

BHARATHAN BALAJI

1762 Boelter Hall, 580 Portola Plaza, Los Angeles, CA, 90095
(858) 344-9608 • bbalaji@ucla.edu • <http://www.synergylabs.org/bharath/>

EDUCATION

- **University of California, San Diego (UCSD)**
Ph.D. in Computer Science and Engineering, GPA 3.64/4.0 Jun 2011 – Jan 2016
M.S. in Electrical and Computer Engineering, GPA 3.58/4.0 Sep 2009 – Jun 2011
- **Visvesvaraya National Institute of Technology (VNIT), Nagpur, India**
B.Tech. in Electronics and Communication Engineering, GPA 9.0/10.0 Jun 2005 – Jun 2009

RESEARCH EXPERIENCE

- **Postdoctoral Scholar: Network and Embedded Systems Laboratory, UCLA** Jan 2016 – Present
Research in internet of things, smart cities and large scale ocean monitoring
Advisor: Prof. Mani Srivastava
- **Graduate Student: Systems, Networking and Energy Efficiency Lab, UCSD** Apr 2010 – Jan 2016
Research in smart buildings, sensor networks and processor variability
Advisors: Prof. Yuvraj Agarwal and Prof. Rajesh Gupta.
- **Summer Research Intern: Ericsson Research** Jul 2012 – Sep 2012
Research in building energy analysis and WiFi based occupancy detection
Mentor: Dr. Du Li.
- **Research Intern: Qualcomm Institute, UCSD** Sep 2009 – Mar 2010
Research in WiFi client energy efficiency
Mentors: Dr. B.S.Manoj and Prof. Ramesh Rao.
- **Summer Research Intern: IIT Bombay** May 2008 – Jul 2008
Research in fabrication and characterization of polymeric micro-sensors for Lab-on-Chip technology
Mentors: Prof. Aliasgar Contractor

PUBLICATIONS — 700+ CITATIONS

Conference Papers

- **Brick: Towards a Unified Metadata Schema For Buildings**
Bharathan Balaji, Arka Bhattacharya, Gabriel Fierro, Jingkun Gao, Joshua Gluck, Dezhi Hong, Aslak Johansen, Jason Koh, Joern Ploennigs, Yuvraj Agarwal, Mario Berges, David Culler, Rajesh Gupta, Mikkel Baun Kjaergaard, Mani Srivastava, Kamin Whitehouse
ACM Conference on Embedded Systems For Energy-Efficient Built Environments (BuildSys), 2016
Audience Choice Award, Nominated for Best Paper Award
- **Genie: A Longitudinal Study Comparing Physical and Software Thermostats in Office Buildings**
Bharathan Balaji, Jason Koh, Nadir Weibel, Yuvraj Agarwal
ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp), 2016
- **Zodiac: Organizing Large Deployment of Sensors to Create Reusable Applications for Buildings**
Bharathan Balaji, Chetan Verma, Balakrishnan Narayanaswamy, Yuvraj Agarwal
ACM Conference on Embedded Systems For Energy-Efficient Built Environments (BuildSys), 2015
Nominated for Best Paper Award
- **Data Driven Investigation of Faults in HVAC Systems with Model, Cluster and Compare (MCC)**
Balakrishnan Narayanaswamy, Bharathan Balaji, Rajesh Gupta, Yuvraj Agarwal
ACM Conference on Embedded Systems for Energy-Efficient Buildings (BuildSys), 2014
- **Sentinel: An Occupancy Based HVAC Actuation System using existing WiFi Infrastructure in Commercial Buildings**
Bharathan Balaji, Jian Xu, Rajesh Gupta, Yuvraj Agarwal
ACM Conference on Embedded Networked Sensor Systems (SenSys), 2013
Citations: 50+
- **Duty-Cycling Buildings Aggressively: The Next Frontier in HVAC Control**
Yuvraj Agarwal, Bharathan Balaji, Seemanta Dutta, Rajesh Gupta, Thomas Weng
ACM Conference on Information Processing in Sensor Networks (IPSN), 2011
Citations: 150+
- **A Novel Power Saving Strategy for Greening IEEE 802.11 based Wireless Networks**
Bharathan Balaji, Bheemarjuna Tamma, B.S.Manoj, Ramesh Rao
IEEE Global Telecommunications Conference (Globecom), 2010

Invited Papers

- **Models, Abstractions, and Architectures: The Missing Links in Cyber-Physical Systems**
Bharathan Balaji, Mohammad Abdullah Al Faruque, Nikil Dutt, Rajesh Gupta, Yuvraj Agarwal
ACM Annual Design Automation Conference (DAC), 2015

Workshop Papers

- **Emu: Engagement Modeling for User Studies**
Bo-Jhang Ho, Nima Nikzad, Bharathan Balaji, Mani Srivastava
ACM International Workshop on Smart & Ambient Notification and Attention Management (Ubittention),
co-located with Ubicomp, 2017
- **ZonePAC: Zonal Power Estimation and Control via HVAC Metering and Occupant Feedback**
Bharathan Balaji, Hidetoshi Teraoka, Rajesh Gupta, Yuvraj Agarwal
ACM Workshop on Embedded Systems For Energy-Efficient Buildings (BuildSys), 2013
- **Accurate Characterization of Variability in Power Consumption in Modern Computing Platforms**
Bharathan Balaji, John McCullough, Rajesh Gupta, Yuvraj Agarwal
USENIX Conference on Power-Aware Computing and Systems (HotPower), 2012
- **Managing Plug-Loads for Demand Response within Buildings**
Thomas Weng, Bharathan Balaji, Seemanta Dutta, Rajesh Gupta, Yuvraj Agarwal
ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Buildings (BuildSys), 2011
Citations: 50+
- **Occupancy-Driven Energy Management for Smart Building Automation**
Yuvraj Agarwal, Bharathan Balaji, Rajesh Gupta, Jacob Lyles, Michael Wei, Thomas Weng
ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Building (BuildSys), 2010
Citations: 300+

Demo Papers

- **PrOLoc: resilient localization with private observers using partial homomorphic encryption**
Amr Alanwar, Yasser Shoukry, Supriyo Chakraborty, Bharathan Balaji, Paul Martin, Paulo Tabuada, Mani Srivastava
ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN), 2017
Best Demo Award
- **Portable Queries Using the Brick Schema for Building Applications**
Bharathan Balaji, Arka Bhattacharya, Gabriel Fierro, Jingkun Gao, Joshua Gluck, Dezhi Hong, Aslak Johansen, Jason Koh, Joern Ploennigs, Yuvraj Agarwal, Mario Berges, David Culler, Rajesh Gupta, Mikkel Baun Kjaergaard, Mani Srivastava, Kamin Whitehouse
ACM Conference on Embedded Systems For Energy-Efficient Built Environments (BuildSys), 2016
Best Demo Award
- **BuildingRules: A Trigger-Action Based System To Manage Complex Commercial Buildings**
Alessandro A. Nacci, Bharathan Balaji, Paola Spoletini, Vincenzo Rana, Rajesh Gupta, Donatella Sciuto, Yuvraj Agarwal
ACM International Joint Conference on Pervasive and Ubiquitous Computing (Ubicomp), 2015
- **BuildingSherlock: Fault Management Framework for HVAC Systems**
Rizhen Zhang, Bharathan Balaji, Yan Zhang, Balakrishnan Narayanaswamy, Yuvraj Agarwal
ACM Conference on Embedded Systems for Energy-Efficient Buildings (BuildSys), 2014
- **A WiFi Based Occupancy Sensing Approach to Smart Energy in Commercial Office Buildings**
Du Li, Bharathan Balaji, Yifei Jiang, Kshitij Singh
ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Buildings (BuildSys), 2012

Posters

- **Controlling Actuation in Central HVAC Systems in Buildings**
Jason Koh, Bharathan Balaji, Rajesh Gupta, Yuvraj Agarwal
ACM Conference on Embedded Systems For Energy-Efficient Built Environments (BuildSys), 2015
Best Poster Award

Technical Reports

- **EmbedInsight: Automated Grading of Embedded Systems Assignments**
Hao Li, Bo-Jhang Ho, Bharathan Balaji, Yue Xin, Paul Martin, Mani Srivastava
arXiv:1703.04514 [cs.CY], arXiv.org, 2017

- **Modeling Actuation Constraints for IoT Applications**
Bharathan Balaji, Brad Campbell, Amit Levy, Xiaozhou Li, Addison Mayberry, Nirupam Roy, Vasuki Narasimha Swamy, Longqi Yang, Victor Bahl, Ranveer Chandra, Ratul Mahajan
arXiv:1701.01894[cs.SY], arXiv.org, 2017
- **Managing Commercial HVAC Systems: What do Building Operators Really Need?**
Bharathan Balaji, Nadir Weibel, Yuvraj Agarwal
arXiv:1612.06025 [cs.HC], arXiv.org, 2017
- **Quiver: Using Control Perturbations to Increase the Observability of Sensor Data in Smart Buildings**
Jason Koh, Bharathan Balaji, Vahideh Akhlaghi, Yuvraj Agarwal, Rajesh Gupta
arXiv:1601.07260 [cs.SY], arXiv.org, 2016
- **HVACMeter: Apportionment of HVAC Power to Thermal Zones and Air Handler Units**
Jason Koh, Bharathan Balaji, Rajesh Gupta, Yuvraj Agarwal
arXiv:1509.05421 [cs.SY], arXiv.org, 2015
- **BuildingSherlock: Fault Management Framework for HVAC Systems in Commercial Buildings**
Hidetoshi Teraoka, Bharathan Balaji, Rizhen Zhang, Anthony Nwokafor, Balakrishnan Narayanaswamy, Yuvraj Agarwal
CSE, UCSD, 2014
- **BuildingRules: A Trigger-Action Based System To Manage Complex Commercial Buildings**
Alessandro Nacci, Bharathan Balaji, Paola Spoletini, Vincenzo Rana, Rajesh Gupta, Donatella Sciuto, Yuvraj Agarwal
CSE, UCSD, 2014

MS Thesis

- **Using Occupancy to Reduce Energy Consumption of Buildings**
Bharathan Balaji, 2011

PhD Dissertation

- **Software Augmented Buildings: Exploiting Existing Infrastructure to Improve Energy Efficiency and Comfort in Commercial Buildings**
Bharathan Balaji, 2016

RESEARCH PROJECTS

- **Automated Grading for Hardware-based Assignments** Jul 2016 – Present
Grading for hardware assignments is an arduous manual process because of elaborate experimental setups. We created EmbedInsight, an auto-grader for hardware-based assignments that accommodates a wide variety of experimental setups and is scalable to large classes. We make hardware systems available as a web service, and supply the necessary inputs for testing and capture the outputs to assess student performance. Using our system, students learn faster with iterative testing and save valuable instructor time.
- **Creating a Metadata Schema for Portable Smart Building Applications** Feb 2016 – Present
Smart building applications rarely experience widespread adoption due to the prohibitive cost of porting them to different buildings. We created a schema, called Brick, that defines an ontology for sensors, subsystems and relationships among them. We demonstrate the effectiveness of Brick by using it to represent six diverse buildings, comprising of 17,700 data points, and running eight unmodified applications on these buildings.
Published in ACM BuildSys 2016
- **Study of Use of Software Thermostats in Commercial Buildings** Sep 2013 – Sept 2016
Research has shown that contemporary thermostats are inadequate to keep occupants satisfied in offices as they can be difficult to use and provide insufficient control. We provide occupants with a personalized web portal through which they can view HVAC status, change temperature settings and send feedback to building manager. We study the impact of use of our software thermostat by 220 registered occupants across 21 months.
Published in ACM Ubicomp 2016
- **Standardization of Sensor Naming using Machine Learning** Sep 2014 – Jul 2015
Sensors already deployed in the field do not have a standard naming convention or ontology to describe them. We collect information for 180,000 sensors across 55 buildings at UCSD, and use their metadata to identify the type of sensor and provide them a uniform name across the system. We first group similar sensors using hierarchical clustering, and then use active learning with random forest classifier to label the sensors.
Published in ACM BuildSys 2015

- **Fault Analysis and Reporting for Commercial HVAC Systems** Sep 2013 – Sep 2014
 Modern fault management systems for HVAC are rudimentary, and fail to detect pertinent faults that may lead to equipment damage or energy wastage. We build a web services based fault management framework for better information integration and flexibility. We also develop a comparative data mining based fault detection technique to identify many faults missed by the traditional system.
Published in ACM BuildSys 2014
- **Building Manager User Study** Mar 2014 – Sep 2014
 Building managers struggle to maintain and operate HVAC, lighting and power systems with the help of sensors and monitoring software. We interview building maintenance personnel across five institutions in US to understand their perspective. We find that management is typically understaffed and current software systems do not provide adequate support for monitoring, fault detection and auditing. We propose design guidelines for next generation building management systems to address these issues.
- **Better Buildings Case Competition** Oct 2013 – Mar 2014
 We participated in a competition hosted by Department of Energy for improved building energy efficiency. We wrote two proposals: (a) Innovative methods for incentivizing building owners and managers to adopt energy efficiency retrofits. (b) Proposal for improving sustainability practices in research laboratories in universities.
Won Most Innovative Award BBCC 2014
- **Data Storage Platform for Building Sensor Information** Mar 2012 – Apr 2015
 Traditional building management systems do not provide adequate support for storing sensor data and contextual metadata. We created BuildingDepot, a RESTful web service based building data store that integrates information from thousands of sensors across a building. We incorporate useful features such as role based access control, sensor tagging for search and contextual information, and RESTful APIs for third party apps.
Published in ACM BuildSys 2013
- **Estimation of Zonal HVAC Power Consumption** Apr 2013 – Nov 2013
 Meters installed in most buildings only provide building level electricity and water consumption, and it is difficult to apportion the energy to individual offices. We exploit the existing sensors used for HVAC operation, and apply heat transfer equation to estimate HVAC energy consumption on a per zone basis. The disaggregation helps to understand the energy flows within the building and to provide energy feedback to occupants.
Published in ACM BuildSys 2013
- **Occupancy Detection using WiFi Infrastructure for HVAC Control** Jul 2012 – Nov 2013
 Occupants of modern buildings typically connect to enterprise WiFi network when they are in the building. We tap in to the authentication logs of the WiFi network to determine when occupants connect to access points near their offices. We use this as a proxy for occupancy, and use it to control the HVAC system.
Published in ACM SenSys 2013
- **Power Variability in Modern Computing Platforms** Nov 2010 – Jun 2012
 As CMOS technology continues to shrink, process variation leads to changes in performance from chip to chip. We characterize the variation in power consumption of Intel Core i5-540M processors using specially instrumented Calpella and Sandy Bridge platforms from Intel for accurately measuring CPU power.
Published in USENIX HotPower 2012
- **Occupancy Controlled HVAC System** Mar 2010 – Mar 2011
 We develop a low cost, battery powered, wireless occupancy sensor that uses a combination of PIR and door sensors. They have 97% accuracy of detection in single room offices. We connect this information to the building management system and control HVAC based on occupancy.
Published in ACM IPSN 2011
- **Plug Energy Meter** Mar 2010 – Jun 2011
 We created an extremely low cost, non-intrusive, wireless energy meter to monitor and actuate plug loads within buildings. The design is modular, and contains a programmable microcontroller. We exploit the meter for managing plug loads during demand response events and estimating energy wastage in offices.
Published in ACM BuildSys 2011
- **Power Modeling vs Measurement of Modern PCs** Jun 2010 – Jun 2011
 We use a specially instrumented Calpella motherboard from Intel to breakdown power consumption of individual components in a computer – processor, memory, solid state disk and ethernet. We design an in house hardware harness and use National Instruments DAQs for power measurement. We model the power consumption of motherboard components using Linux performance counters.
Published in USENIX ATC 2011

- **Sleep over Neighbor Addressed Packets and GreenFrame** Sep 2009 – Mar 2010
802.11b WiFi clients listen to packets even when they are not addressed to them. We use a software defined radio to show significant power savings can be obtained in crowded spaces when the client sleeps after receiving just the header of the packet. QualNet simulations show promising power savings in different environments.
Published in IEEE Globecom 2010
- **Prediction of Handoff in Cellular Networks using Rough-Neuro Approach** Apr 2008 – May 2009
We use prediction of handoff in cellular network as an example application to show that rough set theory is effective in reducing feature set. We simulate a cellular network on Matlab and extract features for prediction. We use rough set theory to reduce the feature set and neural network for handoff prediction.
Published as a Springer chapter in Advances in Machine Learning and Data Analyses 2010

TECHNICAL SKILLS

- **Programming Intermediate:** Python, C
- **Programming Basic:** Bash, Java, L^AT_EX, MySQL, Cassandra, HTML/CSS
- **Machine Learning:** Python Scikit Learn
- **Hardware:** Circuit Design, PCB Design, PCB Assembly
- **RESTful Web Services:** Flask, Django
- **User Study:** Contextual Interviews
- **Building Energy and HVAC Management**

TEACHING EXPERIENCE

- Lecture on Introduction to Programming, Los Angeles Computing Circle (High School Level), UCLA 2017
- Guest Lecture, Principles of Embedded Systems (Graduate Level), UCLA Fall 2016
- Guest Lecture, Ubiquitous Computing (Graduate Level), UCSD Fall 2016
- Guest Lecture, Ubiquitous Computing, UCSD Fall 2015, Fall 2016
- Teaching Assistant, Software for Embedded Systems (Graduate Level), UCSD Spring 2013
- Teaching Assistant, Computer Architecture, UCSD Winter 2011
- Teaching Assistant, Computer Architecture Lab, UCSD Fall 2010

STUDENT ADVISING

- *PhD Students:* Jason Koh, Francesco Fraternali, Bo-Jhang Ho, Sandeep Sandha, Amr Alanwar
- *MS Students:* Rizhen Zhang, Yan Zhang, Eugene Kolinko, Huaipeng Zhang, Charlie Chen, Xiaoxiao Zheng, Qi Li, Eun Sun Lee, Yue Xin, Vikranth Jeyakumar
- *Undergraduate Students:* Xueyang Li, Kevin Chavez, Andrew Yi, Macklin Lee, Danny Zhang, Watson Yim, Jayon Huh, Michelle Tang, Yung Nguyen, Hao Li, Yikai Wang, Corrine Farley, Justin Kuo
- Mentor for Jacobs Undergrad Mentorship Program for 2014, 2015

SERVICE TO RESEARCH COMMUNITY

- Reviewer for Elsevier Computer Communications 2017
- Reviewer for MDPI Sensors 2017
- General Chair for ACM Workshop on the Internet of Safe Things 2017
- Reviewer for IEEE Transactions on Industrial Informatics 2017
- Local Arrangement Chair for SIGCOMM 2017
- Reviewer for IEEE Transactions on Industrial Informatics 2016
- Reviewer for IEEE Transactions on Mobile Computing 2016
- Reviewer for ACM Conference on Pervasive and Ubiquitous Computing (UbiComp) 2016
- Reviewer for IEEE Pervasive Computing 2016
- Reviewer for Elsevier Energy and Buildings 2016
- Reviewer for Elsevier Future Generation Computer Systems 2016
- Reviewer for Elsevier Energy and Buildings 2015
- Reviewer for IEEE Embedded Systems Letters (ESL) 2015
- Reviewer for IEEE/ACM Transaction on Networking 2014
- Session Chair for Data Aware Energy Use Workshop as part of Mathematics for Planet Earth (MPE) 2014
- Reviewer for ACM Conference on Pervasive and Ubiquitous Computing (UbiComp) 2014
- Reviewer for IEEE Micro 2014
- Reviewer for Elsevier Sustainable Computing, Informatics and Systems 2014

- Reviewer for IEEE Embedded System Letters 2013
- Reviewer for IEEE Transactions on Industrial Informatics 2013

AWARDS

- Best Demo Award, IPSN 2017
- Audience Choice Award, Nominated for Best Paper Award, BuildSys 2016
- Best Demo Award, BuildSys 2016
- Best Poster Award, BuildSys 2015
- Nominated for Best Paper Award, BuildSys 2015
- Most Innovative Solution for proposal on Picking up the PACE: Expanding PACE financing programs for Commercial Owned Buildings in Better Buildings Case Competition, 2014
- Highest grade (valedictorian) in my High School, 15th in the state of Maharashtra, India. Ranked in top 0.02% in all India entrance exam.

PROFESSIONAL MEMBERSHIPS

- ACM Professional Member 2016 – Present
- IEEE Professional Member 2016 – Present
- ACM Student Member 2011 – 2015
- IEEE Student Member 2012 – 2015
- UCSD Energy Club 2015
- Engineers for a Sustainable World Student Member 2012
- Association of Energy Engineers Student Member 2013

REFERENCES

- Mani Srivastava, Professor, University of California, Los Angeles
- Yuvraj Agarwal, Assistant Professor, Carnegie Mellon University
- Rajesh Gupta, Professor, University of California, San Diego
- Nadir Weibel, Research Assistant Professor, University of California, San Diego
- Balakrishnan Narayanaswamy, Amazon Research