Undergraduate Research Challenge: Birds of a Feather

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Abstract

In this article, we describe a set of research challenges for undergraduates that allow an excellent formative experience of research, writing, peer review, and potential presentation and publication through a top-tier conference. The focus problem is the analysis and design of a newly-designed solitaire card game, so potentials for discovery abound.

1 Introduction

> "[Play] is our brain's favorite way of learning..." (Ackerman, 1999, p.11)

Games are beautifully crafted microworlds that invite players to explore complex terrains that spring into existence from even simple rules. As AI educators, games can offer fun ways of teaching important concepts and techniques. Just as Martin Gardner employed games and puzzles to engage both amateurs and professionals in the pursuit of Mathematics, a well-chosen game or puzzle can provide a catalyst for AI learning and research.

FreeCell stands out among solitaire card games because it is essentially a random self-generating puzzle that has perfect information and can be solved with high probability. Players over the years have, as a community, researched many aspects of the game (Keller, 2016). In this column, we present a new card solitaire game called Birds of a Feather that is virgin territory for exploration in the hopes that motivated undergraduates and their advisors will enjoy investigating this new challenge.

2 Birds of a Feather Rules

Birds of a Feather is an original perfect-information solitaire game played with a standard 52-card deck. After shuffling, the player deals the cards face-up left-to-right in c columns, and top-to-bottom in r rows to create an r-by-c grid of cards. An example 4-by-4 game's initial layout:

```
5S JC QH 8H
KC 6H 3H 9H
3S JS TH TS
KS 7D AH 5C
```

Think of each grid cell as initially containing a 1-card stack. A stack may be moved on top of another stack in the same row, or in the same column if at least one of two conditions is met: (1) The top card of each stack has the same suit. (2) The top card of each stack has the same rank or an adjacent rank (with Aces low and Kings high and Ace and King non-adjacent). Thus the TS (Ten of Spades) stack can move onto the 9H (9 of Hearts) being adjacent in rank:

```
5S JC QH 8H
KC 6H 3H TS
3S JS TH
KS 7D AH 5C
```

And the AH stack can move onto the TH stack being of the same suit:

```
5S JC QH 8H
KC 6H 3H TS
3S JS AH
KS 7D    5C
```

And the AH stack can move onto the 3H stack being of the same suit:

```
5S JC QH 8H
KC 6H AH TS
3S JS
KS 7D    5C
```

If we notate each move as the top cards of the moving and destination stacks separated by a hyphen, then this entire tableau can be formed into

a single stack from this sequence of moves: `TS-9H AH-TH AH-3H AH-QH 6H-7D JS-JC KS-3S KS-KC 5S-KS 6H-5C 5S-TS AH-8H 6H-AH 5S-6H 5S-JS`.

Let us call this simple solution concept a "single-stack solution". However, we can define a more general solution concept of forming largest stacks by defining the score of a grid to be the sum of the squares of the stack sizes. The general solution of any grid is a sequence of moves that maximizes this grid score.

3 Birds of a Feather Questions

Having defined the puzzle, we can now ask many interesting questions about it. For r rows and c columns,

- What is the probability that a deal will have a single-stack solution?
- What is the maximal score distribution of deals?
- What are heuristics that can be used to guide search more efficiently to solutions?
- What are characteristics of grids without single-stack solutions?

There are also many questions one can ask with regard to the automated design of Birds of a Feather puzzles:

- What are the most important attributes of challenging deals with single-stack solutions?
- How can such attributes best combine to form an objective function that can be used to generate Birds of a Feather puzzles through combinatorial optimization algorithms (e.g. simulated annealing (Neller, Fisher, Choga, Lalvani, & McCarty, 2011))?

To download relevant code and/or share your results via our wiki, visit `http://cs.gettysburg.edu/~tneller/puzzles/boaf/index.html`.

4 Mentored Research Challenge

We are seeking faculty-and-undergraduate-student teams (which may additionally involve graduate students) to explore the many unknowns of this game and submit their research in September 2018 to Educational Advances in Artificial Intelligence 2019 (EAAI-19), collocated with AAAI-19, the Thirty-Third AAAI Conference on Artificial Intelligence.

Research challenge teams should have at least one undergraduate student and at least one faculty mentor. Interested teams should contact Todd Neller (`tneller@gettysburg.edu`).

Accepted papers will be presented at EAAI and published in the AAAI proceedings, and it is expected that judges will present cash prizes totaling $500 for best research. Success of this effort will depend on dedicated faculty mentors to guide and encourage student research, and student researchers with curiosity, grit, and the desire to learn the craft of research. We hope you join us in this exciting endeavor.

References

Ackerman, D. (1999). *Deep play*. New York: Random House.

Keller, M. (2016). *Freecell faq*. `http://solitairelaboratory.com/fcfaq.html`. (Accessed: 2016-09-30)

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