ass4

November 1, 2019

0.1 Assignment 4

0.1.1 Question 2] Coding: Classification with the decision tree model

Write a self-contained and fully functional Jupyter Notebook that:

0.1.2 a) Loads the necessary libraries to run (e.g., scikit-learn)

[281]:
```
import matplotlib.pyplot as plt
from sklearn.datasets import load_digits
from sklearn.tree import DecisionTreeClassifier
import numpy as np
from sklearn import tree
from sklearn.model_selection import KFold
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score
from sklearn import svm
from sklearn.svm import SVC
from sklearn.neighbors import KNeighborsClassifier
from sklearn.model_selection import cross_val_score
```

0.1.3 b) Loads the dataset "digits" (see below for description) from the scikit-learn example datasets package.

digits is a dataset of a hadnwritten digits. Each feature is the intensity of one pixel of an 8x8 image

[284]:
```
# loads digits dataset
digits = load_digits()
#print(digits)

# create feature matrix
x = digits.data

# create target vector - what we are going to predict
y = digits.target
digits.target_names

# view the first observation's feature values
```

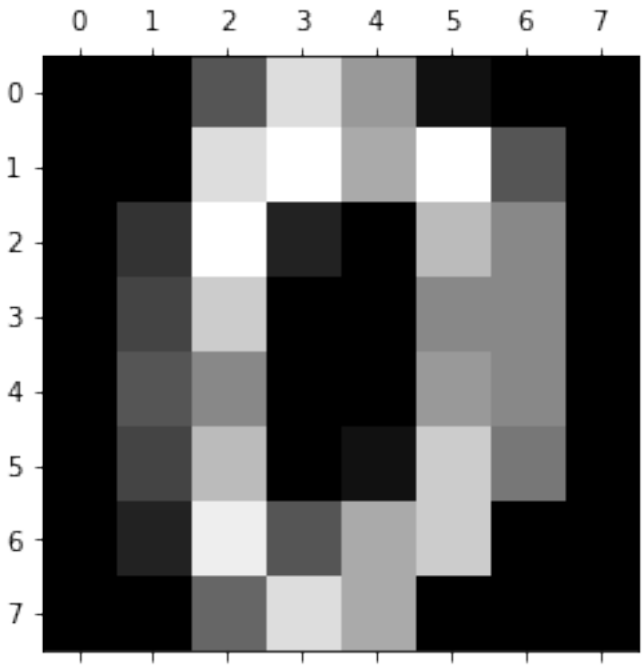
```
x[0]

# view the first observation's feature values as matrix
digits.images[0]
```

[284]:
```
array([[ 0.,  0.,  5., 13.,  9.,  1.,  0.,  0.],
       [ 0.,  0., 13., 15., 10., 15.,  5.,  0.],
       [ 0.,  3., 15.,  2.,  0., 11.,  8.,  0.],
       [ 0.,  4., 12.,  0.,  0.,  8.,  8.,  0.],
       [ 0.,  5.,  8.,  0.,  0.,  9.,  8.,  0.],
       [ 0.,  4., 11.,  0.,  1., 12.,  7.,  0.],
       [ 0.,  2., 14.,  5., 10., 12.,  0.,  0.],
       [ 0.,  0.,  6., 13., 10.,  0.,  0.,  0.]])
```

[285]:
```
#visualize the observation's feature values as image
plt.gray()
plt.matshow(digits.images[0])
plt.show()
```

```
<Figure size 432x288 with 0 Axes>
```



0.1.4 c) Instantiates a sklearn.tree.DecisionTreeClassifier.

[286]:
```
#class sklearn.tree.DecisionTreeClassifier(criterion=gini, splitter=best,␣
↪max_depth=None, min_samples_split=2, min_samples_leaf=1,␣
↪min_weight_fraction_leaf=0.0, max_features=None, random_state=None,␣
↪max_leaf_nodes=None, min_impurity_decrease=0.0, min_impurity_split=None,␣
↪class_weight=None, presort=False)[source]ű

clf = tree.DecisionTreeClassifier(random_state = 1)
clf = clf.fit(digits.data, digits.target)
```

[287]:
```
decision_tree = DecisionTreeClassifier()
print(decision_tree )
```

```
DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=None,
                       max_features=None, max_leaf_nodes=None,
                       min_impurity_decrease=0.0, min_impurity_split=None,
                       min_samples_leaf=1, min_samples_split=2,
                       min_weight_fraction_leaf=0.0, presort=False,
                       random_state=None, splitter='best')
```

0.1.5 d) Splits the dataset in training and testing sets using sklearn.model_selection.KFold cross validation (use K = 5).

[288]:
```
kfold = KFold(n_splits=5)
kfold.get_n_splits(digits)
print(kf)
```

```
<generator object _BaseKFold.split at 0x000001932EA382A0>
```

0.1.6 e) Trains and tests the performance of the classifier in identifying the digits.

[289]:
```
for train_index, test_index in kfold.split(x):
    print('Train: %s, Test: %s' % (train_index, test_index))
    x_train, x_test = x[train_index], x[test_index]
    y_train, y_test = y[train_index], y[test_index]
```

```
Train: [ 360  361  362 ... 1794 1795 1796], Test: [  0   1   2   3   4   5   6
7   8   9  10  11  12  13  14  15  16  17
  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35
  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53
  54  55  56  57  58  59  60  61  62  63  64  65  66  67  68  69  70  71
  72  73  74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89
  90  91  92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107
 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125
 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143
 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161
```

```
 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179
 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197
 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215
 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233
 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251
 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269
 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287
 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305
 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323
 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341
 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359]
Train: [   0    1    2 ... 1794 1795 1796], Test: [360 361 362 363 364 365 366
367 368 369 370 371 372 373 374 375 376 377
 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395
 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413
 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431
 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449
 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467
 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485
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 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539
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 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575
 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593
 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611
 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629
 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647
 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665
 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683
 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701
 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719]
Train: [   0    1    2 ... 1794 1795 1796], Test: [ 720  721  722  723  724  725
726  727  728  729  730  731  732  733
  734  735  736  737  738  739  740  741  742  743  744  745  746  747
  748  749  750  751  752  753  754  755  756  757  758  759  760  761
  762  763  764  765  766  767  768  769  770  771  772  773  774  775
  776  777  778  779  780  781  782  783  784  785  786  787  788  789
  790  791  792  793  794  795  796  797  798  799  800  801  802  803
  804  805  806  807  808  809  810  811  812  813  814  815  816  817
  818  819  820  821  822  823  824  825  826  827  828  829  830  831
  832  833  834  835  836  837  838  839  840  841  842  843  844  845
  846  847  848  849  850  851  852  853  854  855  856  857  858  859
  860  861  862  863  864  865  866  867  868  869  870  871  872  873
  874  875  876  877  878  879  880  881  882  883  884  885  886  887
  888  889  890  891  892  893  894  895  896  897  898  899  900  901
  902  903  904  905  906  907  908  909  910  911  912  913  914  915
  916  917  918  919  920  921  922  923  924  925  926  927  928  929
```

```
  930  931  932  933  934  935  936  937  938  939  940  941  942  943
  944  945  946  947  948  949  950  951  952  953  954  955  956  957
  958  959  960  961  962  963  964  965  966  967  968  969  970  971
  972  973  974  975  976  977  978  979  980  981  982  983  984  985
  986  987  988  989  990  991  992  993  994  995  996  997  998  999
 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013
 1014 1015 1016 1017 1018 1019 1020 1021 1022 1023 1024 1025 1026 1027
 1028 1029 1030 1031 1032 1033 1034 1035 1036 1037 1038 1039 1040 1041
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 1056 1057 1058 1059 1060 1061 1062 1063 1064 1065 1066 1067 1068 1069
 1070 1071 1072 1073 1074 1075 1076 1077 1078]
Train: [   0    1    2 ... 1794 1795 1796], Test: [1079 1080 1081 1082 1083 1084
1085 1086 1087 1088 1089 1090 1091 1092
 1093 1094 1095 1096 1097 1098 1099 1100 1101 1102 1103 1104 1105 1106
 1107 1108 1109 1110 1111 1112 1113 1114 1115 1116 1117 1118 1119 1120
 1121 1122 1123 1124 1125 1126 1127 1128 1129 1130 1131 1132 1133 1134
 1135 1136 1137 1138 1139 1140 1141 1142 1143 1144 1145 1146 1147 1148
 1149 1150 1151 1152 1153 1154 1155 1156 1157 1158 1159 1160 1161 1162
 1163 1164 1165 1166 1167 1168 1169 1170 1171 1172 1173 1174 1175 1176
 1177 1178 1179 1180 1181 1182 1183 1184 1185 1186 1187 1188 1189 1190
 1191 1192 1193 1194 1195 1196 1197 1198 1199 1200 1201 1202 1203 1204
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 1359 1360 1361 1362 1363 1364 1365 1366 1367 1368 1369 1370 1371 1372
 1373 1374 1375 1376 1377 1378 1379 1380 1381 1382 1383 1384 1385 1386
 1387 1388 1389 1390 1391 1392 1393 1394 1395 1396 1397 1398 1399 1400
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 1415 1416 1417 1418 1419 1420 1421 1422 1423 1424 1425 1426 1427 1428
 1429 1430 1431 1432 1433 1434 1435 1436 1437]
Train: [   0    1    2 ... 1435 1436 1437], Test: [1438 1439 1440 1441 1442 1443
1444 1445 1446 1447 1448 1449 1450 1451
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1564 1565 1566 1567 1568 1569 1570 1571 1572 1573 1574 1575 1576 1577
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1592 1593 1594 1595 1596 1597 1598 1599 1600 1601 1602 1603 1604 1605
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1620 1621 1622 1623 1624 1625 1626 1627 1628 1629 1630 1631 1632 1633
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1676 1677 1678 1679 1680 1681 1682 1683 1684 1685 1686 1687 1688 1689
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1718 1719 1720 1721 1722 1723 1724 1725 1726 1727 1728 1729 1730 1731
1732 1733 1734 1735 1736 1737 1738 1739 1740 1741 1742 1743 1744 1745
1746 1747 1748 1749 1750 1751 1752 1753 1754 1755 1756 1757 1758 1759
1760 1761 1762 1763 1764 1765 1766 1767 1768 1769 1770 1771 1772 1773
1774 1775 1776 1777 1778 1779 1780 1781 1782 1783 1784 1785 1786 1787
1788 1789 1790 1791 1792 1793 1794 1795 1796]
```

[290]:
```python
# simulate splitting a dataset of 20 observations into 5 folds

kf = KFold(n_splits=5, shuffle=False).split(range(5))
# print the contents of each training and testing set
print('{} {:^14} {}'.format('Iteration', 'Training', 'Testing '))
for iteration, data in enumerate(kf, start=1):
    print('{:^10} {} {:^22}'.format(iteration, data[0], str(data[1])))
```

```
Iteration    Training    Testing
    1      [1 2 3 4]          [0]
    2      [0 2 3 4]          [1]
    3      [0 1 3 4]          [2]
    4      [0 1 2 4]          [3]
    5      [0 1 2 3]          [4]
```

0.1.7 f) Computes and outputs the accuracy for each of the K folds of cross validation.

[291]:
```python
avg_accuracy = 0
for train_index, test_index in kfold.split(x):
    #print('Train: %s, Test: %s' % (train_index, test_index))
    x_train, x_test = x[train_index], x[test_index]
    y_train, y_test = y[train_index], y[test_index]

    count = 0
    #clf = tree.DecisionTreeClassifier(random_state = 1)
    clf = clf.fit(x_train, y_train)
    predict = clf.predict (x_test)

    for i in range (0, len(predict)):
```

```
        if predict[i] == y_test[i]:
            count +=1
    accuracy = count/len(predict)
    print("accuracy for the K folds of cross validation:", accuracy)
```

```
accuracy for the K folds of cross validation: 0.7583333333333333
accuracy for the K folds of cross validation: 0.7416666666666667
accuracy for the K folds of cross validation: 0.8161559888579387
accuracy for the K folds of cross validation: 0.8495821727019499
accuracy for the K folds of cross validation: 0.8022284122562674
```

[292]:
```
Accuracy_score = cross_val_score(KNeighborsClassifier(n_neighbors=5), x, y,␣
 ↪cv=5, scoring='accuracy')
print(Accuracy_score )
```

```
[0.9478022  0.9558011  0.96657382 0.98039216 0.96338028]
```

0.1.8 g) Computes and outputs the average accuracy across the K folds.

[300]:
```
    avg_accuracy  = (avg_accuracy  + accuracy)
Average = avg_accuracy  / 5
print("Average Accuracy:",Average)
```

```
Average Accuracy: 0.962674094707521
```

[294]:
```
# use average accuracy as an estimate of out-of-sample accuracy
print(Accuracy_score .mean())
```

```
0.9627899114966898
```

[295]:
```
Score = cross_val_score(clf, x_train, y_train, cv=5, scoring ='accuracy')
print("Avg accuracy:", accuracy)
print("Accuracy: %0.3f (+/- %0.3f)" %(Score.mean(), Score.std()*2))
```

```
Avg accuracy: 0.8022284122562674
Accuracy: 0.791 (+/- 0.073)
```

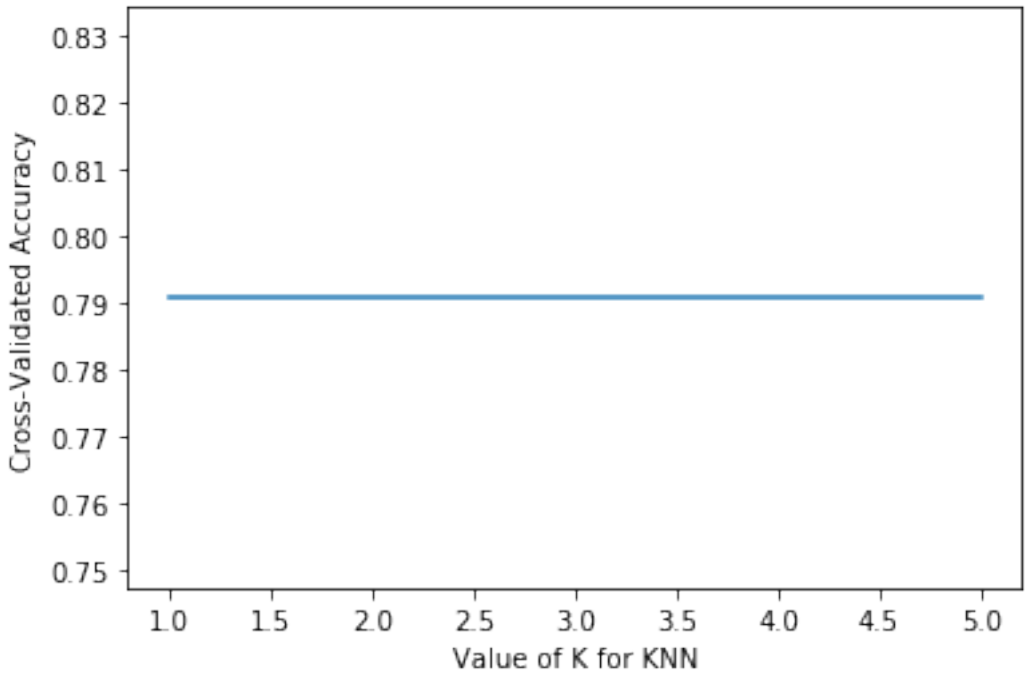
[301]:
```
k_range = list(range(1, 6))
k_scores = []
for k in k_range:
    knn = KNeighborsClassifier(n_neighbors=k)
    Score = cross_val_score(clf, x_train, y_train, cv=5, scoring ='accuracy')
    k_scores.append(Score.mean())
print(k_scores)
```

```
import matplotlib.pyplot as plt
%matplotlib inline

# plot the value of K for KNN (x-axis) versus the cross-validated accuracy␣
 ↪(y-axis)
plt.plot(k_range, k_scores)
plt.xlabel('Value of K for KNN')
plt.ylabel('Cross-Validated Accuracy')
```

```
[0.7909259704254555, 0.7909259704254555, 0.7909259704254555, 0.7909259704254555,
0.7909259704254555]
```

[301]:
```
Text(0, 0.5, 'Cross-Validated Accuracy')
```



0.1.9 Summary:

Commands: pip install scikit-learn or conda install scikit-learn

[ ]:

[ ]: