Abstract

Air pollution is an environmental threat, particularly in countries with a high level of industrialization and dense urban development. Effective forecasting of particulate matter concentrations, especially fractions $PM_{2,5}$ and PM_{10}, is crucial for analyzing the state of the atmosphere and supporting actions taken by institutions responsible for air quality management.

This dissertation proposes and implements modern approaches based on deep learning methods. Various topologies of convolutional neural networks and autoencoders were used to forecast short-term air pollutant concentrations. The research adopted a time-based approach, in which forecasts of short-term pollutant concentrations were obtained based on historical values (data-driven approach). The models were trained and tested on real-world measurement data from automatic air quality monitoring stations located in various regions of Poland. Meteorological and seasonal information were used, allowing for a better representation of the relationships between environmental variables. The study focused on assessing the effectiveness of the proposed models under Poland's diverse environmental conditions, which have rarely been analyzed at such a broad regional scale in the existing literature.

The obtained results showed that deep learning models, especially those with a convolutional architecture, achieve better accuracy parameters than classical statistical approaches or flat neural networks. The accuracy of the methods was assessed using standard error measures (MAE, MSE, RMSE, R^2) and statistical tests. Analysis of the results showed that the proposed methods achieved lower prediction error measures and higher goodness-of-fit values R^2. Analysis of the statistical hypotheses also confirmed the advantages of the proposed methods compared to those from the literature.

The conducted research confirms the validity of using deep learning methods for short-term air quality forecasting in conditions of strong spatial variation. The proposed approach enables the assessment of the effectiveness of forecasting models on a scale encompassing multiple locations with different environmental conditions, which represents a significant extension of previous research, which was usually conducted in limited local conditions. The obtained results can be considered a starting point for further development of the proposed methods towards more complex temporal and spatial analyses. One possible direction for further development is to expand the forecasting aspect to a temporal-spatial approach, which assumes the inclusion of historical information from neighboring measurement stations.