

<b>Short Summary</b>	My research work deals with developing Approximate Dynamic Programming (ADP) and Reinforcement Learning (RL) algorithms with provable performance and guaranteed convergence. I am also interested in applications of RL and stochastic optimization to problems arising in practice. Currently, I am a post-doctoral research fellow in the Department of Computing Science, University of Alberta, and I obtained my PhD from the Department of Computer Science and Automation, Indian Institute of Science.
<b>Interests</b>	Markov Decision Processes, Approximate Dynamic Programming, Reinforcement Learning, Bandits, Machine Learning, Learning Theory, Stochastic Optimization, Stochastic Approximation and Stochastic Control.
<b>Relevant Courses</b>	<ul style="list-style-type: none"><li>• Stochastic Models and Applications, Stochastic Processes and Queuing Theory, Stochastic Approximation Algorithms</li><li>• Convex Optimization, Game Theory, Dynamics of Linear Systems</li><li>• Data mining, Pattern Recognition, Detection and Estimation Theory</li><li>• Real Analysis, Measure Theory, Topology (point-set), Linear Algebra</li></ul>
<b>Thesis (Past Research)</b>	<p><b>Title:</b> “Approximate Dynamic Programming and Reinforcement Learning - Algorithms, Analysis and an Application”</p> <p><b>Advisor:</b> Prof. Shalabh Bhatnagar (shalabh@csa.iisc.ernet.in), Department of Computer Science and Automation, Indian Institute of Science, Bangalore - 560012</p> <p><b>Abstract:</b> MDP is a useful mathematical framework to cast a variety of optimal sequential decision making problems under uncertainty in domains such as engineering, science and economics. However, computing optimal value function and optimal policy is difficult in practice because either the state space is too large or the model information is not available.</p> <p>The primary investigations in the thesis were:</p> <ul style="list-style-type: none"><li>• <i>Approximate Dynamic Programming</i> refers to a gamut of methods that compute an approximate value function and a sub-optimal policy. The thesis investigated a widely used ADP method namely the Approximate Linear Programming (ALP) formulation. In particular, analytical tools were developed to bound the performance degradation that occurs when the constraint of the ALP are reduced or approximated. The analysis is based on ideas of monotone projections in tropical linear algebra.</li><li>• <i>Reinforcement Learning</i> algorithms are stochastic approximation (SA) schemes and solve the MDP by making use of sample trajectories. Actor-Critic algorithms are two timescale SA schemes since they make use of different step-size schedules. The thesis investigated the conditions under which two timescale SA schemes are stable and convergent.</li><li>• <i>Crowd Sourcing</i> is a new mode of organizing work in multiple groups of smaller chunks of tasks and outsourcing them to a distributed and large group of people in the form of an open call. An important task attribute that affects the completion time of a task is its price, and incorrect pricing leads to task starvation. In the thesis, the pricing problem is formulated in the MDP framework to compute a</li></ul>

pricing policy that achieves predictable completion times in simulations as well as real world experiments.

## **Publications (from the thesis)**

### **Journal**

- Chandrashekar, L. and Bhatnagar, S. “A Stability Criterion for Two Timescale Stochastic Approximation Schemes”, Accepted for publication in Automatica, 2017.

### **International Conferences**

- Chandrashekar, L.; Bhatnagar, S., “Approximate Dynamic Programming with  $(\min, +)$  linear function approximation for Markov Decision Processes,” 53rd IEEE Annual Conference on Decision and Control (CDC), December 15 – 17, 2014, Los Angeles California, USA.
- Chandrashekar, L.; Bhatnagar, S., “A Generalized Reduced Linear Program for Markov Decision Processes,” Twenty-Ninth AAAI Conference on Artificial Intelligence, January 25 – 30, 2015, Austin Texas, USA.
- Chandrashekar, L.; Dubey, A.; Bhatnagar, S. and Chithralekha, B., “A Markov Decision Process framework for predictable job completion times on crowdsourcing platforms”, Proceedings of the Second AAAI Conference on Human Computation and Crowdsourcing, HCOMP 2014, Pittsburgh, Nov. 2-4, 2014.
- Maity, R. K.; Chandrashekar, L.; Padakandla, S.; Bhatnagar, S., “Shaping Proto-Value Functions Using Rewards”, European Conference on Artificial Intelligence 2016.

### **Work under consideration**

- Chandrashekar, L.; Bhatnagar, S and Szepesvári C., “A Generalized Reduced Linear Program for Markov Decision Processes”, under review in IEEE Transactions on Automatic Control.

### **Work in Progress**

- “A stochastic gradient approach to parameter tuning in Hadoop”.
- “Robust Temporal Difference Learning Algorithms”.
- “Acceleration in Temporal Difference Learning Algorithms”.

## **Patents**

- Methods and Systems for Crowdsourcing of Tasks (US 20160071048 A1)
- System and method for improving dynamic performance of a circuit (US 7538701 B2)
- System and method for reducing power dissipation in an analog to digital converter (US 7821436 B2)

**Industry Experience**

Designation: Analog Design Engineer

Organization: Cosmic Circuits Pvt Ltd, Bangalore

Period: 3 years (2005 – 2008)

Role: I was part of the High Speed Analog to Digital Converters (ADC) Team. I was involved the following tasks:

- Design of blocks such as
  - Amplifiers with state-of-the-art feedback compensation schemes.
  - Comparators.
  - Digital Error Correction Logic.
- Full system simulation, testing and debugging of 10 to 12 bit ADCs.
- Worked in CMOS technologies varying from 0.360 $\mu$ m to 65nm.

**Industrial Collaboration**

Organization: Xerox Research Center India

Project Title: Methods and Systems for Crowdsourcing of Tasks

Period: 2012 – 2014

Objective: To propose automatic pricing of tasks posted in a crowdsourcing platform

Co-investigator: Dr. Suijt P. Gujar and Dr. Chithralekha Balamurugan, Xerox Research Center, India, and Dr. Shalabh Bhatnagar and Srujana Sadula, Indian Institute of Science, Bangalore.

Achievements: Filed a patent titled “Methods and Systems for Crowdsourcing of Tasks (US 20160071048 A1)” and a published a paper titled “A Markov Decision Process framework for predictable job completion times on crowdsourcing platforms”, Proceedings of the Second AAAI Conference on Human Computation and Crowdsourcing, HCOMP 2014, Pittsburgh, Nov. 2-4, 2014.

**Talks and Posters**

- *Approximate Dynamic Programming with (min, +) linear function approximation for Markov Decision Processes*, 53rd IEEE Annual Conference on Decision and Control (CDC), December 15 – 17, 2014, Los Angeles California, USA.
- *A Generalized Reduced Linear Program for Markov Decision Processes*, Twenty-Ninth AAAI Conference on Artificial Intelligence, January 25 – 30, 2015, Austin Texas, USA.
- *A Generalized Reduced Linear Program for Markov Decision Processes*, 3<sup>rd</sup> IKDD Conference on Data Science, March 13 – 16, 2016, Pune, India.
- *Introduction to Reinforcement Learning*, I-CARE Big Data Analytics and Cognitive Computing winter school, Bangalore 2014.
- *Introduction to Probability*, Computer Science and Automation Undergraduate Summer School, Bangalore 2013.
- *Introduction to Linear Algebra*, Computer Science and Automation Undergraduate Summer School, Bangalore 2014.

**Accomplishments**

1. I was All India Rank 1 in the Graduate Aptitude Test in Engineering conducted in the year 2008 with a score of 1000/1000.
2. Presented with Medal of Honor for Best Pass out student in Systems Science and Automation, Indian Institute of Science.
3. Best research presentation award in the IIST-Research Scholars Day held at Indian Institute of Space Technology, Trivandrum, December 2013.
4. Best research presentation award in the Electrical Engineering and Computer Science Colloquium held at IISc, Bangalore, February 2015.

## Academics

**Ph.D.**[2010-2015]  
Department of Computer Science and Automation (CSA),  
Indian Institute of Science (IISc), Bangalore, India.

**M.E.** [2008 - 2010]  
Systems Science and Automation,  
Department of Electrical Engineering (EE),  
Indian Institute of Science (IISc), Bangalore, India.  
**C.G.P.A:** 7.2/8

**B.Tech.** [2001 - 2005]  
Instrumentation and Control Engineering,  
National Institute of Technology, Tiruchirapalli.  
**C.G.P.A:** 8.61/10

## References

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