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Cover letter

Denizalp Goktas

Dear Workshop Organizers,

I am writing to apply for the second annual Workshop on Heterogeneous-Agent Macroeconomics, scheduled to be held on June 12-14, 2023, in Cambridge, MA. I am a computer science Ph.D. candidate at Brown University advised by Amy Greenwald, working at the intersection of economics and computer science. In my research, I design and analyze algorithms to compute solutions to markets and games. Through my work, I have introduced algorithms to compute competitive equilibrium in Arrow-Debreu competitive economies and Nash equilibrium in games. More recently, I have been interested in solving dynamic general equilibrium models; to this end I have provided a computational characterization of recursive competitive equilibrium in stochastic Fisher markets. As I am approaching the final years of my PhD, I am interested in solving even more computational problems within heterogeneous agent macroeconomics, and I believe that this workshop would provide me with an excellent opportunity to enhance my research skills and expand my knowledge of the field.

While my primary field of study is computer science, I have a strong interest in economics, with all my published papers making important advances in the computation of economic solution concepts. While this workshop will allow me to get an overview of the most recent computational problems faced by macroeconomists, I believe that my computational background and my experience working with game-theoretic algorithms would also be an asset to the workshop and its participants. I have completed the first three years of my Ph.D. program, and I possess a solid research-level understanding of microeconomics, and in particular general equilibrium theory. I am also familiar with macroeconomics at the level of a first-year Ph.D. course, including dynamic programming and the standard 3-equation New Keynesian model. Additionally, I am an expert Python user who is familiar with many mathematical libraries.

I am beyond excited about the workshop's objectives, which would help me better understand the computational problems faced by macroeconomists, thereby providing me with new research directions. I also hope to meet economists at this workshop, which would give rise to new collaborations, in which I would hope to help economists with their most pressing computational needs. Attending this workshop would provide me with the necessary knowledge and tools to further my own research at the intersection of computer science and macroeconomics. Finally, I am eager to learn from the distinguished lecturers who will lead the workshop.

I attach to this letter a recent CV, and a brief statement explaining my motivation for attending the workshop and my current research interests. I am also providing the contact information of a faculty member who could provide a recommendation if I am shortlisted for participation.

Thank you for your consideration. I look forward to hearing back from you.

Sincerely,
Denizalp Goktas

Recommender Information:
Amy Greenwald
Brown University, Box 1910
Providence, RI 02912
amy_greenwald@brown.edu
+1 (401) 863-7678

DENIZALP GOKTAS

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Providence, RI

Research Interests

My research aims to devise and/or analyze decentralized multi-agent learning algorithms in games and markets, with the ultimate goal of building welfare-improving technology based on these algorithms. The tools I bring to bear, stem from algorithms, optimization, and microeconomics.

Education

Brown University — Providence, RI
Ph.D. in Computer Science — *May 2024 (expected)*

Brown University — Providence, RI
M.S. in Computer Science; ***GPA****:* 3.85/4.00 — *May 2023*
Thesis: *Tâtonnement Beyond Constant Elasticity of Substitution*

Columbia University — New York, NY
B.A. in Computer Science-Statistics, Magna Cum Laude; ***GPA****:* 3.80/4.00 — *May 2019*

Paris Institute of Political Studies — Paris, France
B.A. in Political Science-Economics, Magna Cum Laude; ***GPA****:* 4.00/4.00 — *May 2019*

Experience

Google DeepMind — London, United Kingdom
Research Scientist Intern — *Aug. 2022 - Dec. 2022*

- **Economics and AI**: Led and published research at the intersection of AI and Economics.

Simons Institute, University of California, Berkeley — Berkeley, California
Visting Scholar — *Jan. 2022 - May. 2022*

- **Visiting scholar under Peter Bartlett**: Participated in research seminars and gave a talk on convex-concave min-max Stackelberg games as part of the Learning in Games workshop.

Carnegie Mellon University
Research Assistant — *May. 2019 - Sep. 2020*

- **Computational Mathematics**: Used the Blaze C++ library to create a proprietary pseudo-inverse routine.
- **Object-Oriented Programming**: Designed classes and routines using OOP for an agent-based simulation.
- **Visualization**: Created R scripts using ggplot2 and the Tidyverse packages to analyze output data.

Columbia University — New York, NY
Research Assistant — *Jan. 2018 - May 2019*

- **Mathematical Modeling**: Developed the mathematical model used in the agent-based simulation.
- **Algorithm Creation**: Invented a many-to-many matching algorithm and proved its mathematical properties.

DNB Markets — New York, NY
Investment Banking Summer Analyst — *Jun. 2018 - Aug. 2018*

- **Automation**: Coded VBA scripts reducing the time needed to create a bond cross-holders list by ∼95%.
- **Data Aggregation**: Created an automated transaction dashboard template for healthcare IPOs.

Hikma Pharmaceuticals — Amman, Jordan
Mergers & Acquisitions Summer Analyst — *Jun. 2017 - Aug. 2017*

- **Automation**: Automated data querying for risk models using python scripts.

Teaching Experience

Algorithmic Game Theory — Brown, RI, USA
Teaching Assistant — *Spring 2021*

Conference Proceedings

Zhao, S., **Goktas**, D., & Greenwald, A. (2023). Fisher markets with social influence. *American Association for Artificial Intelligence Conference on Artificial Intelligence, AAAI'23.*

Goktas, D. (2022b). An algorithmic theory of markets and their application to decentralized markets. *American Association for Artificial Intelligence Conference on Artificial Intelligence, AAAI'22.*

Goktas, D., & Greenwald, A. (2022b). Robust no-regret learning in min-max Stackelberg games. *International Conference on Autonomous Agents and Multi-Agent Systems 2022, AAMAS'22.*

Goktas, D., Zhao, S., & Greenwald, A. (2022a). Exploitability minimization in games and beyond. *Neural Information Processing Systems 2022, NeurIPS'22.*

Goktas, D., Zhao, S., & Greenwald, A. (2022c). Zero-sum stochastic Stackelberg games. *Neural Information Processing Systems 2022, NeurIPS'22.*

Goktas, D., & Greenwald, A. (2021a). Convex-concave min-max Stackelberg games. *Neural Information Processing Systems 2021, NeurIPS'21.*

Goktas, D., Viqueira, E. A., & Greenwald, A. (2021a). A consumer-theoretic characterization of fisher market equilibria. *Conference on Web and Internet Economics, WINE'21.*

Refereed Workshop Papers

Goktas, D., & Greenwald, A. (2022c). Robust no-regret learning in min-max Stackelberg games. *Adversarial Machine Learning and Beyond Workshop at the American Association for Artificial Intelligence Conference on Artificial Intelligence, AAAI'22.*

Goktas, D., Zhao, S., & Greenwald, A. (2022b). Zero-sum stochastic Stackelberg games. *Workshop on Gamification and Multiagent Solutions, ICLR'22.*

Goktas, D., & Greenwald, A. (2021b). Gradient descent ascent in min-max Stackelberg games. *Games, Agents, and Incentives Workshop at International Conference on Autonomous Agents and Multi-Agent Systems 2022, AAMAS'22.*

Goldstein, S. C., **Goktas, Denizalp**, Conn, M., Pitchuka, S. P. T., Sameer, M., Shah, M., Colin Swett, H. T., Viswanathan, S., & Xiao, J. (2020). Bolt: Building on local trust to solve lending market failure. *Mechanism Design for Social Good, MD4SG'20.*

Presentations and Posters

Goktas, D. (2022a). Algorithmic general equilibrium theory. *Economics for AI group, Google DeepMind.*

Goktas, D. (2022b). An algorithmic theory of markets and their application to decentralized markets. *American Association for Artificial Intelligence Conference on Artificial Intelligence, AAAI'22.*

Goktas, D. (2022c). Stackelberg games and their applications to general equilibrium theory. *Oxford University Computer Science Seminar.*

Goktas, D. (2022d). Stackelberg games and their applications to general equilibrium theory. *London School of Economics, Mathematics Seminar.*

Goktas, D., & Greenwald, A. (2022a). Convex-concave min-max Stackelberg games. *Learing in Games Worshop, University of California, Berkeley.*

Goktas, D. (2021a). Min-max games with dependent strategy sets. *Brown Robotics Group.*

Goktas, D. (2021b). Network-theoretic market equilibrium models. *CUNY Philosophy and Logic Seminar.*

Goktas, D. (2021c). Tâtonnement beyond constant elasticity of substitution. *INFORMS 2021, Forthcoming.*

Goktas, D. (2021d). Tâtonnement beyond constant elasticity of substitution. *GAMES 2020.*

Goktas, D. (2020). Tâtonnement beyond constant elasticity of substitution. *Faculty Flash Talks Brown University.*

Zhao, S., **Goktas**, D., & Greenwald, A. (2023). Fisher markets with social influence. *American Association for Artificial Intelligence Conference on Artificial Intelligence, AAAI'23.*

Goktas, D., Zhao, S., & Greenwald, A. (2022a). Exploitability minimization in games and beyond. *Neural Information Processing Systems 2022, NeurIPS'22.*

Goktas, D., Zhao, S., & Greenwald, A. (2022c). Zero-sum stochastic Stackelberg games. *Neural Information Processing Systems 2022, NeurIPS'22.*

Goktas, D., Viqueira, E. A., & Greenwald, A. (2021b). Tâtonnement beyond constant elasticity of substitution. *Stony Brook International Conference on Game Theory.*

Goktas, D., Viqueira, E. A., & Greenwald, A. (2021c). Tâtonnement beyond constant elasticity of substitution. *Twenty-Second ACM Conference on Economics and Computation (EC 2021) Contributed Poster.*

Goldstein, S. C., **Goktas, Denizalp**, Conn, M., Pitchuka, S. P. T., Sameer, M., Shah, M., Colin Swett, H. T., Viswanathan, S., & Xiao, J. (2020). Bolt: Building on local trust to solve lending market failure. *Mechanism Design for Social Good, MD4SG'20.*

Community Service

HAPPIH — Paris, France
Co-founder and Co-director — *Nov. 2017 - Jun. 2020*

- Led an international gender equality campaign through the production and distribution of reusable sanitary pads.
- The campaign was endorsed by the government of Monaco and numerous local and international news outlets.
- **Grant Management:** Was awarded a grant of 10,000€ to execute a humanitarian aid project in Morocco.

Academic Service

International Joint Conferences on Artificial Intelligence (IJCAI) — *2023*
Main Track Program Committee Member

International Joint Conferences on Artificial Intelligence (IJCAI) — *2023*
Special Track on AI and Social Good Program Committee Member

Journal of Autonomous Agents and Multi-Agent Systems (JAAMAS) — *2023*
Reviewer

American Association for the Advancement of Artificial Intelligence (AAAI) — *2023*
Main Track Program Committee Member, Session Chair

American Association for the Advancement of Artificial Intelligence (AAAI) — *2023*
AI for Social Impact Track Program Committee Member, Session Chair

Gamification and Multiagent Solutions Workshop @ ICLR — *2022*
Program Committee Member

Conference on Web, Internet, Economics and Networks (WINE) — *2021*
Reviewer

Cooperative AI Workshop @ NeurIPS — *2021*
Program Committee Member

Games, Agents, and Incentives Workshop (GAIW) @ AAMAS — *2021*
Program Committee Member

Algorithmic Game Theory Research Group — Brown, RI, USA
Manager — *Sept. 2020 - Present*

Algorithmic Game Theory Reading Group — Brown, RI, USA
Organizer — *Sept. 2020 - Present*

Google ExploreCSR — Brown, RI, USA
Mentor — *Spring 2021*

Award and Honors

American Association for Artificial Intelligence Student Scholarship — *Jan. 2023*

JP Morgan AI Fellowship — *Jan. 2022*

Royce Graduate Fellowship — *Oct. 2019*

Columbia Honor Society — *May. 2019*

Pi Sigma Beta Honor Society — *May. 2019*

Jean Louis Dreyfus Scholar — *May. 2017*

Open Source Software

Competitive Equilibrium Solver — *Sep. 2020 - Present*
Python library to solve for the allocations and prices of a large class of Fisher markets
https://github.com/denizalp/fisher

Mentorship

Sadie Zhao *Graduating May 2023*
Headed for PhD at Stanford

Jack Ciabaton *Graduated May 2022*
Now at Jane Street

John Randolph *Graduated May 2022*
Now at Meta (Previously Facebook)

Shray Mishra *Graduated May 2022*
Now at Weiss Asset Management

Jackson De Campos *Graduated May 2022*
Now at Netflix

Skills

Languages : French (fluent), Turkish (fluent), Spanish (advanced), Arabic (intermediate)
Programming : C++, CSS, CVXPY, ggplot2, Haiku, Html, Java, Jax, JaxOPT, Keras, NumPy, Pandas, Python, R, SciPy, SQL, Tensorflow, Tidyverse, VBA

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Research Statement

Denizalp Goktas

One of the biggest obstacles to the widespread adoption of equilibrium-based economic models has been the theoretical intractability results that computer scientists have established over the last two decades [1, 2, 3]. These results suggest that the solutions to many popular economic models such as dynamic stochastic general equilibirium models can in general not be computed by modern computers in a reasonable amount of time, i.e., in a human's life time. This computational impossibility result, although highly discouraging as it limits the possibility of fitting expressive economic models onto data, is only a worst-case result, meaning that it only applies to the hardest economic models within the class of all economic models. This means that it could still be possible that to solve a large number of economic models of interest efficiently. Unfortunately, we do not know of general-purpose algorithms that could solve most economic models, and most models require specialized algorithms to solve them. This points for a need to develop algorithms with computational guarantees that can compute solutions to arbitrary economic models when these models are indeed solable efficiently. My research aims to meet this need by building general-purpose algorithms and methods to compute or approximate solutions to economic models allowing economists and the like to solve expressive and possibly complex economic models.

Arguably, the first economist to pursue the use of computational methods to solve economic models was Herbert Scarf. Scarf, who introduced the first fixed-point computation algorithms [4] to compute competitive equilibrium in Arrow-Debreu competitive economies, wanted to solve economic models on computers to eventually estimate the parameters of these models from data, and in some sense simulate the economy. Unfortunately, soon after his foray in what today is known as computable general equilibrium theory, Scarf would realize that the computation of equilibrium in economic models were often intractable for computers. Thirty years later, Scarf's agenda would once again see the light of day, albeit this time within the computer science community [5]. Over the last twenty years, computer scientists have developed a large number of computationally efficient algorithms to compute equilibria in certain economic models; however, we do not know of any general-purpose methods suitable for solving arbitrary economic models. Such a general-purpose method is quite desirable as it would allow practitioners, who might not necessarily be familiar with the intricacies of computational complexity theory, to solve their models based on which they could offer insights to policy makers.

At a high-level, most well-known economic models, such as Arrow-Debreu competitive economies or the real business cycle model [6, 7] can be seen as pseudo-games [8, 9], first introduced by Arrow and Debreu under the name of abstract economies. Exploiting this relationship, I have introduced methods to solve pseudo-games which can in turn be used to solve arbitrary economic models. In more precise terms, I have shown that any pseudo-game can be solved as a min-max optimization problem. Using this relationship I have then introduced first-order methods to solve or approximate solutions pseudo-games [10]. Even more recently, in a collaboration with researchers at DeepMind, I have shown that we can use a specific type of neural network known as the generative adversarial network to solve pseudo-games, and have used our method to solve Arrow-Debreu competitive economies accurately [11], a problem which was first posed by Herbert Scarf, which remains one of the most challenging problems in computational microeconomics.

Traditionally, the computer science-economics community has focused on microeconomic problems; however, moving forward, I hope to tackle macroeconomic computational problems, as I believe that the algorithms I have developed during my PhD can be used to solve impactful problems that macroeconomist face. I am beyond excited about the workshop's objectives, which would help me better understand the computational problems faced by macroeconomists, thereby providing me with new research directions. I also hope to meet economists at this workshop, which would give rise to new collaborations, in which I would hope to help economists with their most pressing computational needs.

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References

[1] Xi Chen and Shang-Hua Teng. "Spending is not easier than trading: on the computational equivalence of Fisher and Arrow-Debreu equilibria". In: *International Symposium on Algorithms and Computation*. Springer. 2009, pp. 647–656.

[2] Constantinos Daskalakis, Stratis Skoulakis, and Manolis Zampetakis. *The Complexity of Constrained Min-Max Optimization*. 2020. arXiv: 2009.09623 [cs.CC].

[3] Constantinos Daskalakis, Paul W Goldberg, and Christos H Papadimitriou. "The complexity of computing a Nash equilibrium". In: *SIAM Journal on Computing* 39.1 (2009), pp. 195–259.

[4] Herbert E Scarf. "On the computation of equilibrium prices". In: (1967).

[5] N. R. Devanur et al. "Market equilibrium via a primal-dual-type algorithm". In: *The 43rd Annual IEEE Symposium on Foundations of Computer Science, 2002. Proceedings.* 2002, pp. 389–395. DOI: 10.1109/SFCS.2002.1181963.

[6] Robert E Lucas. "Understanding business cycles". In: *Essential readings in economics* (1995), pp. 306–327.

[7] Finn E Kydland and Edward C Prescott. "Time to build and aggregate fluctuations". In: *Econometrica: Journal of the Econometric Society* (1982), pp. 1345–1370.

[8] Kenneth Arrow and Gerard Debreu. "Existence of an equilibrium for a competitive economy". In: *Econometrica: Journal of the Econometric Society* (1954), pp. 265–290.

[9] Francisco Facchinei and Christian Kanzow. "Generalized Nash equilibrium problems". In: *Annals of Operations Research* 175.1 (2010), pp. 177–211.

[10] Denizalp Goktas and Amy Greenwald. "Exploitability Minimization in Games and Beyond". In: *Advances in Neural Information Processing Systems*. 2022.

[11] Denizalp Goktas et al. "Generative Adversarial Equilibrium Solvers". In: *arXiv preprint arXiv:2302.06607* (2023).