

Long Nguyen

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1)

[decision_tree.py](#) [pendigits_training](#) [pendigits_test](#) optimized 50

tree= 1, node= 1, feature=16, thr= 21.57, gain=0.621424

tree= 1, node= 2, feature= 5, thr= 41.18, gain=0.587628

tree= 1, node= 3, feature=14, thr= 58.82, gain=0.697235

tree= 1, node= 4, feature=10, thr= 15.69, gain=0.670083

tree= 1, node= 5, feature=11, thr= 39.22, gain=0.629044

tree= 1, node= 6, feature= 1, thr= 35.29, gain=0.712500

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tree= 1, node= 8, feature=15, thr= 60.78, gain=0.475710

tree= 1, node= 9, feature= 6, thr= 64.71, gain=0.620325

tree= 1, node= 10, feature=15, thr= 37.25, gain=0.224713

tree= 1, node= 11, feature= 4, thr= 90.20, gain=0.686759

tree= 1, node= 12, feature=15, thr= 37.25, gain=0.281171

tree= 1, node= 13, feature=11, thr= 29.41, gain=0.584898

tree= 1, node= 14, feature=15, thr= 96.08, gain=0.737506

tree= 1, node= 15, feature= 8, thr= 24.33, gain=0.205385

tree= 1, node= 16, feature= 2, thr= 73.53, gain=0.027989

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tree= 1, node= 19, feature=10, thr= 60.47, gain=0.530651

tree= 1, node= 20, feature=13, thr= 30.06, gain=0.640257

tree= 1, node= 21, feature= 9, thr= 34.59, gain=0.140904

tree= 1, node= 22, feature= 7, thr= 72.55, gain=0.509615

tree= 1, node= 23, feature= 8, thr= 77.10, gain=0.409412

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tree= 1, node= 25, feature=14, thr= 14.78, gain=0.131381

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tree= 1, node=181, feature= 1, thr= 60.78, gain=0.098830
tree= 1, node=184, feature=10, thr= 18.55, gain=0.134335
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tree= 1, node=187, feature= 2, thr= 79.29, gain=0.678954
tree= 1, node=190, feature= 5, thr= 48.04, gain=0.291818
tree= 1, node=191, feature=12, thr= 39.69, gain=0.517478
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tree= 1, node=363, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=383, feature= 3, thr= 45.71, gain=0.103275
tree= 1, node=582, feature= 8, thr= 17.69, gain=0.008314
tree= 1, node=583, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=608, feature= 2, thr= 81.37, gain=0.056120
tree= 1, node=609, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=767, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=1164, feature=-1, thr= -1.00, gain=0.000000

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tree= 1, node=1477, feature= 4, thr= 99.12, gain=0.041635
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tree= 1, node=2954, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=5910, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=5911, feature=-1, thr= -1.00, gain=0.000000
classification accuracy=0.8382

[decision_tree.py](#) pendigits_training pendigits_test 1 50

tree= 1, node= 1, feature= 5, thr= 43.14, gain=0.537612
tree= 1, node= 2, feature=16, thr= 1.96, gain=0.686381
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tree= 1, node= 4, feature=10, thr= 64.71, gain=0.341164
tree= 1, node= 5, feature=16, thr= 51.96, gain=0.644854
tree= 1, node= 6, feature=15, thr= 96.08, gain=0.759929
tree= 1, node= 7, feature=12, thr= 37.25, gain=0.372431
tree= 1, node= 8, feature= 9, thr= 21.57, gain=0.151739
tree= 1, node= 9, feature=15, thr= 3.92, gain=0.092880
tree= 1, node= 10, feature=13, thr= 37.25, gain=0.254323
tree= 1, node= 11, feature=14, thr= 69.94, gain=0.360596
tree= 1, node= 12, feature=14, thr= 50.98, gain=0.704006
tree= 1, node= 13, feature=12, thr= 26.08, gain=0.778659
tree= 1, node= 14, feature=12, thr= 3.63, gain=0.178268

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tree= 1, node= 16, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 17, feature= 4, thr= 97.06, gain=0.214045
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tree= 1, node= 27, feature= 2, thr= 70.24, gain=0.207253
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tree= 1, node= 35, feature= 4, thr= 99.02, gain=0.074933
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tree= 1, node= 43, feature=15, thr= 54.90, gain=0.532888
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tree= 1, node= 47, feature=11, thr= 68.63, gain=0.529922

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tree= 1, node= 61, feature=12, thr= 63.10, gain=0.099891
tree= 1, node= 62, feature=12, thr= 84.20, gain=0.207180
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tree= 1, node= 78, feature= 6, thr= 60.82, gain=0.604223
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tree= 1, node= 81, feature= 7, thr= 67.33, gain=0.061236
tree= 1, node= 84, feature=15, thr= 60.78, gain=0.150666
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tree= 1, node= 86, feature= 8, thr= 56.00, gain=0.519550

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tree= 1, node= 93, feature=14, thr= 82.35, gain=0.393353
tree= 1, node= 94, feature=13, thr= 65.10, gain=0.924457
tree= 1, node= 95, feature= 3, thr= 27.59, gain=0.090463
tree= 1, node= 96, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 97, feature=10, thr= 66.47, gain=0.226220
tree= 1, node= 98, feature= 6, thr= 82.00, gain=0.514354
tree= 1, node= 99, feature= 6, thr= 90.00, gain=0.431695
tree= 1, node=100, feature= 4, thr= 36.59, gain=0.721928
tree= 1, node=101, feature=15, thr= 13.18, gain=0.259159
tree= 1, node=106, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=107, feature= 2, thr= 79.49, gain=0.086949
tree= 1, node=110, feature= 8, thr= 33.76, gain=0.029646
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tree= 1, node=112, feature=16, thr= 14.65, gain=0.898243
tree= 1, node=113, feature=15, thr= 92.16, gain=0.335852
tree= 1, node=114, feature= 9, thr= 43.14, gain=0.497424
tree= 1, node=115, feature= 7, thr= 76.39, gain=0.268263
tree= 1, node=116, feature= 3, thr= 73.18, gain=0.264408
tree= 1, node=117, feature=16, thr= 21.96, gain=0.290227
tree= 1, node=118, feature= 8, thr= 47.33, gain=0.088524
tree= 1, node=119, feature= 2, thr= 66.82, gain=0.239616
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tree= 1, node=122, feature=16, thr= 1.25, gain=0.152711
tree= 1, node=123, feature=-1, thr= -1.00, gain=0.000000

tree= 1, node=124, feature= 7, thr= 3.92, gain=0.122319
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tree= 1, node=61259, feature=-1, thr= -1.00, gain=0.000000
classification accuracy=0.7147

[decision_tree.py pendigits_training pendigits_test 3 50](#)

tree= 1, node= 1, feature=11, thr= 56.86, gain=0.474440
tree= 1, node= 2, feature=12, thr= 37.25, gain=0.497929
tree= 1, node= 3, feature= 4, thr= 90.20, gain=0.466987
tree= 1, node= 4, feature=16, thr= 19.61, gain=0.848456
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tree= 1, node= 11, feature= 2, thr= 96.24, gain=0.015999
tree= 1, node= 12, feature=11, thr= 85.67, gain=0.062353
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tree= 3, node=976, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=977, feature= 1, thr= 60.78, gain=0.982859
tree= 3, node=978, feature= 1, thr= 10.29, gain=0.072244
tree= 3, node=979, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=988, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=989, feature= 5, thr= 43.14, gain=0.096003
tree= 3, node=994, feature=13, thr= 51.98, gain=0.163428
tree= 3, node=995, feature= 8, thr= 37.18, gain=0.038525
tree= 3, node=998, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=999, feature= 9, thr= 11.65, gain=0.445810
tree= 3, node=1000, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=1001, feature= 9, thr= 75.41, gain=0.190150
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tree= 3, node=1007, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=1017, feature=12, thr= 0.94, gain=0.210268
tree= 3, node=1018, feature=13, thr= 80.39, gain=0.109499

tree= 3, node=1019, feature= 8, thr= 68.12, gain=0.482554
tree= 3, node=1102, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=1103, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=1316, feature=11, thr= 37.04, gain=0.125658
tree= 3, node=1317, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=1366, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=1367, feature= 3, thr= 95.06, gain=0.135100
tree= 3, node=1372, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=1373, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=1388, feature= 5, thr= 98.98, gain=0.010256
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tree= 3, node=1507, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=1991, feature= 5, thr= 51.82, gain=0.070388
tree= 3, node=1998, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=2036, feature= 5, thr= 83.41, gain=0.059503
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tree= 3, node=3021, feature= 5, thr= 9.80, gain=0.452273
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tree= 3, node=15935, feature= 5, thr= 79.82, gain=0.023718
tree= 3, node=16020, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=16021, feature= 6, thr= 85.51, gain=0.043208
tree= 3, node=16022, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=16283, feature= 2, thr= 86.29, gain=0.037698
tree= 3, node=16294, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=16295, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=22211, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=32043, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=32566, feature= 3, thr= 70.65, gain=0.029180
tree= 3, node=32567, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=65132, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=65133, feature=-1, thr= -1.00, gain=0.000000
classification accuracy=0.7966

$$2a) H(A) = -\frac{80}{100}\log_2 \frac{80}{100} - \frac{20}{100}\log_2 \frac{20}{100} = .7219$$

$$2b) I(A) = .7219 - \frac{35}{100} * \left(-\frac{20}{35}\log_2 \frac{20}{35} - \frac{15}{35}\log_2 \frac{15}{35}\right) - \frac{65}{100} * \left(-\frac{60}{65}\log_2 \frac{60}{65} - \frac{5}{65}\log_2 \frac{5}{65}\right) = .1227$$

2c) $H(E) = 0$; since node A already performed the weekend test

2d) A->C->F; therefore, the customer will wait

2e) A->B->E->H; therefore, the customer will not wait

3)

Before split: $x = 5, y = 5$

$$H(S) = -\frac{5}{10}\log_2 \frac{5}{10} - \frac{5}{10}\log_2 \frac{5}{10} = 1$$

A = 1: $x = 3, y = 0$

$$H(A_1) = -\frac{3}{3} \log_2 \frac{3}{3} = 0$$

$$A = 2: x = 1, y = 3$$

$$H(A_2) = -\frac{1}{4} \log_2 \frac{1}{4} - \frac{3}{4} \log_2 \frac{3}{4} = .811$$

$$A = 3: x = 1, y = 2$$

$$H(A_3) = -\frac{1}{3} \log_2 \frac{1}{3} - \frac{2}{3} \log_2 \frac{2}{3} = .918$$

$$I(A) = 1 - \frac{3}{10} * H(A_1) - \frac{4}{10} * H(A_2) - \frac{3}{10} * H(A_3) = .4002$$

$$B = 1: x = 1, y = 3$$

$$H(B_1) = -\frac{1}{4} \log_2 \frac{1}{4} - \frac{3}{4} \log_2 \frac{3}{4} = .811$$

$$B = 2: x = 3, y = 1$$

$$H(B_2) = -\frac{3}{4} \log_2 \frac{3}{4} - \frac{1}{4} \log_2 \frac{1}{4} = .811$$

$$B = 3: x = 1, y = 1$$

$$H(B_3) = -\frac{1}{2} \log_2 \frac{1}{2} - \frac{1}{2} \log_2 \frac{1}{2} = 1$$

$$I(B) = 1 - \frac{4}{10} * H(B_1) - \frac{4}{10} * H(B_2) - \frac{2}{10} * H(B_3) = .1512$$

$$C = 1: x = 1, y = 4$$

$$H(C_1) = -\frac{1}{5} \log_2 \frac{1}{5} - \frac{4}{5} \log_2 \frac{4}{5} = .722$$

$$C = 2: x = 3, y = 1$$

$$H(C_2) = -\frac{3}{4} \log_2 \frac{3}{4} - \frac{1}{4} \log_2 \frac{1}{4} = .811$$

$$C = 3: x = 1, y = 0$$

$$H(C_3) = -\frac{1}{1} \log_2 \frac{1}{1} = 0$$

$$I(C) = 1 - \frac{5}{10} * H(C_1) - \frac{4}{10} * H(C_2) - \frac{1}{10} * H(C_3) = .3146$$

Attribute A has the highest information gain.

$$4a) 0 \leq H(N) \leq \log_2 4$$

$$4b) 0 \leq I(K) \leq \log_2 4$$

5) Yes, you can guarantee achieving better than 60% by just predicting the opposite of what the classifier is predicting. Since the binary classifier can only output 2 answers, whether the home team will win or not, and it is getting an accuracy of 28%, that means that by predicting the opposite of what it was originally predicted we could achieve an accuracy of around ~72%.

