Bayesian Poker

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Overview

- The Monash Poker Project
- Poker
- A Bayesian Network for poker
- Betting curves for randomisation
- Bluffing
- Opponent Modelling
- Experimentation to date
Poker and AI

- Poker is ideal for testing automated reasoning under uncertainty
  - Physical randomisation
  - Incomplete information
  - Unpredictable opponent (strategies, bluffing, etc)

- Bayesian networks are a good representation for complex game playing.

- Our Bayesian Poker Player (BPP) plays at the level of a good amateur human player.
The History of Monash BPP

Started with Kevin Korb in 1993 (5 card stud).

- Nathalie Jitnah, 1993. Bayesian Poker (the basic BN)
- Scott Thomson, 1994. Bayesian Poker (some improvements)
- Darren Boulton, 2002-03. Extended to Texas Hold’em Poker. Improved bluffing and opponent modelling.
- 2006
  - Inaugural Bot Poker competition, Conference of the American Artificial Intelligence Association. (3rd)
  - New Web Interface (Steven Mascaro), demo at Open Day (this Sunday!).
Five-Card Stud Poker

Players start with an *ante* (initial fixed bet) and are dealt a sequence of 5 cards, first face down (hidden), the rest face up.

Player actions after each card is dealt:

- **PASS** - first player may make no bet
- **CALL** - match the current bet on the table
- **RAISE** - increase the bet
- **FOLD** - drop out of this hand
Texas Hold’em Poker

Players dealt 2 card face down, then round of betting (pre-flop).

Remaining dealt cards (5) are “shared”.

Betting round after 3 shared cards (flop).

Betting round after 4th shared card (turn).

Betting round after 5th shared card (river).
## Poker Hands

Poker Hands from weakest to strongest:

<table>
<thead>
<tr>
<th>Hand Type</th>
<th>Example</th>
<th>Probability 5 card stud</th>
<th>Probability Texas Hold’em</th>
</tr>
</thead>
<tbody>
<tr>
<td>Busted</td>
<td>A♣ K♣ J♦ 10♥ 4♥</td>
<td>0.5015629</td>
<td>0.1728400</td>
</tr>
<tr>
<td>Pair</td>
<td>2♥ 2♦ J♣ 8♦ 4♥</td>
<td>0.4225703</td>
<td>0.4380000</td>
</tr>
<tr>
<td>Two Pair</td>
<td>5♥ 5♣ Q♣ Q♣ K♣</td>
<td>0.0475431</td>
<td>0.2351900</td>
</tr>
<tr>
<td>3 of a Kind</td>
<td>7♠ 7♥ 7♠ 3♥ 4♦</td>
<td>0.0211037</td>
<td>0.0483400</td>
</tr>
<tr>
<td>Straight</td>
<td>3♠ 4♣ 5♥ 6♥ 7♣</td>
<td>0.0035492</td>
<td>0.0479900</td>
</tr>
<tr>
<td>Flush</td>
<td>A♣ K♣ 7♣ 4♣ 2♣</td>
<td>0.0019693</td>
<td>0.0299000</td>
</tr>
<tr>
<td>Full House</td>
<td>7♠ 7♦ 7♠ 10♦ 10♣</td>
<td>0.0014405</td>
<td>0.0255000</td>
</tr>
<tr>
<td>4 of a Kind</td>
<td>3♥ 3♠ 3♦ 3♣ J♣</td>
<td>0.0002476</td>
<td>0.0018800</td>
</tr>
<tr>
<td>Straight Flush</td>
<td>3♠ 4♠ 5♠ 6♠ 7♠</td>
<td>0.0000134</td>
<td>0.0003600</td>
</tr>
</tbody>
</table>

Bayesian Poker
Pot Odds & Probabilities

Let $p =$ probability of winning the pot if the hand is played to showdown,

$n - 1 =$ number of opponents remaining in game,

$k =$ expected cost of reaching the showdown.

\[
\text{pot odds} = \frac{k}{c + k - 1} \tag{1}
\]

The calling threshold, $\theta$, identifies the probability of winning at which the expected values of calling a bet versus folding are equal.

\[
\theta = \frac{k}{c + 2k - 1} \tag{2}
\]
Poker BN (circa 99)
Bayesian Poker Network
(cont.)

- 4 different networks: 1 for each round of play.
- **OPP Current, BPP Current**: (partial) hand types with cards dealt to now.
- **OPP Final, BPP Final**: hand types after all 5 cards dealt.

- Observation nodes:
  - **OPP Upcards**: All opponents cards except first are visible to BPP.
  - **OPP Action**: BPP knows opponents action.
Hand Types

- Initial 9 hand types too coarse.

- Actual number of distinct poker hand values is 7462

(\text{http://www.suffecool.net/poker/evaluator.html})

<table>
<thead>
<tr>
<th>Type</th>
<th>Unique</th>
<th>Distinct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight Flush</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Four of a Kind</td>
<td>624</td>
<td>156</td>
</tr>
<tr>
<td>Full Houses</td>
<td>3744</td>
<td>156</td>
</tr>
<tr>
<td>Flush</td>
<td>5108</td>
<td>1277</td>
</tr>
<tr>
<td>Straight</td>
<td>10200</td>
<td>10</td>
</tr>
<tr>
<td>Three of a Kind</td>
<td>54912</td>
<td>858</td>
</tr>
<tr>
<td>Two Pair</td>
<td>123552</td>
<td>858</td>
</tr>
<tr>
<td>One Pair</td>
<td>1098240</td>
<td>2860</td>
</tr>
<tr>
<td>High Card</td>
<td>1302540</td>
<td>1277</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2598960</strong></td>
<td><strong>7462</strong></td>
</tr>
</tbody>
</table>

- Current BPP recognises 25 hand types a pair):
  - busted-low \((\leq 8)\) busted-medium \((9,10,J)\)
    - busted-Q-high, busted-K-high, busted-A-high
  - all pairs represented separately
  - 7 other hand-types
Conditional Probability Tables

In general, for BNs:

- Each node has an associated CPT
- CPT gives probability of child node given the combination of values of the parent node.

For this BPP:

- Prior for “Final” hand as per table
- $P(\text{Current}|\text{Final})$ obtained by dealing many hands
- $P(\text{OppAction}|\text{Current})$ - very simplistic, can start with “rules”, learn as play opponent(s)
Belief Updating

Given evidence for $BPP_{Current}$ and $OPP_{Action}$, belief updating produces

- belief vectors for both players’ final hand types
- a posterior probability of BPP winning the game.
A Decision Network for Poker

(Carlton 2000 version)
Making the decision

The utility node, *Winnings*, measures the dollar value BPP expects to make based on the possible combinations of the states of the parent nodes (*BPP_Win* and *BPP_Next_Action*).

<table>
<thead>
<tr>
<th><em>BPP_Next_Action</em></th>
<th><em>BPP_Win</em></th>
<th>Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bet</td>
<td>Win</td>
<td>$F_{bet} - B_{bet}$</td>
</tr>
<tr>
<td>Bet</td>
<td>Lose</td>
<td>$-B_{bet}$</td>
</tr>
<tr>
<td>Pass</td>
<td>Win</td>
<td>$F_{pass} - B_{pass}$</td>
</tr>
<tr>
<td>Pass</td>
<td>Lose</td>
<td>$-B_{pass}$</td>
</tr>
<tr>
<td>Fold</td>
<td>Win</td>
<td>0</td>
</tr>
<tr>
<td>Fold</td>
<td>Lose</td>
<td>0</td>
</tr>
</tbody>
</table>

*B* size of betting unit; *R* no. of betting round remaining; *C* current pot size.

If betting, need to estimate:

$F_{bet}$ – final pot

$B_{bet}$ – BPP’s future contribution
Betting with Randomization

- *Betting curves* are used to randomize betting actions.

- The horizontal axis shows the difference between the EW of folding and calling.

- Betting curves were generated with exponential functions.

- “Good” parameters found using stochastic search with BPP vs. a Rule-Based Opponent.
Bluffing

- Bluffing is the intentional misrepresentation of the strength of one’s hand (e.g. over-representing that strength).
- With low probability (5%) BPP will enter “bluffing” mode.
- Bluffing done by modifying predicted belief in winning (by halving probability of losing).
- E.g. If predicted 60% chance of winning, modify to 80%.
- Decisions then made the same way.
Current Decision Network for Texas Hold’em Poker

(Boulton 2003 version)
How good is BPP?

• Beats
  – A Simple Probabilistic Opponent
  – A Rule-Based Opponent
  – Some amateur human Opponents
  – Some bots (AAAI competition)

• Loses to
  – Good bots (AAAI competition) - U. of Alberta (Billings group), CMU bot.
  – experienced humans
Extensions

- BN Improvements
  - Adding bluffing to the opponent model
  - Improved learning of opponent model

- More complex poker
  - Multi-opponent games
  - Table stake games

- Dynamic Bayesian network to represent play over time