

ML-5

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1 Task-1

1) decision_tree.py pendigits_training pendigits_test optimized 50

```
tree= 1, node= 1, feature=15, thr= 21.57, gain=0.621424
tree= 1, node= 2, feature= 4, thr= 41.18, gain=0.587628
tree= 1, node= 3, feature=13, thr= 58.82, gain=0.697235
tree= 1, node= 4, feature= 9, thr= 15.69, gain=0.670083
tree= 1, node= 5, feature=10, thr= 39.22, gain=0.629044
tree= 1, node= 6, feature= 0, thr= 35.29, gain=0.712500
tree= 1, node= 7, feature= 8, thr= 56.86, gain=0.814218
tree= 1, node= 8, feature=14, thr= 60.78, gain=0.475710
tree= 1, node= 9, feature= 5, thr= 64.71, gain=0.620325
tree= 1, node=10, feature=14, thr= 37.25, gain=0.224713
tree= 1, node=11, feature= 3, thr= 90.20, gain=0.686759
tree= 1, node=12, feature=14, thr= 37.25, gain=0.281171
tree= 1, node=13, feature=10, thr= 29.41, gain=0.584898
tree= 1, node=14, feature=14, thr= 96.08, gain=0.737506
tree= 1, node=15, feature= 7, thr= 24.33, gain=0.205385
tree= 1, node=16, feature= 1, thr= 73.53, gain=0.027989
tree= 1, node=17, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=18, feature=15, thr= 0.41, gain=0.188928
tree= 1, node=19, feature= 9, thr= 60.47, gain=0.530651
tree= 1, node=20, feature=12, thr= 30.06, gain=0.640257
tree= 1, node=21, feature= 8, thr= 34.59, gain=0.140904
tree= 1, node=22, feature= 6, thr= 72.55, gain=0.509615
tree= 1, node=23, feature= 7, thr= 77.10, gain=0.409412
tree= 1, node=24, feature= 1, thr= 84.51, gain=0.550957
tree= 1, node=25, feature=13, thr= 14.78, gain=0.131381
tree= 1, node=26, feature=15, thr= 31.18, gain=0.222560
tree= 1, node=27, feature= 9, thr= 19.61, gain=0.464511
tree= 1, node=28, feature=11, thr= 31.67, gain=0.157508
tree= 1, node=29, feature=13, thr= 71.06, gain=0.344859
tree= 1, node=30, feature= 2, thr= 54.90, gain=0.092930
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tree= 1, node= 31, feature= 9, thr= 58.82, gain=0.918296
tree= 1, node= 32, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 33, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 34, feature= 7, thr= 66.47, gain=0.110097
tree= 1, node= 35, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 36, feature=14, thr= 25.49, gain=0.773333
tree= 1, node= 37, feature= 0, thr= 39.22, gain=0.203813
tree= 1, node= 38, feature= 3, thr= 96.71, gain=0.374672
tree= 1, node= 39, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 40, feature= 9, thr= 1.43, gain=0.077936
tree= 1, node= 41, feature= 6, thr= 68.14, gain=0.274080
tree= 1, node= 42, feature=14, thr= 96.08, gain=0.341335
tree= 1, node= 43, feature= 1, thr= 82.35, gain=0.324193
tree= 1, node= 44, feature= 2, thr= 88.59, gain=0.253482
tree= 1, node= 45, feature= 5, thr= 89.29, gain=0.811518
tree= 1, node= 46, feature= 8, thr= 76.47, gain=0.650022
tree= 1, node= 47, feature= 6, thr= 50.47, gain=0.757526
tree= 1, node= 48, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 49, feature= 3, thr= 87.45, gain=0.051386
tree= 1, node= 50, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 51, feature= 0, thr= 53.57, gain=0.129949
tree= 1, node= 52, feature=15, thr= 67.29, gain=0.265884
tree= 1, node= 53, feature=10, thr= 67.06, gain=0.773029
tree= 1, node= 54, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 55, feature=12, thr= 21.57, gain=0.159034
tree= 1, node= 56, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 57, feature= 5, thr= 54.41, gain=0.006884
tree= 1, node= 58, feature= 6, thr= 96.08, gain=0.024998
tree= 1, node= 59, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 60, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 61, feature= 1, thr= 3.92, gain=0.998846
tree= 1, node= 62, feature= 5, thr= 13.35, gain=0.035341
tree= 1, node= 63, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 64, feature= 7, thr= 71.86, gain=0.496889
tree= 1, node= 65, feature=10, thr= 60.78, gain=0.864204
tree= 1, node= 66, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 67, feature= 1, thr= 92.47, gain=0.078528
tree= 1, node= 68, feature= 5, thr= 68.63, gain=0.135036
tree= 1, node= 69, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 70, feature= 8, thr= 18.67, gain=0.368566
tree= 1, node= 71, feature= 7, thr= 73.02, gain=0.050120
tree= 1, node= 72, feature=12, thr= 55.47, gain=0.287642
tree= 1, node= 73, feature= 8, thr= 49.82, gain=0.208356
tree= 1, node= 74, feature= 1, thr= 39.18, gain=0.308576
tree= 1, node= 75, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 76, feature= 5, thr= 15.69, gain=0.106446

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tree= 1, node= 77, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 78, feature= 0, thr= 78.43, gain=0.174910
tree= 1, node= 79, feature= 5, thr= 84.31, gain=0.901825
tree= 1, node= 80, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 81, feature= 6, thr= 70.59, gain=0.988057
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tree= 1, node= 87, feature= 8, thr= 1.96, gain=0.027154
tree= 1, node= 88, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 89, feature=14, thr= 1.96, gain=0.057144
tree= 1, node= 90, feature= 4, thr= 62.75, gain=0.149994
tree= 1, node= 91, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 92, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 93, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 94, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 95, feature= 1, thr= 26.47, gain=0.028970
tree= 1, node= 96, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 97, feature= 6, thr= 45.33, gain=0.097300
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tree= 1, node=103, feature=13, thr= 6.08, gain=0.024501
tree= 1, node=104, feature=13, thr= 5.10, gain=0.465185
tree= 1, node=105, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=107, feature= 7, thr= 54.53, gain=0.349184
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tree= 1, node=116, feature= 6, thr= 58.29, gain=0.175730
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tree= 1, node=118, feature= 0, thr= 73.33, gain=0.054012
tree= 1, node=119, feature=11, thr= 9.06, gain=0.541116
tree= 1, node=120, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=121, feature= 7, thr= 67.06, gain=0.321696
tree= 1, node=122, feature=-1, thr= -1.00, gain=0.000000

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tree= 1, node=123, feature= 0, thr= 60.78, gain=0.098830
tree= 1, node=124, feature= 9, thr= 18.55, gain=0.134335
tree= 1, node=125, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=126, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=127, feature= 1, thr= 79.29, gain=0.678954
tree= 1, node=128, feature= 4, thr= 48.04, gain=0.291818
tree= 1, node=129, feature=11, thr= 39.69, gain=0.517478
tree= 1, node=130, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=141, feature= 9, thr= 88.47, gain=0.008575
tree= 1, node=142, feature= 6, thr= 67.45, gain=0.250919
tree= 1, node=143, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=152, feature= 1, thr= 89.59, gain=0.025926
tree= 1, node=153, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=154, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=156, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=157, feature= 3, thr= 89.02, gain=0.028237
tree= 1, node=158, feature= 8, thr= 24.51, gain=0.021367
tree= 1, node=159, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=160, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=161, feature=14, thr= 52.94, gain=0.111623
tree= 1, node=162, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=163, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=164, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=165, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=166, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=167, feature= 2, thr= 45.71, gain=0.103275
tree= 1, node=168, feature= 7, thr= 17.69, gain=0.008314

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tree= 1, node=169, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=170, feature= 1, thr= 81.37, gain=0.056120
tree= 1, node=171, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=172, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=173, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=174, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=175, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=176, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=177, feature=15, thr=  9.12, gain=0.021405
tree= 1, node=178, feature= 6, thr= 21.57, gain=0.053910
tree= 1, node=179, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=180, feature= 1, thr= 66.67, gain=0.077022
tree= 1, node=181, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=182, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=183, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=184, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=185, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=186, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=187, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=188, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=189, feature= 3, thr= 99.12, gain=0.041635
tree= 1, node=190, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=191, feature= 2, thr= 41.47, gain=0.067329
tree= 1, node=192, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=193, feature= 2, thr= 86.33, gain=0.018695
tree= 1, node=194, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=195, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=196, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=197, feature=-1, thr= -1.00, gain=0.000000
classification accuracy=0.8382

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2) decision_tree.py pendigits_training pendigits_test 1 50

```

tree= 1, node=  1, feature= 4, thr= 43.14, gain=0.537612
tree= 1, node=  2, feature= 3, thr= 70.59, gain=0.261618
tree= 1, node=  3, feature=11, thr= 37.25, gain=0.418093
tree= 1, node=  4, feature= 7, thr= 23.53, gain=0.574468
tree= 1, node=  5, feature= 3, thr= 97.16, gain=0.292564
tree= 1, node=  6, feature= 8, thr= 50.98, gain=0.433211
tree= 1, node=  7, feature= 4, thr= 65.96, gain=0.085822
tree= 1, node=  8, feature= 5, thr= 30.08, gain=0.164518
tree= 1, node=  9, feature= 4, thr= 17.71, gain=0.291495
tree= 1, node= 10, feature=13, thr= 52.94, gain=0.549189
tree= 1, node= 11, feature= 2, thr= 31.37, gain=0.221505
tree= 1, node= 12, feature= 8, thr= 19.61, gain=0.194337
tree= 1, node= 13, feature= 7, thr= 48.33, gain=0.288529

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tree= 1, node= 14, feature=11, thr= 69.61, gain=0.347908
tree= 1, node= 15, feature=12, thr= 52.94, gain=0.300967
tree= 1, node= 16, feature= 2, thr= 31.24, gain=0.207713
tree= 1, node= 17, feature= 2, thr= 7.00, gain=0.628306
tree= 1, node= 18, feature= 2, thr= 16.94, gain=0.122610
tree= 1, node= 19, feature= 7, thr= 61.25, gain=0.672212
tree= 1, node= 20, feature= 5, thr= 70.24, gain=0.270620
tree= 1, node= 21, feature= 7, thr= 10.45, gain=0.189349
tree= 1, node= 22, feature=14, thr= 88.24, gain=0.457438
tree= 1, node= 23, feature= 8, thr= 50.98, gain=0.411331
tree= 1, node= 24, feature= 5, thr= 93.92, gain=0.139603
tree= 1, node= 25, feature= 3, thr= 84.96, gain=0.202034
tree= 1, node= 26, feature=11, thr= 23.22, gain=0.062843
tree= 1, node= 27, feature= 0, thr= 1.96, gain=0.276664
tree= 1, node= 28, feature= 0, thr= 11.76, gain=0.603789
tree= 1, node= 29, feature= 2, thr= 58.82, gain=0.269382
tree= 1, node= 30, feature= 8, thr= 41.18, gain=0.754621
tree= 1, node= 31, feature= 9, thr= 47.06, gain=0.832859
tree= 1, node= 32, feature= 2, thr= 14.59, gain=0.071912
tree= 1, node= 33, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 34, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node= 37, feature=11, thr= 70.20, gain=0.321318
tree= 1, node= 38, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 39, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 40, feature=13, thr= 13.25, gain=0.076136
tree= 1, node= 41, feature=11, thr= 1.61, gain=0.478834
tree= 1, node= 42, feature= 3, thr= 82.22, gain=0.112226
tree= 1, node= 43, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 44, feature= 5, thr= 66.35, gain=0.657174
tree= 1, node= 45, feature= 1, thr= 80.16, gain=0.300054
tree= 1, node= 46, feature= 1, thr= 79.61, gain=0.379200
tree= 1, node= 47, feature=11, thr= 25.53, gain=0.556679
tree= 1, node= 48, feature=13, thr= 23.22, gain=0.385449
tree= 1, node= 49, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 50, feature=15, thr= 13.73, gain=0.643914
tree= 1, node= 51, feature= 4, thr= 84.63, gain=0.119877
tree= 1, node= 52, feature= 6, thr= 60.82, gain=0.142956
tree= 1, node= 53, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 54, feature= 2, thr= 45.94, gain=0.229455
tree= 1, node= 55, feature= 8, thr= 80.78, gain=0.160522
tree= 1, node= 56, feature= 9, thr= 72.55, gain=0.499759
tree= 1, node= 57, feature= 8, thr= 50.98, gain=0.441853
tree= 1, node= 58, feature= 0, thr= 1.08, gain=0.188154
tree= 1, node= 59, feature=-1, thr= -1.00, gain=0.000000

tree= 1, node= 60, feature= 3, thr= 72.49, gain=0.219709
tree= 1, node= 61, feature= 0, thr= 3.73, gain=0.129918
tree= 1, node= 62, feature=10, thr= 19.90, gain=0.073226
tree= 1, node= 63, feature= 9, thr= 64.31, gain=0.166819
tree= 1, node= 64, feature= 7, thr= 9.02, gain=0.035331
tree= 1, node= 65, feature=12, thr= 64.37, gain=0.260654
tree= 1, node= 66, feature=13, thr= 33.33, gain=0.494510
tree= 1, node= 67, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 68, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 69, feature= 5, thr= 54.47, gain=0.037439
tree= 1, node= 70, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 71, feature=15, thr= 1.20, gain=0.291534
tree= 1, node= 72, feature=13, thr= 89.29, gain=0.090472
tree= 1, node= 73, feature=14, thr= 84.31, gain=0.187176
tree= 1, node= 74, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 75, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 76, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 77, feature= 9, thr= 5.06, gain=0.758145
tree= 1, node= 78, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 79, feature= 2, thr= 57.33, gain=0.151562
tree= 1, node= 80, feature= 9, thr= 22.27, gain=0.999911
tree= 1, node= 81, feature= 5, thr= 63.49, gain=0.298482
tree= 1, node= 82, feature= 7, thr= 62.75, gain=0.101719
tree= 1, node= 83, feature= 5, thr= 68.59, gain=0.267805
tree= 1, node= 84, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 85, feature=12, thr= 62.75, gain=0.133119
tree= 1, node= 86, feature=10, thr= 45.10, gain=0.347006
tree= 1, node= 87, feature= 5, thr= 87.33, gain=0.163689
tree= 1, node= 88, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 89, feature=10, thr= 62.75, gain=0.216468
tree= 1, node= 90, feature= 6, thr= 64.98, gain=0.371341
tree= 1, node= 91, feature= 5, thr= 96.39, gain=0.368818
tree= 1, node= 92, feature=15, thr= 20.29, gain=0.341752
tree= 1, node= 93, feature= 0, thr= 63.49, gain=0.406235
tree= 1, node= 94, feature= 5, thr= 47.84, gain=0.714352
tree= 1, node= 95, feature= 9, thr= 86.24, gain=0.075008
tree= 1, node= 96, feature= 6, thr= 3.92, gain=0.262037
tree= 1, node= 97, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 98, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 99, feature= 8, thr= 31.37, gain=0.843642
tree= 1, node=100, feature= 1, thr= 88.47, gain=0.010042
tree= 1, node=101, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=102, feature=10, thr= 72.71, gain=0.142853
tree= 1, node=103, feature= 8, thr= 80.00, gain=0.667896
tree= 1, node=104, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=105, feature=13, thr= 53.92, gain=0.053093

tree= 1, node=106, feature= 0, thr= 2.82, gain=0.524002
tree= 1, node=107, feature= 1, thr= 76.47, gain=0.498008
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tree= 1, node=109, feature= 1, thr= 97.53, gain=0.331306
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tree= 1, node=420, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=421, feature= 4, thr= 75.59, gain=0.142778
tree= 1, node=422, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=423, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=424, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=425, feature=14, thr= 0.00, gain=0.000000
tree= 1, node=426, feature= 1, thr= 83.31, gain=0.023520
tree= 1, node=427, feature=-1, thr= -1.00, gain=0.000000

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tree= 1, node=428, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=429, feature= 4, thr= 67.65, gain=0.075570
tree= 1, node=430, feature= 1, thr=100.00, gain=0.000000
tree= 1, node=431, feature= 0, thr= 70.88, gain=0.199028
tree= 1, node=432, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=433, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=434, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=435, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=436, feature=13, thr= 16.47, gain=0.035622
tree= 1, node=437, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=438, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=439, feature= 8, thr= 77.18, gain=0.035506
tree= 1, node=440, feature= 3, thr=100.00, gain=0.000000
tree= 1, node=441, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=443, feature= 5, thr= 99.02, gain=0.013858
tree= 1, node=444, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=445, feature= 0, thr= 98.92, gain=0.017880
tree= 1, node=446, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=447, feature= 2, thr= 44.65, gain=0.132120
tree= 1, node=448, feature= 9, thr=  5.49, gain=0.644683
tree= 1, node=449, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=450, feature= 7, thr= 70.47, gain=0.054673
tree= 1, node=451, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=452, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=453, feature=12, thr=  1.10, gain=0.260863
tree= 1, node=454, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=455, feature= 2, thr= 45.43, gain=0.105759
tree= 1, node=456, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=457, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=458, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=459, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=466, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=467, feature=-1, thr= -1.00, gain=0.000000
classification accuracy=0.6841

```

3) decision_tree.py pendigits_training pendigits_test 3 50

```

tree= 1, node=  1, feature=11, thr= 35.29, gain=0.466267

```

tree= 1, node= 2, feature=12, thr= 33.33, gain=0.165063
tree= 1, node= 3, feature= 6, thr= 74.51, gain=0.272258
tree= 1, node= 4, feature= 9, thr= 15.53, gain=0.317618
tree= 1, node= 5, feature= 8, thr= 58.82, gain=0.435289
tree= 1, node= 6, feature= 6, thr= 20.31, gain=0.068681
tree= 1, node= 7, feature= 1, thr= 76.47, gain=0.592826
tree= 1, node= 8, feature=15, thr= 58.82, gain=0.652532
tree= 1, node= 9, feature= 7, thr= 57.65, gain=0.108046
tree= 1, node= 10, feature= 8, thr= 28.43, gain=0.174521
tree= 1, node= 11, feature= 6, thr= 39.22, gain=0.366164
tree= 1, node= 12, feature= 9, thr= 50.98, gain=0.514041
tree= 1, node= 13, feature=12, thr= 54.90, gain=0.302186
tree= 1, node= 14, feature=12, thr= 45.10, gain=0.215404
tree= 1, node= 15, feature= 7, thr= 70.59, gain=0.753256
tree= 1, node= 16, feature= 0, thr= 58.82, gain=0.279482
tree= 1, node= 17, feature= 3, thr= 66.35, gain=0.203074
tree= 1, node= 18, feature= 9, thr= 27.61, gain=0.430319
tree= 1, node= 19, feature= 7, thr= 74.47, gain=0.084963
tree= 1, node= 20, feature= 0, thr= 64.71, gain=0.787744
tree= 1, node= 21, feature= 7, thr= 37.25, gain=0.575870
tree= 1, node= 22, feature= 7, thr= 25.49, gain=0.999571
tree= 1, node= 23, feature=11, thr= 1.37, gain=0.183395
tree= 1, node= 24, feature= 9, thr= 20.59, gain=0.335045
tree= 1, node= 25, feature= 6, thr= 12.16, gain=0.032418
tree= 1, node= 26, feature= 7, thr= 15.69, gain=0.557152
tree= 1, node= 27, feature= 8, thr= 64.71, gain=0.598245
tree= 1, node= 28, feature= 4, thr= 58.82, gain=0.469262
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tree= 1, node= 38, feature= 8, thr= 92.16, gain=0.266111
tree= 1, node= 39, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 40, feature= 7, thr= 66.67, gain=0.225958
tree= 1, node= 41, feature= 1, thr= 99.39, gain=0.085734
tree= 1, node= 42, feature= 1, thr= 97.71, gain=0.456251
tree= 1, node= 43, feature= 3, thr= 87.27, gain=0.243342
tree= 1, node= 44, feature= 2, thr= 31.37, gain=0.203527
tree= 1, node= 45, feature=10, thr= 98.04, gain=0.327338
tree= 1, node= 46, feature=14, thr= 15.69, gain=0.358817
tree= 1, node= 47, feature= 8, thr= 75.08, gain=0.133979

tree= 1, node= 48, feature=15, thr= 19.61, gain=0.927527
tree= 1, node= 49, feature= 8, thr= 35.29, gain=0.697032
tree= 1, node= 50, feature= 1, thr= 85.12, gain=0.371465
tree= 1, node= 51, feature=12, thr= 78.14, gain=0.145867
tree= 1, node= 52, feature=11, thr= 73.65, gain=0.412839
tree= 1, node= 53, feature= 1, thr= 96.35, gain=0.571387
tree= 1, node= 54, feature= 9, thr= 44.12, gain=0.867933
tree= 1, node= 55, feature= 4, thr= 31.37, gain=0.175811
tree= 1, node= 56, feature= 4, thr= 47.29, gain=0.170150
tree= 1, node= 57, feature=11, thr= 62.31, gain=0.713147
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tree= 1, node= 73, feature= 3, thr= 92.31, gain=0.157155
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tree= 1, node= 83, feature= 3, thr= 90.08, gain=0.217555
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classification accuracy=0.8008

```

2 Task-2

2.1 part-a

$$\begin{aligned}
 H(S) &= -\frac{80}{100} \log_2 \frac{80}{100} - \frac{20}{100} \log_2 \frac{20}{100} \\
 &= -\frac{4}{5} \log_2 \frac{4}{5} - \frac{1}{5} \log_2 \frac{1}{5} \\
 &= -0.8 * -0.321 + (-0.2 * -2.32) \quad H(S) = 0.70
 \end{aligned}$$

2.2 Part-b

When weekend entropy:

$$\begin{aligned}
 H(W) &= -\frac{20}{35} \log_2 \frac{20}{35} - \frac{15}{35} \log_2 \frac{15}{35} \\
 &= -4/7 * -0.807 + (-3/7 * -1.22) \\
 H(W) &= 0.984
 \end{aligned}$$

When not-a-weekend entropy:

$$\begin{aligned}
 H(not - W) &= -\frac{60}{65} \log_2 \frac{60}{65} - \frac{5}{65} \log_2 \frac{5}{65} \\
 &= -\frac{12}{13} \log_2 \frac{12}{13} - \frac{1}{13} \log_2 \frac{1}{13} \\
 &= -0.92 * -0.115 + (-0.08 * -3.700) \\
 H(not - W) &= 0.402
 \end{aligned}$$

The Information gain is: $I(A) = H(S) - \frac{K_1}{K} H(W) - \frac{K_2}{K} H(not - W)$

$$\begin{aligned}
 I(A) &= 0.70 - \frac{35}{100} * 0.984 - \frac{65}{100} * 0.402 \\
 I(A) &= 0.0943
 \end{aligned}$$

2.3 Part-c

There will be no information gain on NODE E since it's the same exact test.
The information gain will be 0 on NODE E

2.4 Part-d

The leaf node the patron will land on is node E and it will wait
Weekend? - > *NO(go-right)*

Raining? $\rightarrow YES(go_left)$
Leafnode? $\rightarrow will_wait!$

2.5 Part-E

The Leaf node the patron will land on is node H and it will not wait:

Weekend? $\rightarrow YES(go_left)$
Hungry? $\rightarrow NO(go_right)$
Weekend? $\rightarrow YES(go_left)$
Leafnode? $\rightarrow will_not_wait!$

3 Task-3

initial entropy:

$$\begin{aligned} H(S) &= -\frac{5}{10} \log_2 \frac{5}{10} - \frac{5}{10} \log_2 \frac{5}{10} \\ &= -\frac{1}{2} \log_2 \frac{1}{2} - \frac{1}{2} \log_2 \frac{1}{2} \\ &= -0.5 * -1 + (-0.5 * -1) \\ &= 1 \end{aligned}$$

when class A is attribute:

$$\begin{aligned} A = 1, X = 3 \text{ and } Y = 0 \\ H(A_1) &= -\frac{3}{3} \log_2 \frac{3}{3} - \frac{0}{3} \log_2 \frac{0}{3} \\ &= -1 * 0 + (-0) \\ H(A_1) &= 0 \end{aligned}$$

$$\begin{aligned} A = 2, X = 1 \text{ and } Y = 3 \\ H(A_2) &= -\frac{1}{4} \log_2 \frac{1}{4} - \frac{3}{4} \log_2 \frac{3}{4} \\ &= -0.25 * -2 + (-0.75 * -0.41) \\ H(A_2) &= 0.5 + 0.315 \\ H(A_2) &= 0.815 \end{aligned}$$

$$\begin{aligned} A = 3, X = 1 \text{ and } Y = 2 \\ H(A_3) &= -\frac{1}{3} \log_2 \frac{1}{3} - \frac{2}{3} \log_2 \frac{2}{3} \\ &= -0.33 * -1.58 + (-0.66 * -0.584) \\ H(A_3) &= 0.526 + 0.386 \\ H(A_3) &= 0.912 \end{aligned}$$

The Information gain of A is

$$\begin{aligned} I(A) &= H(S) - \frac{K_1}{K} H(A_1) - \frac{K_2}{K} H(A_2) - \frac{K_3}{K} H(A_3) \\ &= 1 - \frac{3}{10} * 0 - \frac{4}{10} * 0.815 - \frac{3}{10} * 0.912 \\ I(A) &= 0.4 \end{aligned}$$

when class B is attribute:

$$\begin{aligned}
& B = 1, X = 1 \text{ and } Y = 3 \\
H(B_1) &= -\frac{1}{4} \log_2 \frac{1}{4} - \frac{3}{4} \log_2 \frac{3}{4} \\
&= -0.25 * -2 + (-0.75 * -0.41) \\
H(B_1) &= 0.5 + 0.315 \\
H(B_1) &= 0.815
\end{aligned}$$

$$\begin{aligned}
& B = 2, X = 3 \text{ and } Y = 1 \\
H(B_1) &= -\frac{3}{4} \log_2 \frac{3}{4} - \frac{1}{4} \log_2 \frac{1}{4} \\
&= -0.75 * -0.41 + (-0.25 * -2) \\
H(B_1) &= 0.315 + 0.5 \\
H(B_1) &= 0.815
\end{aligned}$$

$$\begin{aligned}
& B = 3, X = 1 \text{ and } Y = 1 \\
H(B_1) &= -\frac{1}{2} \log_2 \frac{1}{2} - \frac{1}{2} \log_2 \frac{1}{2} \\
&= -0.5 * -1 + (-0.5 * -1) \\
H(B_1) &= 1
\end{aligned}$$

$$\begin{aligned}
& \text{The Information gain of B is} \\
I(B) &= H(S) - \frac{K_1}{K} H(B_1) - \frac{K_2}{K} H(B_2) - \frac{K_3}{K} H(B_3) \\
&= 1 - \frac{4}{10} * 0.815 - \frac{4}{10} * 0.815 - \frac{2}{10} * 1 \\
I(B) &= 0.145
\end{aligned}$$

$$\begin{aligned}
& \text{when class C is attribute:} \\
C = 1, X = 1 \text{ and } Y = 4 \\
H(C_1) &= -\frac{1}{5} \log_2 \frac{1}{5} - \frac{4}{5} \log_2 \frac{4}{5} \\
&= -0.2 * -2.32 + (-0.8 * -0.32) \\
H(C_1) &= 0.464 + 0.256 \\
H(C_1) &= 0.72
\end{aligned}$$

$$\begin{aligned}
& C = 2, X = 3 \text{ and } Y = 1 \\
H(C_2) &= -\frac{3}{4} \log_2 \frac{3}{4} - \frac{1}{4} \log_2 \frac{1}{4} \\
&= -0.75 * -0.41 + (-0.25 * -2) \\
H(C_2) &= 0.315 + 0.5 \\
H(C_2) &= 0.815
\end{aligned}$$

$$\begin{aligned}
& C = 3, X = 1 \text{ and } Y = 0 \\
H(C_3) &= -\frac{1}{1} \log_2 \frac{1}{1} - \frac{0}{1} \log_2 \frac{0}{1} \\
&= -1 * -0 + (-0 * -0) \\
H(C_3) &= 0
\end{aligned}$$

$$\begin{aligned}
& \text{The Information gain of C is} \\
I(C) &= H(S) - \frac{K_1}{K} H(C_1) - \frac{K_2}{K} H(C_2) - \frac{K_3}{K} H(C_3) \\
&= 1 - \frac{5}{10} * 0.72 - \frac{4}{10} * 0.815 - \frac{1}{10} * 0 \\
I(C) &= 0.314
\end{aligned}$$

I(A) has the highest information gain.

4 Task-4

4.1 Part-a

The highest entropy will occur when the sample is equally divided i.e. $1000/4 = 250$

and the entropy will be

$$\begin{aligned} H\left(\frac{250}{1000}, \frac{250}{1000}, \frac{250}{1000}, \frac{250}{1000}\right) &= -\frac{250}{1000} \log_2\left(\frac{250}{1000}\right) - \frac{250}{1000} \log_2\left(\frac{250}{1000}\right) - \frac{250}{1000} \log_2\left(\frac{250}{1000}\right) - \\ &\quad \frac{250}{1000} \log_2\left(\frac{250}{1000}\right) \\ &= -\frac{1}{4} \log_2\left(\frac{1}{4}\right) - \frac{1}{4} \log_2\left(\frac{1}{4}\right) - \frac{1}{4} \log_2\left(\frac{1}{4}\right) - \frac{1}{4} \log_2\left(\frac{1}{4}\right) \\ &= \left(-\frac{1}{4} * -2\right) + \left(-\frac{1}{4} * -2\right) + \left(-\frac{1}{4} * -2\right) + \left(-\frac{1}{4} * -2\right) \\ &= \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} \\ &= 1 + 1 \\ H\left(\frac{250}{1000}, \frac{250}{1000}, \frac{250}{1000}, \frac{250}{1000}\right) &= 2 \end{aligned}$$

The lowest entropy will occur when all the examples belong to the same class
i.e A = 1000, B=0, C=0, D=0

$$\begin{aligned} H\left(\frac{1000}{1000}, \frac{0}{1000}, \frac{0}{1000}, \frac{0}{1000}\right) &= -\frac{1000}{1000} \log_2\left(\frac{1000}{1000}\right) - \frac{0}{1000} \log_2\left(\frac{0}{1000}\right) - \frac{0}{1000} \log_2\left(\frac{0}{1000}\right) - \\ &\quad \frac{0}{1000} \log_2\left(\frac{0}{1000}\right) \\ &= -1 * \log_2(1) - 0 * \log_2(0) - 0 * \log_2(0) - 0 * \log_2(0) \\ &= 0 \end{aligned}$$

4.2 Part-b

So the maximum information gain happens when the attribute K perfectly divide the classes. So the highest entropy will be the entropy current of that node (A, B, C, D).

The minimum information gain happens when the attribute K perfectly divides the classes into equal numbers. So the Minimum information gain will be zero.
 $0 \leq I(S, K) \leq H(S) \leq 2$

5 Task-5

The accuracy will be improved to 72% if we change the classifier to negate(answer) the answer. In other words, if we flip the answer from true to false and vice-versa. it can have an accuracy of 72%. Therefore, We can achieve the accuracy of more than 60%