Strategy Evaluation in Extensive Games with Importance Sampling

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UNIVERSITY OF ALBERTA

University of Alberta
Computer Poker Research Group

Making IT happen Computing Science

Second Man-Machine Poker Championship

- Just arrived from the Second Man-Machine Poker Championship in Las Vegas
- Our program, Polaris, played six 500 hand duplicate matches against six poker pros over 4 days
- Final score: 3 wins, 2 losses, 1 tie! AI Wins!
- This research played a critical role in our success

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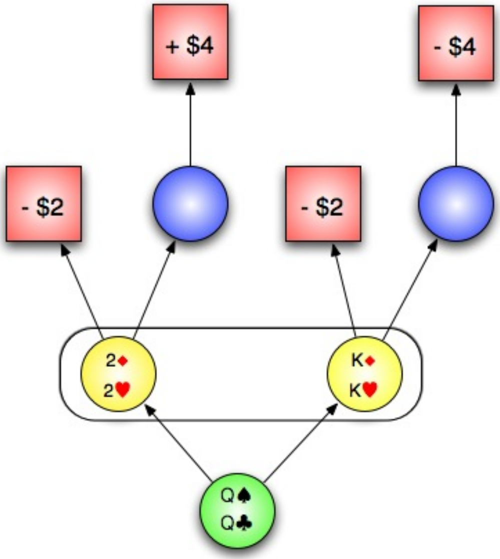
- Problem 1: How can we estimate the performance of the other strategies, based on these samples?
- Problem 2: How can we reduce luck (variance) in our estimates?
  - Money = Skill + Luck + Position

The Solution

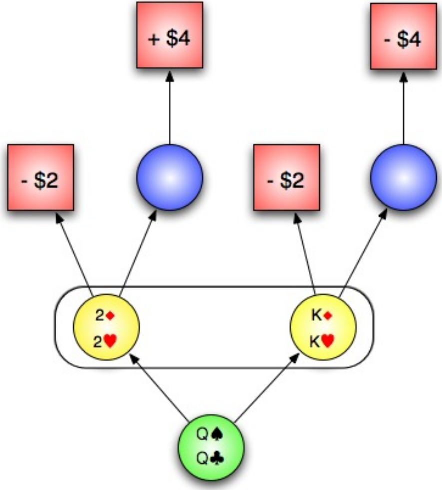
- Importance Sampling for evaluating other strategies
- Combine with existing estimators to reduce variance
- Create additional synthetic data (Main contribution)
- Assumes that the opponent's strategy is static
- General approach, not poker specific

	On Policy	Off Policy
Perfect Information	Unbiased	Bias
Partial Information	Bias	Bias

Repeated Extensive Form Games



Extensive Form Games



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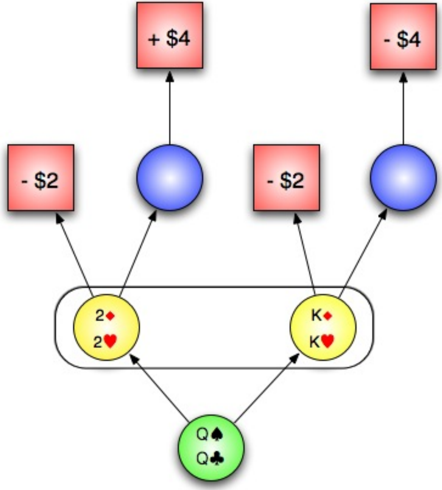
  Action probabilities for player i
- σ - A strategy profile.
  Strategy for each player

Extensive Form Games



- σ_i - A strategy.
  Action probabilities for player i
- σ - A strategy profile.
  Strategy for each player
- $\pi^\sigma(h)$ -Probability of σ reaching h
- $\pi_i^\sigma(h)$ - i's contribution to $\pi^\sigma(h)$
- $\pi_{-i}^\sigma(h)$ - Everyone but i's contribution to $\pi^\sigma(h)$

Importance Sampling

For the terminal nodes $z \in Z$, we can evaluate strategy profile σ with Monte Carlo estimation:

$$E_{z|\sigma}[V(z)] = \frac{1}{t}\sum_{i=1}^{t} V(z_i) \tag{1}$$

- Importance Sampling is a well known technique for estimating the value of one distribution by drawing samples from another distribution
- Useful if one distribution is "expensive" to draw samples from

Importance Sampling for Strategy Evaluation

- σ - strategy profile containing a strategy we want to evaluate
- $\hat{\sigma}$ - strategy profile containing an observed strategy
- In the on-policy case, $\sigma = \hat{\sigma}$

$$E_{z|\hat{\sigma}}[V(z)] = \frac{1}{t}\sum_{i=1}^{t} V(z_i)\frac{\pi^{\sigma}(z)}{\pi^{\hat{\sigma}}(z)} \tag{2}$$

$$= \frac{1}{t}\sum_{i=1}^{t} V(z_i)\frac{\pi_i^{\sigma}(z)\pi_{-i}^{\sigma}(z)}{\pi_i^{\hat{\sigma}}(z)\pi_{-i}^{\hat{\sigma}}(z)} \tag{3}$$

$$= \frac{1}{t}\sum_{i=1}^{t} V(z_i)\frac{\pi_i^{\sigma}(z)}{\pi_i^{\hat{\sigma}}(z)} \tag{4}$$

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$$= \frac{1}{t}\sum_{i=1}^{t} V(z_i)\frac{\pi_i^{\sigma}(z)}{\pi_i^{\hat{\sigma}}(z)} \quad (4)$$

- Note that the probabilities that depend on the opponent and chance players cancel out!

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Basic Importance Sampling and alternate estimators

- On-policy basic importance sampling: just monte-carlo sampling
- Off-policy basic importance sampling: high variance, some bias
- Any value function can be used
  - For example - the DIVAT estimator for Poker, which is unbiased and low variance
- We can also create synthetic data. This is the main contribution of the paper.

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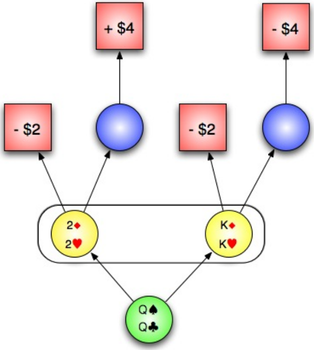
- Equivalently, if we see a member of $U(z')$, we can also evaluate z'
- If we choose U carefully, we can still cancel out the opponent's probabilities!
- Two examples - Game-Ending Actions and Other Private Information

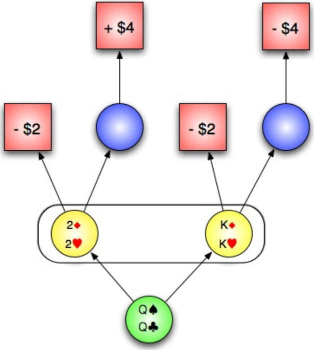
Game-Ending Actions



- h is an observed history

(5)

Game-Ending Actions



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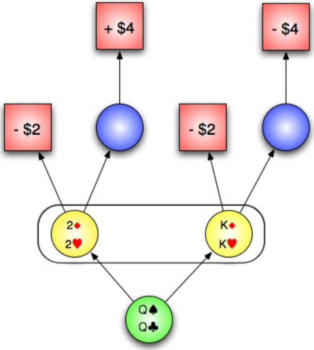
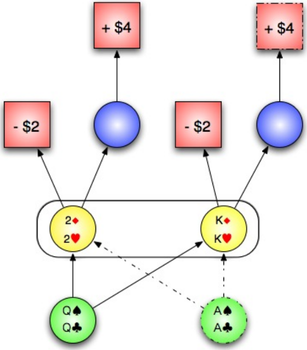


- h is an observed history
- $S_{-i}(z') \in H$ is a place we could have ended the game
- $z' \in U^{-1}(z)$ is the set of synthetic histories where we do end the game

$$\sum_{z' \in U^{-1}(z)} V(z') \frac{\pi_i^{\sigma}(z')}{\pi_i^{\hat{\sigma}}(S_{-i}(z'))} = E_{z|\hat{\sigma}}\left[V(z)\right] \tag{5}$$

Provably unbiased in the on-policy, full information case

Private Information



- Pretend you had other private information than you actually received
- Opponent's strategy can't depend on our private information

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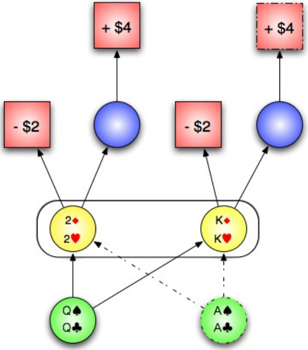
Private Information



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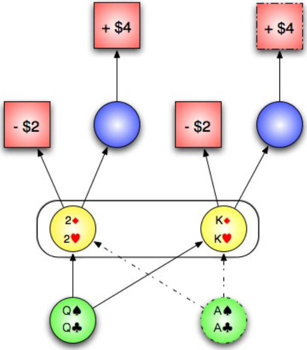

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- $U(z) = \{z' \in Z : \forall \sigma\ \pi^{\sigma}_{-i}(z') = \pi^{\sigma}_{-i}(z)\}$ (6)

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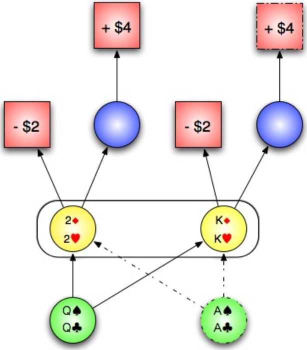

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- Opponent's strategy can't depend on our private information
- In poker, pretend you held different 'hole cards'. 2375 more samples per game!
- $U(z) = \{z' \in Z : \forall \sigma \; \pi^{\sigma}_{-i}(z') = \pi^{\sigma}_{-i}(z)\}$

$$\sum_{z' \in U^{-1}(z)} V(z') \frac{\pi_i^{\sigma}(z')}{\pi_i^{\hat{\sigma}}(U(z'))} = E_{z|\hat{\sigma}}[V(z)] \tag{6}$$

Provably unbiased in on-policy, full information case

Results

	Bias	StdDev	RMSE
On-Policy: S2298			
Basic	0*	5103	161
BC-DIVAT	0*	2891	91
Game Ending Actions	0*	5126	162
Private Information	0*	4213	133
PI+BC-DIVAT	0*	2146	68
PI+GEA+BC-DIVAT	0*	1778	56
Off-Policy: CFR8			
Basic	200 ± 122	62543	1988
BC-DIVAT	84 ± 45	22303	710
Game Ending Actions	123 ± 120	61481	1948
Private Information	12 ± 16	8518	270
PI+BC-DIVAT	35 ± 13	3254	109
PI+GEA+BC-DIVAT	2 ± 12	2514	80

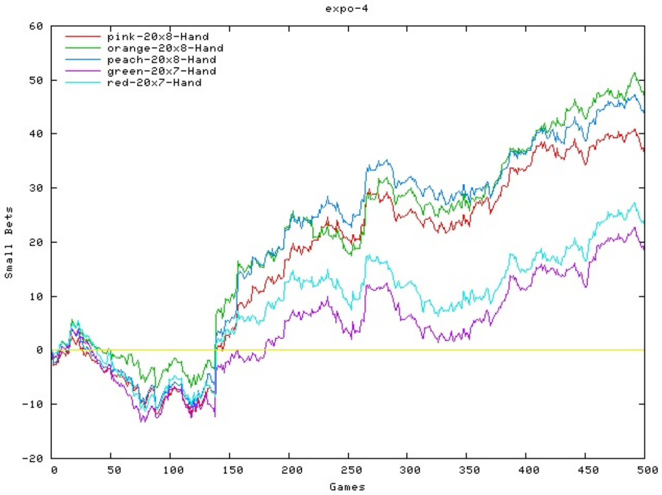
- 1 million hands of S2298 vs PsOpti4
- Units: millibets/game
- RMSE is Root Mean Squared Error over 500 games

Results

	Bias			StdDev			RMSE		
	Min	–	Max	Min	–	Max	Min	–	Max
On Policy									
Basic	0*	–	0*	5102	–	5385	161	–	170
BC-DIVAT	0*	–	0*	2891	–	2930	91	–	92
PI+GEA+BC-DIVAT	0*	–	0*	1701	–	1778	54	–	56
Off Policy									
Basic	49	–	200	20559	–	244469	669	–	7732
BC-DIVAT	10	–	103	12862	–	173715	419	–	5493
PI+GEA+BC-DIVAT	2	–	9	1816	–	2857	58	–	90

- 1 million hands of S2298, CFR8, Orange against PsOpti4
- Units: millibets/game
- RMSE is Root Mean Squared Error over 500 games

Conclusion: Man Machine Poker Championship



Highest Standard Deviation: 1228 millibets/game