

Dr. Madhur Behl

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Education

- 2015 **Ph.D. in Electrical & Systems Engineering**,
University of Pennsylvania, USA,
Advisor: Rahul Mangharam,
Thesis Title: Data-Driven Modeling, Control and Tools for Cyber-Physical Energy Systems.
Thesis Committee: George Pappas (Penn), Rajesh Gupta (UCSD), Ruben Lobel (Wharton) and Jin Wen (Drexel)
- 2012 **M.S. in Electrical Engineering**,
University of Pennsylvania.
- 2009 **B.E. in Electronics & Communication Engineering**,
PEC University of Technology, India,
*Graduated *summa cum laude*.*

Appointments

- June 2016 **Assistant Professor in the department of Computer Science, and the dept. of Systems & Information Engineering.**,
onward *University of Virginia.*
- Dec 2015 - **Postdoctoral research fellow in Electrical & Systems Engineering**,
June 2016 *University of Pennsylvania.*

Research Interests

Cyber Physical Systems, Foundations of Data Predictive Control, Machine Learning, Control Systems, Statistics, and Optimization. Applications in Energy-Efficient Buildings, Smart Cities, Industrial Automation, Advanced Manufacturing, Autonomous Vehicles, Internet of Things, and Medical Devices.

Honors and Awards

- 2016 **1st prize winner (\$50K)** , *DoE EERE's Allegheny Region Cleantech University Prize*,
Carnegie Mellon University,
Pittsburgh, USA.
- 2015 **Best Paper Award** ,
For "Sometimes, Money Does Grow on Trees: Data-Driven Demand Response with DR-Advisor,
Internet of Things Session at the Semiconductor Research Corporation's (SRC) TECHCON,
Austin, USA.
- 2015 **Finalist at the inaugural \$50K iDesign Prize**,
For MotionView: gesture based interaction for medical imaging,
University of Pennsylvania, Philadelphia, USA.
- 2014 **Student Travel Award**,
IEEE International Conference on Automation Science and Engineering (Taipei, Taiwan);
Mathematics of Planet Earth Workshop on Data-aware Energy Use (San Diego, USA).

- 2012 **Best Demo Award at BuildSys**,
4th ACM Workshop On Embedded Systems For Energy-Efficiency In Buildings,
Toronto, Canada.
- 2011 **School of Engineering and Applied Science Student Award**,
Richard K. Dentel Memorial Prize in Urban Transportation,
University of Pennsylvania, Philadelphia, USA.
- 2010 **First prize (Award of Excellence) in World Embedded Software Contest**,
Korean Ministry of Knowledge Economy and Electronics and Telecommunications Research Institute (ETRI),
Seoul, South Korea.
- 2009 **Award for excellence in Robotics**,
Highest honor for consistent performance and contribution,
PEC University of Technology,
Chandigarh, India.
- 2007 **First runner up at the Young Business Development (YBD) Competition**,
Saïd Business School,
University of Oxford, UK.

Publications [215 citations, h-index 7, i10 index 5 as of Feb 2017 on Google Scholar]

Journal Papers

- [1] Madhur Behl, Francesco Smarra, and Rahul Mangharam. **DR-Advisor: A data-driven demand response recommender system**. *Applied Energy*, 170:30–46, 2016.
- [2] Achin Jain, Rahul Mangharam, and Madhur Behl. **Data Predictive Control for Cyber-Physical Energy Systems**. *ACM Transactions on Cyber-Physical Systems*, 2016. [Under Review].
- [3] Madhur Behl and Rahul Mangharam. **A Data-Driven Open-Ended Energy Analytics Engine**. *Buildings Journal- Special Issue Understanding Human-Building Interactions for Intelligent Built Environments*, 2016. [In Preperation].

Peer Reviewed Conference Papers

- [1] Achin Jain, Madhur Behl, and Rahul Mangharam. **Data Predictive Control for building energy management**. *Proceedings of the American Control Conference (ACC)*, 2017.
- [2] Achin Jain, Madhur Behl, and Rahul Mangharam. **Data Predictive Control for Peak Power Reduction**. *3rd ACM International Conference on Embedded Systems For Energy-Efficient Built Environments (BuildSys)*, 2016. **[Best Presentation Award]**.
- [3] Madhur Behl and Rahul Mangharam. **Interactive analytics for smart cities infrastructures**. In *Science of Smart City Operations and Platforms Engineering (SCOPE) in partnership with Global City Teams Challenge (GCTC)(SCOPE-GCTC), 2016 1st International Workshop on*, pages 1–6. IEEE, 2016.
- [4] Rahul Mangharam, Houssam Abbas, Madhur Behl, Kuk Jang, Miroslav Pajic, and Zhihao Jiang. **Three challenges in cyber-physical systems**. In *2016 8th International Conference on Communication Systems and Networks (COMSNETS)*, pages 1–8. IEEE, 2016.
- [5] Madhur Behl, Achin Jain, and Rahul Mangharam. **Data-Driven Modeling, Control and Tools for**

- Cyber-Physical energy Systems.** *International Conference on Cyber-Physical Systems (ICCPS)*, 2016.
- [6] Madhur Behl and Rahul Mangharam. **Sometimes, Money Does Grow On Trees: Real-Time Demand Response With DR-Advisor.** *2nd ACM International Conference on Embedded Systems For Energy-Efficient Built Environments (BuildSys)*, Seoul, South Korea, 2015.
- [7] Madhur Behl and Rahul Mangharam. **Sometimes, Money Does Grow on Trees: DR-Advisor, A Data Driven Demand Response Recommender System.** *Semiconductor Research Corporation (SRC) TECHCON*, 2015. [**Best in Session (Internet Of Things) Award**].
- [8] Madhur Behl, Truong Nghiem, and Rahul Mangharam. **DR-Advisor: A Data Driven Demand Response Recommender System.** *CISBAT International Conference: future buildings and districts sustainability from nano to urban scale*, 2015.
- [9] Willy Bernal, Madhur Behl, Truong Nghiem, and Rahul Mangharam. **Campus-Wide Integrated Building Energy Simulation.** *IBPSA, Building Simulation Conference*, 2015.
- [10] Madhur Behl, Truong Nghiem, and Rahul Mangharam. **IMpACT: Inverse Model Accuracy and Control Performance Toolbox for Buildings.** *IEEE International Conference on Automation Science and Engineering*, 2014.
- [11] Madhur Behl, Truong Nghiem, and Rahul Mangharam. **Model-IQ: Uncertainty Propagation from Sensing to Modeling and Control in Buildings.** *ACM/IEEE International Conference on Cyber-Physical Systems*, 2014.
- [12] Madhur Behl, Truong Nghiem, and Rahul Mangharam. **Green Scheduling for Energy-Efficient Operation for Multiple Chiller Plants.** In *Real-Time Systems Symposium (RTSS 2012)*, San Juan, Puerto Rico, December 2012.
- [13] Truong Nghiem, Madhur Behl, George Pappas, and Rahul Mangharam. **Green Scheduling for Radiant Systems in Buildings.** In *IEEE Conference on Decision and Control (CDC 2012)*, Maui, Hawaii, December 2012.
- [14] Willy Bernal, Madhur Behl, Truong Nghiem, and Rahul Mangharam. **MLE+: A Tool for Integrated Design and Deployment of Energy Efficient Building Controls.** In *4th ACM Workshop On Embedded Systems For Energy-Efficiency In Buildings (BuildSys)*, Toronto, Canada, Nov 2012.
- [15] Truong Nghiem, Madhur Behl, Rahul Mangharam, and George Pappas. **Scalable Scheduling of Building Control Systems for Peak Demand Reduction.** In *American Control Conference (ACC12)*, June 2012.
- [16] Truong X. Nghiem, Madhur Behl, Rahul Mangharam, and George J. Pappas. **Green Scheduling of Control Systems for Peak Demand Reduction.** In *IEEE Conference on Decision and Control (CDC 2011)*, December 2011.
- [17] Zheng Li, Pei-Chi Huang, Aloysius Mok, Truong Nghiem, Madhur Behl, George Pappas, and Rahul Mangharam. **On the Feasibility of Linear Discrete-Time Systems of the Green Scheduling Problem.** In *Real-Time Systems Symposium (RTSS)*, 2011 IEEE 32nd, pages 295 –304, 29 2011-dec. 2 2011.
- [18] Truong X. Nghiem, Madhur Behl, George J. Pappas, and Rahul Mangharam. **Green Scheduling: Scheduling of Control Systems for Peak Power Reduction.** In *2nd IEEE International Green Computing Conference*, Orlando, Florida, USA, July 2011.

Workshop and Demo Papers

- [1] Aksanli Baris, Akyurek Alper, Madhur Behl, Meghan Clark, Alexandre Donz , Prabal Dutta, Patrick Lazik, Mehdi Maasoumy, Rahul Mangharam, Truong X Nghiem, et al. **Distributed Control of a Swarm of Buildings Connected to a Smart Grid**. In *1st ACM International Conference on Embedded Systems For Energy-Efficient Buildings*, Memphis, 2014.
- [2] Madhur Behl, Neel D. Shah, Larry Vadakedathu, Dan Wheeler, and Rahul Mangharam. **Demo Abstract: EnergyLab: Building Energy Testbed for Demand-response**. In *Proceedings of the 12th International Conference on Information Processing in Sensor Networks*, IPSN '13, pages 303–304, 2013.
- [3] Willy Bernal, Madhur Behl, Truong Nghiem, and Rahul Mangharam. **MLE+: A Tool for Integrated Design and Deployment of Energy Efficient Building Controls**. In *Real-Time Systems Symposium/ Work in Progress (RTSS-Wip 2012)*, San Juan, Puerto Rico, December 2012. **[Best Demo Award]**.
- [4] Madhur Behl, Mansimar Aneja, Harsh Jain, and Rahul Mangharam. **EnRoute: An Energy Router for Energy-Efficient Buildings**. In *Demo and Poster at International Conference on Information Processing in Sensor Networks (IPSN)*, CPS Week 2011, Chicago, April 2011.
- [5] Utsav Drolia, Z. Wang, Srinivas Vemuri, Madhur Behl, and Rahul Mangharam. **AutoPlug - An Automotive Test-bed for ECU Testing, Validation and Verification**. In *Demo and Poster at International Conference on Information Processing in Sensor Networks (IPSN)*, CPS Week 2011, Chicago, 2011.
- [6] Madhur Behl and Rahul Mangharam. **Pacer Cars: Real-Time Traffic Shockwave Suppression**. In *In Proceedings of the 32nd IEEE Real-Time Systems Symposium (Work in Progress session - RTSS11-WiP)*, San Diego, CA, USA, Nov 2010.
- [7] Madhur Behl, Willy Bernal, and Rahul Mangharam. **From Control to Scheduling: An Elastic Execution Model**. In *In Proceedings of the 32nd IEEE Real-Time Systems Symposium (Work in Progress session - RTSS11-WiP)*, San Diego, CA, USA, Nov 2010.

Technical Reports

- [1] Madhur Behl and Rahul Mangharam. **Evaluation of DR-Advisor on the ASHRAE Great Energy Predictor Shootout Challenge**. Technical report, University of Pennsylvania, 2015.
- [2] Madhur Behl, Truong Nghiem, and Rahul Mangharam. **Uncertainty Propagation from Sensing to Modeling and Control in Buildings-Technical Report**. Technical report, University of Pennsylvania, 2013.
- [3] Madhur Behl. **Mobility Modeling of Swarm Robots**. Technical report, ETH Zurich and Punjab Engineering College, 2008.

Book Chapter

- o Madhur Behl and Rahul Mangharam, "Data-Driven Modeling and Control for Demand Response", *Smart Cities: Foundations and Principles*, John Wiley & Sons Inc, Expected: May 2017

Patent

- Madhur Behl and Rahul Mangharam, "Methods, Systems, and Computer Readable Media for a Data-Driven Demand Response (DR) Recommender", Patent Application Number 62/267,817, Filing Date: 15 December 2015

Software Artifacts

- **MLE+**, An open-source Matlab/Simulink toolbox for co-simulation with the whole-building energy simulator EnergyPlus. Listed as an official third party tool for EnergyPlus by the U.S. Department of Energy.
<http://mlab.seas.upenn.edu/mllep/>
- **DR-Advisor**, A data-driven demand response recommender system Matlab toolbox.
<http://mlab.seas.upenn.edu/dr-advisor/>
- **MotionView**, Responsive, Intuitive, touch free control for medical images
<http://www.motionview.co/>

Teaching Experience

- **Instructor**, University of Pennsylvania, Philadelphia, PA
Autonomous Racing - Control, Algorithms and Embedded Design Spring [2016]
- **Student Advisor**, University of Pennsylvania, Philadelphia, PA
For Summer Undergraduate Fellowship in Sensor Technologies (SUNFEST) 2015 program as part of the NSF's Research Experiences for Undergraduates (REU) program.
- **Teaching Assistant**, University of Pennsylvania, Philadelphia, PA
ESE 519 - Real-Time & Embedded Systems [2010, 2011 & 2012]
Delivered substitute lectures, developed and graded labs and final projects.
- **Teaching Assistant**, University of Pennsylvania, Philadelphia, PA
ESE 350 - Introduction to Embedded Systems [2012&2013]
Guest lectures on embedded systems and data science.
- **Project Mentor**
I have mentored the following projects as a part of my teaching responsibilities:
 - *AutoNET*: An automotive engine control unit (ECU) network test-bed.
 - *Robo Soccer face off* [2010, 2011, 2012]: Fully autonomous soccer playing robots.
 - *Mortal Kombat face off*: Nintendo game control hack with gesture recognition.
 - *Body Sensor Networks* - Wireless electrocardiograph (ECG) sensor.
 - *Autonomous Obstacle Avoidance* using a IR depth sensor, roomba and a laser range sensor (LIDAR).
 - *KinectVR*: Robotic arm control using the MS Kinect sensor.
 - *Sensor Logistics*: GPS based real time tracking for shipments/packages.

Selected Talks

- **DoE Building Technologies Office, Invited talk**, 'Data Predictive Control', Nov 2016
- **Embedded Systems Week, Invited talk**, 'F1/10-The Autonomous Racing Platform', October 2016
- **Cyber-Physical Systems Week, Invited talk**, 'F1/10-3 Day Tutorials', April 2016

- **University of California San Diego (UCSD), Invited talk**, 'Data-Driven Cyber-Physical Energy Systems', October 2015
- **Electric Power Research Institute (EPRI), Invited talk**, 'Data-Driven Modeling, Control and Tools for Cyber-Physical Energy Systems', Palo Alto, CA, October 2015
- **Stanford University, Invited talk**, 'Data-Driven Modeling, Control and Tools for Cyber-Physical Energy Systems', October 2015
- **IEEE Philadelphia Section Night**, 'Data-Driven Modeling, Control and Tools for Cyber-Physical Energy Systems', October 2015
- **Texas Instruments, Invited talk**, 'Data-Driven Modeling, Control and Tools for Cyber-Physical Energy Systems', Dallas, TX, September 2015
- **Texas A&M University, Invited talk**, 'Data-Driven Modeling, Control and Tools for Cyber-Physical Energy Systems', September 2015
- **SRC TECHCON**, 'Sometimes, Money Does Grow On Trees: Data-driven demand response with DR-Advisor', Austin, September 2015
- **Penn iTalks finals**, 'Sometimes, Money Does Grow On Trees', TED style research talk, March 2015
- **StarNet e-Workshop**, 'Low cost model capture in buildings for model based control', January 2015
- **Data Aware Energy Use Workshop**, Mathematics of Planet Earth Initiative, UCSD 'Low-cost building inverse modeling', September 2014
- **Conference on Automation Science and Engineering**, 'Inverse Model Accuracy and Control Performance Toolbox for Buildings', Taipei, August 2014
- **Honeywell Automation and Control Labs**, 'Low-cost inverse modeling for buildings', Golden Valley, MN, July 2014
- **International Conference on Cyber-Physical Systems**, 'Model-IQ: Uncertainty Propagation from Sensing to Modeling and Control in Buildings', Berlin, April 2014
- **Young Researchers Transatlantic Academy, Invited Talk**, 'Green Scheduling for Peak Power Reduction', Aachen, June 2012

Professional Experience

- 2015 - 2016 **Research Fellow**,
Electrical and Systems Engineering,
University of Pennsylvania, Philadelphia, USA.
- The foundations of data predictive control.
 - F1/10 autonomous racing platform.
- 2013 - 2015 **Research Assistant**,
Electrical and Systems Engineering,
University of Pennsylvania, Philadelphia, USA.
- Data-driven cyber-physical energy systems.
 - Model-IQ: Developed low-cost sensing and building model capture methods.
- 2009 - 2013 **Research Assistant**,
Electrical and Systems Engineering,
University of Pennsylvania, Philadelphia, USA.
- MLE+: Co-developed the energy-efficient building automation design, co-simulation and analysis toolbox.
 - Green scheduling: Developed scalable and lightweight scheduling algorithm to coordinate multiple energy consuming systems. Applied to radiant heating systems and multiple chiller plants.
 - En-Route- The energy router: Designed two scaled building test-beds with a fully functional forced air HVAC system and BACnet interface.

- June - August 2014 **Control, Modeling and Optimization Intern,**
ACS Global Labs, Honeywell Automation and Control Solutions,
Golden Valley, MN, USA.
- Developed a virtual test bed for campus-wide simulation with OPC interface to Honeywell's chiller optimization software.
- February - July 2008 **Guest Researcher,**
Department of Information Technology and Electrical Engineering,
ETH, Zurich, Switzerland,
Mobility Modeling of Swarm Robots.
- Jun- August 2007 **Research Internship,**
Indian Institute of Technology (IIT),
Delhi, India,
Energy harvesting from ambient Rf signals..

Professional Service

- **Organizer**

1. **Workshop/Demo Chair:** 4th ACM International Conference on Systems for Energy-Efficient Built Environments (BuildSys 2017)
2. **Program Committee:** International Conference on Cyber Physical Systems, ICCPS 2017.
3. **Program Committee:** Second International Workshop on Science of Smart City Operations and Platforms Engineering (SCOPE) 2016, 2017.
4. **Program Committee:** 9th International Conference on COMmunication Systems & NETworkS, COMSNETS 2017.
5. **Program Committee:** Workshop on Wild and Crazy Ideas on the interplay between IoT and Big Data, WACI 2017.
6. **Industry Chair:** 3rd ACM International Conference on Systems for Energy-Efficient Built Environments (BuildSys 2016)
7. **General Chair:** F1/10 International Autonomous competition, ES-Week 2016. CPS Week 2017
8. **Review Panelist:** Department of Energy (DoE) Building Technologies Office (BTO) 2017

- **Journal Reviewer**

1. ACM Transactions on Cyber-Physical Systems (TCPS) 2017
2. Journal of Applied Energy 2017
3. IEEE Transactions on Control Systems Technology 2017
4. Real-Time Systems Journal (2012, 2015)
5. ACM Foundations and Trends in Electronic Design Automation (2015)
6. IEEE Special Issue on CPS 2011,
7. ACM Computing Surveys 2010

○ **Conference Reviewer**

1. ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS 2013 to 2017),
2. IEEE International Conference on Cyber-Physical Systems, Networks, and Applications(CPSNA 2013, 2014),
3. ACM/IEEE Conference on Information Processing in Sensor Networks (IPSN 2012 to 2015),
4. IEEE Real-Time Systems Symposium (RTSS 2015, 2012, 2011),
5. Design, Automation and Test in Europe (DATE 2012),
6. BuildSys (2012 to 2016),
7. American Control Conference (ACC 2012, 2013, 2014, 2015, 2017),
8. European Control Conference (ECC 2015),
9. IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON 2012),
10. IEEE Conference on Decision and Control (CDC 2011, 2012, 2013),
11. International Conference on Embedded Software (EMSOFT 2013),
12. International Conference on Automation Science and Engineering (CASE 2014),
13. European Wireless Sensor Networks Conference (EWSN 2014)

Affiliations

- IEEE Power and Energy Society Future Directions (Long-Range Planning) subcommittee member.
- IEEE Member (7+ years)
- IEEE Young Professionals (2013-Present)
- IEEE Control Systems Society (2013-2015)
- IEEE Robotics and Automation Society (2013-2015)
- Member at the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (2012-2014)
- Rittenhouse Astronomical Society, Philadelphia, US