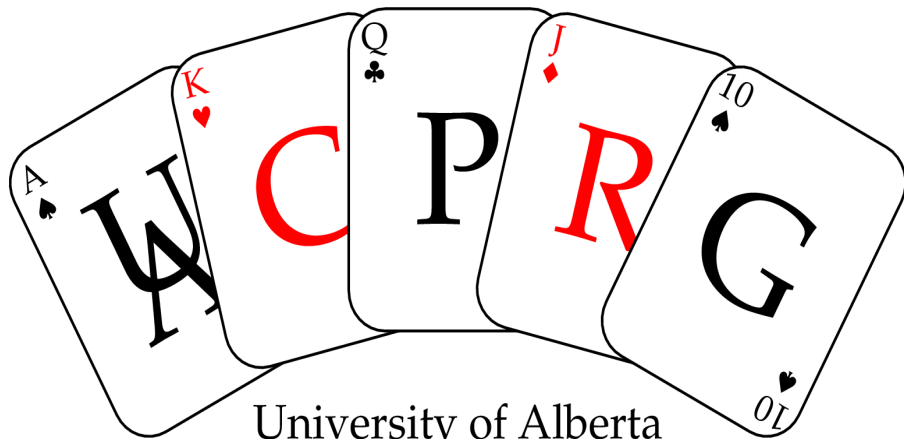# Evaluating State-Space Abstractions in Extensive-Form Games

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UNIVERSITY OF ALBERTA

Alberta Innovates

compute • calcul
CANADA

NSERC
CRSNG

Computing Science

Outline

- Using CFR-BR to evaluate abstractions

- Using imperfect recall in abstractions

- ~~New abstraction features~~
    - Read our paper!

Extensive-Form Games
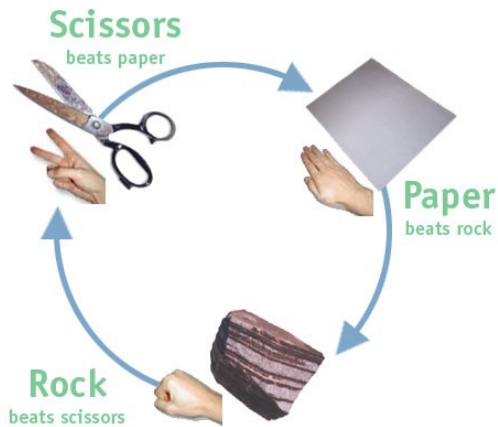
Rock Paper Scissors
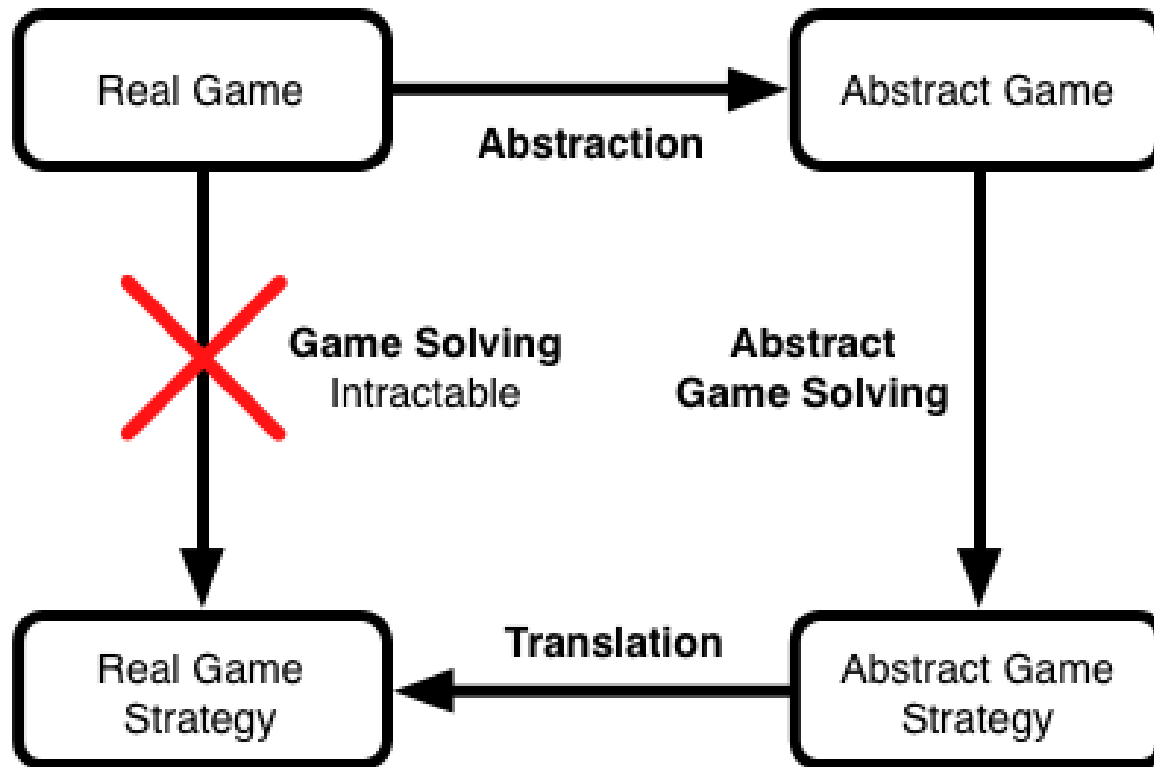9 states

Limit Texas Hold'em
~10^{18} states

RTS Games
many states

TOO BIG!

Abstraction

- Combine strategically similar situations to create a smaller (hopefully) strategically similar game
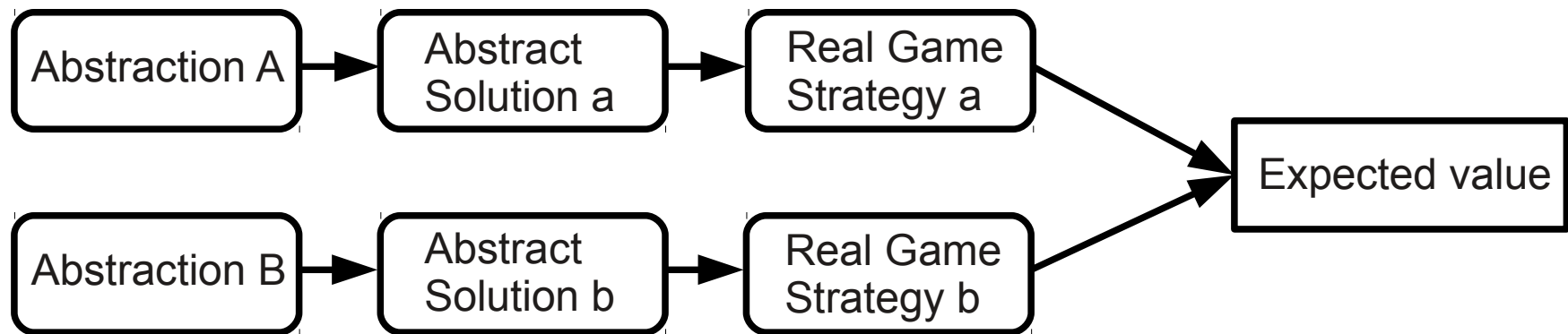
Evaluating an Abstraction

- Gilpin and Sandholm (AAAI '08) listed three methods for evaluating abstractions

  - One on one comparison

  - Play versus real-game equilibrium
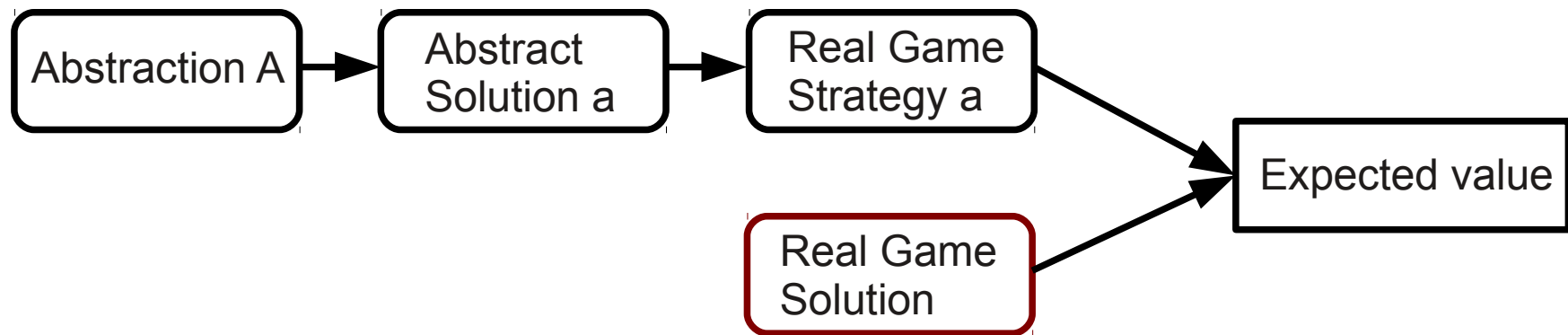
  - Play versus best-response

Evaluating an Abstraction

- One on one comparison
  - Not transitive: cycles of winners
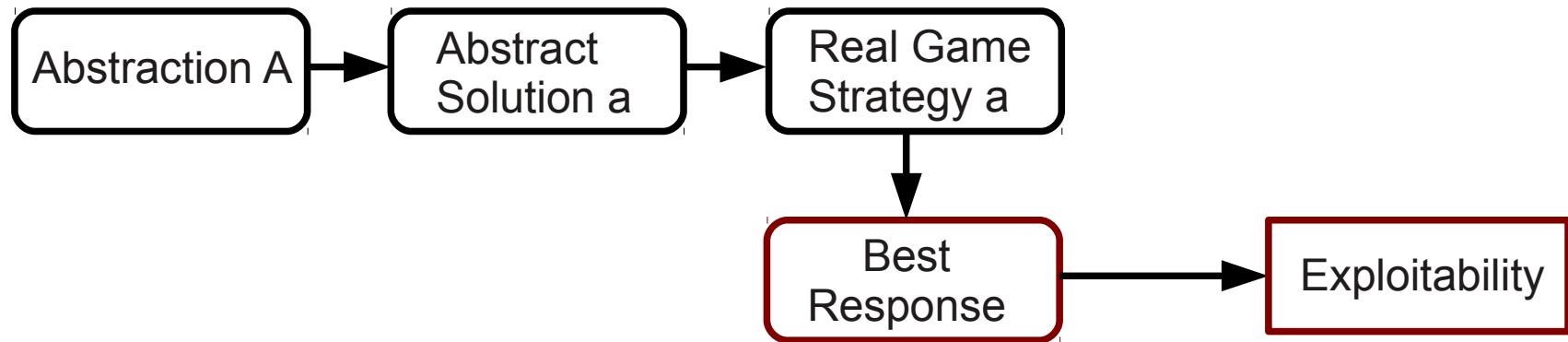 - Depends on the particular abstract solutions

```
Abstraction A  →  Abstract Solution a  →  Real Game Strategy a  ↘
                                                                   Expected value
Abstraction B  →  Abstract Solution b  →  Real Game Strategy b  ↗
```

Evaluating an Abstraction

- Play versus real-game equilibrium
  - Generally intractable
  - Depends on the particular abstract solutions

```
[Abstraction A] → [Abstract Solution a] → [Real Game Strategy a] ↘
                                                                    [Expected value]
                                         [Real Game Solution] ↗
```
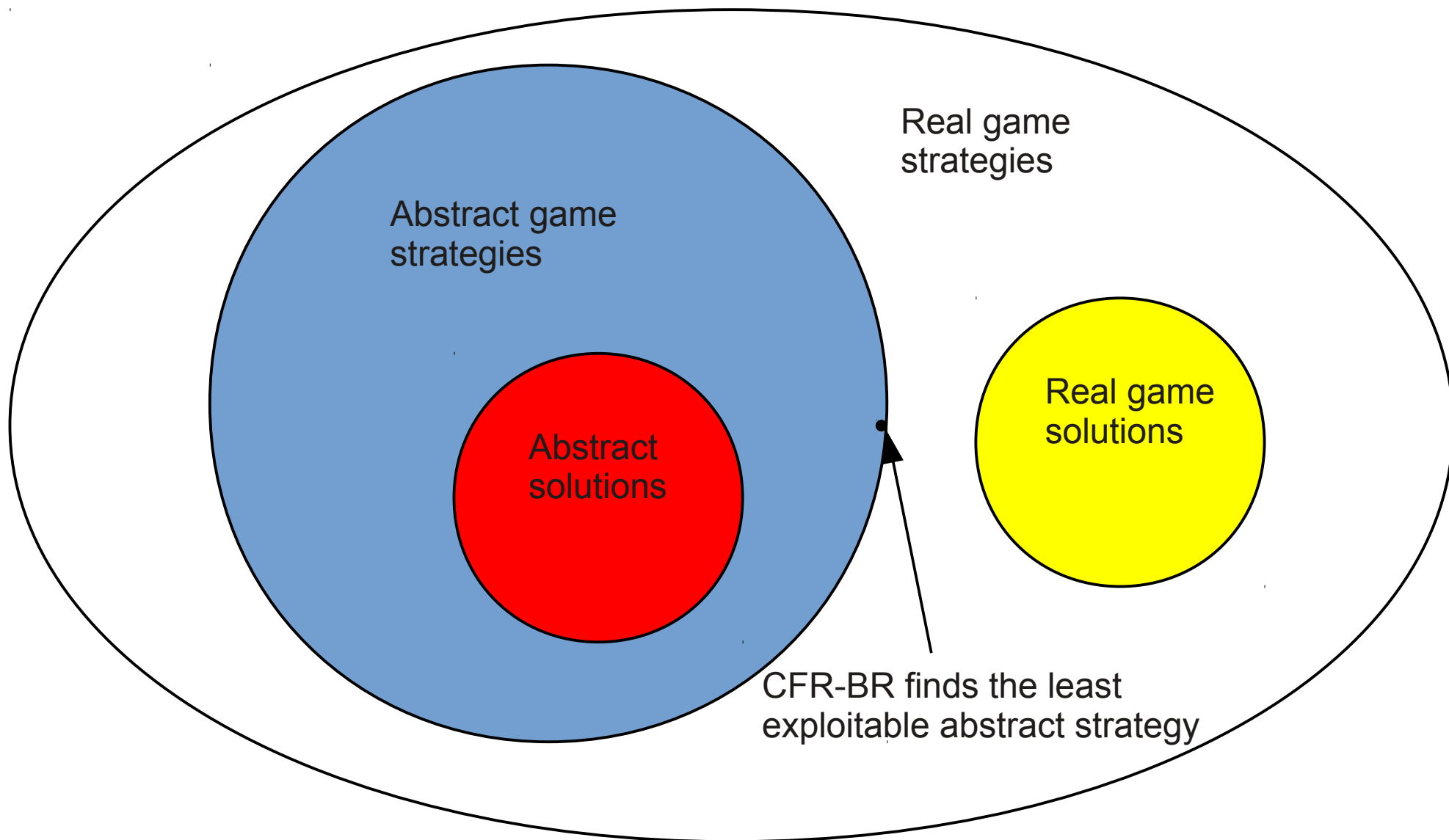
Evaluating an Abstraction

- Play versus best-response
  - Depends on the particular abstract solutions
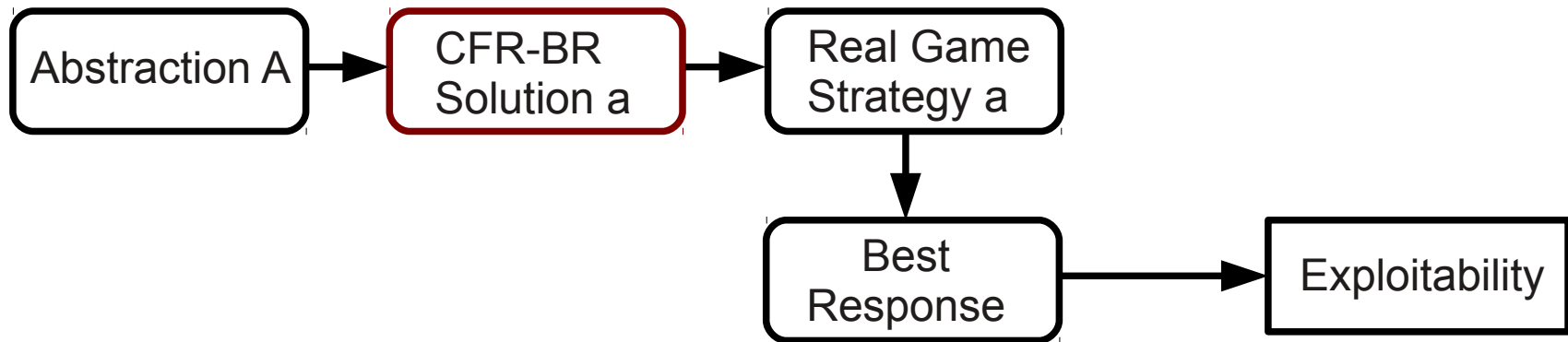 - Does not match observed one-on-on performance

CFR-BR

[Johanson et al. 2012]

Real game strategies
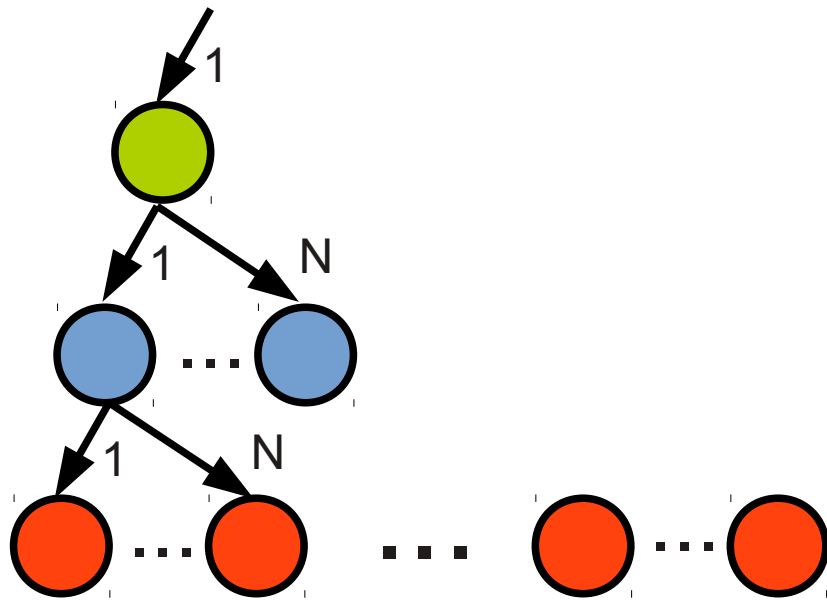
Abstract game strategies

Abstract solutions

Real game solutions

CFR-BR finds the least exploitable abstract strategy

Evaluation using CFR-BR

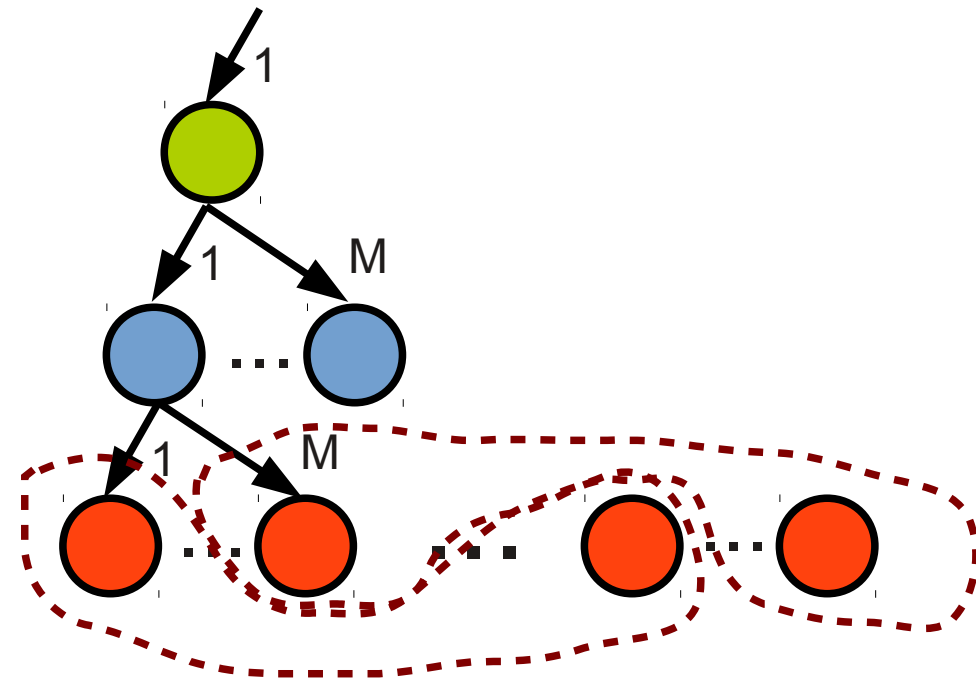- CFR-BR (Johanson *et al.* AAAI '12) can be used to find an abstract strategy with lowest real-game exploitability

```
┌──────────────┐     ┌──────────────┐     ┌──────────────┐
│ Abstraction A│ ──▶ │   CFR-BR     │ ──▶ │  Real Game   │
│              │     │  Solution a  │     │  Strategy a  │
└──────────────┘     └──────────────┘     └──────────────┘
                                                  │
                                                  ▼
                                          ┌──────────────┐     ┌──────────────┐
                                          │     Best     │ ──▶ │ Exploitability│
                                          │   Response   │     │              │
                                          └──────────────┘     └──────────────┘
```

Imperfect Recall

Perfect Recall

Imperfect Recall

N^{Depth} information sets

K information sets

Imperfect Recall

Texas Limit Hold'em

Round 1 — Chance / Player Actions

Round 2 — Chance / Player Actions

Round 3 — Chance / Player Action

Round 4 — Chance / Player Actions
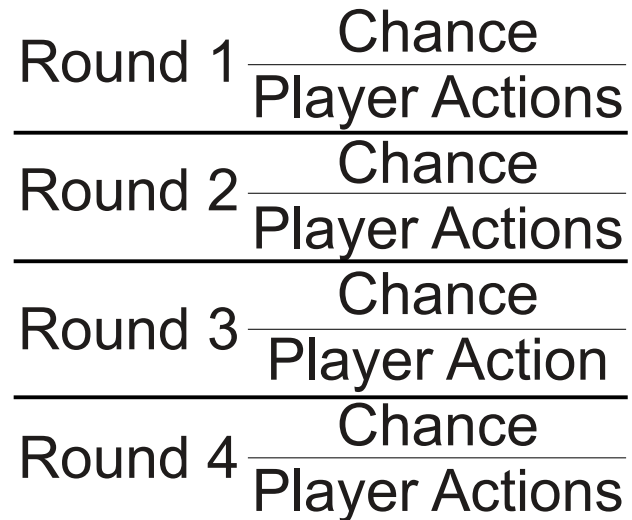
Abstraction	# Information Sets
10/10/10/10 perfect recall	57,330,780
10/100/1000/10000 imperfect recall	57,330,780
169/9000/9000/9000 imperfect recall	57,331,352

Evaluating Imperfect Recall Abstractions

Should we use imperfect recall in an abstraction?

Yes!

Abstraction	One-on-One Performance	vs. Best Response	CFR-BR vs. Best Response
10/10/10/10 PR	-24.8	-282.856	-84.039
169/9000/9000/9000 IR	24.8	-282.395	≥ -64.820

Comparison of perfect and imperfect recall abstraction of limit Texas Hold'em
All values are big blinds per thousand hands

Summary

- Use CFR-BR to evaluate abstractions

  - Transitive measure

  - Tracks one-on-one performance well

  - Not dependent on a particular strategy

- Use imperfect recall in abstractions

  - More flexibility in abstraction choices

  - Demonstrable improvement in abstraction quality

Thank you!