

## **Background and Implementation**

See web site.

## **Challenges**

Originally, the continuous attributes of “probability of winning” and “bet amount” were given the “numeric” type in Weka. But this created difficulties because the resulting decision tree became enormous in size with hundreds of leaves. This made it difficult to interpret the results and finding useful patterns. Therefore I made the decision to convert these numeric attributes into nominal ones by categorizing the percents by 10% intervals: 0-10%, 10-20%, ..., 90-100%. The bets were converted as follows: 100, 200, 300, 400, 500, 600, 700-900, 1000-2400, 2500-5000, 5100-10000, 10100-20000. Although the conversion resulted in some loss of granularity, the new decision trees were much simpler to interpret and suffered a loss of 2-4% classification accuracy.

## **Detailed Results**

Looking at figures 1 and 2 below, it's clear that both the Hyperborean and SartreNL programs achieve better classification accuracy as it progresses to later rounds. For example, the Hyperborean program starts out with ~65% classification accuracy during the flop round if all flop and preflop information (9 attributes) is taken into account. Even when all preflop information is removed, the classification is still ~63% accurate. This means the preflop info does not significantly affect flop classification. Taking this one step further, after removing the probability of winning given the opponent's hand, the accuracy dropped by merely 1%. Finally, dropping the opposing player's 1<sup>st</sup> bet amount during the flop decreased accuracy by another 1%. Overall classification accuracy dropped from ~65% to ~61% when the 9 original attributes were reduced to just 2 attributes. Similar trends occur during the turn and river phases of play. Therefore there are only two important attributes, both of which are only in the current round of play: the opposing player's first action and the probability of winning.

### Classification Accuracy vs. Number of Attributes (Hyperborean)

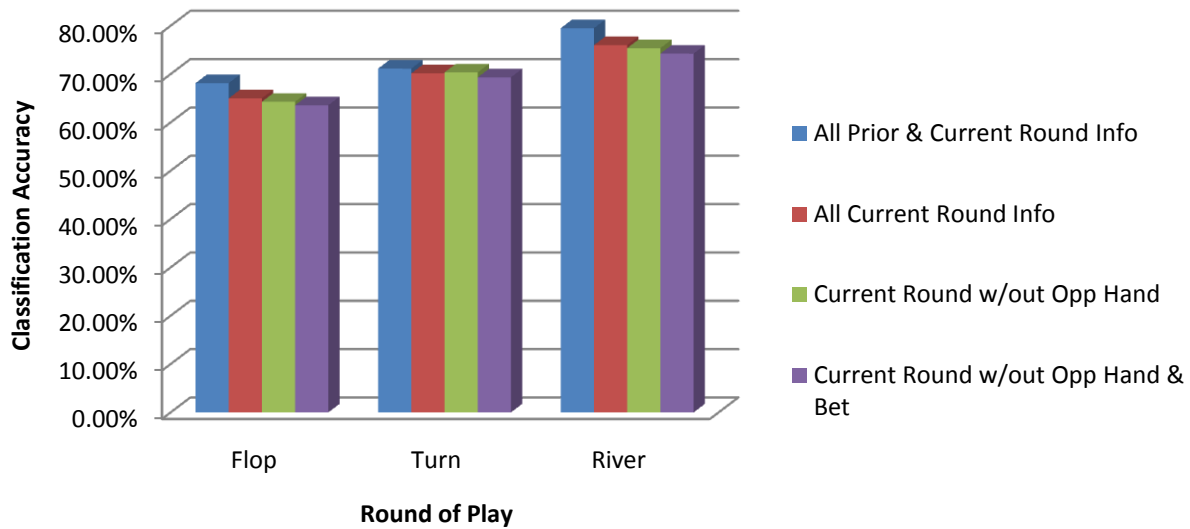


Figure 1

### Classification Accuracy vs. Number of Attributes (SartreNL)

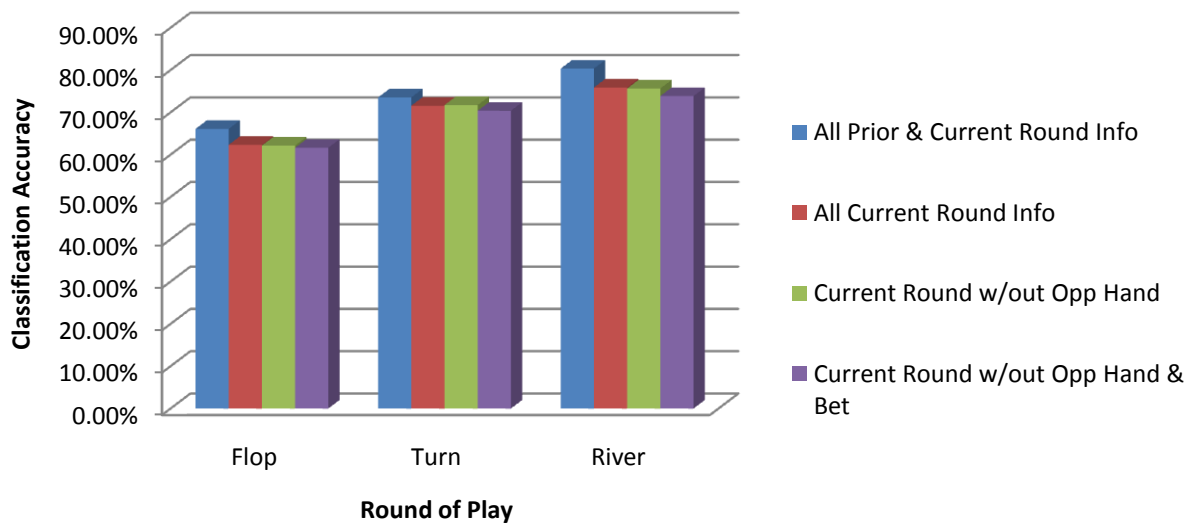


Figure 2

The other important trend discerned from these graphs is that the accuracy of classification improves as we head into later rounds. For example, for the SartreNL program, accuracy of classification is only 59-63% during the flop round of play but increases to 69-71% for the turn phase. By the time it gets to the river, the classification accuracy improves to nearly 80%. It's not entirely clear why this is happening for both programs. One possibility is that the programs are making bigger gambles or simply bluffing more in the earlier stages. Later on, when the pots get large, they tend to stick with straight-forward winning probability more than before. Another possibility is that some more sophisticated modeling is occurring behind the scenes that we're simply not aware of.

Another set of useful information can be gleaned from the generated decision trees for each round of play. For instance, looking at the flop round in figure 3 below, we see that when the opponent first raises, the reacting move would be to fold for winning percentage of 0-50%, to call for winning percentage of 50-90%, and to raise for winning % of >90%. Notice the (1867.0/1062.0) in the 40-50% category, it means that 1062 of the 1867 classifications are wrong, indicating that a fold would be a better move. Therefore the 40-50% category is controversial. For opponent first action of call, however, the recommended move is to raise for 0-40% change of winning, to call for 40-60% change of winning, and to raise for >60% change of winning. This is curious because it seems counterintuitive to raise with such low chance of winning, but perhaps some bluffing is taking place.

| Decision Tree (Hyperborean)                   |  |   |
|---|--|---|
| Flop  | Turn   | River   |
| flop p1 1st action = r                        | turn p1 1st action = r                       | river p1 1st action = r                       |
| flop p2 only win % = 0-10: f (0.0)            | turn p2 only win % = 0-10: f (43.0/8.0)      | river p2 only win % = 0-10: f (365.0/46.0)    |
| flop p2 only win % = 10-20: f (284.0/1.0)     | turn p2 only win % = 10-20: f (346.0/42.0)   | river p2 only win % = 10-20: f (415.0/70.0)   |
| flop p2 only win % = 20-30: f (1196.0/128.0)  | turn p2 only win % = 20-30: f (584.0/156.0)  | river p2 only win % = 20-30: f (477.0/96.0)   |
| flop p2 only win % = 30-40: f (1602.0/452.0)  | turn p2 only win % = 30-40: f (842.0/250.0)  | river p2 only win % = 30-40: f (611.0/192.0)  |
| flop p2 only win % = 40-50: f (1867.0/1062.0) | turn p2 only win % = 40-50: f (1015.0/461.0) | river p2 only win % = 40-50: f (668.0/277.0)  |
| flop p2 only win % = 50-60: c (1441.0/354.0)  | turn p2 only win % = 50-60: c (932.0/367.0)  | river p2 only win % = 50-60: c (675.0/314.0)  |
| flop p2 only win % = 60-70: c (1020.0/189.0)  | turn p2 only win % = 60-70: c (796.0/161.0)  | river p2 only win % = 60-70: c (642.0/221.0)  |
| flop p2 only win % = 70-80: c (854.0/184.0)   | turn p2 only win % = 70-80: c (694.0/99.0)   | river p2 only win % = 70-80: c (621.0/147.0)  |
| flop p2 only win % = 80-90: c (555.0/197.0)   | turn p2 only win % = 80-90: c (513.0/116.0)  | river p2 only win % = 80-90: c (513.0/131.0)  |
| flop p2 only win % = 90-100: r (248.0/81.0)   | turn p2 only win % = 90-100: r (278.0/122.0) | river p2 only win % = 90-100: r (464.0/155.0) |
| flop p1 1st action = c                        | turn p1 1st action = c                       | river p1 1st action = c                       |
| flop p2 only win % = 0-10: r (0.0)            | turn p2 only win % = 0-10: c (125.0/36.0)    | river p2 only win % = 0-10: c (905.0/416.0)   |
| flop p2 only win % = 10-20: r (893.0/391.0)   | turn p2 only win % = 10-20: c (1298.0/448.0) | river p2 only win % = 10-20: c (950.0/369.0)  |
| flop p2 only win % = 20-30: r (3369.0/1112.0) | turn p2 only win % = 20-30: c (2000.0/886.0) | river p2 only win % = 20-30: c (1004.0/244.0) |
| flop p2 only win % = 30-40: r (4530.0/1804.0) | turn p2 only win % = 30-40: c (2351.0/803.0) | river p2 only win % = 30-40: c (1170.0/126.0) |
| flop p2 only win % = 40-50: c (4938.0/2279.0) | turn p2 only win % = 40-50: c (2544.0/606.0) | river p2 only win % = 40-50: c (1326.0/98.0)  |
| flop p2 only win % = 50-60: c (3963.0/1912.0) | turn p2 only win % = 50-60: c (2368.0/584.0) | river p2 only win % = 50-60: c (1219.0/149.0) |
| flop p2 only win % = 60-70: r (2950.0/1207.0) | turn p2 only win % = 60-70: c (1919.0/606.0) | river p2 only win % = 60-70: c (1141.0/314.0) |
| flop p2 only win % = 70-80: r (2512.0/938.0)  | turn p2 only win % = 70-80: r (1860.0/869.0) | river p2 only win % = 70-80: r (1299.0/634.0) |
| flop p2 only win % = 80-90: r (1830.0/346.0)  | turn p2 only win % = 80-90: r (1687.0/427.0) | river p2 only win % = 80-90: r (1281.0/325.0) |
| flop p2 only win % = 90-100: r (719.0/32.0)   | turn p2 only win % = 90-100: r (963.0/55.0)  | river p2 only win % = 90-100: r (1308.0/69.0) |

Figure 3

Also note that in the turn and river stages, no unusual actions take place. A similar pattern occurs for the SartreNL program in figure 4 below. One interesting difference between the two programs is that SartreNL rarely raises in the flop and turn rounds when the opponent first raises. But it does raise in the river phase when it has strong chance of winning.

| <b>Decision Tree (SartreNL)</b>               |  |   |
|---|--|---|
| <b>Flop</b>                                   | <b>Turn</b>                                  | <b>River</b>                                  |
| flop p1 1st action = r                        | turn p1 1st action = r                       | river p1 1st action = r                       |
| flop p2 only win % = 0-10: f (0.0)            | turn p2 only win % = 0-10: f (42.0/6.0)      | river p2 only win % = 0-10: f (421.0/55.0)    |
| flop p2 only win % = 10-20: f (90.0)          | turn p2 only win % = 10-20: f (365.0/44.0)   | river p2 only win % = 10-20: f (443.0/91.0)   |
| flop p2 only win % = 20-30: f (399.0/18.0)    | turn p2 only win % = 20-30: f (579.0/131.0)  | river p2 only win % = 20-30: f (497.0/119.0)  |
| flop p2 only win % = 30-40: f (705.0/176.0)   | turn p2 only win % = 30-40: f (797.0/279.0)  | river p2 only win % = 30-40: f (639.0/221.0)  |
| flop p2 only win % = 40-50: f (965.0/521.0)   | turn p2 only win % = 40-50: c (964.0/490.0)  | river p2 only win % = 40-50: f (709.0/331.0)  |
| flop p2 only win % = 50-60: c (695.0/125.0)   | turn p2 only win % = 50-60: c (739.0/234.0)  | river p2 only win % = 50-60: c (659.0/291.0)  |
| flop p2 only win % = 60-70: c (471.0/41.0)    | turn p2 only win % = 60-70: c (696.0/101.0)  | river p2 only win % = 60-70: c (614.0/229.0)  |
| flop p2 only win % = 70-80: c (394.0/27.0)    | turn p2 only win % = 70-80: c (594.0/55.0)   | river p2 only win % = 70-80: c (568.0/129.0)  |
| flop p2 only win % = 80-90: c (268.0/62.0)    | turn p2 only win % = 80-90: c (446.0/48.0)   | river p2 only win % = 80-90: c (494.0/144.0)  |
| flop p2 only win % = 90-100: c (128.0/55.0)   | turn p2 only win % = 90-100: c (211.0/99.0)  | river p2 only win % = 90-100: r (454.0/135.0) |
| flop p1 1st action = c                        | turn p1 1st action = c                       | river p1 1st action = c                       |
| flop p2 only win % = 0-10: c (0.0)            | turn p2 only win % = 0-10: c (117.0/18.0)    | river p2 only win % = 0-10: c (838.0/373.0)   |
| flop p2 only win % = 10-20: c (793.0/376.0)   | turn p2 only win % = 10-20: c (1310.0/474.0) | river p2 only win % = 10-20: c (957.0/363.0)  |
| flop p2 only win % = 20-30: r (3460.0/1364.0) | turn p2 only win % = 20-30: c (2065.0/985.0) | river p2 only win % = 20-30: c (981.0/213.0)  |
| flop p2 only win % = 30-40: r (4625.0/2121.0) | turn p2 only win % = 30-40: c (2421.0/764.0) | river p2 only win % = 30-40: c (1162.0/138.0) |
| flop p2 only win % = 40-50: c (4897.0/1782.0) | turn p2 only win % = 40-50: c (2460.0/493.0) | river p2 only win % = 40-50: c (1239.0/119.0) |
| flop p2 only win % = 50-60: c (3937.0/1718.0) | turn p2 only win % = 50-60: c (2211.0/453.0) | river p2 only win % = 50-60: c (1065.0/121.0) |
| flop p2 only win % = 60-70: r (2960.0/1363.0) | turn p2 only win % = 60-70: c (1791.0/534.0) | river p2 only win % = 60-70: c (1085.0/276.0) |
| flop p2 only win % = 70-80: r (2531.0/1176.0) | turn p2 only win % = 70-80: c (1754.0/863.0) | river p2 only win % = 70-80: c (1243.0/596.0) |
| flop p2 only win % = 80-90: r (1760.0/472.0)  | turn p2 only win % = 80-90: r (1549.0/411.0) | river p2 only win % = 80-90: r (1160.0/289.0) |
| flop p2 only win % = 90-100: r (716.0/33.0)   | turn p2 only win % = 90-100: r (927.0/44.0)  | river p2 only win % = 90-100: r (1263.0/77.0) |

Figure 4