Mendell AY, Siegel JA, Lee S. 2025. Evaluating the benefit of indoor air quality forecasting for controlling particle filter systems. *ACS ES&T Air*, **2(4)**, 599-606. doi:10.1021/acsestair.4c00330

Abstract

Predicting future concentrations of fine particulate matter ($PM_{2.5}$) and other indoor air pollutants using machine learning is an increasingly frequent topic of research. Although prediction has several proposed applications, the potential benefit has remained largely unevaluated. This study examines whether prediction can improve how particle filter systems such as portable air cleaners are automated by comparing a model predictive control (MPC) strategy with a traditional threshold-based control (TBC) strategy. The MPC controller is designed to optimize the balance between mean reduction in $PM_{2.5}$ concentration (i.e., keep concentrations as low as possible following health-based guidance) and reductions in system runtime. These two parameters are compared for both control strategies using 104 simulations of week-long continuous $PM_{2.5}$ measurements in occupied apartments. Our findings suggest that there is no meaningful difference in performance between the two control strategies. Additionally, we find only a marginal improvement in performance for MPC controllers that operate using longer prediction horizons. Given the numerous challenges associated with accurately predicting future $PM_{2.5}$ concentrations, as well as the additional challenges associated with implementing MPC, controlling particle filter systems may not be an appropriate application for prediction given the lack of benefit over TBC. We would recommend that particle filter systems continue to be controlled using nonpredictive strategies such as TBC, and that prediction tools be used for other applications or adapted to different areas of indoor air quality research and practice.

Main findings

1. Threshold-based control (TBC) achieves near optimal performance, given that model predictive control (MPC) offers only a marginal improvement.
2. MPC is not substantially improved when a longer prediction horizon is used.
3. Unless additional performance parameters are required, TBC may be preferred for controlling particle filter systems due to its relative simplicity.
4. Predicting future pollutant concentrations may be appropriate for applications other than MPC.

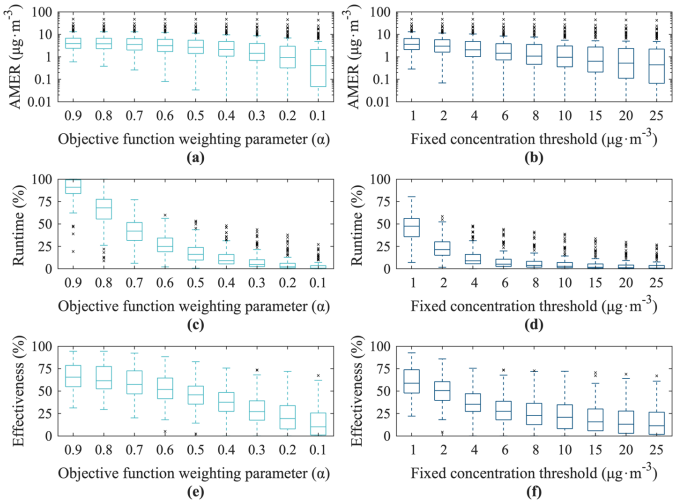

Figure 1. Comparison of absolute mean exposure reduction (AMER) and runtime between model predictive control (MPC) and threshold-based control (TBC) across all simulation environments (N = 104) for a range of objective function weighting parameter values (α) and fixed concentration threshold values, respectively. MPC uses a 10-minute prediction horizon. AMER is shown in parts (a) and (b) for MPC and TBC, respectively, with a logarithmic scale. Total runtime is shown in parts (c) and (d) for MPC and TBC, respectively. Effectiveness is shown in parts (e) and (f) for MPC and TBC, respectively. For each box shown, the middle line represents the median concentration, the upper and lower box boundaries represent the 25th and 75th percentiles of concentrations, and the whiskers represent 1.5 times the interquartile range from the upper or lower quartile.

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