

¹ Control Strainer (ConStrain): a data-driven control verification framework

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Software

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⁶ Summary

The Control Strainer, or ConStrain, is a python-based framework that can be used by energy modelers, building engineers, and researchers to conduct consistent and automated verification of building system controls using either timeseries data generated from whole-building energy simulations or from actual building automation system (BAS) trend data. ConStrain is made of two distinct components: an expandable control verification algorithms library, and a standardized performance evaluation and reporting workflow framework. At its roots, ConStrain's verification library was developed with the verification of control related building energy code requirements in mind, but it is built such that its library is expandable and can cover user-customized control verifications.

¹⁶ Statement of need

Robust HVAC control is a “no regrets” strategy for building decarbonization, reducing energy use, enabling flexibility and resilience, and supporting the transition to electrified heating, all with low embodied carbon. The Buildings Technology Office (BTO) of the United States Department of Energy’s blueprint has a goal of “more than 50% of all homes and businesses have automated control platforms that reduce energy waste and enable flexibility” ([U.S. Department of Energy, n.d.](#)).

Advances in building control have shown significant potential for improving building energy performance and decarbonization. Studies show that designs utilizing optimized controls that are properly tuned could cut commercial building energy consumption by approximately 29% - equivalent to 4-5 Quads, or 4-5% of the energy consumed in the United States ([Fernandez, Nicholas EP, et al., 2017](#)). Driven by the significant control-related energy-saving potential, commercial building energy codes and standards (such as American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1 ([ASHRAE, 2019](#)))) have progressed with many control-related addenda. For example, from the publication of 90.1-2004 to 90.1-2016 (four code cycles), 30% of the new requirements are related to building control (with most of them focused on Heating, Ventilation, and Air Conditioning (HVAC) system control) ([Rosenberg, M.I., P.R. Hart, M. Hatten, D. Jones, and M. Cooper, 2017](#)).

However, one of the challenges to realizing those savings is the correct implementation of such advanced control strategies and regularly verifying their actual operational performance. A field study found that only 50% of systems observed have their control system correctly configured to meet the energy codes requirement ([Rosenberg, M.I., P.R. Hart, M. Hatten, D. Jones, and M. Cooper, 2017](#)), and control-related compliance verification is typically not included in the commissioning scope.

Current control verification is often conducted manually, which is time-consuming, ad-hoc,

⁴¹ incomplete, and error-prone.

⁴² ConStrain focuses on formalizing and automating verification of HVAC controls by analyzing
⁴³ sensor and actuator data streams from building control systems.

⁴⁴ ConStrain is an open-source library and application programming interface (API) for analyzing
⁴⁵ BAS data streams for adherence to an operational specification, which can correspond to code
⁴⁶ (e.g., ASHRAE 90.1) or to a high-performance control guideline (e.g., ASHRAE Guideline 36
⁴⁷ @[g36]).

⁴⁸ ConStrain is also incorporating semantic modeling capabilities to enable automated
⁴⁹ configuration and deployment of verification. ConStrain has applications to code-compliance
⁵⁰ building performance standards (BPS), and commissioning.

⁵¹ ConStrain can be used as a standalone tool and can also be integrated into established
⁵² workflows of third-party tools and practices. For instance, ConStrain has been successfully
⁵³ integrated as part of the continuous integration software development process of whole-building
⁵⁴ energy simulation-based software tool (e.g., Washington State's Total System Performance
⁵⁵ Ratio Analysis Tool ([Pacific Northwest National Laboratory, n.d.](#))) to make sure that software
⁵⁶ code contributions as well as simulation software updates do not have unexpected impacts
⁵⁷ on the simulated performance of building system controls. Moreover, a set of OpenStudio
⁵⁸ ([National Renewable Energy Laboratory, Argonne National Laboratory, Lawrence Berkeley](#)
⁵⁹ [National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory,](#)
⁶⁰ [n.d.-a](#)) measures ([National Renewable Energy Laboratory, Argonne National Laboratory,](#)
⁶¹ [Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, Pacific Northwest](#)
⁶² [National Laboratory, n.d.-b](#)) have also been developed to enable building energy modelers using
⁶³ OpenStudio to have access to perform verification on their models with minimal configurations
⁶⁴ required.

⁶⁵ Acknowledgements

⁶⁶ ConStrain was developed at the Pacific Northwest National Laboratory and was funded under
⁶⁷ contract with the U.S. Department of Energy (DOE). It is actively being developed as an
⁶⁸ open-source project.

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