

Noam Brown

Noam Brown
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RESEARCH AREA

Artificial intelligence, game theory, machine learning, reinforcement learning, no-regret learning, equilibrium computation, extensive-form games, imperfect-information games.

EDUCATION

Ph.D., Computer Science
Carnegie Mellon University

August 2014 – *Present*

MS, Robotics
Carnegie Mellon University

August 2012 – August 2014

BA, Mathematics and Computer Science (*Summa Cum Laude*)
Rutgers University

September 2005 – December 2008

PUBLICATIONS

Journal Papers

- **Superhuman AI for Heads-Up No-Limit Poker: Libratus Beats Top Professionals.** Noam Brown and Tuomas Sandholm. *Science*, 2017.

Highly Refereed Conference Papers

- **Safe and Nested Subgame Solving for Imperfect-Information Games.** Noam Brown and Tuomas Sandholm. To appear in *Neural Information Processing Systems (NIPS)*, 2017. **Best Paper Award.**
- **Reduced Space and Faster Convergence in Imperfect-Information Games via Pruning.** Noam Brown and Tuomas Sandholm. *International Conference on Machine Learning (ICML)*, 2017.
- **Dynamic Thresholding and Pruning for Regret Minimization.** Noam Brown, Christian Kroer, and Tuomas Sandholm. *Conference on Artificial Intelligence (AAAI)*, 2017.
- **Strategy-Based Warm Starting for Regret Minimization in Games.** Noam Brown and Tuomas Sandholm. *Conference on Artificial Intelligence (AAAI)*, 2016.
- **Regret-Based Pruning in Extensive-Form Games.** Noam Brown and Tuomas Sandholm. *Neural Information Processing Systems (NIPS)*, 2015.
- **Simultaneous Abstraction and Equilibrium Finding in Games.** Noam Brown and Tuomas Sandholm. *International Joint Conference on Artificial Intelligence (IJCAI)*, 2015.

- **Hierarchical Abstraction, Distributed Equilibrium Computation, and Post-Processing, with Application to a Champion No-Limit Texas Hold'em Agent.** Noam Brown, Sam Ganzfried, Tuomas Sandholm. *International Conference on Autonomous Agents and Multiagent Systems (AAMAS)*, 2015.
- **Regret Transfer and Parameter Optimization.** Noam Brown and Tuomas Sandholm. *Conference on Artificial Intelligence (AAAI)*, 2014.

Refereed Demonstrations

- ***Libratus*: Beating Top Humans in No-Limit Poker.** Noam Brown and Tuomas Sandholm. To appear in Demonstrations Program at *Neural Information Processing Systems (NIPS)*, 2017.
- ***Libratus*: The Superhuman AI for No-Limit Poker.** Noam Brown and Tuomas Sandholm. Demonstrations Program at the *International Joint Conference on Artificial Intelligence (IJCAI)*, 2017.
- **Baby Tartanian8: Winning Agent from the 2016 Annual Computer Poker Competition.** Noam Brown and Tuomas Sandholm. Demonstrations Program at the *International Joint Conference on Artificial Intelligence (IJCAI)*, 2016.
- **Claudico: The World's Strongest No-Limit Texas Hold'em Poker AI.** Noam Brown and Tuomas Sandholm. Demonstrations Program at *Neural Information Processing Systems (NIPS)*, 2015.
- **Tartanian7: A Champion Two-Player No-Limit Texas Hold'em Poker-Playing Program.** Noam Brown, Sam Ganzfried, Tuomas Sandholm. Demonstrations Program at the *AAAI Conference on Artificial Intelligence (AAAI)*, 2015.

Additional Talks

- ***Libratus*: Beating Top Pros in No-Limit Poker.** Invited talk at: Facebook AI Research, OpenAI, MIT, Harvard, Princeton, Rutgers, University of Michigan, CMU, Hertz Fellowship Retreat, Cubist Systems, Jane Street Capital.
- **Simultaneous Abstraction and Equilibrium Finding in Games.** Noam Brown and Tuomas Sandholm. In: *INFORMS Annual Conference*, 2015. Invited talk, Optimization cluster.
- **Regret Transfer and Parameter Optimization.** Noam Brown and Tuomas Sandholm. In: *INFORMS Annual Conference*, 2015. Contributed presentations.

HONORS AND AWARDS

- Best Paper Award at NIPS 2017
- *Libratus* (together with University of Alberta's *DeepStack*) selected as one of 12 finalists for Science Magazine's Scientific Breakthrough of the Year for 2017
- *Libratus* listed in La Recherche as one of the top ten scientific achievements of 2017
- *Libratus* won HPCWire's "Best Use of AI" Award for 2017
- Co-created *Libratus*, the first AI to defeat top humans in no-limit poker
- 1st place in the Annual Computer Poker Competition No-Limit Texas Hold'em Instant Runoff Event, 2014 - 2016

- 1st place in the Annual Computer Poker Competition No-Limit Texas Hold'em Total Bankroll Event, 2014 - 2016
- NSF Graduate Research Fellowship Honorable Mention
- Rutgers Computer Science Department Highest Honors
- Rutgers College Scholarship Recipient
- Rutgers College Honors Program

WORK EXPERIENCE

Carnegie Mellon University, Pittsburgh, PA August 2012 – *Present*
Research Assistant, Electronic Marketplaces Lab

- Created the equilibrium-finding algorithm that generated the strategy of the strongest no-limit Texas Hold'em poker AIs in the world. The equilibrium-finding code implements a distributed regret minimization algorithm in C++ across thousands of cores on a supercomputer using MPI.
- Developed pruning techniques that reduce the runtime of the state of the art equilibrium-finding algorithm by orders of magnitude. These techniques provably improve the asymptotic convergence rate of the algorithm.
- Created a method to warm start the solving of imperfect-information games based on human-generated strategies or on the solutions to related games. This method provably warm starts equilibrium finding without penalty or loss.
- Developed a method for simultaneously abstracting and solving large imperfect-information games. Unlike past methods, this allows large games to be solved without relying on domain-specific knowledge.

Google DeepMind, London, UK Summer 2017
Research Intern

Freshplum, Menlo Park, CA Summer 2012
Software Engineer Intern

- Implemented a demand forecasting algorithm to predict future daily sales for clients based on historical time series data and client-supplied variables.
- Wrote software that allowed clients to provide targeted discounts to users based on collected data.

Federal Reserve Board of Governors, Washington, DC April 2010 – *May 2012*
Research Assistant, International Finance Division

- Conducted research on the impact of algorithmic trading on liquidity, volatility, and triangular arbitrage in the foreign exchange market as part of a research paper published in the *Journal of Finance*.
- Analyzed tick data to determine the effects of imposing a Minimum Quote Life on algorithmic trading in foreign exchange markets.
- Applied machine learning to classify the cause of price movements in the crude oil market based on news articles.

MJM Trading Group, Jersey City, NJ November 2006 – April 2010
Algorithmic Trading Engineer

- Developed and tested numerous algorithmic trading programs focused on equities in Java and C++.
- Created programs to interpret breaking news headlines from Bloomberg and corporate SEC filings in order to place trades immediately based on sentiment before other market participants react.
- Developed underlying programs to handle incoming data, manage trades, and safeguard against excessive risk across numerous separately running automated trading strategies.

Merrill Lynch, New York, NY Summer 2008
Technology Analyst Intern

TEACHING EXPERIENCE

Carnegie Mellon University

Teaching Assistant	Artificial Intelligence	Fall 2017
Teaching Assistant	Artificial Intelligence	Fall 2014

Rutgers University

Recitation Instructor	Calculus I	Spring 2009
Recitation Instructor	Calculus I	Fall 2008
Recitation Instructor	Pre-Calculus	Spring 2008
Recitation Instructor	Pre-Calculus	Fall 2007
Peer Mentor	Calculus II	Spring 2007
Peer Mentor	Calculus II	Fall 2006
Teaching Assistant	Young Scholars Program	Summer 2006

OUTREACH AND SERVICE TO THE ACADEMIC COMMUNITY

Outreach

CMU Creative Technologies Nights 2015 – *Present*

- Introduce middle school girls to various technology-related topics in weekly presentations.

Rutgers Young Scholars Programs Summers 2009 – 2016

- Presented lessons on game theory to gifted high school students.

Federal Reserve FedEd 2010 – 2012

- Taught financial literacy and monetary policy through guest lectures to D.C.-area high school students.

Reviewing

Conferences: IJCAI 2015, AAMAS 2016, IJCAI 2016, NIPS 2017, AAAI 2018

Journals: Artificial Intelligence, JAIR, Cognitive Science

Departmental Service

CSD Immigration Course 2014, 2015, 2016, 2017

CSD Open House 2015, 2016, 2017

CMU Speakers Club 2017