CSE 4309 – 001 Machine Learning
Assignment 5

Task – 2

a) $E = - (K1 / K) \log2(K1/K) - (K2 / K) \log2(K2/K)$
$K1 = 80, K2 = 20, K = K1 + K2 = 100$
$E = - (80/100) \log_2(80/100) – (20/100) \log_2(20/100)$
$E = - (0.8) (-0.32192809) – (0.2) (-2.32192809)$
$E = 0.25754247 + 0.46438562$
$E = 0.72192809$

b) From 80 who decided to wait, 20 weekend, 60 not weekend
From 20 not decided to wait, 15 weekend, 5 not weekend
Entropy for weekend,
$E1 = - (20/35) \log_2(20/35) – (15/35) \log_2(15/35)$
$E1 = - (0.57142857) (-0.80735492) – (0.43857143) (-1.22239242)$
$E1 = 0.46134567 + 0.52388247$
$E1 = 0.98522814$
Entropy for weekend,
$E2 = - (60/65) \log_2(60/65) – (5/65) \log_2(5/65)$
$E2 = -(0.92307692) (-0.11547721) – (0.07692308) (-3.70043971)$
$E2 = 0.10659435 + 0.28464921$
$E2 = 0.39124356$

$I = E – (35/100) E1 – (65/100) E2$
$I = 0.72192809 – (0.35) (0.98522814) – (0.65) (0.39124356)$
$I = 0.72192809 – 0.34482985 – 0.25430831$
$I = 0.12278993$

c) There will be no information gain at node E since the exact same test has been used before to separate the data. This means that all the examples at node E will already be of the same type, which will give us information gain of 0.

d) The test case will end up in node F, and will output will wait. This is because it first checks if it is a weekend which it is not, then check if it is rainy which it is, and then it will lead to node F.

e) The test case will end up in node H and patron will not wait. It goes through node A, node B, node E, and node H.

Task – 3

A as a root
$A = 1, X = 3, Y = 0$
$A = 2, X = 1, Y = 3$

$A = 3$, $X = 1$, $Y = 2$

$H_A = -(5/10) \log_2(5/10) - (5/10) \log_2(5/10) = 1$
$H_{A1} = -(3/3) \log_2(3/3) - (0/3) \log_2(0/3) = 0$
$H_{A2} = -(1/4) \log_2(1/4) - (3/4) \log_2(3/4)$
$\quad = -(1/4) * (-2) – (3/4) * (-0.415036)$
$\quad = 0.5 + 0.31128$
$\quad = 0.81128$
$H_{A3} = -(1/3) \log_2(1/3) - (2/3) \log_2(2/3)$
$\quad = 0.52837 + 0.38997$
$\quad = 0.91834$

Information gain-

$I_A = H_A – (3/10) H_{A1} – (4/10) H_{A2} – (3/10) H_{A3}$
$\quad = 1 – 0 – 0.4(0.81128) – 0.3 (0.91834)$
$\quad = 1 – 0.3245 – 0.2755$
$\quad = 0.399998$

B as a root
$B = 1$, $X = 1$, $Y = 3$
$B = 2$, $X = 3$, $Y = 1$
$B = 3$, $X = 1$, $Y = 1$

$H_B = -(5/10) \log_2(5/10) - (5/10) \log_2(5/10) = 1$
$H_{B1} = -(1/4) \log_2(1/4) - (3/4) \log_2(3/4) = 0.81128$
$H_{B2} = -(3/4) \log_2(3/4) - (1/4) \log_2(1/4) = 0.81128$
$H_{B3} = -(1/2) \log_2(1/2) - (1/2) \log_2(1/2) = 1$

Information gain-

$I_B = H_B – (4/10) H_{B1} – (4/10) H_{B2} – (2/10) H_{B3}$
$\quad = 1 – (4/10) (0.81128) – 0.4(0.81128) – 0.2 (1)$
$\quad = 1 – 0.3245 – 0.3245 – 0.2$
$\quad = 0.1509$

C as a root
$C = 1$, $X = 1$, $Y = 4$
$C = 2$, $X = 3$, $Y = 1$
$C = 3$, $X = 1$, $Y = 0$

$H_C = -(5/10) \log_2(5/10) - (5/10) \log_2(5/10) = 1$
$H_{C1} = -(1/5) \log_2(1/5) - (4/5) \log_2(4/5)$
$\quad = 0.46439 + 0.25754$
$\quad = 0.72193$
$H_{C2} = -(3/4) \log_2(3/4) - (1/4) \log_2(1/4) = 0.81128$

H_{C3} = -(1/1) $\log_2$(1/1) - (0/1) $\log_2$(0/1) = 0

Information gain-

I_C = H_C – (5/10) H_{C1} – (4/10) H_{C2} – (1/10) H_{C3}
     = 1 – 0.360965 – 0.324512
     = 0.314523

I_A is greater than I_B and I_C, so A provides the highest information gain at root.

Task – 4

a) The highest possible entropy possible for 1000 training examples with classes would be in a case where all the classes have equal distribution in these training examples. Therefore, each class label will have 250 examples each distributed equally in the 1000 training examples. The entropy for this case will be

H = -(250/1000) $\log_2$(250/1000) -(250/1000) $\log_2$(250/1000) -(250/1000) $\log_2$(250/1000) -(250/1000) $\log_2$(250/1000)
H = 0.5 + 0.5 + 0.5 + 0.5
H = 2 is the max entropy

The lowest possible for entropy happens when the classes are unequally distributed. So if one class has 1000 examples, and the other 3 classes have 0 examples each, then the entropy for such a case will be

H = -(1000/1000) $\log_2$(1000/1000) -(0/1000) $\log_2$(0/1000) -(0/1000) $\log_2$(0/1000) - (0/1000) $\log_2$(0/1000)
H = 0

b) The highest possible information gain will occur when the parents are evenly split and each child contains only one class. In this case, the information gain will be
Each Child entropy will be -250/250 $\log_2$ (250/250) = 0
So I = H – (child entropies)
I = 2 - 0
I = 2

The lowest possible information gain will occur when both the parents and each child are evenly split. In this case, the information gain will be 0.

Task – 5

Since this is a binary classifier, if the classifier for whether home team will win gives accuracy of 28%, then the case where the home team loses will give an accuracy of 72%. So to improve the accuracy, we could just switch our classifier to predict it correctly 72% of the time. Therefore, with that classifier, we can guarantee achieving accuracy of over 60%.

Task – 1

1) decision_tree('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
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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
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tree= 1, node= 62, feature= 5, thr= 13.35, gain=0.035341
tree= 1, node= 63, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node= 64, feature= 7, thr= 71.86, gain=0.496889
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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
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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
```

   2) decision_tree('pendigits_training', 'pendigits_test', 'randomized', 50)

```
tree= 1, node=  1, feature= 0, thr= 52.94, gain=0.321120
tree= 1, node=  2, feature=12, thr= 66.67, gain=0.193578
tree= 1, node=  3, feature= 5, thr= 68.63, gain=0.373574
```

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tree= 1, node=  4, feature= 6, thr= 37.25, gain=0.162585
tree= 1, node=  5, feature= 5, thr= 66.67, gain=0.618223
tree= 1, node=  6, feature= 6, thr= 33.33, gain=0.446692
tree= 1, node=  7, feature= 6, thr= 56.86, gain=0.279033
tree= 1, node=  8, feature=15, thr= 33.33, gain=0.556373
tree= 1, node=  9, feature= 2, thr= 21.57, gain=0.431898
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tree= 1, node= 11, feature= 5, thr= 76.06, gain=0.237615
tree= 1, node= 12, feature= 5, thr= 45.33, gain=0.282911
tree= 1, node= 13, feature=11, thr= 52.94, gain=0.398312
tree= 1, node= 14, feature= 9, thr= 29.41, gain=0.745544
tree= 1, node= 15, feature=11, thr= 14.65, gain=0.276116
tree= 1, node= 16, feature=10, thr= 41.18, gain=0.959119
tree= 1, node= 17, feature= 2, thr= 58.82, gain=0.368548
tree= 1, node= 18, feature= 1, thr= 79.51, gain=0.287244
tree= 1, node= 19, feature=10, thr= 60.78, gain=0.565042
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tree= 1, node= 22, feature= 6, thr= 56.86, gain=0.813871
tree= 1, node= 23, feature=15, thr= 10.94, gain=0.504168
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tree= 1, node= 25, feature= 1, thr= 96.37, gain=0.197355
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tree= 1, node= 74, feature= 9, thr=  2.16, gain=0.226806
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tree= 1, node=332, feature= 2, thr= 29.10, gain=0.318756
tree= 1, node=333, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=334, feature= 8, thr= 41.47, gain=0.010325
tree= 1, node=335, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=336, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=337, feature= 0, thr= 62.61, gain=0.040523
tree= 1, node=338, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=339, feature=15, thr=   1.04, gain=0.109619
tree= 1, node=340, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=341, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=342, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=343, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=344, feature= 9, thr= 48.49, gain=0.025858
tree= 1, node=345, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=346, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=347, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=348, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=349, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=350, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=351, feature= 5, thr= 93.06, gain=0.043242
tree= 1, node=352, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=353, feature= 4, thr= 71.45, gain=0.026454
tree= 1, node=354, feature=13, thr=   2.06, gain=0.029101
tree= 1, node=355, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=356, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=357, feature=-1, thr=  -1.00, gain=0.000000
tree= 1, node=358, feature= 8, thr= 34.12, gain=0.676779
```

```
tree= 1, node=359, feature= 6, thr= 88.71, gain=0.133020
tree= 1, node=360, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=361, feature=13, thr=  3.45, gain=0.042889
tree= 1, node=362, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=363, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=364, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=365, feature=15, thr= 20.29, gain=0.293541
tree= 1, node=366, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=367, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=368, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=369, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=370, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=371, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=372, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=373, feature=13, thr=  9.12, gain=0.048487
tree= 1, node=374, feature= 6, thr= 19.02, gain=0.223357
tree= 1, node=375, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=376, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=377, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=378, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=379, feature= 5, thr= 52.33, gain=0.351197
tree= 1, node=380, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=381, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=382, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=383, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=384, feature= 8, thr= 44.82, gain=0.053159
tree= 1, node=385, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=386, feature= 2, thr= 23.02, gain=0.079087
tree= 1, node=387, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=388, feature=10, thr= 34.04, gain=0.205923
tree= 1, node=389, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=390, feature= 4, thr= 37.98, gain=0.114676
tree= 1, node=391, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=392, feature= 3, thr= 93.10, gain=0.190558
tree= 1, node=393, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=394, feature=10, thr= 32.04, gain=0.013650
tree= 1, node=395, feature= 1, thr= 96.18, gain=0.036773
tree= 1, node=396, feature=10, thr= 73.18, gain=0.722102
tree= 1, node=397, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=398, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=399, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=400, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=401, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=402, feature= 0, thr= 66.43, gain=0.029717
tree= 1, node=403, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=404, feature= 1, thr= 63.73, gain=0.053905
tree= 1, node=405, feature= 9, thr=  0.00, gain=0.000000
tree= 1, node=406, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=407, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=408, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=409, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=410, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=411, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=412, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=413, feature= 6, thr= 72.47, gain=0.112098
tree= 1, node=414, feature= 1, thr= 70.76, gain=0.074852
tree= 1, node=415, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=416, feature= 4, thr= 99.00, gain=0.030111
tree= 1, node=417, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=418, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=419, feature= 5, thr= 79.29, gain=0.083057
tree= 1, node=420, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=421, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=422, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=423, feature= 5, thr= 64.47, gain=0.020910
tree= 1, node=424, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=425, feature=12, thr= 29.49, gain=0.067435
tree= 1, node=426, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=427, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=428, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=429, feature= 6, thr= 49.53, gain=0.015409
```

```
tree= 1, node=430, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=431, feature=-1, thr= -1.00, gain=0.000000
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=-1, thr= -1.00, gain=0.000000
tree= 1, node=437, feature= 5, thr= 84.29, gain=0.025325
tree= 1, node=438, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=439, feature=11, thr=  6.12, gain=0.049484
tree= 1, node=440, feature= 6, thr= 48.55, gain=0.316286
tree= 1, node=441, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=442, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=443, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=444, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=445, feature=-1, thr= -1.00, gain=0.000000
classification accuracy= 0.7218

    3)  decision_tree('pendigits_training', 'pendigits_test', 'forest3', 50)

tree= 1, node=  1, feature= 4, thr= 43.14, gain=0.537612
tree= 1, node=  2, feature=11, thr= 33.33, gain=0.526390
tree= 1, node=  3, feature= 8, thr= 49.02, gain=0.421835
tree= 1, node=  4, feature= 9, thr= 25.33, gain=0.631573
tree= 1, node=  5, feature= 9, thr= 66.67, gain=0.336785
tree= 1, node=  6, feature=15, thr= 21.57, gain=0.726182
tree= 1, node=  7, feature=12, thr= 33.33, gain=0.141094
tree= 1, node=  8, feature= 3, thr= 94.90, gain=0.347732
tree= 1, node=  9, feature= 7, thr= 64.86, gain=0.402792
tree= 1, node= 10, feature= 3, thr= 69.65, gain=0.280568
tree= 1, node= 11, feature=14, thr= 15.69, gain=0.081115
tree= 1, node= 12, feature= 0, thr= 68.63, gain=0.137858
tree= 1, node= 13, feature=11, thr= 41.18, gain=0.623800
tree= 1, node= 14, feature= 2, thr= 45.10, gain=0.213175
tree= 1, node= 15, feature= 0, thr=  1.96, gain=0.469978
tree= 1, node= 16, feature=11, thr= 18.12, gain=0.139926
tree= 1, node= 17, feature= 7, thr= 25.88, gain=0.135460
tree= 1, node= 18, feature= 1, thr= 83.94, gain=0.285452
tree= 1, node= 19, feature=10, thr= 60.78, gain=0.582519
tree= 1, node= 20, feature= 2, thr= 25.33, gain=0.274359
tree= 1, node= 21, feature= 9, thr= 24.59, gain=0.486355
tree= 1, node= 22, feature= 4, thr= 11.80, gain=0.110954
tree= 1, node= 23, feature=13, thr= 34.51, gain=0.231133
tree= 1, node= 24, feature=14, thr= 86.27, gain=0.645220
tree= 1, node= 25, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 26, feature=15, thr= 58.71, gain=0.290834
tree= 1, node= 27, feature=15, thr= 90.67, gain=0.215311
tree= 1, node= 28, feature= 5, thr= 66.67, gain=0.877349
tree= 1, node= 29, feature= 4, thr= 72.55, gain=0.166791
tree= 1, node= 30, feature= 8, thr= 75.49, gain=0.251025
tree= 1, node= 31, feature= 8, thr= 66.67, gain=0.129560
tree= 1, node= 32, feature= 4, thr= 26.14, gain=0.036243
tree= 1, node= 33, feature= 6, thr= 56.86, gain=0.218382
tree= 1, node= 34, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 35, feature= 0, thr= 21.57, gain=0.481939
tree= 1, node= 36, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 37, feature= 2, thr= 45.10, gain=0.227652
tree= 1, node= 38, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 39, feature= 3, thr= 90.08, gain=0.068814
tree= 1, node= 40, feature=14, thr= 52.94, gain=0.499356
tree= 1, node= 41, feature= 0, thr= 37.25, gain=0.533098
tree= 1, node= 42, feature= 5, thr= 37.47, gain=0.355969
tree= 1, node= 43, feature= 9, thr= 50.73, gain=0.081786
tree= 1, node= 44, feature=13, thr= 24.47, gain=0.487612
tree= 1, node= 45, feature=10, thr= 70.59, gain=0.398753
tree= 1, node= 46, feature= 2, thr= 15.69, gain=0.446541
tree= 1, node= 47, feature= 7, thr= 26.35, gain=0.220026
tree= 1, node= 48, feature= 0, thr= 17.33, gain=0.177807
tree= 1, node= 49, feature=12, thr= 50.98, gain=0.073372
tree= 1, node= 50, feature= 9, thr= 35.47, gain=0.406635
tree= 1, node= 51, feature=12, thr= 44.71, gain=0.151782
```

```
tree= 1, node= 52, feature=13, thr= 64.86, gain=0.254695
tree= 1, node= 53, feature= 3, thr= 69.96, gain=0.105939
tree= 1, node= 54, feature= 9, thr= 88.24, gain=0.243348
tree= 1, node= 55, feature=10, thr= 19.41, gain=0.226520
tree= 1, node= 56, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 57, feature= 2, thr= 65.06, gain=0.126978
tree= 1, node= 58, feature=14, thr= 52.94, gain=0.480190
tree= 1, node= 59, feature=15, thr=  1.57, gain=0.365948
tree= 1, node= 60, feature= 5, thr= 72.55, gain=0.316834
tree= 1, node= 61, feature= 7, thr= 76.47, gain=0.572471
tree= 1, node= 62, feature=10, thr= 35.29, gain=0.140327
tree= 1, node= 63, feature= 7, thr= 49.94, gain=0.452086
tree= 1, node= 64, feature= 0, thr= 81.88, gain=0.097635
tree= 1, node= 65, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 66, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 67, feature=11, thr= 13.59, gain=0.131430
tree= 1, node= 68, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 69, feature= 1, thr= 98.12, gain=0.076584
tree= 1, node= 70, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 71, feature=10, thr= 82.43, gain=0.028392
tree= 1, node= 72, feature= 8, thr= 56.86, gain=0.071759
tree= 1, node= 73, feature=10, thr= 31.37, gain=0.980686
tree= 1, node= 74, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 75, feature= 4, thr= 19.61, gain=0.509863
tree= 1, node= 76, feature=15, thr= 31.37, gain=0.238685
tree= 1, node= 77, feature= 9, thr= 12.24, gain=0.460754
tree= 1, node= 78, feature=15, thr=  1.96, gain=0.478979
tree= 1, node= 79, feature=10, thr= 70.00, gain=0.095326
tree= 1, node= 80, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node= 82, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 83, feature= 8, thr= 99.41, gain=0.016630
tree= 1, node= 84, feature=14, thr= 45.65, gain=0.074657
tree= 1, node= 85, feature=15, thr=  0.14, gain=0.046120
tree= 1, node= 86, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node= 88, feature= 4, thr= 59.37, gain=0.248168
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tree= 1, node= 90, feature= 7, thr= 34.45, gain=0.035741
tree= 1, node= 91, feature=12, thr= 84.63, gain=0.101938
tree= 1, node= 92, feature= 8, thr=  5.76, gain=0.277986
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= 9, thr=  1.24, gain=0.089558
tree= 1, node= 96, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node= 97, feature= 4, thr= 64.00, gain=0.158359
tree= 1, node= 98, feature=15, thr= 95.06, gain=0.028907
tree= 1, node= 99, feature=11, thr= 69.29, gain=0.160612
tree= 1, node=100, feature=11, thr= 57.18, gain=0.305401
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tree= 1, node=103, feature= 2, thr= 41.47, gain=0.051778
tree= 1, node=104, feature= 9, thr= 39.22, gain=0.578194
tree= 1, node=105, feature=12, thr= 25.24, gain=0.355935
tree= 1, node=106, feature= 5, thr= 74.51, gain=0.192942
tree= 1, node=107, feature= 8, thr= 63.24, gain=0.131475
tree= 1, node=108, feature= 4, thr= 67.65, gain=0.045992
tree= 1, node=109, feature= 2, thr= 18.41, gain=0.304537
tree= 1, node=110, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=111, feature= 8, thr= 51.25, gain=0.084049
tree= 1, node=112, feature=10, thr= 83.53, gain=0.040335
tree= 1, node=113, feature= 3, thr= 83.00, gain=0.190530
tree= 1, node=114, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=115, feature= 6, thr=  1.29, gain=0.002972
tree= 1, node=116, feature=11, thr=  4.24, gain=0.013385
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tree= 1, node=118, feature=10, thr= 99.39, gain=0.250662
tree= 1, node=119, feature= 3, thr= 93.14, gain=0.062859
tree= 1, node=120, feature= 7, thr= 33.33, gain=0.151657
tree= 1, node=121, feature=13, thr= 42.25, gain=0.513195
tree= 1, node=122, feature=-1, thr= -1.00, gain=0.000000
```

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tree= 1, node=123, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=124, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=125, feature=11, thr= 29.29, gain=0.046809
tree= 1, node=126, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=127, feature= 8, thr= 93.53, gain=0.010377
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tree= 1, node=129, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=130, feature= 1, thr= 97.29, gain=0.322038
tree= 1, node=131, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=132, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=133, feature= 1, thr= 96.18, gain=0.050885
tree= 1, node=134, feature=13, thr= 52.00, gain=0.597950
tree= 1, node=135, feature= 2, thr= 10.41, gain=0.214701
tree= 1, node=136, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=137, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=138, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=139, feature=14, thr=  5.88, gain=0.159510
tree= 1, node=140, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=141, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=142, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=143, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=144, feature=14, thr= 60.47, gain=0.097384
tree= 1, node=145, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=146, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=147, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=148, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=149, feature=10, thr= 23.63, gain=0.350011
tree= 1, node=150, feature= 5, thr= 91.59, gain=0.122413
tree= 1, node=151, feature= 3, thr= 94.12, gain=0.703488
tree= 1, node=152, feature= 3, thr= 94.10, gain=0.170966
tree= 1, node=153, feature=11, thr=  1.45, gain=0.045876
tree= 1, node=154, feature=14, thr= 99.06, gain=0.000384
tree= 1, node=155, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=156, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=157, feature= 6, thr= 44.86, gain=0.161226
tree= 1, node=158, feature=13, thr= 57.53, gain=0.360657
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= 8, thr= 37.78, gain=0.021061
tree= 1, node=162, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=163, feature= 2, thr= 41.94, gain=0.107883
tree= 1, node=164, feature= 8, thr=  0.84, gain=0.018746
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=-1, thr= -1.00, gain=0.000000
tree= 1, node=168, feature=13, thr= 26.53, gain=0.171168
tree= 1, node=169, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=170, feature= 2, thr= 59.06, gain=0.038681
tree= 1, node=171, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=172, feature=14, thr= 29.41, gain=0.227190
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= 2, thr= 42.00, gain=0.083158
tree= 1, node=176, feature=14, thr= 94.04, gain=0.008874
tree= 1, node=177, feature=14, thr= 99.10, gain=0.152662
tree= 1, node=178, feature= 0, thr=  0.02, gain=0.014863
tree= 1, node=179, feature=12, thr= 67.65, gain=0.081822
tree= 1, node=180, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=181, feature= 0, thr=  0.02, gain=0.048211
tree= 1, node=182, feature=-1, thr= -1.00, gain=0.000000
tree= 1, node=183, feature=13, thr= 17.71, gain=0.260656
tree= 1, node=184, feature= 6, thr= 84.47, gain=0.266209
tree= 1, node=185, feature= 9, thr= 59.02, gain=0.215559
tree= 1, node=186, feature= 4, thr= 57.94, gain=0.070280
tree= 1, node=187, feature= 3, thr= 99.33, gain=0.082807
tree= 1, node=188, feature= 6, thr=  0.02, gain=0.010091
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tree= 1, node=190, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=193, feature= 2, thr= 20.33, gain=0.126720
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tree= 1, node=258, feature= 8, thr= 95.61, gain=0.078031
tree= 1, node=259, feature=-1, thr= -1.00, gain=0.000000
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tree= 1, node=264, feature= 4, thr= 69.25, gain=0.260114
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tree= 1, node=274, feature= 2, thr= 55.86, gain=0.127358
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tree= 2, node=  8, feature= 6, thr= 49.02, gain=0.158499
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tree= 2, node= 63, feature= 2, thr= 53.96, gain=0.044268
tree= 2, node= 64, feature= 3, thr= 99.04, gain=0.480590
tree= 2, node= 65, feature=13, thr= 27.18, gain=0.480976
tree= 2, node= 66, feature= 5, thr= 99.12, gain=0.318554
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tree= 2, node= 71, feature=14, thr= 35.29, gain=0.117126
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tree= 2, node=162, feature= 1, thr= 44.14, gain=0.119542
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tree= 3, node=162, feature=13, thr= 39.29, gain=0.074367
tree= 3, node=163, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=164, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=165, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=166, feature= 6, thr= 67.04, gain=0.014477
tree= 3, node=167, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=168, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=169, feature= 8, thr= 95.29, gain=0.152023
tree= 3, node=170, feature= 5, thr= 83.12, gain=0.087169
tree= 3, node=171, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=173, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=174, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=175, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=176, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=177, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=178, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=179, feature= 3, thr= 75.06, gain=0.027864
tree= 3, node=180, feature= 9, thr=  0.78, gain=0.144487
tree= 3, node=181, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=182, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=183, feature=14, thr= 72.43, gain=0.000912
tree= 3, node=184, feature= 9, thr=  8.78, gain=0.141344
tree= 3, node=185, feature= 6, thr= 51.41, gain=0.129096
tree= 3, node=186, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=187, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=188, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=189, feature= 4, thr= 86.27, gain=0.369132
tree= 3, node=190, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=191, feature= 6, thr= 20.59, gain=0.117595
tree= 3, node=192, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=193, feature=12, thr= 39.41, gain=0.110236
tree= 3, node=194, feature=10, thr= 40.24, gain=0.036096
tree= 3, node=195, feature= 3, thr= 94.12, gain=0.193133
tree= 3, node=196, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=199, feature=12, thr= 63.41, gain=0.046316
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tree= 3, node=203, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=205, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=206, feature= 2, thr=  5.18, gain=0.216305
tree= 3, node=207, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=208, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=209, feature=13, thr= 41.12, gain=0.191433
tree= 3, node=210, feature=11, thr= 32.78, gain=0.596594
tree= 3, node=211, feature= 1, thr= 98.04, gain=0.048830
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tree= 3, node=216, feature= 9, thr= 60.49, gain=0.081020
tree= 3, node=217, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=218, feature=14, thr= 31.06, gain=0.383150
tree= 3, node=219, feature= 8, thr= 47.06, gain=0.010649
tree= 3, node=220, feature= 5, thr= 43.65, gain=0.091165
tree= 3, node=221, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=222, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=223, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=224, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=225, feature=11, thr= 31.47, gain=0.303595
tree= 3, node=226, feature= 6, thr= 37.25, gain=0.384884
tree= 3, node=227, feature=13, thr=  5.29, gain=0.044518
tree= 3, node=228, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=229, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=230, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=231, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=232, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=233, feature=11, thr=  1.76, gain=0.086858
tree= 3, node=234, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=235, feature= 3, thr= 94.71, gain=0.141975
```

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tree= 3, node=236, feature= 6, thr= 40.12, gain=0.078140
tree= 3, node=237, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=238, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=239, feature=11, thr=  2.18, gain=0.035291
tree= 3, node=240, feature=11, thr= 53.29, gain=0.038840
tree= 3, node=241, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=242, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=243, feature=11, thr= 19.61, gain=0.183122
tree= 3, node=244, feature=15, thr=  0.14, gain=0.000279
tree= 3, node=245, feature= 4, thr=  1.80, gain=0.799738
tree= 3, node=246, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=247, feature=12, thr= 42.35, gain=0.211755
tree= 3, node=248, feature= 7, thr=  0.00, gain=0.000000
tree= 3, node=249, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=250, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=251, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=252, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=253, feature=15, thr= 99.06, gain=0.014381
tree= 3, node=254, feature=11, thr= 16.08, gain=0.041266
tree= 3, node=255, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=256, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=257, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=258, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=260, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=261, feature=10, thr= 21.49, gain=0.086858
tree= 3, node=262, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=263, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=265, feature= 0, thr=  3.10, gain=0.154239
tree= 3, node=266, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=267, feature= 1, thr= 89.41, gain=0.091860
tree= 3, node=268, feature= 1, thr= 94.61, gain=0.084231
tree= 3, node=269, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=270, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=271, feature= 2, thr= 19.06, gain=0.158843
tree= 3, node=272, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=273, feature=14, thr= 27.24, gain=0.010027
tree= 3, node=274, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=275, feature=10, thr= 99.49, gain=0.139069
tree= 3, node=276, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=277, feature= 0, thr= 34.67, gain=0.181739
tree= 3, node=278, feature= 9, thr= 44.04, gain=0.044724
tree= 3, node=279, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=280, feature= 9, thr= 10.16, gain=0.188512
tree= 3, node=281, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=282, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=283, feature= 4, thr= 10.61, gain=0.034135
tree= 3, node=284, feature=15, thr= 68.63, gain=0.016163
tree= 3, node=285, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=286, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=287, feature= 1, thr= 67.22, gain=0.318528
tree= 3, node=288, feature= 0, thr= 12.29, gain=0.331251
tree= 3, node=289, feature=11, thr=  7.76, gain=0.138157
tree= 3, node=290, feature= 1, thr= 86.24, gain=0.031745
tree= 3, node=291, feature=12, thr= 39.02, gain=0.070126
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tree= 3, node=296, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=297, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=298, feature= 3, thr= 99.06, gain=0.001698
tree= 3, node=299, feature=12, thr= 47.00, gain=0.010197
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tree= 3, node=301, feature= 3, thr= 96.16, gain=0.100211
tree= 3, node=302, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=303, feature= 3, thr= 85.33, gain=0.108023
tree= 3, node=304, feature= 8, thr= 68.02, gain=0.021969
tree= 3, node=305, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=306, feature=-1, thr= -1.00, gain=0.000000
```

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tree= 3, node=307, feature= 4, thr= 50.53, gain=0.042374
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tree= 3, node=330, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=331, feature=12, thr= 62.06, gain=0.175856
tree= 3, node=332, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=333, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=342, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=343, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=344, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=345, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=348, feature= 7, thr= 67.47, gain=0.039629
tree= 3, node=349, feature=15, thr= 15.20, gain=0.039781
tree= 3, node=350, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=351, feature= 7, thr= 70.71, gain=0.174507
tree= 3, node=352, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=359, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=360, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=362, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=363, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=364, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=365, feature=11, thr= 68.47, gain=0.041315
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tree= 3, node=367, feature= 6, thr= 48.37, gain=0.068614
tree= 3, node=368, feature= 7, thr= 27.24, gain=0.119967
tree= 3, node=369, feature= 9, thr=  0.00, gain=0.000000
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tree= 3, node=372, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=376, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=377, feature=-1, thr= -1.00, gain=0.000000
```

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tree= 3, node=378, feature= 9, thr=  0.20, gain=0.025283
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tree= 3, node=383, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=384, feature=10, thr= 94.18, gain=0.043304
tree= 3, node=385, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=386, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=387, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=388, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=389, feature= 5, thr= 85.65, gain=0.062826
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tree= 3, node=392, feature= 1, thr= 72.06, gain=0.033856
tree= 3, node=393, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=394, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=395, feature=-1, thr= -1.00, gain=0.000000
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tree= 3, node=418, feature= 1, thr= 64.71, gain=0.024052
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tree= 3, node=432, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=433, feature=10, thr=  1.53, gain=0.124302
tree= 3, node=434, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=435, feature= 7, thr= 72.06, gain=0.200622
tree= 3, node=436, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=437, feature=10, thr=  7.08, gain=0.039104
tree= 3, node=438, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=439, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=440, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=441, feature= 7, thr= 32.29, gain=0.016102
tree= 3, node=442, feature=-1, thr= -1.00, gain=0.000000
tree= 3, node=443, feature=-1, thr= -1.00, gain=0.000000
classification accuracy= 0.8053
```