

Urban Microscale Air Quality Monitoring Using Low-Cost Sensors and Artificial Intelligence Applied to Atmospheric Time Series

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Atmospheric pollution is one of the main environmental and public health problems worldwide, which make population vulnerable and extremely exposed to high concentrations of pollutants. In highly urbanized areas such as Mexico City (CDMX), the combination of high population density, intense vehicular and industrial activity, and unfavorable meteorological and topographic conditions favors the accumulation of pollutants, especially fine particulate matter (PM_{2.5}), which causes an increase in respiratory and cardiovascular diseases and premature mortality. Although meteorological stations (reference monitoring stations) are available and provide accurate and reliable measurements, their spatial coverage is limited due to the high costs of installation, operation, and maintenance, which hinders analysis at the urban microscale, where other local factors also play a role, such as vehicular traffic, the geometric distribution of streets, and micrometeorological processes.

In response to this problem, low-cost sensor systems (LCS) have emerged as an alternative to complement the analysis carried out by reference stations, since these networks have much lower costs, allowing the deployment of several well-distributed LCS units. However, these systems present a problem in their measurements, as data quality is lower compared to reference stations, which may be a consequence of their sensitivity to environmental variables. In this context, the calibration of these LCS using tools such as artificial intelligence (AI) and machine learning is proposed in order to improve the reliability of the data generated by low-cost sensors through the advanced analysis of atmospheric time series.

The present research aims to apply artificial intelligence techniques to the analysis and calibration of PM_{2.5} time series obtained from a low-cost sensor installed in an urban microscale environment. The study is based on the co-location of the LCS with a reference monitoring station in Mexico City, which allows the generation of paired time series for the training and evaluation of supervised models. A methodological workflow was implemented that included data quality control, treatment of missing values, and detection of outliers, in order to reduce noise in the measurements without losing the temporal variability associated with urban processes.

Subsequently, different machine learning models were evaluated for sensor calibration, including linear regression, multiple linear regression with meteorological variables, and a multilayer perceptron neural network. These models allow capturing non-linear relationships between the low-cost sensor signals and the reference measurements, as well as exploiting the temporal structure of the data. These results confirm that artificial intelligence provides an effective framework for improving the reliability and interpretability of atmospheric time series obtained from low-cost sensors. The proposed approach supports the use of dense sensor networks for urban microscale air quality monitoring, particularly in resource-limited settings, and represents a solid basis for future integration with forecasting systems, satellite observations, and community-based monitoring initiatives.

From an applied perspective, this work highlights the potential of artificial intelligence to strengthen the use of low-cost sensor networks in urban microscale air quality monitoring, especially in resource-limited contexts. The integration of time series analysis methods, accessible sensors, and local atmospheric knowledge contributes to generating more detailed and equitable information on population exposure to pollutants, with potential applications in the verification of air quality forecasting systems, community monitoring initiatives, and support for public health decision-making. Likewise, the importance of institutional collaboration is emphasized to ensure the sustainability and impact of these technologies in

air quality management.

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Keywords: microscale urban air quality, low-cost sensors, artificial intelligence, atmospheric pollution, micrometeorology

