

Research Statement—Kyle Burke

Theoretical Computer Science is a field with two competing sides. Algorithm design gives programmers new tools to speed up computing, while results in complexity theory deliver the bad news: some tasks are likely not reasonable for computers to perform. Through my research, I have had results in both of these two fields. My recent concentration in computational game theory offers a unique opportunity to investigate both sides of the coin: I am designing efficient algorithms for finding optimal play strategies as well as determining which games are not efficiently solvable.

After my adviser presented new work on Nash Equilibria, I forged my own research path with the design of the game Atropos. This two-player game is based on Sperner's Lemma, a classic result with modern implications in computational economics. With our game in place, we moved to prove the PSPACE-completeness of determining which player had a winning strategy in a game state. We completed this proof, and the results were presented at the Workshop on Internet and Network Economics (WINE) in 2007.

This result is not the end of research with this game; slight changes to the rules lead us to an alternative version of Atropos. One of my current thesis projects includes analyzing the complexity of this new game.

The classification of these two-player games into complexity classes is an active field of study, and a fundamental part of computational game theory. Economics, in particular, has derived great utility from recent complexity theory developments. The desire to determine feasibility of equilibrium computations drives this inter-curricular research. Personally, I find the competition of games to be a natural motivation for searching out optimal strategies. This has led to the generation and study of other games.

One of the games developed through my research is Matchmaker, an impartial game based on the Stable Marriage problem. In this game, we abstract the players away from the participants of the matches so they instead create matches within the game. Our version of the game, Stubborn Matchmaker, uses universal ranking amongst the candidates and strict rules for matching these candidates. More formally, we can describe this game as follows.

Consider the two candidate sets to be copies of the label set, $S = \{1, \dots, n\}$. Then, for any matching, M of the candidates, a player moves by proposing a marriage pair, $(l, r) \in S \times S$ legal for M . Here a matching is legal if either both l and r are unmatched (meaning $\forall x, y : (x, r)$ and $(l, y) \notin M$) or both l and r are matched (meaning $\exists x, y$ such that $(x, r), (l, y) \in M$). That pair is incorporated to M and the game continues with the next player. The winner is the player whose move creates the (only) stable matching: $\{(1, 1), (2, 2), \dots, (n, n)\}$. Finding an efficient algorithm capable of determining the winning strategy for the current player is also part of my thesis.

During the process of studying these impartial games, I found it necessary to have a quick way to perform Grundy evaluation on game states. Thus, I wrote a small Java package which finds the Nimber of any impartial game. In order to accomplish this, I included the necessary pieces of an ImpartialGame interface.

Users must supply code which conforms to a few small rules in order to have the evaluator work properly. The code has been tested on different versions of Matchmaker.

Work on these economically-founded games provides many avenues for continuing research. Beyond my thesis, I plan to analyze more variations of Matchmaker, looking for both computationally easy and hard cases. A great goal in this would be to discover small rule changes which shift the game between known complexity classes. Also, I would like to investigate the potential for a game based on Arrow's Theorem. This sort of voting game would be another bridge between economics and computer science. In addition to this connection, these games provide interactive means for relating difficult concepts; Atropos has already been described as "a lovely pedagogical device"¹.

Results in the computational game theory field encompass both sides of the theoretical computer science coin, and my research is well-practiced in each. Furthermore, my specific research field of computational game theory is an engaging, relevant and connecting science, with multidisciplinary motivation and results.

¹Comment by Professor Herbert Scarf. A video of the talk where he mentions Atropos is available at the Atropos website: <http://cs-people.bu.edu/paithan/atropos/>