Sujit Prakash Gujar

CONTACT INFORMATION

E-Mail: sujit.gujar@epfl.ch Office: (+41)2169-36622
Web: http://lcm.csa.iisc.ernet.in/sujit Mobile: +41762776195

RESEARCH INTERESTS

Game Theory and Mechanism Design, Algorithmic Game Theory Multi-Agent Systems, Optimization, Machine Learning and Game Theory. CrowdSourcing, Cryptography, Security.
(Appendix 1, for research statement).

CURRENT AFFILIATION

January 2014-Till Date
Currently I am post-doctoral researcher in Artificial Intelligence Laboratory at École Polytechnique Fédérale de Lausanne with Prof Boi Faltings. We are working to design combinatorial auctions that preserve privacy. We are also working on various aspects of Crowd Sourcing in game theoretic settings.

EDUCATION

Ph.D. [2006 - 2011]
Department of Computer Science and Automation (CSA),
Indian Institute of Science (IISc), Bangalore.
Advisor: Prof Y Narahari.
Title: Novel Mechanisms for Allocation of Heterogeneous Items in Strategic Settings
(Received the best thesis award. For summary, please see Appendix 2)
CGPA: 6.9/8.0.

M.E., [2004 - 2006]
Department of Computer Science and Automation (CSA), IISc, Bangalore.
Thesis Title: Measures for Classification and Detection in Steganalysis
Thesis Supervisor: Prof. C. E. Veni Madhavan.
CGPA: 7.2/8.0 **Rank 1**

B.E. (ECE), [1997 - 2001], Govt. College of Engineering, Pune
GATE Score: 99.66 percentile

HSC, [1995-1997],
Maharashtra State Board of Secondary and Higher Secondary Education.
Score: 90.00%

ACADEMIC HONORS

Recipient of **Alumni Medal** of IISc for the Best Doctoral Thesis in the Dept Computer Science and Automation, Indian Institute of Science, for the academic year 2012-13, March 2012.

Recipient of **Infosys Fellowship**.

Rank 1, ME ISE, IISc, 2004-2006 batch.

GATE Score **99.66** percentile, MHRD Scholarship holder.

Stood 5th in **'Ganit Parangat'** state level (Maharashtra) examination.

Ganit Paragat is Mathematical examination conducted at school level for testing mathematical abilities.

Selected through **IIT JEE** (Joint Entrance Examination) for admission to IIT. (AIR2255).

SUMMER INTERNSHIP

Prof David C Parkes. Harvard EconCS Group, School of Engineering and Applied Sciences, *Harvard University*. (Summer 2009.)

PUBLICATIONS

Journal Publications

1. Sujit Gujar and Y. Narahari, *"Optimal Multi-Unit Combinatorial Auctions"*. Operational Research, April 2013, Volume 13, Issue 1, pp 27-46. (Citations: 1)

2. Akash Das Sarma, Sujit Gujar, Y Narahari, *"Truthful Multi-Armed Bandit Mechanisms for Multi-Slot Sponsored Search Auctions"*, Current Science, Special Issue on Game Theory, Volume 103(9), pp 1064-1077, November 2012. (Citations: 5)

3. Sujit Gujar and Y. Narahari,*"Redistribution Mechanisms for Assignment of Heterogeneous Objects"*. Journal of Artificial Intelligence Research, Volume 41, pp 131-154, 2011. (Citations: 14)

4. Dinesh Garg, Y. Narahari, Sujit Gujar, *"Foundations of Mechanism Design: A Tutorial - Part 1: Key Concepts and Classical Results."* Sadhana - Indian Academy Proceedings in Engineering Sciences, Volume 33, Part 2, pp 83-130, April 2008. (Citations: 36)

5. Dinesh Garg, Y. Narahari, Sujit Gujar, *"Foundations of Mechanism Design: A Tutorial - Part 2: Advanced Concepts and Results."* Sadhana - Indian Academy Proceedings in Engineering Sciences, Volume 33, Part 2, pp 131-174, April 2008. (Citations: 17)

Conference Publications

6. Satyanath Bhat, Shweta Jain, Sujit Gujar and Y Narahari, *An Optimal Bidimensional Multi-Armed Bandit Auction*?. To Appear in Iternational Conference on Autonomous Agents and Multi-Agent Systems, AAMAS 2015.

7. Tridib Mukherjee, Partha Dutta, Vinay Hegde and Sujit Gujar "*RISC: Robust Infrastructure over Shared Computing Resources Through Dynamic Pricing and Incentivization"*, To appear in 29^{th} IEEE International Parallel & Distributed Processing Symposium, IPDPS 2015.

8 Bhat Satyanath, Swaprava Nath, Sujit Gujar, Onno Zoeter, Y. Narahari and Chris Dance, *"A mechanism to optimally balance cost and quality of labeling tasks outsourced to strategic agents."* In Proceedings of the 2014 international conference on Autonomous Agents and Multi-Agent Systems (pp. 917-924), AAMAS'14. (Citations 2)

9. Jain Shweta, Sujit Gujar, Onno Zoeter, and Y. Narahari, *"A quality assuring multi-armed bandit crowdsourcing mechanism with incentive compatible learning."* In Proceedings of the 2014 international conference on Autonomous Agents and Multi-Agent Systems (pp. 1609-1610), AAMAS'14. (Citations 1)

10. Dutta, Partha, Tridib Mukherjee, Vinay Hegde, and Sujit Gujar. *"C-Cloud: A Cost-Efficient Reliable Cloud of Surplus Computing Resources."* In Cloud Computing (CLOUD), 2014 IEEE 7^{th} International Conference on, pp. 986-987. IEEE, 2014. (Citation 1)

11. Shourya Roy, Chithralekha B and Sujit Gujar, *"Sustainable Employment in India by Crowd-sourcing Enterprise Tasks.* In Proceedings of the third annual Symposium on Computing for Development, ACM DEV 2013. (Citations 3)

12. Sujit Gujar and David Parkes, *"Dynamic Matching with a Fall-back Option"*, In the Proceedings 19th European Conference on Artificial Intelligence (ECAI '10), 2010, pp 263-268. (Citations: 4)

13. James Zou, Sujit Gujar and David Parkes, *"Tolerable Manipulability in Dynamic Assignment without Money "*. In the Proceedings 24th AAAI Conference on Artificial Intelligence (AAAI '10), 2010. (Citations: 10)

14. Sujit Gujar and Y. Narahari, *"Optimal Multi-Unit Combinatorial Auctions with Single Minded Bidders"*. The 11th IEEE Conference on Commerce and Enterprise Computing (CEC'09), pp 74-81. (Citations: 8)

15. Sujit Gujar and Y Narahari, *"Redistribution of VCG Payments in Assignment of Heterogeneous Objects".* In Proceedings of the 4th International Workshop on Internet and Network Economics (WINE), 2008, pp 438-445. (Citations: 8)

Workshop Publications

16. Sujit Gujar and Boi Faltings, *"Dynamic Task Assignments: An Online Two Sided Matching Approach".* To Appear in 3rd International Workshop on Matching Under Preferences (MATCHUP 2015)

17. Mukharjee, Koustuv Dasgupta, Sujit Gujar, Gueyoung Jung and Haengju Lee, *"An Economic Model for Green Cloud".* In the proceedings of 10th International Workshop on Middleware for Grids, Clouds and e-Science - MGC 2012. (Citations: 3)

18. Sujit Gujar, James Zou and David Parkes, *"Dynamic House Allocation"*, In the Proceedings of 5^{th} Multidisciplinary Workshop on Advances in Preference Handling (M-PREF '10), 2010, pp 43-48.

19. Sujit Gujar and Y. Narahari, *"Redistribution Mechanisms for Assignment of Heterogeneous Objects".* Formal Approaches to Multi-Agent Systems, (FAMAS'09). Torino, Italy.

20. Sujit Gujar and Y Narahari, *"An Optimal Multi-Unit Combinatorial Procurement Auction with Single Minded Bidders".* Managing Complexity in a Distributed World, a Centenary Conference of Division of Electrical Sciences, Indian Institute of Science, (MCDES) 2008.

21. Sujit P Gujar and C E Veni Madhavan, "*Measures for Classification and Detection in Steganalysis"*, In Proceedings of 3^{rd} Workshop on Computer Vision, Graphics and Image Processing-WCVGIP 2006, pp. 210-214, January 2006. (Citations: 2)

Working Papers

22. Sujit Gujar and Boi Faltings *"Dynamic Allocation of Tasks to Strategic Workers in Expert Crowdsourcing"*,

23. Sujit Gujar and Boi Faltings *"Privacy Preserving Multi-Seller Combinatorial Auctions".*

24. Shweta Jain, Sujit Gujar, Satyanath Bhat, Onno Zoeter and Y. Narahari, *" An Incentive Compatible Multi-Armed-Bandit Crowdsourcing Mechanism with Quality Assurance"*, a working paper. (Available as arXiv:1406.7157).

Book Chapters

25. Y. Narahari and Sujit Gujar, *"Auctions in Electronic Commerce"*. Invited Book Chapter in: The Handbook of Technology Management, Volume III, pg 612-625, John Wiley and Sons.

PATENTS FILED

1. Methods and Systems for Creating Tasks of Digitizing Electronic Document (US20140359418)
2. Methods and Systems for Crowdsourcing a Task (US20140358605)
3. Method and System for Providing access to CrowdSourcing Tasks (US20140304833)
4. Methods and Systems for Regulating Service Layer Agreements for Multiple Cloud Services (US20140200947)
5. Method and system for a text data entry from an electronic document (US20140072222)
6. Method and System for Recommending CrowdSourcability of a Business Process (US20140058784)
7. Feedback Based Technique Towards Total Completion of Tasks in CrowdSourcing (US20130185138)

REVIWER

Reviewed Papers for WINE'12, AAAI'14, Games and Economic Behaviour (GEB), Artificial Intelligence (AI), Int. Conf. on Operational Research'12, Electronic Commerce Research and Applications (ECRA).

TEACHING EXPERIENCE

- Teaching assistant for CS-430: Intelligent Agents at EPFL (Fall 2014).
- Teaching assistant for CS-436: Computational Game Theory and Applications at EPFL (Fall 2014).

STUDENTS

Co-supervised Tasorn Sornnarong. "Dynamic matching in crowdsourcing platform".

Co-supervised Mizraji Thomas. "Securing Auctions".

COURSE WORK AT IISc

ME Courses (Grade)		**PhD Courses** (Grade)
Cryptography (**S**)	Game Theory(**S**)	Analysis-I (**S**)
Network Storage and Security.(**S**)	Design and Analysis of Algorithms(A)	Topology(A)
Data Structures(B)	E-commerce(**S**)	Linear Algebra(A)
Computational Methods of Optimization(A)	Computer Communication Network (A)	Topics in Approximation Algorithms(B)
Discrete Structures(A)	Pattern Recognition(B)	

(S Grade: 8/8; A Grade: 7/8; B Grade: 6/8)

Other Courses (Audit)

Stochastic Modeling and Applications, Topology-II, Discrete Structures,
Analysis-II (Measure Theory), Topics in Graph Theory,
Algebra and Computation, Modelling and Algorithms for Large Data Sets, Calculus on Manifolds.
Stochastic Approximation Algorithms, Convex Optimization (@EPFL)

INDUSTRY EXPERIENCE

January 2011-Nov 2013
I worked as **Research Scientist** at Xerox Research Centre, India (XRCI). I worked on *Enterprise crowdsourcing* where we explored opportunities for enterprises to leverage advantages of crowdsourcing proposed methodologies to enable it. I also worked on *economic models for cloud computing.* Based on the work at XRCI, I have filed 7 patents and 9 patents are under preparations. I co-authored 4 papers based on my work at XRCI.

July 2001 - July 2004.
I worked as Software Engineer in PACE Soft Silicon Pvt. Ltd. During this period I acquainted various skills such as programming for multiprocessor environment, cryptography, network security and multimedia related technologies. I got exposure to work with various embedded OS/ RTOS, (Real Time Operating Systems) on different platforms.

SKILLS

Programming for multiprocessor environment.

Programming Languages: C, C++, MFC, Java.

Tools: Matlab, VC++, Net-beans, Eclipse.

Operating Systems Exposure: Windows, Linux. RTOS: Symbian, RTLinux, WinCE.

Date of Birth: May 9, 1980.

REFERENCES

Available on request.

APPENDIX 1

Research Statement

Algorithmic Mechanism design and game theory are my primary research interests. Mechanism design is an important game theoretic tool in microeconomics. It has found widespread applications in modeling and solving decentralized design problems in many branches of engineering, notably computer science, electronic commerce, and network economics. Mechanism design is concerned with settings where a social planner faces the problem of aggregating the announced preferences of multiple agents into a collective decision when the agents exhibit strategic behaviour [1]. The system designer's goal is to achieve certain desired optimality based on the reported preferences. The strategic agents can manipulate underlying optimization algorithm by misreporting their preferences. Mechanism design is reverse engineering of game theory. It involves inducing a game among agents such that, at equilibrium, the strategic agents report their preferences truthfully.

My research aims to build solutions to mechanism design problems that are having strong theoretical foundation, are of practical use and are computationally efficient. Mechanism design has numerous applications in computer science, esp building autonomous agent systems where the agents are intelligent and strategic. Algorithm design plays important role as the underlying problem that a mechanism solves may be computationally hard. The traditional approximation algorithms might fail to ensure game theoretic properties. Thus, the mechanism needs to design algorithm ingeniously that safeguards incentive constraints.

Allocation of heterogeneous objects or resources to competing agents is a ubiquitous problem in the real world. For example, a federal government may wish to allocate different types of spectrum licenses to telecom service providers; a search engine has to assign different sponsored slots to the ads of advertisers; etc. The agents involved in such situations have private preferences over the allocations. The agents, being strategic, may manipulate the allocation procedure to get a favorable allocation. If the objects to be allocated are heterogeneous (rather than homogeneous), the information that agents posses, needs to be represented in multi-dimensional spaces. This makes the allocation problem complex as the agents get more degrees of freedom for manipulating the algorithm. It becomes even more formidable in the presence of a dynamic supply and/or demand. My doctoral thesis work is motivated by such problems involving strategic agents, heterogeneous objects, and dynamic supply and/or demand. My thesis proposed novel solutions to the problems in resource allocations using techniques from mechanism design theory, game theory, online algorithms and machine learning.

Currently, I am excited about exploring other frontiers of the mechanism design theory namely, algorithmic mechanism design, computational social choice, interface between cryptography and game theory, using game theory and mechanism design for social networks, crowdsourcing. All these problems are mechanism design problems The following are the research directions I would like to pursue in coming years.

Game Theory and Cryptography

Many times participating agents are very sensitive about their preferences and it is desired to take decision without revealing their preferences to the designer [2, 3]. For example, it is very important to design good auctions that preserve the privacy of the bids as well as the fact of bidding itself from the remaining agents. The theory of secure multi-party computation using homomorphic encryption is handy in designing such auction mechanisms [4]. However, the state of the art does not address preserving privacy of the fact of bidding itself in combinatorial auctions, that is who is bidding for what. We have made progress in designing such privacy preserving combinatorial auctions. There are many interesting challenges to be addressed here. Yet most of the proposed solutions having good privacy properties are not scalable and when adopted for combinatorial auctions where underlying auctions themselves are hard, the privacy concerns makes solutions further away from usable. It is desired to build scalable solutions for privacy preserving combinatorial auctions. Privacy preserving exchanges are not yet designed. A distributed constraint optimization with privacy guarantees [5] can be used to design such exchange protocols. I am interested in pursuing these research problems.

Differential Privacy and Mechanism Design for Secure Auctions

The researchers de-anonymized the famous Netflix challenge database, by linking it with IMDb database. Thus, leading to a compromise on individual privacy. The notion of differential privacy, introduced by [6], is very important to address this issue. It protects the data from identifying any specific record while performing statistical queries onto it. The connection between differential privacy and mechanism design was shown in [7, 8]. However, it has not yet been explored to build stronger secure auction protocols. I am interested in building secure auctions using differential privacy.

Learning Mechanisms

Whenever autonomous agents as well as the system designer are learning about the environment to optimize certain parameters whose values are unknown, techniques from machine learning/reinforcement learning are deployed. In such systems, the selfish agents may manipulate the learning algorithms [9, 10, 11] and mechanism design is a natural tool. This calls for combining mechanism design and machine learning techniques, which is referred to as Incentive Compatible Machine Learning. The following examples depict the need of incentive compatible machine learning.

- In sponsored search auctions over search engines like google, an advertiser pays to the search engine only when his advertisement receives a click. This probability of click for the advertiser, popularly known as click through rate (CTR), is an important parameter in the sponsored search auctions. These CTRs are not known beforehand. CTRs can be learned over repeated auctions [9, 12, 10]. This represents a strong case to combine machine learning with mechanism design theory. We have characterized truthful mechanisms in such contexts.
- In the later half of last decade, crowdsourcing has emerged as a new paradigm in outsourcing. Crowdsourcing, according to Jeff Howe, is the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call. A challenge here is that the workers are undefined and we do not know the quality of the workers as well as costs of performing the tasks are private to the workers. These qualities can be learned over a period. At the same time, the requesters have to balance between retaining good workers by appropriate incentives and not overpaying spammers. Mechanism design/game theory and machine learning/reinforcement learning need to be combined to design better systems in such contexts. [13, 11] make progress in this direction.

There are many interesting research problems which I am currently focusing on, a complete characterization of truthful machine learning algorithms for general settings is not available. The optimization problems which the system designer is solving may be NP complete and needs to solve it approximately. We need to then design ingenious algorithms which satisfy certain monotonicity for ensuring game theoretic properties. In certain settings, the parameters that mechanism is trying to learn might change over the period. Designing an incentive compatible mechanism with such dynamic nature of the unknown parameters makes the problem more challenging.

Algorithmic Mechanism Design in Multi-dimensional Settings

In his seminal work, Myerson [14] characterized an optimal auction for selling a single unit of a single item. Some limited generalizations for multi-unit single item auctions have been proposed [15, 16]. In multi-item settings, the representation of agents' preferences is multi-dimensional and this makes the mechanism design highly non-trivial. Ensuring truthful behaviour becomes extremely challenging mathematical problem and very little is known for general settings. My doctoral work contributed towards designing mechanisms in special multi-dimensional settings. Here, structure of the problems was exploited to design novel mechanisms. We made progress in designing optimal multi-unit combinatorial auctions under certain assumptions [17]. Until the recent break-throughs [18, 19], exact optimal auctions for multi-items were not available. In [18], designing an optimal multi-item auction is reduced to a problem of social welfare maximization via mapping the preferences of the agents to virtual preferences and then solved using geometric algorithms. However, structure of these transformations for general settings are yet to be analyzed. At the same time, the underlying algorithms for social welfare maximization are computationally too intensive for many interesting situations. Therefore we need to solve such problems approximately but at the same time, we need to ensure that the game theoretic properties of mechanisms are within tolerable limits. This calls for algorithmic mechanism design [20]. I am very much interested in addressing design of computationally efficient, multi-dimensional optimal auction that has good approximation bounds.

Dynamic Mechanism Design without Money

In certain settings, monetary transfers are not allowed. Kidney exchanges, campus recruitment and university dorm allocations are some such scenarios. In these problems the agents have preferences over their matches. Such problems are broadly classified into two categories, one sided matching and two sided matching. The theory developed to address incentive constraints in such settings assumes that all the agents are simultaneously available and they are static. However, in reality the agents are dynamic and are available only for a limited period. The mechanism needs to take a decision pertaining an agent before he or she leaves the system. [21, 22, 23] show that we can adopt static solutions to build dynamic solutions preserving an important game theoretic property, incentive compatibility. However, these solutions lead to poor performance on other desirable properties such as rank efficiency and stability (where no pair of agents can prefer to be matched with each other than their match). There are many interesting unsolved questions here: characterize all mechanisms that can be implemented truthfully, study the right trade-off between incentive constraints and the other desirable properties needs to be studied. I am keen on continuing the work in this direction. In particular, to introduce weaker notion of desirable properties like stability, to look for weaker solution concepts such as Bayesian incentive compatibility and improve on the performance for rank efficiency, stability.

Applications

The research topics discussed above are different sub-fields under the broad umbrella of mechanism design theory. These advances have widespread applications across multiple domains: social networks, crowdsourcing, online advertising, market prediction, intelligent transportation and even online education, to name a few. The participants in such marketplaces are intelligent and rational agents. Therefore, to achieve a large system-wide goal, it is important to provide them with good motivation in the form of proper incentives. Using mechanism design theory, I would like to contribute in building applications for such marketplaces ensuring that the marketplace is robust to agent's manipulations.

APPENDIX 2

Summary of Doctoral Work

Novel Mechanisms for Allocation of Heterogeneous Items in Strategic Settings

Allocation of heterogeneous objects or resources to competing agents is a ubiquitous problem in the real world. For example, a federal government may wish to allocate different types of spectrum licenses to telecom service providers; a search engine has to assign different sponsored slots to the ads of advertisers; etc. The agents involved in such situations have private preferences over the allocations. The agents, being strategic, may manipulate the allocation procedure to get a favourable allocation. If the objects to be allocated are heterogeneous (rather than homogeneous), the problem becomes quite complex. The allocation problem becomes even more formidable in the presence of a dynamic supply and/or demand. Our thesis work is motivated by such problems involving strategic agents, heterogeneous objects, and dynamic supply and/or demand. In this thesis, we model such problems in a standard game theoretic setting and use mechanism design to propose novel solutions to the problems. We extend the current state-of-the-art in a non-trivial way by solving the following problems:

Mechanism Design with Money

- Optimal combinatorial auctions with single minded bidders, generalizing the existing methods to take into account multiple units of heterogeneous objects.

  In this work, we address designing of optimal combinatorial auctions. We extend the current art by proposing an optimal auction for procuring multiple units of multiple items when the bidders are single minded and capaciated. We develop a procurement auction that minimizes the cost of procurement while satisfying Bayesian incentive compatibility and interim individual rationality. Under appropriate regularity conditions, this optimal auction also satisfies dominant strategy incentive compatibility. The results presented here hold true for equivalent forward auction settings as well. We design an combinatorial procurement auction for the case of two item multi-unit case when single minded bidders are willing to offer volume discounts. We also, study design of optimal auction in the presence of XOR minded bidders who submit an XOR bid on two disjoint subsets of items.

- Multi-armed bandit mechanisms for sponsored search auctions with multiple slots, generalizing the current methods that only consider a single slot.

  Search engines display various ads on their sites whenever there is a search. Display of these ads occur through auctions, namely sponsored search auctions. In such auctions, the advertisers pay only if their ad receives a click. Thus, the probabilities of clicks, click through rates, (CTRs) play an important role in designing sponsored search auctions. However, typically, neither search engine nor the advertisers know the CTRs before hand. The search engine can learn the CTRs by displaying the ads from various advertisers over repeated auctions. The question we address in this work is how to design a truthful multi-slot sponsored search auction which learns CTRs.

- Strategy-proof redistribution mechanisms for heterogeneous objects, expanding the scope of the current state of practice beyond homogeneous objects.

  We study problem of designing redistribution mechanisms for assignment of p heterogeneous objects among n competing agents ($n > p$), each with unit demand. To measure a performance of a redistribution mechanism, we propose a redistribution index. Our main result states that, in general settings, no linear redistribution mechanism can have non-zero redistribution index. We propose two escape routes around this impossibility theorem. In first approach, we restrict the agents' valuations to the case of having scaling based relation, and designed an optimal redistribution mechanism with non-zero redistribution index. In second approach, we show an existence of non-linear redistribution mechanism with non-zero redistribution index if $n > 2p$. Moulin as well as Guo and Conitzer have designed an optimal redistribution mechanism for homogeneous object settings. We extend their linear redistribution mechanism into a non-linear redistribution mechanism, namely HETERO, that is applicable to homogeneous as well as heterogeneous settings. We conjecture that HETERO is optimal redistribution mechanism as well as redistribution index in heterogeneous settings is also same as homogeneous settings. Recently, it has been shown by Guo, that HETERO is indeed an optimal redistribution mechanism.

On-line Mechanisms without Money

- Dynamic stable matching in two sided markets.

  In their seminal work, Gale and Shapley addressed the college admission problem where colleges have preferences over students and the students have preferences over various colleges. They proposed an ingenious algorithm, deferred acceptance, for such two sided matching markets where monetary transfers are not feasible. This algorithm yields a stable matching and is strategy-proof for one side of the market. However, an inherent assumption here is that the all the agents are available. Consider the situation of campus recruitment or faculty recruitment where not all agents are simultaneously present, that is agents arrive dynamically. Any decision pertaining to a dynamic agent needs to be taken before he/she leaves the system. In the thesis, we generalize the deferred acceptance algorithm namely, GSODAS. The GSODAS is strategy-proof for static side of the market and always produces the stable matching. In general, stable matching is not possible in online settings. However, GSODAS uses the fallback option for the departing agents to achieve stability.

- Dynamic house allocation

  In the house allocation problem, each of a set of self-interested agents owns a distinct object (a house) and has strict preferences over houses. The problem is to find a reallocation of objects amongst agents that is robust against misreports of preferences by agents while identifying beneficial trades and without using money. The top-trading cycle algorithm (TTCA) by Shapley and Scarf is strategy-proof and finds an allocation in the core. An allocation in the core is stable. In the dynamic model of the house allocation problem discussed, each agent has an arrival period and a departure period and is only able to trade with other agents present simultaneously in the market at the same time. For a motivating example, consider college housing, with students on different leases and willing to trade during the month before their lease expires. Given TTCA, has very nice properties, it is natural to use TTCA as basic trading algorithm in online settings as well. We show that a naive usage of TTCA in online settings fails. We establish general conditions under which no mechanism in which an agent can influence the set of agents with which it participates in a TTCA (e.g., the period in which it trades and thus the other agents that it trades with) can be strategy-proof. Based on these conditions, we study partition mechanisms, in which each agent is assigned online to a group of agents with which it will engage in a single TTCA. We propose various partition mechanisms and experimentally shows that stochastic optimization based partition mechanism (SO-TTCA) performs quite well on rank-efficiency analysis.

- Dynamic allocation mechanisms for allocations of heterogeneous objects

  It has been shown that for allocation of goods to the agents, serial dictatorship is the only mechanism that is strategyproof. We study allocation of goods to dynamically arriving agents. We first show that, arrival-priority serial dictatorship (APSD) is the only strategyproof mechanisms for this problem and it performs poor on rank analysis. We propose a mechanism, namely Scoring Rule, (SR) which improves rank efficiency, but is manipulable. If every agent manipulates optimally, it reduces to APSD and hence we say it has tolerable manipulability.

References

[1] D. Garg, Y. Narahari, and S. Gujar, "Foundations of mechanism design: A tutorial - part 1: Key concepts and classical results," *Sadhana - Indian Academy Proceedings in Engineering Sciences*, vol. 33, pp. 83–130, April 2008.

[2] A. C. Yao, "Protocols for secure computations," in *Proceedings of the 23rd Annual Symposium on Foundations of Computer Science*, pp. 160–164, 1982.

[3] S. Izmalkov, S. Micali, and M. Lepinski, "Rational secure computation and ideal mechanism design," in *Foundations of Computer Science, 2005. FOCS 2005. 46th Annual IEEE Symposium on*, pp. 585–594, IEEE, 2005.

[4] F. Brandt and T. Sandholm, "On the existence of unconditionally privacy-preserving auction protocols," *ACM Transactions on Information and System Security (TISSEC)*, vol. 11, no. 2, p. 6, 2008.

[5] T. Léauté and B. Faltings, "Protecting privacy through distributed computation in multi-agent decision making," *Journal of Artificial Intelligence Research*, vol. 47, no. 1, pp. 649–695, 2013.

[6] C. Dwork, "Differential privacy," in *Automata, languages and programming*, pp. 1–12, Springer, 2006.

[7] F. McSherry and K. Talwar, "Mechanism design via differential privacy," in *Foundations of Computer Science, 2007. FOCS'07. 48th Annual IEEE Symposium on*, pp. 94–103, IEEE, 2007.

[8] K. Nissim, R. Smorodinsky, and M. Tennenholtz, "Approximately optimal mechanism design via differential privacy," in *Proceedings of the 3rd Innovations in Theoretical Computer Science Conference*, pp. 203–213, ACM, 2012.

[9] M. Babaioff, Y. Sharma, and A. Slivkins, "Characterizing truthful multi-armed bandit mechanisms," in *EC09: Proceedings of the 10th ACM Conference on Electronic Commerce*, (Stanford, California), pp. 79–88, 2009.

[10] A. Das Sharma, S. Gujar, and Y. Narahari, "Truthful multi-armed bandit mechanisms for multi-slot sponsored search auctions," *CURRENT SCIENCE*, vol. 103, no. 9, pp. 1064–1077, 2012.

[11] S. Jain, S. Gujar, O. Zoeter, and Y. Narahari, "A quality assuring multi-armed bandit crowdsourcing mechanism with incentive compatible learning," in *Thirtheenth International Conference on Autonomous Agents and Multiagent Systems*, pp. 1609–1610, 2014.

[12] N. R. Devanur and S. M. Kakade, "The price of truthfulness for pay-per-click auctions," in *EC09: Proceedings of the 10th ACM Conference on Electronic Commerce*, pp. 99–106, 2009.

[13] S. Bhat, S. Nath, O. Zoeter, S. Gujar, Y. Narahari, and C. Dance, "A mechanism to optimally balance cost and quality of labeling tasks outsourced to strategic agents," in *Thirtheenth International Conference on Autonomous Agents and Multiagent Systems*, pp. 917–924, 2014.

[14] R. B. Myerson, "Optimal auction design," *Mathematics of Operations Research*, vol. 6, pp. 58–73, February 1981.

[15] G. Iyengar and A. Kumar, "Optimal procurement mechanisms for divisible goods with capacitated suppliers," *Review of Economic Design*, vol. 12, pp. 129–154, June 2008.

[16] A. Malakhov and R. V. Vohra, "Single and multi-dimensional optimal auctions - a network perspective," discussion papers, Kellogg School of Management, Northwestern University, December 2005.

[17] S. Gujar and Y. Narahari, "Optimal multi-unit combinatorial auctions," *Operational Research*, vol. 13, pp. 27–46, 2013.

[18] Y. Cai, C. Daskalakis, and S. M. Weinberg, "Optimal multi-dimensional mechanism design: Reducing revenue to welfare maximization," in *Foundations of Computer Science (FOCS), 2012 IEEE 53rd Annual Symposium on*, pp. 130–139, IEEE, 2012.

[19] Y. Cai, C. Daskalakis, and S. M. Weinberg, "An algorithmic characterization of multi-dimensional mechanisms," in *Proceedings of the forty-fourth annual ACM symposium on Theory of computing*, pp. 459–478, ACM, 2012.

[20] N. Nisan and A. Ronen, “Algorithmic mechanism design,” in *Proceedings of the thirty-first annual ACM symposium on Theory of computing*, pp. 129–140, ACM, 1999.

[21] S. Gujar and D. C. Parkes, “Dynamic Matching with a Fall-back Option,” in *In Proceedings of 19th European Conference on Artifitial Intelligence*, pp. 263–268, 2010.

[22] J. Zou, S. Gujar, and D. C. Parkes, “Tolerable Manipulability in Dynamic Assignment without Money,” in *Proceedings 24th AAAI Conference on Artificial Intelligence (AAAI '10)*, 2010.

[23] S. Guajr and B. Faltings, “Dynamic task assignments: An online two sided matching approach,” in *Proceedings of the 3rd International workshop on Matching Under Preferences, MATCHUP, to appear*, 2015.