

# Autotune

The Autotune technology is a set of automated calibration techniques for tuning software models to match measured data. It has been applied to building energy simulation and is relevant to existing residential and commercial buildings in all climate zones. Manual modeling calibration accuracy has demonstrated 22-97% difference from monthly utility bills from studies covering 3,349 buildings and constitutes the current status of the field[22][23] with significant costs in terms of manual calibration effort. For more information, the technological approach and techniques of the Autotune project are well-documented in 20+ publications, and 5+ internal reports.

- 1) Autotune Simulation Overview [[YouTube](#)][4][5][24][25]
- 2) Large Ensemble Simulations and Big Data Challenges [1][9]
- 3) Uncertainty Quantification – sensitivity analysis of 156 inputs on 82 outputs [33], design of experiments[37], GPU-accelerated statistics[26]
- 4) Machine Learning Techniques – ML on sensor data [7][18], MLSuite algorithm scalability on supercomputers [9][15][16][28]
- 5) Machine Learning applied to Calibration - EnergyPlus approximation of 8min in 3secs with surrogate AI model (160x speedup) [10], inverse EnergyPlus approximation of tuned inputs [11], PhD dissertation on machine learning for calibration [2]
- 6) Fixing time-series (sensor) data – statistical methods [3], filtering methods [13], machine learning methods [27][28][29]
- 7) Provenance for tracking sensor data usage – provDMS sensor data download, experiments, visualization of historical usage, and software interoperability [30][31][32]
- 8) Weather data – Actual Meteorological Year variability vendor survey [6]
- 9) Autotune System Results – evolutionary approach initial Autotune testing[17] applied to:
  - a. Residential buildings – field demonstration ZEBRAAlliance building WC1 [20][21] compared to manual effort for monthly data [8], hourly data [34], 15-minute data and multiple channels[11]
  - b. Commercial buildings – 3 commercial buildings at monthly whole-building energy and hourly data for 20 channels involving 3-79 tunable variables with error metrics for output matching measured data as well as for input matching the real building [19]
    - i. Two case studies quantifying Autotune’s calibration ability for recovering a detuned model and Autotune vs. Manual calibration comparison shows ability to recover most building performance parameters and calibrate as well as an expert while replacing ~50 man-hours per building[38].
  - c. Standard Method of Test for Calibration Performance – “trinity testing” of, calibration of 20,000 buildings shows <40% correlation between an accurate building description and matching hourly whole-building data [35][36].

## References:

- [1] Sanyal, Jibonananda and New, Joshua R. (2013). "Simulation and Big Data Challenges in Tuning Building Energy Models." In *Proceedings of the IEEE Workshop on Modeling and Simulation of Cyber-Physical Energy Systems (MSCPES)*, Berkeley, CA, May 20, 2013. Republished in *IEEE Xplore* October, 2013. [[IEEE](#)] [[PDF](#)] [[PPT](#)]

- [2] Edwards, Richard E. (2013). "Automating Large-Scale Simulation Calibration to Real-World Sensor Data". A Dissertation presented for the Doctor of Philosophy Degree in the Archives of The University of Tennessee, Knoxville, TN, May 2013. 178 pages [\[PDF\]](#) [\[PPT\]](#)
- [3] Castello, Charles C. and New, Joshua R. (2012). "Autonomous Correction of Sensor Data Applied to Building Technologies Utilizing Statistical Processing Methods." In *Proceedings of the 2nd Energy Informatics Conference*, Atlanta, GA, Oct. 6, 2012. [\[AIS\]](#) [\[PDF\]](#) [\[PPT\]](#)
- [4] New, Joshua R., Sanyal, Jibonananda, Bhandari, Mahabir S., Shrestha, Som S. (2012). "Autotune E+ Building Energy Models." In *Proceedings of the 5th National SimBuild of IBPSA-USA*, International Building Performance Simulation Association (IBPSA), August 1-3, 2012. [\[PDF\]](#) [\[PPT\]](#)
- [5] Sanyal, Jibonananda, Al-Wadei, Yusof H., Bhandari, Mahabir S., Shrestha, Som S., Karpay, Buzz, Garret, Aaron L., Edwards, Richard E., Parker, Lynne E., and New, Joshua R. (2012). "Autotune: Building Energy Model Calibration using EnergyPlus, Machine Learning, and Supercomputing." In *Proceedings of the 5th National SimBuild of IBPSA-USA*, International Building Performance Simulation Association (IBPSA), August 1-3, 2012. [\[Poster\]](#)
- [6] Bhandari, Mahabir S., Shrestha, Som S., and New, Joshua R. (2012). "Evaluation of Weather Data for Building Energy Simulations." In *Journal of Energy and Buildings*, volume 49, issue 0, pp. 109-118, June 2012. [\[PDF\]](#)
- [7] Edwards, Richard E., New, Joshua R., and Parker, Lynne E. (2012). "Predicting Future Hourly Residential Electrical Consumption: A Machine Learning Case Study." In *Journal of Energy and Buildings*, volume 49, issue 0, pp. 591-603, June 2012. [\[PDF\]](#)
- [8] Garrett, Aaron, New, Joshua R., and Chandler, Theodore (2013). "Evolutionary Tuning of Building Models to Monthly Electrical Consumption." Technical paper DE-13-008. In *Proceedings of the ASHRAE Annual Conference*, Denver, CO, June 22-26, 2013. [\[PDF\]](#) [\[PPT\]](#)
- [9] Sanyal, Jibonananda, New, Joshua R., and Edwards, Richard E. (2013). "Supercomputer Assisted Generation of Machine Learning Agents for the Calibration of Building Energy Models." In *Proceedings of the Extreme Science and Engineering Discovery Environment (XSEDE13) Conference* and selected to be featured in *Lightning Talks*, San Diego, CA, July 22-25, 2013. [\[PDF\]](#) [\[PPT\]](#) [\[Poster\]](#)
- [10] Edwards, Richard E., New, Joshua R., and Parker, Lynne E. "Constructing Large Scale EnergyPlus Surrogates from Big Data". Submitted to *Journal of Buildings and Environment*.
- [11] Edwards, Richard E., New, Joshua R., and Parker, Lynne E. (2013). "Estimating Building Simulation Parameters via Bayesian Structure Learning." In *Proceedings of the 2nd International Workshop on Big Data, Streams and Heterogeneous Source Mining: Algorithms, Systems, Programming Models and Applications (BigMine13)*, part of the *19th ACM SIGKDD Conference on Knowledge Discovery and Data Mining (KDD2013)*, Chicago, IL, August 11, 2013. [\[PDF\]](#) [\[Poster\]](#)
- [12] Garrett, Aaron and New, Joshua R. "Scalable Evolutionary Tuning of Building Models to Multiple Channels of Sub-Hourly Data". To be submitted to *Journal Energy*, 2013.
- [13] Castello, Charles C., New, Joshua R., and Smith, Matt K. (2013). "Autonomous Correction of Sensor Data Applied to Building Technologies Using Filtering Methods." In *Proceedings of the IEEE Global Conference on Signal and Information Processing (GlobalSIP)*, Austin, TX, December 3-5, 2013. [\[PDF\]](#) [\[Poster\]](#)

- [14] Edwards, Richard E., Parker, Lynne E., and New, Joshua R. (2013). "MLSuite Software Transfer Document." ORNL internal report ORNL/TM-2013, May 2013, 36 pages. [[PPT](#)]
- [15] Edwards, Richard E., New, Joshua R., and Parker, Lynne E. (2012). "MLSuite - FY2012 Final Report." ORNL internal report ORNL/TM-2013/385, October 2012, 68 pages.
- [16] Edwards, Richard E., Zhang, Hao, Parker, Lynne E. and New, Joshua R. (2012). "Approximate I-fold Cross-Validation with Least Squares SVM and Kernel Ridge Regression." ORNL internal report ORNL/TM-2012/419, August 2012, 9 pages.
- [17] Garrett, Aaron and New, Joshua R. (2012). "An Evolutionary Approach to Parameter Tuning of Building Models (Experiments 1-17)." ORNL internal report ORNL/TM-2012/418, April 2012, 68 pages.
- [18] Edwards, Richard E., New, Joshua R., and Parker, Lynne E. (2011). "Sensor-based Building Energy Modeling." ORNL internal report ORNL/TM-2011/328, September 2011, 79 pages.
- [19] Garret, Aaron and New, Joshua R. (2013). "Trinity Test: Effectiveness of Automatic Tuning for Commercial Building Models." ORNL internal report ORNL/TM-2013/130, March 7, 2013, 24 pages.
- [20] Miller, W.A. et al. 2012. "ZEBRAlliance: An Alliance Maximizing Cost-Effective Energy Efficiency in Buildings." Available: <http://www.zebralliance.org>.
- [21] Biswas, K., Gehl, A., Jackson, R., Boudreaux, P., and Christian, J. "Comparison of Two High-Performance Energy Efficient Homes: Annual Performance Report", December 1, 2010 – November 30, 2011. Oak Ridge National Laboratory report ORNL/TM-2011/539. [[PDF](#)]
- [22] Earth Advantage Institute and Conservation Services Group (2009). "Energy Performance Score 2008 Pilot: Findings and Recommendations Report."
- [23] Roberts, D., N. Merket, B. Polly, M. Heahey, S. Casey, and J. Robertson (2012). "Assessment of the U.S. Department of Energy Scoring Tool." National Renewable Energy Laboratory.
- [24] New, Joshua R. (2013). "Autotune Building Energy Models." *DOE Building Technology Office (BTO) Peer Review*, Washington DC, April 2, 2013. [[PPT](#)]
- [25] Sanyal, Jibonananda, New, Joshua R., and Edwards, Richard E. (2013). "Calibration of Building Energy Models: Supercomputing, Big-Data and Machine-Learning." In *Proceedings of the ORNL Postdoc Symposium*. Oak Ridge, TN, July 19, 2013. [[PDF](#)]
- [26] Ranjan, Niloo, Sanyal, Jibonananda, and New, Joshua R. (2013). "In-Situ Statistical Analysis of Autotune Simulation Data using Graphical Processing Units." Presented as part of the Science Undergraduate Laboratory Internships (SULI) program, August 8, 2013. [[PDF](#)] [[Poster](#)]
- [27] Smith, Matt K., Castello, Charles C., and New, Joshua R. (2013). "Sensor Validation with Machine Learning." Presented as part of the Science Undergraduate Laboratory Internships (SULI) program, August 2013. [[PDF](#)] [[Poster](#)]
- [28] Edwards, Richard E., Zhang, Hao, New, Joshua R., and Parker, Lynne E. (2013). "Approximate I-fold Cross-Validation with Least Squares SVM and Kernel Ridge Regression." In *Proceedings of the IEEE 12th International Conference on Machine Learning and Applications (ICMLA13)*, Miami, FL, December 4-7, 2013. [[PDF](#)] [[PPT](#)] [[PPT](#)]
- [29] Smith, Matt K., Castello, Charles C., and New, Joshua R. (2013). "Machine Learning Techniques Applied to Sensor Data Correction in Building Technologies." In *Proceedings of the IEEE 12th*

*International Conference on Machine Learning and Applications (ICMLA13)*, Miami, FL, December 4-7, 2013. [[PDF](#)] [[Poster](#)]

- [30] Hensley, Zachary, Sanyal, Jibonananda, and New, Joshua R. (2013). "ProvDMS -- A Provenance Data Management System for Sensor Data." Presented as part of the Science Undergraduate Laboratory Internships (SULI) program, August 8, 2013. [[PDF](#)] [[Poster](#)]
- [31] Hensley, Zachary P., Sanyal, Jibonananda, and New, Joshua R. (2014). "Provenance in Sensor Data Management: A Cohesive, Independent Solution for Bringing Provenance to Scientific Research." In *Communications of the ACM*, volume 57, issue 2, pp. 55-62, December 2013 and *ACM Queue*, volume 11, issue 12, pp. 1-14, December 2013. [[PDF](#)] [[ACM](#)] [[Queue](#)]
- [32] Castello, Charles C., Sanyal, Jibonananda, Rossiter, Jeffrey S., Hensley, Zachary P., and New, Joshua R. (2014). "Sensor Data Management, Validation, Correction, and Provenance for Building Technologies." Technical paper TRNS-00223-2013.R1. In *Proceedings of the ASHRAE Annual Conference and ASHRAE Transactions 2014*, Seattle, WA, June 28-July 2, 2014. [[PDF](#)] [[PPT](#)]
- [33] Ostrouchov, George, New, Joshua R., Sanyal, Jibonananda, and Patel, Pragnesh (2014). "Uncertainty Analysis of a Heavily Instrumented Building at Different Scales of Simulation." In *Proceedings of the 3rd International High Performance Buildings Conference*, Purdue, West Lafayette, IN, July 14-17, 2014. [[PDF](#)] [[PPT](#)]
- [34] Garrett, Aaron and New, Joshua R. (2015). "Scalable Tuning of Building Energy Models to Hourly Data." In *Journal of Energy*, volume 84, pp. 493-502, April 2015. [[Energy](#)] [[PDF](#)]
- [35] Garrett, Aaron and New, Joshua R. (2016). "Suitability of ASHRAE Guideline 14 Metrics for Calibration." Technical paper OR-16-037. In *Proceedings of the ASHRAE Winter Conference and ASHRAE Transactions 2016*, volume 122, part 1, pp. 469-477, Orlando, FL, January 23-27, 2016. [[PDF](#)] [[PPT](#)]
- [36] New, Joshua R. (2016). "Autotune Calibration and Trinity Test Evaluation" presented as part of "Seminar 59 - Simulation Calibration Methods: Which Should I Choose?" In *Proceedings of the ASHRAE Winter Conference*, 21 slides. Orlando, FL, January 27, 2016. [[PPT](#)]
- [37] New, Joshua R. (2016). "Design of Experiments: Statistical Confidence with Fewer Simulations" presented as part of "Seminar 22 - Large-Scale Computing." In *Proceedings of the ASHRAE Annual Conference*, 25 slides, St. Louis, MO, June 27, 2016. [[PPT](#)]
- [38] Chaudhary, Gaurav, New, Joshua R., Sanyal, Jibonananda, Im, Piljae, O'Neill, Zheng, and Garg, Vishal (2016). "Evaluation of 'Autotune' Calibration Against Manual Calibration of Building Energy Models." In *Journal of Applied Energy*, volume 182, pp. 115-134, August 2016. [[Applied Energy](#)]
- New, Joshua R. (2016). "Autotune calibrates models to building use data." Oak Ridge, TN, August 26, 2016. [[YouTube](#)]