Modelling Air Quality via Machine Learning and IoT Technologies

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This dissertation is submitted for the degree of Master of Science (by Research)

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Thesis Certificate

This is to certify that the work contained in the thesis entitled **"Modelling air quality via machine learning and IoT technologies"** being submitted by **Mr Tushar Saini** (Enrolment No: S19011) has been carried out under my supervision. In my opinion, the thesis has reached the standard fulfilling the requirement of regulation of the MS degree. The results embodied in this thesis have not been submitted elsewhere for the award of any degree or diploma.

03rd Jan 2022

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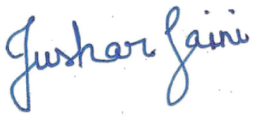
Declaration by the Research Scholar

I hereby declare that the entire work embodied in this Thesis is the result of investigations carried out by me in the ***School of Computing and Electrical Engineering***, Indian Institute of Technology Mandi, under the supervision of **Dr. Varun Dutt**, and that it has not been submitted elsewhere for any degree or diploma. In keeping with the general practice, due acknowledgments have been made wherever the work described is based on findings of other investigators.



Place: IIT Mandi, Kamand

Date: 03rd Jan 2022

Name: Tushar Saini

Declaration by the Research Advisor

This is to certify that the Thesis entitled "**Modelling air quality via machine learning and IoT technologies",** submitted by **Tushar Saini** to the Indian Institute of Technology Mandi for the award of the Degree of Master of Science (by research) is a bonafide record of research work carried out by him under my supervision. The content of this Thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any Degree or Diploma.

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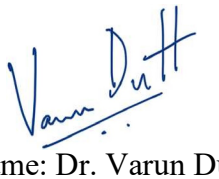

Date: 03rd Jan 2022 Name: Dr. Varun Dutt

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Abstract

Air quality is degrading in developing countries, and severe health issues are associated with increasing air pollution. It is imperative to monitor and predict air quality online in real-time. Although offline air-quality monitoring using hand-held devices is common, online air-quality monitoring is still expensive and uncommon, especially in developing countries. Also, existing technologies do not perform forecasting of air pollution ahead of time. This thesis's first objective was to address these literature gaps and propose a scalable, low-cost real-time air-quality monitoring, prediction, and warning system (AQMPWS). The proposed AQMPWS monitored and predicted seven pollutants: $PM_{1.0}$, $PM_{2.5}$, PM_{10}, carbon monoxide, nitrogen dioxide, ozone, and sulphur dioxide. The AQMPWS also monitored five weather variables: temperature, pressure, relative humidity, wind speed, and wind direction.

This thesis' second objective involved the forecasting of air pollution ahead of time. Individual and ensemble univariate and multivariate time-series forecasting models were developed and tested for predicting air pollution, which could forecast one step ahead in time (i.e., forecasting was done on the time dimension). Five individual time-series forecasting models, namely, multilayer perceptron (MLP), convolution neural network (CNN), long short-term memory (LSTM), and seasonal autoregressive integrated moving average (SARIMA), were investigated. Also, a new weighted ensemble model of these individual models was developed. Among the individual univariate models, the CNN performed the best, and this model was followed by the LSTM, MLP, and SARIMA models both during training and test. The investigation revealed that multivariate models performed better than their counterpart univariate models. Furthermore, the weighted ensemble model performed the best among all models.

In the third objective, the developed AQMPWS was benchmarked against an industrial-grade air-quality monitoring system deployed at the ACC Cement Factory in Barmana, India. A high correlation between the collected data from AQMPWS and the industrial-grade system showed that the developed system was on par with the industrial system. Three statistical models, namely, Vector Autoregressive (VAR), Vector Autoregressive Moving Average (VARMA), and SARIMA and an ensemble model, were developed to predict the future values of $PM_{2.5}$ and PM_{10} in the industrial system from the $PM_{2.5}$ and PM_{10} values measured by the

AQMPWS. Results showed that the ensemble model performed the best, and VAR performed the second-best in predicting the $PM_{2.5}$ and PM_{10} values in the industrial system.

Lastly, we performed a preliminary study to find the public perception of the adverse effects of air pollution. About 90 percent of those surveyed (N = 500) requested a daily update on their localities' air pollution. Results showed that people preferred periodic SMS alerts to learn about air quality compared to other methods. Results from the study helped shape the alerting system in the AQMPWS.

Keywords: *Air pollution, IoT, Time-series forecasting, Machine Learning, Deep Learning, Statistical Modelling*

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