Mohan Krishnamoorthy

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Research interests

Model-driven and algorithm engineering; global optimization; derivative-free optimization; big data analytics; high performance computing

Education

2012–2018 **Ph.D. in Computer Science**, *George Mason University*, *Fairfax, VA*.
Advisors: Prof. Alexander Brodsky, Prof. Daniel Menascé

2007–2010 **M.S. in Computer Science**, *Rochester Institute of Technology*, *Rochester, NY*.

2003–2007 **B. Engg. in Computer Engineering**, *Mumbai University*, *Mumbai, India*.

Positions held

10/2018–Present Postdoctoral Appointee, Argonne National Laboratory, Lemont, IL.

01/2013–08/2018 Graduate Research Assistant, George Mason University, Fairfax, VA.

01/2015–12/2017 Guest Researcher, National Institute of Standards and Technology, Gaithersburgh, MD.

08/2012–12/2012 Graduate Teaching Assistant, George Mason University, Fairfax, VA.

05/2010–06/2012 Research Technologist, Los Alamos National Laboratory, Los Alamos, NM.

07/2008–04/2010 Research Assistant, Los Alamos National Laboratory, Los Alamos, NM.

Software packages

apprentice
link An open source High Energy Physics analysis package.
Construct polynomial and rational approximations of a given order and perform χ^2 minimization with diagonal variance or full covariance matrix.
Currently working on integrating apprentice with Pythia DIY PyCOMPSs workflow to solve the derivative free χ^2 minimization problem with model values obtained from the physics Monte Carlo simulator (Pythia).

SODA
link An open source package containing the algorithm to perform stochastic optimization based on deterministic approximations to efficiently solve the problem of finding control settings for stochastic processes in a large manufacturing service network subject to the satisfaction of stochastic feasibility constraints.

FactoryOptima
link Web-based prototype system that allows manufacturing process engineers to compose, optimize and perform trade-off analysis of manufacturing service networks based on a reusable repository of performance models.

Peer-reviewed journal articles

[CPC'20]
DOI A. Austin, **M. Krishnamoorthy**, S. Leyffer, S. Mrenna, J. Muller, H. Schulz. *Practical algorithms for multivariate rational approximation.* In the Computer Physics Communications (**CPC'20**), October 2020.

[IJCIM'19]
DOI A. Brodsky, M. O. Nachawati, **M. Krishnamoorthy**, W. Z. Bernstein, and D. A. Menascé. *Factory optima: a web-based system for composition and analysis of manufacturing service networks based on a reusable model repository.* In the International Journal of Computer Integrated Manufacturing (**IJCIM'19**), February 2019.

[JDS'18] **M. Krishnamoorthy**, A. Brodsky, and D. Menascé. *Stochastic Decision Optimization based on Deterministic Approximations of Processes described as Closed-form Arithmetic Simulation.* In the Journal of Decision Systems (**JDS'18**), May 2018.
DOI

[IJAMT'16] A. Brodsky, G. Shao, **M. Krishnamoorthy**, A. Narayanan, D Menascé, and R. Ak. *Analysis and Optimization in Smart Manufacturing based on a Reusable Knowledge Base for Process Performance Models.* In the International Journal of Advanced Manufacturing Technology (**IJAMT'16**), April 2016.
DOI

[JDS'15] D. Menascé, **M. Krishnamoorthy**, A. Brodsky. *Autonomic Smart Manufacturing.* In the Journal of Decision Systems, Special Issue on Integrated Decision Support Systems (**JDS'15**), June 2015.
DOI

[BMCbio'13] J. Brodin, **M. Krishnamoorthy**, G. Athreya, W. Fischer, P. Hraber, C. Gleasner, L. Green, B. Korber, T. Leitner. *A multiple-alignment based primer design algorithm for genetically highly variable DNA targets.* In BMC bioinformatics Journal (**BMCbio'13**), August 2013.
DOI

[BMCbio'11] **M. Krishnamoorthy**, P. Patel, M. Dimitrijevic, J. Dietrich, M. Green, C. Macken. *Tree pruner: An efficient tool for selecting data from a biased genetic database.* In BMC bioinformatics Journal (**BMCbio'11**), January 2011.
DOI

Peer-reviewed conference publications

[ICORES'21] **M. Krishnamoorthy**, A. Brodsky, and D. Menascé. *Stochastic Optimization for Steady State Production Processes based on Deterministic Approximations.* In the International Conference on Operations Research and Enterprise Systems 2021 (**ICORES'21**), February 2021.

[IFIP-DSS'18] **M. Krishnamoorthy**, A. Brodsky, and D. Menascé. *Stochastic Decision Optimization based on Deterministic Approximations of Processes described as Closed-form Arithmetic Simulation.* In Proceedings of the IFIP WG 8.3 on Decision Support Systems (**IFIP-DSS'18**), June 2018. **Best Paper Award.**

[IEEE-BD'17] A. Brodsky, **M. Krishnamoorthy**, M. O. Nachawati, and W.Z. Bernstein, D Menascé. *Manufacturing and Contract Service Networks: Composition, Optimization and Tradeoff Analysis based on a Reusable Repository of Performance Models.* In Proceedings of the 2017 IEEE International Conference on Big Data (**IEEE-BD'17**), Boston, MA.

[IEEE-BD'16] A. Brodsky, **M. Krishnamoorthy**, W. Z. Bernstein, M. O. Nachawati. *A System and Architecture for Reusable Abstractions of Manufacturing Processes.* In Proceedings of the 2016 IEEE International Conference on Big Data (**IEEE-BD'16**), Washington DC.

[HICSS'16] **M. Krishnamoorthy**, A. Brodsky, and D. Menascé. *Modular Modeling & Optimization of Temporal Manufacturing Processes with Inventories.* In Proceedings of the 2016 Hawaii International Conference on System Sciences (**HICSS'16**), Kauai, HI.

[IEEE-BD'15] A. Brodsky, G. Shao, **M. Krishnamoorthy**, A. Narayanan, D Menascé, and R. Ak. *Analysis and Optimization in Smart Manufacturing based on a Reusable Knowledge Base for Process Performance Models.* In Proceedings of the 2015 IEEE International Conference on Big Data (**IEEE-BD'15**), Santa Clara, CA.

[ICS'15] **M. Krishnamoorthy**, A. Brodsky, D. Menascé. *Optimizing Stochastic Temporal Manufacturing Processes with Inventories: An Efficient Heuristic Algorithm Based on Deterministic Approximations.* In Proceedings of the 2015 INFORMS Computing Society Conf. (**ICS'15**), Richmond, VA.

[ICS-pr'15] (***Abstract***) **M. Krishnamoorthy**, A. Brodsky, and D. A. Menascé. *Temporal manufacturing query language (tMQL) for domain specific composition, what-if analysis, and optimization of manufacturing processes with inventories.* As presented at the 2015 INFORMS Computing Society, did not appear in proceedings (**ICS-pr'15**), Richmond, VA.

[IEEE-BD'14] A. Brodsky, **M. Krishamoorthy**, D. Menascé, G. Shao, S.Rachuri. *Toward Smart Manufacturing Using Decision Analytics.* In Proceedings of the 2014 IEEE International Conference on Big Data (**IEEE-BD'14**), Washington DC.

Under review

[**CHEP**] (***Conf. Proc.***) **M. Krishnamoorthy**, H. Schulz, X. Ju, W. Wang, S. Leyffer, Z. Marshall, S. Mrenna, J. Muller, and J. B.Kowalkowski. *Apprentice for Event Generator Tuning.* In 25th International Conference on Computing in High-Energy and Nuclear Physics (**CHEP**). *arXiv:2103.05748.*

[**SPP**] (***Journal***) X. Ju, **M. Krishnamoorthy**, S. Leyffer, Z. Marshall, S. Mrenna, J. Muller, H. Schulz, and W. Wang. *BROOD: Bilevel and Robust Optimization and Outlier Detectionfor Efficient Tuning of High-Energy Physics Event Generators.* In SciPost Pysics (**SPP**). *arXiv:2103.05751.*

Talks

2021 *Stochastic Optimization Algorithm based on Deterministic Approximations.* International Conference on Operations Research and Enterprise Systems 2021, Vienna, Austria (Online).

2020 *A Framework for Large-Scale Nonlinear Optimization.* SIAM Conference on Parallel Processing for Scientific Computing 2020, Seattle, WA.

2019 *Bi-level Optimization for Design of Experiments.* INFORMS Annual Meeting 2019, Seattle, WA.

2018 *Optimization based on White-Box Deterministic Approximations: Models, Algorithms, and Application to Service Networks.* Argonne National Laboratory, Lemont, IL.

2017 *Service Networks: Stochastic Optimization based on Deterministic Approximations and Repository of Performance Models.* Doctoral Candidate Student Presentations at the 29^{th} International Conference on Tools for Artificial Intelligence 2017, Boston, MA.

2017 *Manufacturing and Contract Service Networks: Composition, Optimization and Tradeoff Analysis based on a Reusable Repository of Performance Models.* IEEE International Conference on Big Data 2017, Boston, MA.

2016 *A System and Architecture for Reusable Abstractions of Manufacturing Processes.* IEEE International Conference on Big Data 2016, Washington DC.

2016 *Efficient Decision Support System for Discrete Manufacturing Processes.* Computer Science PhD Symposium, George Mason University, Fairfax, VA.

2015 *Analysis and Optimization in Smart Manufacturing based on a Reusable Knowledge Base for Process Performance Models.* IEEE International Conference on Big Data 2015, Santa Clara, CA.

2015 *Temporal manufacturing query language (tMQL) for domain specific composition, what-if analysis, and optimization of manufacturing processes with inventories.* INFORMS Computing Society Conference 2015, Richmond, VA.

2015 *Optimizing Stochastic Temporal Manufacturing Processes with Inventories: An Efficient Heuristic Algorithm Based on Deterministic Approximations.* INFORMS Computing Society Conference 2015, Richmond, VA.

2010 *Tree prune & decorator: An efficient tool for selecting and annotating data from a biased genetic database.* Theoretical Biology and Biophysics Seminar, Los Alamos National Laboratory, Los Alamos, NM.

Awards & accomplishments

2021 Travel Grant (conference registration fee vaiwer) to attend and present at the International Conference on Operations Research and Enterprise Systems (ICORES), February 4-6, 2021.

2018 Best Paper Award for the paper "Stochastic Decision Optimization based on Deterministic Approximations of Processes described as Closed-form Arithmetic Simulation," IFIP WG 8.3 on Decision Support Systems, Ljubljana, Slovenia, June 13-15, 2018.

2018 Outstanding PhD Student Award from Computer Science Dept. at George Mason University, Fairfax, VA.

2014–2017 Travel Grant to attend the IEEE International Conference on Big Data.

2017 Travel Grant to attend the International Conference on Tools for Artificial Intelligence, Boston, MA.

2014–2017 Helped write three proposals to NIST and DFW airport, two of which were successfully funded.

2015 Travel Grant to attend the INFORMS Computing Society Conference, Richmond, VA.

2015–2017 Research Grant from National Institute of Standards and Technology, Gaithersburgh, MD.

2013–Present Graduate Research assistantship from George Mason University, Fairfax, VA.

2012–2017 Invited to join multiple honor societies for being an outstanding student.

2012–2013 Dean Fellowship Award from George Mason University, Fairfax, VA.

2008–2010 Research Assistantship from Los Alamos National Laboratory, Los Alamos, NM.

2007 Certificate of excellence for creating a budget database back end in SQL Server and web user interface for monitoring quarterly budgets, Mumbai, India.

Research experience

10/2018–Present **Postdoctoral Appointee**, *Argonne National Laboratory (ANL)*, Lemont, IL.

- Developed and implemented mathematical and algorithmic techniques for approximating expensive functions in High Energy Physics (HEP).
- Developed, maintained, and published the an HEP analysis package called *apprentice* for efficiently constructing polynomial/rational approximations and for performing χ^2 minimization.
- Developed robust optimization and design of experiment formulations to decide weights of importance with the goal of tuning a HEP Monte Carlo simulator.

01/2013–08/2018 **Graduate Research Assistant**, *George Mason University (GMU)*, Fairfax, VA.

- Designed and developed reusable mathematical models for non-linear, stochastic, hierarchical, and temporal manufacturing processes from real-world data.
- Designed and developed one-stage stochastic optimization algorithms based on deterministic approximation heuristics.
- Developed and published the stochastic optimization algorithm based on deterministic approximations (*SODA*) to efficiently solve the problem of finding controls for stochastic processes in a large manufacturing service network.

01/2015–12/2017 **Guest Researcher**, *National Institute of Standards and Technology (NIST)*, Gaithersburgh, MD.

- Designed and populated a repository of reusable mathematical models that were sourced from real-world data, publications, and crowdsourced data.
- Developed a software framework and prototype (*FactoryOptima*) to perform composition, analysis, and optimization on reusable models.

05/2010–06/2012 **Research Technologist**, *Los Alamos National Laboratory (LANL)*, Los Alamos, NM.

- Designed and developed scientific algorithms for highly variable and large scale bioinformatics tools.

- Developed and debugged multiple backend modules of the HIV project.
- Redesigned the HIV website using Model-View-Controller (MVC) framework and web services.

07/2008–04/2010 **Research Assistant**, *Los Alamos National Laboratory (LANL)*, Los Alamos, NM.

- Designed and developed Tree Viewer, Pruner and Decorator tools to perform selection and annotation of Influenza sequences.
- Designed and developed a schema for a large Influenza Sequence Database.

Teaching experience

08/2012–12/2012 **Graduate Teaching Assistant**, *George Mason University (GMU)*, Fairfax, VA.
Prepared and conducted labs, discussions, quizzes, and examinations of undergraduate courses in C/C++.

Professional service

Supervising

2020 Supervised a graduate student over the summer to do research on parameter tuning using Monte Carlo simulations.

2019 Supervised a graduate student over the summer to do research on design of HEP experiments.

Minisymposia

2020 Co-organized a mini symposium for the 19th SIAM Conference on Parallel Processing for Scientific Computing titled "High Performance Computing in Scientific Applications".

2019 Co-organized a a mini symposium for the INFORMS Annual Meeting 2019 titled "Simulation-Based Optimization and Design of Experiments".

Mentoring

2014 Mentored undergraduate students in *Logic Programming* and *C++ Programming* courses and graduate students in *Decision Guidance Systems* course.

2014 Mentored a graduate student in *Advanced Algorithms* course.

Reviews

Journal of Decision Systems, Hawaii International Conference on System Sciences, INFORMS Computing Society Conference,Winter Simulation Conference, IEEE Conference on Inventive Computing and Informatics, BMC Bioinformatics, IEEE Big Data 2019

Skills, expertise & tools

Programming Languages & Libraries: Java (expert), C (proficient), C++ (proficient), LaTex (proficient), SQL (proficient), NoSQL (proficient), Ruby (familiar), Perl (proficient), Python (proficient), Shell script (familiar), R (proficient), JavaScript (familiar), jQuery (familiar), XQuery (competent), JSONiq (proficient).

Technical Skills: Data analytics, Analytical Modeling, Data Science, Algorithm Design, Decision Optimization, Operations Research, Decision Systems, Model Simulation & Prediction, Database Management Systems, Software Development Life Cycle.

OS: Linux, Windows 7/8/10, MAC OS/X.

Version control: GIT, Repo, SVN.

Functional abilities: Software Architecture, Object Oriented Programming, Distributed Business and Scientific Applications, Software Development and Testing, Data Mining and Analytics.

Tools: Docker, Eclipse, Emacs and VI editors, Oxygen XML editor, Rational Rose, Microsoft Visio, Microsoft Office, Microsoft Visual C++, Microsoft Visual Studio, gedit, Atom.

Mathematical modeling & Optimization Solvers: OPL, AMPL, CPLEX, Gurobi, MINOS, SNOPT, LGO, Coin OR, BARON, BONMIN.

Internet Technology: Amazon AWS, Azure, Hadoop, OpenStack, Apache Spark.

Research project details (not updated)

08/2014–08/2018 Stochastic optimization algorithms based on deterministic approximations, *GMU*.

Purpose: Stochastic optimization algorithms that make use of the mathematical structure of the original problem are inefficient especially for real-world processes composed of complex process networks because they extract the mathematical structure using samples from a black-box simulation. The goal here is to improve the computation complexity and convergence of these algorithms for probabilistic models.
Contribution: Extracted the mathematical structure of the problem from a white-box simulation code analysis as part of a heuristic algorithm based on deterministic approximations to find the most optimal decision points for the system using statistics of the simulated probabilistic model.
Results: Experimental study on a 22-variable and 21-constraint real-world use case demonstrated that this approach significantly outperforms popular simulation-based optimization approaches. (**ICS'15, JDS'18, IFIP-DSS'18**)

01/2016–12/2017 Framework for composition, analysis, and optimization of real-world processes, *NIST*.

Purpose: To build a system of reusable process models in manufacturing such that it is easy to use, simple, and cost-effective so that the end user can perform multiple analysis and optimization operations on these models.
Contribution: Built a software framework and prototype using Generic Model Environment and cloud architectures that allowed hierarchical composition, visualization, and analysis of manufacturing systems consisting of real-world processes from a reusable model repository.
Results: Demonstrated the prototype system to compose an hierarchical model for a real-world supply chain use case and performed simulation, prediction, optimization, and trade-off analysis using Pareto optimal graphs on this model. (**IEEE-BD'16, IEEE-BD'17**)

01/2015–12/2017 Reusable repository of process performance models, *GMU, NIST*.

Purpose: To build a reusable repository of models for manufacturing so that analysis and optimization solutions need not be implemented *de novo* because it leads to cost and time intensive development of models and algorithms, which are difficult to modify, extend, and reuse.
Contribution: Designed and developed a reusable repository of mathematical models called performance models for manufacturing end-users with the goal of ease of use and reusability to compose and perform analysis and optimization on complex real-world hierarchical processes.
Results: This repository was used as the basis for a competition to crowdsource Reusable Abstractions of Manufacturing Processes (RAMP) (tinyurl.com/y8fyakcl). For this competition, I also demonstrated the structure of a process performance model in an instructional webinar available at tinyurl.com/y87q4udv (**IEEE-BD'14, ICS-pr'15, JDS'15, IEEE-BD'15, IJAMT'16, HICSS'16**)

01/2011–07/2011 Scientific algorithm for Primer design, *LANL*.

Purpose: To build a tool for primer design, which is difficult to do for highly variable DNA sequences and for which experimental success requires attention to many interacting constraints.
Contribution: Designed and developed scalable scientific algorithm for primer design that included recursive generation of combinatorial bio-barcodes of specified length with design constraints and dimer risk filtration among the generated primer constructs in C and Perl.
Results: Primer design tool (v1.0) was included among the HIV analysis tools (current tool (v2.0) is at tinyurl.com/yd5hajbc). (**BMCbio'13**)

05/2010–12/2011 Redesign of computing architecture to improve analysis efficiency, *LANL*.

Purpose: To redesign scientific tools in order to ensure high performance and minimize compute time and file system usage.
Contribution: Designed and deployed five scientific tools using a Model-View-Controller (MVC) framework and web services using XML-RPC on the MVC model provided by Perl Catalyst and object oriented Moose libraries.
Results: The five tools were successfully deployed with an improvement of 35% in performance and 50% in file-system usage.

05/2009–06/2010 Masters Thesis: Compression and caching in distributed file system, *RIT*.

Purpose: To perform research on compression and caching algorithms to improve data fetch time in a distributed system.
Contribution & Results: Implemented a distributed system using the Java NIO framework and reduced data and file fetch time by 14%.

02/2009–04/2010 Tree Viewer, Pruner, and Decorator, *LANL*.

Purpose: To build tools that automate the selection and annotation of influenza genetic data by making the correct trade-off between speed and simplicity on the one hand and control over quality and contents of the data set on the other.
Contribution: Designed and developed the tree pruner and decorator tools to perform this selection and annotation for Influenza Sequence Database (ISD). This project was based on the open source project Archaeopteryx using Java Applets, AJAX, and REST web services with the JSON and phyloXML data formats.
Results: Pruner and Decorator tools were made available among influenza analysis tools and were also made open source. (**BMCbio'11**)

07/2008–04/2010 Database and Web architecture development, *LANL.*

Purpose: Design a schema to accommodate millions of records in ISD and develop a website over ISD to serve influenza analysis tools.
Contribution & Results: Designed a new schema in PostgreSQL. Also, developed a website over ISD using Perl, Mason Perl, HTML, XML, Java Scripts and SQL. Further, redesign of the website using jQuery and AJAX request objects yielded 23% better performance.