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Geometry-Weighted Regression for Stable Amortized Optimization in HVAC Control

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Abstract

Modern HVAC control requires repeatedly solving optimization problems to determine heating and cooling actions under changing weather and building conditions. These problems are dynamic, multi-step, and computationally expensive, making real-time optimization difficult. Amortized optimization offers an alternative: instead of solving a new optimization problem at every time step, a neural network is trained to directly predict near optimal control actions from the current building state and environmental conditions. Training such networks is challenging. Regression-based approaches that learn from optimal solutions are stable but ignore how sensitive the objective function is to control errors. Objective-based approaches directly minimize control cost through rollout simulations, but often suffer from instability and high computational burden, especially for long horizons and nonlinear dynamics. We propose Geometry-Weighted Regression (GWR), a hybrid training method that preserves the stability of regression while incorporating local geometric information from the control objective. The key idea is to weight prediction errors using a context-dependent positive semidefinite matrix that captures the curvature of the HVAC cost function around the optimal solution. To evaluate the method in a realistic setting, we develop a data-driven thermal dynamics model for HVAC control. A finite-horizon, multi-objective cost balancing thermal comfort and grid electricity use is then defined. We compare standard regression, objective-based training, and GWR. GWR improves training stability, mitigates early performance degradation seen in standard regression, and avoids the instability common in objective-based training. These results demonstrate the value of incorporating objective geometry into regression-based learning for stable and efficient amortized HVAC control.

Keywords
Amortized Optimization, Geometry-Weighted Regression, HVAC Control, Building Energy Management

Biographies

Metin Turkay is a Prof. of Industrial Engineering at Koc University, Istanbul. He completed his BS and MS education at METU, Ankara and PhD at Carnegie Mellon University. His research interests include optimization theory and algorithms and their applications in sustainable supply chain and logistics systems, process systems engineering, computational biology, bioinformatics and systems biology. His specialties include optimization, mixed-integer programming models, theory and algorithms, sustainable supply chain and logistics systems, systems biology, structure-based drug discovery and design.

Erdal Aydin is an Assistant Professor in the Department of Chemical and Biological Engineering at Koç University in Istanbul, Türkiye. He earned his BS degree at Middle East Technical University and continued his academic journey with an MSc at Koç University. He then completed his PhD at the Max Planck Institute and conducted postdoctoral research at the Massachusetts Institute of Technology (MIT). His research focuses on process systems engineering, optimization, control, energy systems, and decision making under uncertainty. His work integrates advanced mathematical modeling, optimization techniques, and artificial intelligence to address complex engineering problems such as energy system design, optimal operation planning, and sustainable process design.

Kiran Anwar is a PhD candidate and researcher in Computational Sciences and Engineering at Koç University in Istanbul, Türkiye. She holds an MSc degree in the same field and has a strong academic background focused on advanced analytical and computational methods. Her research interests span data mining, optimization, and applications of mixed-integer linear programming (MILP) and other computational techniques to real-world problems such as food supply chain systems and related optimization challenges.