Improving the efficiency of mechanical ventilation systems using artificial neural networks: A model based on indoor carbon dioxide concentration prediction

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ABSTRACT

The growing demand for energy-efficient and health-conscious indoor environments highlighted the need for smarter, more responsive ventilation systems. This study investigates the use of artificial neural networks (ANNs) to improve the performance of mechanical ventilation systems by accurately predicting indoor carbon dioxide (CO2) concentrations—an essential indicator of indoor air quality (IAQ) that is closely linked to occupancy patterns and ventilation behavior.

In this study, a predictive model was built using MATLAB R2024b and trained with both real-time and historical data collected from a classroom environment. The model, based on an artificial neural network (ANN), was developed to automatically adjust ventilation rates in response to predicted CO_2 levels. This approach helps maintain good indoor air quality while also cutting down on unnecessary energy use. To achieve this, the research involved collecting environmental data, preparing and processing it, designing the ANN model, and then evaluating its performance across different occupancy scenarios.

The smart ventilation system developed through this work was able to regulate fan speeds and control the intake of fresh air based on the model's CO_2 predictions. Test results showed that the system performed very well—accurately predicting indoor CO_2 concentrations and significantly reducing energy consumption. In particular, the system led to a 44.5% reduction in heating energy during winter and 54.05% energy savings in summer, compared to conventional ventilation setups that run at a constant rate.

Beyond the technical results, this research points to a broader shift in how buildings can be managed using artificial intelligence. The ANN-based system not only meets established indoor air quality standards but also supports healthier, more energy-efficient indoor environments. Because of its flexibility, the approach could easily be applied to other building types, such as offices, schools, or healthcare facilities. In all, this work contributes to the fields of sustainable design and smart building systems, showing how AI can play a key role in creating intelligent and responsive indoor environments.