
       0      1
0  40477      0
1      0  34739
Test Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Training Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Test Set Confusion Matrix by 95% CI:
            0            1
0  (1.0, 1.0)  (-0.0, 0.0)
1  (0.0, 0.0)   (1.0, 1.0)
Training Set Confusion Matrix by 95% CI:
            0           1
0  (1.0, 1.0)  (0.0, 0.0)
1  (0.0, 0.0)  (1.0, 1.0)
95 percent CI for test set performance: 1.000, 1.000
95 percent CI for training set performance: 1.000, 1.000

Time: 2637.981 seconds.
```

Interpretation:

This SVM also performed incredibly well on both test and training set! The 95% confidence interval of these performances is shown above. There were only 550 support vectors in the training set, which represents .007% of all cases in the training set. Performance accuracy is 100% for the training set, while performance accuracy for the test set is also virtually 100%, with only 3 erroneous classification out of the entire test set of 28,279 cases. There is only a minuscule difference in performance between test and training sets. It is evident that CL1 and CL3 are very well separated by this SVM. While such high accuracy may arouse skepticism, we must note the distinction between the classes 'sitting' and 'walking.' We can surmise that these activities are indeed distinct enough to be truly well-separable.

Parameter tuning: Out of the list of cost parameters: [.1,1,5,25], this SVM found best cost of 5. And out of the list of gamma parameters: [.01,.1,.5,1], this SVM found the best gamma to be .1. Since these 'best' parameters are different than the best parameters found previously, we proceed by specifying the best parameters for radial kernel as the average of these 'best' parameters.

Question 3 : for the largest 3 classes CL1 CL2 CL3 , compute 3 SVMs with best parameters from above:
See code document for all code. Output displayed below:
SVM1 to classify CL1 vs (not CL1) - using radial kernel

```
Number of support vectors in training set: 272
Ratio of support vectors in training set = 0.002
Test set prediction accuracy = 1.000
Training set prediction accuracy = 1.000
Test Set Confusion Matrix:
       0      1
0  10123      0
1      2  18154
Training Set Confusion Matrix:
       0      1
0  40506      0
1      0  72606
Test Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Training Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Test Set Confusion Matrix by 95% CI:
            0           1
0  (1.0, 1.0)  (0.0, 0.0)
1  (0.0, 0.0)  (1.0, 1.0)
Training Set Confusion Matrix by 95% CI:
            0           1
0  (1.0, 1.0)  (0.0, 0.0)
1  (0.0, 0.0)  (1.0, 1.0)
95 percent CI for test set performance: 1.000, 1.000
95 percent CI for training set performance: 1.000, 1.000

Time: 3.587 seconds.
```

Interpretation:
Once again, there is only a minuscule difference in performance between test and training sets. The 95% confidence interval of these performances is shown above, which tells us that we can be confident in the incredibly high accuracy. It is evident that CL1 and (not CL1) are very well separated by this SVM. While such high accuracy may arouse skepticism, I think skepticism would be misplaced here—because there truly is a well-well-separated difference between the activities of sitting and (standing or walking). Remarkably, it only took 3.6 seconds to perform these computations, which further indicates the well-separability of CL1 from the other classes.

SVM2 to classify CL2 vs (not CL2) - using radial kernel

```
Number of support vectors in training set: 3355
Ratio of support vectors in training set = 0.030
Test set prediction accuracy = 0.993
Training set prediction accuracy = 0.994
Test Set Confusion Matrix:
      0     1
0  9355   162
1    24 18738
Training Set Confusion Matrix:
       0     1
0  37883   591
1    108 74530
Test Set Confusion Matrix by %:
       0     1
0  0.983  0.017
1  0.001  0.999
Training Set Confusion Matrix by %:
       0     1
0  0.985  0.015
1  0.001  0.999
Test Set Confusion Matrix by 95% CI:
                0               1
0  (0.982, 0.984)  (0.016, 0.018)
1  (0.001, 0.002)  (0.998, 0.999)
Training Set Confusion Matrix by 95% CI:
                0               1
0  (0.984, 0.986)  (0.014, 0.016)
1  (0.001, 0.002)  (0.998, 0.999)
95 percent CI for test set performance: 0.993, 0.994
95 percent CI for training set performance: 0.993, 0.994

Time: 41.062 seconds.
```

Interpretation:

Once again, there is only a minuscule difference in performance between test and training sets. The 95% confidence interval of these performances is shown above, which tells us that we can be 95% confident that the accuracy is between 99.3% and 99.4%, which is very high accuracy. It is evident that CL2 and (not CL2) are very well separated by this SVM, though marginally less so than SVM1 for CL1 vs. (not CL1), which suggests that it is marginally more difficult to separate the activities of standing vs. (sitting or walking), given this particular dataset. At 41 seconds, it also took the longer to perform the computations for SVM2 than it did for the SVM1 with radial kernel, which suggests the increased difficulty of doing so.

SVM3 to classify CL3 vs (not CL3) - using radial kernel

```
Number of support vectors in training set: 3758
Ratio of support vectors in training set = 0.033
Test set prediction accuracy = 0.993
Training set prediction accuracy = 0.993
Test Set Confusion Matrix:
      0      1
0  8598     26
1   177  19478
Training Set Confusion Matrix:
       0      1
0  33949    107
1    666  78390
Test Set Confusion Matrix by %:
       0      1
0  0.997  0.003
1  0.009  0.991
Training Set Confusion Matrix by %:
       0      1
0  0.997  0.003
1  0.008  0.992
Test Set Confusion Matrix by 95% CI:
                0               1
0  (0.997, 0.997)  (0.003, 0.003)
1   (0.008, 0.01)   (0.99, 0.992)
Training Set Confusion Matrix by 95% CI:
                0               1
0  (0.996, 0.997)  (0.003, 0.004)
1  (0.008, 0.009)  (0.991, 0.992)
95 percent CI for test set performance: 0.992, 0.994
95 percent CI for training set performance: 0.992, 0.994

Time: 50.184 seconds.
```

Interpretation:
Once again, there is only a minuscule difference in performance between test and training sets. The 95% confidence interval of these performances is shown above, which tells us that we can be 95% confident that the accuracy is between 99.2% and 99.4%, which is very high accuracy. It is evident that CL3 and (not CL3) are very well separated by this SVM3, though marginally less so than SVM1 for CL1 vs. (not CL1), which suggests that it is marginally more difficult to separate the activities of walking vs. (sitting or standing), given this particular dataset. At 50 seconds, it also took the longer to perform the computations for SVM3 than it did for the SVMs with radial kernel, suggesting the greater difficulty of doing so. Moreover, the performance of SVM3 and SVM2 are very similar for the radial kernel. The results of these 3 SVMs suggest that ‘sitting’ is the class which is easiest to separate from the others.

Question 4 : for the largest 3 classes CL1 CL2 CL3 , combine the three SVMs to classify all cases

```
Confusion Matrix for Radial Kernel Training Set:

Predicted    1      2      3
True
1          1.0  0.000  0.000
2          0.0  0.997  0.003
3          0.0  0.014  0.984

Time: 8.704 seconds.
```

```
Confusion Matrix for Radial Kernel Test Set:

Predicted    1      2      3
True
1          1.0  0.000  0.000
2          0.0  0.997  0.003
3          0.0  0.016  0.983

Time: 2.306 seconds.
```

Interpretation:

I combined the results of the 3 SVMs by implementing the weighted majority voting system, as outlined in the lectures. Each case *x* was classified by SVM1 as either in CL1 or not in CL1; classified by SVM2 as either in CL2 or not in CL2; and classified by SVM3 as either in CL3 or not in CL3. Each of these decisions was multiplied by the accuracy of classification, as given by the diagonal of the confusion matrixes. Without loss of generality, when *x* was classified by SVM1 as not being in CL1, the vote for both CL2 and CL3 was the accuracy of (not CL1) from the confusion matrix, divided by two. The total votes were summed for each *x*, with the decision of class for each *x* given by the class who had the most votes in the end. An snapshot of the process is shown below:

```
SVM1  SVM2  SVM3  SVM1_reli_sit  SVM1_reli_stand  SVM1_reli_walk  \
23.0  13.0   3.0              0              0.5             0.5
23.0   2.0  12.0              0              0.5             0.5
23.0   2.0  12.0              0              0.5             0.5
23.0  13.0   3.0              0              0.5             0.5
 1.0  13.0  12.0              1              0.0             0.0
 1.0  13.0  12.0              1              0.0             0.0
 1.0  13.0  12.0              1              0.0             0.0
23.0   2.0  12.0              0              0.5             0.5
23.0   2.0  12.0              0              0.5             0.5
 1.0  13.0  12.0              1              0.0             0.0

SVM2_reli_sit  SVM2_reli_stand  SVM2_reli_walk  SVM3_reli_sit  \
       0.4995            0.000          0.4995         0.0000
       1.0000            0.983          0.0000         0.4955
       1.0000            0.983          0.0000         0.4955
       0.4995            0.000          0.4995         0.0000
       0.4995            0.000          0.4995         0.4955
       0.4995            0.000          0.4995         0.4955
       0.4995            0.000          0.4995         0.4955
       1.0000            0.983          0.0000         0.4955
       1.0000            0.983          0.0000         0.4955
       0.4995            0.000          0.4995         0.4955

SVM3_reli_stand  SVM3_reli_walk  score_sit  score_stand  score_walk  \
         0.0000           0.997     0.4995       0.5000      1.9965
         0.4955           0.000     1.4955       1.9785      0.5000
         0.4955           0.000     1.4955       1.9785      0.5000
         0.0000           0.997     0.4995       0.5000      1.9965
         0.4955           0.000     1.9950       0.4955      0.4995
         0.4955           0.000     1.9950       0.4955      0.4995
         0.4955           0.000     1.9950       0.4955      0.4995
         0.4955           0.000     1.4955       1.9785      0.5000
         0.4955           0.000     1.4955       1.9785      0.5000
         0.4955           0.000     1.9950       0.4955      0.4995

class_decision  true_class
             3           3
             2           2
             2           2
             3           3
             1           1
             1           1
             1           1
             2           2
             2           2
             1           1
```

Furthermore, the two confusion matrixes above are virtually identical. They suggest that CL1 is easiest to classify correctly. CL2 is the class with the next-highest accuracy, followed by CL3. Accuracy of classification is above 98% in all cases, which is very good. Moreover, we can see that the most mistakes were classifying cases in CL3 (walking) into CL2(standing).

Question 5: Repeat the whole preceding procedure using the polynomial kernel
First, we tune cost parameter for classification CL1 vs. CL2

```
Best parameters from list of options: {'SVM__C': 1, 'SVM__coef0': 1}
Number of support vectors in training set: 118
Ratio of support vectors in training set = 0.002
Test set accuracy = 1.000
Training set accuracy = 1.000
Test Set Confusion Matrix:
       0     1
0  10115     0
1      0  9486
Training Set Confusion Matrix:
       0      1
0  40516      1
1      0  37883
Test Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Training Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Test Set Confusion Matrix by 95% CI:
            0           1
0  (1.0, 1.0)  (0.0, 0.0)
1  (0.0, 0.0)  (1.0, 1.0)
Training Set Confusion Matrix by 95% CI:
            0            1
0  (1.0, 1.0)  (-0.0, 0.0)
1  (0.0, 0.0)   (1.0, 1.0)
95 percent CI for test set performance: 1.000, 1.000
95 percent CI for training set performance: 1.000, 1.000

Time: 21.81 seconds.
```

Interpretation:
This SVM performed incredibly well on both test and training set! The 95% confidence interval of these performances is shown above. There were only 118 support vectors in the training set, which represents about .002% of the training set. Performance accuracy is 100% for the test set, while performance accuracy for the training set is also virtually 100%. There is only a minuscule difference in performance between test and training sets. It is evident that CL1 and CL2 are very well separated by this SVM.

Parameter tuning: Out of the list of cost parameters: [.1,1,5,25], this SVM found best cost of 1.

Re-evaluation of tuning cost parameter for classification CL1 vs. CL3

```
Best parameters from list of options: {'SVM__C': 1, 'SVM__coef0': 1}
Number of support vectors in training set: 150
Ratio of support vectors in training set = 0.002
Test set accuracy = 1.000
Training set accuracy = 1.000
Test Set Confusion Matrix:
       0     1
0  10154     1
1      0  8650
Training Set Confusion Matrix:
       0      1
0  40477      0
1      0  34739
Test Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Training Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Test Set Confusion Matrix by 95% CI:
            0            1
0  (1.0, 1.0)  (-0.0, 0.0)
1  (0.0, 0.0)   (1.0, 1.0)
Training Set Confusion Matrix by 95% CI:
            0           1
0  (1.0, 1.0)  (0.0, 0.0)
1  (0.0, 0.0)  (1.0, 1.0)
95 percent CI for test set performance: 1.000, 1.000
95 percent CI for training set performance: 1.000, 1.000

Time: 29.634 seconds.
```

Interpretation:
This SVM performed incredibly well on both test and training set! The 95% confidence interval of these performances is shown above. There were only 150 support vectors in the training set, which represents about .002% of the training set. Performance accuracy is 100% for the test set, while performance accuracy for the training set is also virtually 100%. There is only a minuscule difference in performance between test and training sets. It is evident that CL1 and CL3 are very well separated by this SVM.

Parameter tuning: Out of the list of cost parameters: [.1,1,5,25], this SVM found best cost of 1. Since both of the above polynomial kernel SVMs found the best cost parameter to be 1, we proceed with best cost =1.

SVM1 to classify CL1 vs (not CL1) - using polynomial kernel
See code document for all code. Output displayed below:

```
Number of support vectors in training set: 178
Ratio of support vectors in training set = 0.002
Test set prediction accuracy = 1.000
Training set prediction accuracy = 1.000
Test Set Confusion Matrix:
       0      1
0  10125      1
1      0  18153
Training Set Confusion Matrix:
       0      1
0  40506      0
1      0  72606
Test Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Training Set Confusion Matrix by %:
     0    1
0  1.0  0.0
1  0.0  1.0
Test Set Confusion Matrix by 95% CI:
            0           1
0  (1.0, 1.0)  (0.0, 0.0)
1  (0.0, 0.0)  (1.0, 1.0)
Training Set Confusion Matrix by 95% CI:
            0           1
0  (1.0, 1.0)  (0.0, 0.0)
1  (0.0, 0.0)  (1.0, 1.0)
95 percent CI for test set performance: 1.000, 1.000
95 percent CI for training set performance: 1.000, 1.000

Time: 2.136 seconds.
```

Interpretation:
There is only a minuscule difference in performance between test and training sets. The 95% confidence interval of these performances is shown above, which tells us that we can be 95% confident that the accuracy is between 100%. It is evident that CL1 and (not CL1) are well separated by this SVM1, which is consistent with the other SVMs for the radial kernel and all of our previous findings. Remarkably, it only took 2 seconds to perform these computations, which further indicates the well-separability of CL1 from the other classes.

SVM2 to classify CL2 vs (not CL2) - using polynomial kernel

```
Number of support vectors in training set: 7628
Ratio of support vectors in training set = 0.067
Test set prediction accuracy = 0.985
Training set prediction accuracy = 0.985
Test Set Confusion Matrix:
      0      1
0  9316    369
1    63  18531
Training Set Confusion Matrix:
       0      1
0  37706   1445
1    285  73676
Test Set Confusion Matrix by %:
       0      1
0  0.962  0.038
1  0.003  0.997
Training Set Confusion Matrix by %:
       0      1
0  0.963  0.037
1  0.004  0.996
Test Set Confusion Matrix by 95% CI:
                0               1
0   (0.96, 0.963)   (0.037, 0.04)
1  (0.003, 0.004)  (0.996, 0.997)
Training Set Confusion Matrix by 95% CI:
                0               1
0  (0.962, 0.965)  (0.035, 0.038)
1  (0.003, 0.004)  (0.996, 0.997)
95 percent CI for test set performance: 0.984, 0.986
95 percent CI for training set performance: 0.984, 0.986

Time: 57.253 seconds.
```

Interpretation:

There is only a minuscule difference in performance between test and training sets. The 95% confidence interval of these performances is shown above, which tells us that we can be 95% confident that the accuracy is between 98.4% and 98.6%, which is very high accuracy, albeit less than our other SVMs for this dataset and less than the polynomial SVM. It is evident that CL2 and (not CL2) are well separated by this SVM2, though marginally less so than SVM1 for CL1 vs. (not CL1), which is consistent with the other SVMs for the radial kernel. At 57 seconds, it also took the longer to perform the computations for SVM2 than it did for SVM1 with polynomial kernel.

SVM3 to classify CL3 vs (not CL3) - using polynomial kernel

```
Number of support vectors in training set: 9411
Ratio of support vectors in training set = 0.083
Test set prediction accuracy = 0.978
Training set prediction accuracy = 0.978
Test Set Confusion Matrix:
      0      1
0  8233     72
1   542  19432
Training Set Confusion Matrix:
       0      1
0  32471    325
1   2144  78172
Test Set Confusion Matrix by %:
       0      1
0  0.991  0.009
1  0.027  0.973
Training Set Confusion Matrix by %:
       0      1
0  0.990  0.010
1  0.027  0.973
Test Set Confusion Matrix by 95% CI:
                0               1
0  (0.991, 0.992)  (0.008, 0.009)
1  (0.026, 0.028)  (0.972, 0.974)
Training Set Confusion Matrix by 95% CI:
                0               1
0  (0.989, 0.991)  (0.009, 0.011)
1  (0.025, 0.028)  (0.972, 0.975)
95 percent CI for test set performance: 0.977, 0.979
95 percent CI for training set performance: 0.977, 0.979

Time: 75.314 seconds.
```

Interpretation:
Once again, there is only a minuscule difference in performance between test and training sets. The 95% confidence interval of these performances is shown above, which tells us that we can be 95% confident that the accuracy is between 97.7% and 97.9%, which is high accuracy, but the lowest accuracy in the context of all the other SVMs for this dataset. CL3 and (not CL3) are nonetheless well-separated by this SVM3, though less so than SVM1 for CL1 vs. (not CL1) and SVM2, which suggests that it is more difficult to separate the activities of walking vs. (sitting or standing), given this particular dataset. Moreover, while the performance of SVM3 and SVM2 were very similar for the radial kernel, there is a larger difference in performance for the polynomial kernel. The results of these 3 SVMs suggest that 'sitting' is the class which is easiest to separate from the others, followed by 'standing', followed by 'walking.' At 75 seconds, it also took the longer to perform the computations for SVM3 than it did for the other SVMs with polynomial kernel.

For the largest 3 classes CL1 CL2 CL3 , combine the three Polynomial SVMs to classify all cases

See code document for all code. Output displayed below:

```
Confusion Matrix for Polynomial Kernel Training Set:

Predicted    1      2      3
True
1          1.0  0.000  0.000
2          0.0  0.990  0.011
3          0.0  0.034  0.963

Time: 8.652 seconds.
```

```
Confusion Matrix for Polynomial Kernel Test Set:

Predicted    1      2      3
True
1          1.0  0.000  0.000
2          0.0  0.991  0.009
3          0.0  0.036  0.962

Time: 2.288 seconds.
```

These results were obtained in the same was as described in Question 4 above. As with the radial kernel, the two confusion matrixes that combine the results of the 3 SVMs above are virtually identical. They suggest that CL1 is easiest to classify correctly. CL2 is the class with the next-highest accuracy, followed by CL3. Accuracy of classification is above 96% in all cases, which is rather good. Moreover, we can see that the most mistakes were classifying cases in CL3 (walking) into CL2(standing).

These performance results are slightly less good as when we used the radial kernel, where the accuracy was no less than 98%. The combined radial kernel results shown above are shown once again here, for reference.

```
Confusion Matrix for Radial Kernel Training Set:

Predicted    1      2      3
True
1          1.0  0.000  0.000
2          0.0  0.997  0.003
3          0.0  0.014  0.984

Time: 8.704 seconds.
```

```
Confusion Matrix for Radial Kernel Test Set:

Predicted    1      2      3
True
1          1.0  0.000  0.000
2          0.0  0.997  0.003
3          0.0  0.016  0.983

Time: 2.306 seconds.
```

We can see that the differences are small, and that with both radial and polynomial kernel, CL1 is easiest to classify correctly, followed by CL2, followed by CL3. The polynomial kernel SVMs are as accurate as the radial SVMs when it comes to correctly classifying CL1, but the performance decreases from about 99.7% to about 99.0% for CL2 and from about 98% to 96% for CL3. This indicates that we'd want to use a radial kernel SVM to separate the classes in this dataset, because it gives us the best results.

We can conclude that Human Activity Recognition is promising for SVM classification. The original study from which this data set came ended up with 99.4% classification accuracy—which is roughly equivalent to the overall accuracy that I was able to reproduce in this analysis.

See links below for data source:

http://groupware.les.inf.puc-rio.br/har#dataset

"Wearable Computing: Classification of Body Postures and Movements (PUC-Rio) Data Set"
https://archive.ics.uci.edu/ml/datasets/Wearable+Computing%3A+Classification+of+Body+Postures+and+Movements+%28PUC-Rio%29#