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Study of Indoor Air Quality Impact During Building Demolition: A Case Study of the 2009 L'Aquila Earthquake Reconstruction

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I. ABSTRACT

This study focuses on the 2009 earthquake in L'Aquila, Italy, as a case study. A user-friendly household monitoring method was adopted for systematic data collection, aiming to enhance the comprehensive understanding of particle pollution. Multivariate statistical methods, such as principal component analysis and partial least squares regression, were implemented for data analysis. Additionally, a deep learning model is developed to predict the diffusion patterns of dust around demolished buildings. By combining traditional statistical techniques with advanced analytical tools, it is expected to gain deeper insights into the complex dynamics of air quality during the building demolition process.

II. INTRODUCTION

L'Aquila, known for its seismic vulnerability and rich historical heritage, suffered considerable damage from the 2009 earthquake. The subsequent building demolitions during the reconstruction process in the affected areas led to increased concentrations of particulate matter in the air, potentially causing health issues. Consequently, effective monitoring of these particles is essential. Monitoring and mitigating airborne pollutants during demolitions is particularly crucial for the holistic safeguarding of communities, which is important to informing resilient and sustainable reconstruction plans. Previous studies have convincingly demonstrated the link between air pollution and climate variables [1, 2]. In this study, in-home monitoring was conducted in houses adjacent to demolition sites. The analysis specifically examined the relationship between weather parameters and suspended particulate matter.

III. DATA COLLECTION AND ANALYSIS METHODOLOGIES

For this study, data collection was carried out using the Particle Counter PC220, manufactured by Trotec. This instrument was placed on the windowsill opposite a building being demolished due to earthquake damage, as depicted in Figure 1. It was designed to capture particle sizes of 0.3μm, 0.5μm, 1.0μm, 2.5μm, 5.0μm, and 10μm, thereby facilitating the measurement of suspended particulate matter in the atmosphere. In addition to this, the instrument simultaneously monitored environmental parameters such as atmospheric temperature (AT), relative humidity (RH), dew point (DP), and wet-bulb temperature (WB). Wind speed (WS) was also measured, utilizing the central control system located in proximity to PC220. This setup provided a comprehensive overview of the environmental conditions prevailing during the demolition process.

Fig. 1. Target building and instrument setup

Four key techniques were employed for data analysis in this study: principal component analysis (PCA) [3], partial least squares (PLS) [4] mutual information (MI) analysis [5], and deep neural networks (DNN) [6]. PCA is a widely-used multivariate statistical method for reducing dimensionality. It transforms data into uncorrelated principal components (or scores), arranged so that the initial

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components retain most of the variations from the original variables. The coefficients, known as loadings, link the original variables to the scores and offer insights into the data's structure and relationships. PCA is particularly effective for exploratory data analysis. PLS, on the other hand, is a linear regression technique well-suited for situations with highly collinear variables. MI analysis, meanwhile, measures the information one variable contains about another, quantifying the degree of dependency between variables. This tool is especially valuable for identifying nonlinear correlations among variables. DNNs are sophisticated machine learning models composed of multiple layers of interconnected neurons. These networks are capable of learning complex data patterns. In this research, a fully connected feedforward neural network was utilized, selecting the rectified linear unit as the activation function.

IV. RESULTS AND DISCUSSIONS

The collected data, including five climate parameters and the particle amount for six different particle sizes, were subjected to the PCA method for dimensionality reduction. The results are presented in Figures 2(a) and (b). Specifically, the loading plot shows that climate parameters and amounts of suspended particles are nearly orthogonal, indicating the particle amounts cannot be accurately predicted with a linear model. This finding aligns with the results of the PLS model, which uses climate parameters as input variables and outputs not only the total quantity of particles but also the specific amounts for each of the six distinct particle size categories. The prediction outcomes for both the training and test sets, as illustrated in Figures 2(c) and 2(d), demonstrate subpar performance. The R2 values, indicating prediction performance, were less than 0.15, with even negative values observed in the test set. However, the MI values for climate parameters in relation to total particle amount are 5.09, 5.78, 4.38, 4.46, and 4.52, respectively, indicating that the variables may be nonlinearly correlated. Therefore, it is reasonable to adopt a DNN model. The initial findings are shown in Figure 3. The R2 values for the total particle amount in these datasets, at 0.36 and 0.31 respectively, indicate a moderate level of predictability. This outcome might stem from limitations in the data collection methodology, particularly oversights in parameters like local wind direction around the monitoring site, leading to an incomplete assessment of atmospheric disturbances. However, this presents opportunities for future research to enhance the dataset collection process.

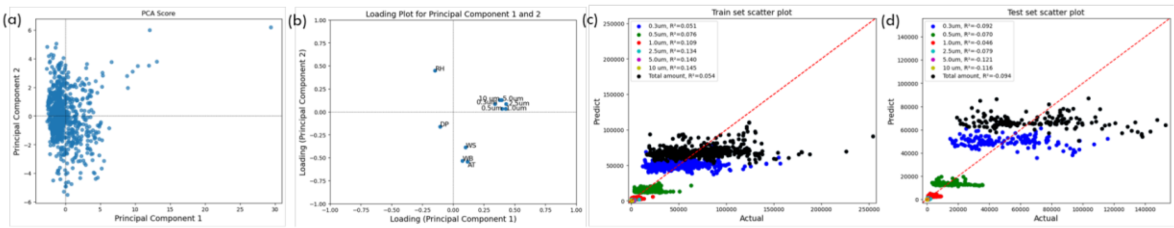

Fig. 2. (a) PCA score plot, (b) PCA loading plot, (c) PLS training set predictions, and (d) PLS test set predictions.

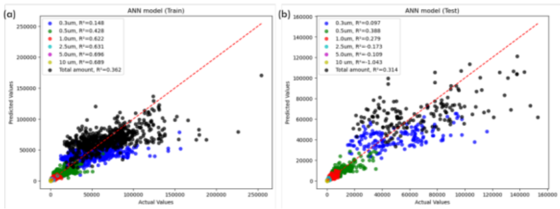

Fig. 3. DNN model predictions: (a) training set, and (b) test set

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V. REFERENCES

[1] M. Amodio et al., "A statistical investigation about sources of PM in South Italy," *Atmospheric Research*, vol. 98, no. 2- 4, pp. 207-218, 2010.

[2] H. Zhang, Y. Wang, J. Hu, Q. Ying, and X.-M. Hu, "Relationships between meteorological parameters and criteria air pollutants in three megacities in China," *Environmental research*, vol. 140, pp. 242-254, 2015.

[3] S. Wold, K. Esbensen, and P. Geladi, "Principal component analysis," *Chemometrics and Intelligent Laboratory Systems*, vol. 2, no. 1, pp. 37-52, 1987/08/01 1987.

[4] P. Geladi and B. R. Kowalski, "Partial least-squares regression: a tutorial," Analytica chimica acta, vol. 185, pp. 1-17, 1986.

[5] C. E. Shannon, "A mathematical theory of communication," *The Bell system technical journal*, vol. 27, no. 3, pp. 379-423, 1948.

[6] Y. LeCun, Y. Bengio, and G. Hinton, "Deep learning," *nature*, vol. 521, no. 7553, pp. 436-444, 2015.