REVIEW

OF THE DISSERTATION BY PETAR RUMENOV ZHIVKOV ON THE TOPIC "MODELING THE QUALITY OF ATMOSPHERIC AIR ON HEALTH AND ECONOMIC ASPECTS"

BY PROF., D.SC. PH.D. IVAN DIMOV, DEPARTMENT "PARALLEL ALGORITHMS AND MACHINE LEARNING WITH LABORATORY OF NEUROTECHNOLOGY", INSTITUTE OF INFORMATION AND COMMUNICATION TECHNOLOGIES AT THE BULGARIAN ACADEMY OF SCIENCES (IICT-BAS)

With Order No. 276/06.11.2024 of the Director of IICT-BAS, I have been appointed as a member of the Scientific Jury in connection with the procedure for obtaining the educational and scientific degree "Doctor" in doctoral program 4.6, professional field "Informatics and Computer Science" by Petar Zhivkov with a dissertation on the topic "Modeling the Quality of Atmospheric Air on Health and Economic Aspects," supervised by Prof. D.Sc. Stefka Fidanova, IICT-BAS. At the first meeting of the Scientific Jury, held on November 11, 2014, at IICT-BAS, I was elected as a reviewer.

1. Research Area, Relevance, Objectives, and Tasks

The presented dissertation by Petar Zhivkov focuses on an undeniably current and developing area within informatics and mathematical modeling.

The dissertation is dedicated to modeling the quality of atmospheric air and studying its impact on human health and various aspects of the economy.

The research work presented in the dissertation is focused on innovations in one of the dynamic areas of contemporary research related to air quality. The motivation and application object of this work stem from the importance of analyzing the health and economic consequences of three main pollutants in European cities, namely: fine particulate matter (FPM), nitrogen dioxide, and ozone. The results show that FPM is the primary cause of economic damage due to diseases and mortality caused by dirty air. Therefore, there is a growing need for models that can investigate acute condition morbidity based on air quality data. There is an urgent need for comprehensive research efforts and improved data collection methods to overcome existing knowledge gaps and pave the way for informed decision-making in the fight against PM pollution and improving health quality in large cities, particularly in Sofia.

The main goal of the dissertation is to investigate the influence of FPM on acute illnesses in Sofia and to find prevention methods. To achieve this goal, the following tasks have been formulated:

Task 1: Finding a correlation between fine particulate matter and health indicators for acute morbidity in Sofia.
Task 2: Improving data from citizen stations measuring air quality through calibration using machine learning: a two-step method.
Task 3: Developing a software tool for optimizing and evaluating bicycle routes by characterizing cyclists' exposure to air pollution.

Task 4: Developing an IoT platform for aggregating and modeling sensor data on air quality.

2. Understanding the State of the Problem by the Dissertation Author

It is clear to me that the dissertation author, Petar Zhivkov, has a good understanding of the subject matter, the current state, and the results achieved so far in solving the tasks set out in the dissertation.

3. Methodology of the Study

The reviewed dissertation uses a multidisciplinary approach combining quantitative analysis and statistical modeling. A systematic review of existing studies was conducted to summarize and synthesize current evidence on the relationship between air quality and health outcomes. Epidemiological studies and data from health monitoring agencies were analyzed to quantify the relationship between specific pollutants and health outcomes. Data on admissions and hospitalizations from two major hospitals in Sofia, emergency registry data, and measurements of FPM from both official environmental agency stations (Executive Environment Agency - EEA) and citizen laser stations were collected and used. Meteorological data, including humidity, atmospheric pressure, temperature, and traffic data, were also gathered.

An important part of the work is the developed model for optimizing cycling routes to minimize FPM inhalation. This includes using a modified shortest path algorithm and conducting real-field tests to validate the methodology. A new approach for aggregating, organizing, processing, modeling, and exchanging data in the IoT system was applied. The methodology presented allows for a comprehensive analysis of the impact of FPM on acute illnesses, calibrating citizen laser stations, visualizing data through the IoT platform, and optimizing cycling paths to reduce FPM inhalation.

4. Characterization and Evaluation of the Contributions of the Dissertation

Petar Zhivkov's dissertation consists of six chapters: an introductory chapter followed by four chapters addressing each task and a conclusion. The dissertation contains 115 pages, 17 tables, 12 graphs, and 108 literary sources.

In the second chapter, an analytical overview of the impact of FPM on acute illnesses in Sofia is provided. Data from two major Sofia hospitals (Pirogov Emergency Medical Institute and Tokuda Hospital) and cases in the capital's emergency services are examined. Changes in hospital admissions and hospitalizations during days of air pollution above and below the World Health Organization (WHO) healthy norms are compared. The necessity of using citizen laser stations to supplement representative data from official Ministry of Environment and Water (MOEW) measurement stations is justified. The results of this chapter are published in article [102].

In the third chapter, a two-step automatic calibration method for data from citizen laser stations measuring FPM using controlled and uncontrolled "machine learning" models is presented. Official MOEW measurement stations are used as reference data. The influence of humidity, atmospheric

pressure, and temperature on the models is investigated and included. Five "machine learning" models are used to calibrate the data, and their accuracy is compared. The results of this chapter are published in article [101].

In the fourth chapter, a model for finding the "most suitable cycling route" to minimize cyclist FPM inhalation is described. For this purpose, a modified shortest path algorithm is used. An experimental implementation and validation of the developed methodology through real-world tests are performed. Results from pollution and FPM inhalation on two routes – the one proposed by the software and a route following bike lanes – are compared. The results of this chapter are published in article [103].

In the fifth chapter, the process of developing an IoT platform architecture is described, using a new approach for data aggregation, organization, intelligent processing, and exchange in the IoT system. The construction of the system, which displays the location and indicators of measurement stations on a geographical map, is described in [104].

The sixth chapter contains the conclusion, summarizing the results obtained in the dissertation and outlining the scientific and applied contributions. Future research and development directions are identified, and strategies for addressing challenges related to air pollution and its impact on human health are proposed.

The main scientific and applied contributions of the dissertation can be summarized as follows:

Scientific and Applied Contributions:

1. Statistical analysis of the correlation between air pollution and hospital admissions and emergency services is performed, identifying important causal relationships.
2. An algorithm for calibrating laser sensors using a two-step method with artificial neural networks and anomaly detection is developed. This innovative method supports more reliable and accurate measurements from laser sensors and has the potential to be used in a wide range of sensor applications.
3. An algorithm assessing the influence of humidity, altitude, and atmospheric pressure on air pollution data from laser sensors is developed. This allows for a fuller and more accurate understanding of factors influencing air pollution and can be applicable in vertical planning.
4. An algorithm for calculating the most suitable cycling route based on FPM concentration is developed. This routing method supports a healthy lifestyle and encourages sustainable urban mobility.

I agree with the statement made in the dissertation that the obtained results can be utilized in **applied fields of science and engineering practice**, which include:

1. Software for calibrating FPM data from laser sensors, taking reference data from official MOEW measurement stations. It is important that this software allows organizations controlling air quality to use more reliable data for decision-making and pollution management.
2. Software accounting for the influence of humidity, altitude, and atmospheric pressure and improving FPM data from laser sensors. This software can be used by city authorities and health

organizations to monitor and manage air quality in real time.

3. Software for finding the most suitable cycling route based on FPM inhalation. This software can be useful for individual cyclists and urban infrastructures promoting cycling.
4. An IoT platform for aggregating and analyzing sensor data on air quality. This software supports automation and facilitates data integration from different sources, improving the efficiency and accuracy of air quality monitoring. In addition to meteorological data, it integrates traffic data and GIS. The platform visualizes maps, supplementing them with air quality sensor measurements and current traffic status data.

Considering the research and results presented in this dissertation, we can conclude that this project brings significant scientific and applied contributions that affect the development and improvement of systems for measuring air pollution and related technologies

5. Publications on the dissertation

The dissertation work is based on **4 scientific publications, of which 3 have been published in specialized international journals with IF or SJR rank** referenced in the global referencing and indexing system and also published in international journals and conference volumes. According to the Regulations on the Specific Conditions for Acquiring Scientific Degrees and for Holding Academic Positions at IICT-BAS, the requirement is for three scientific publications, at least one of which must be in a journal with an impact factor or in a specialized international publication. In this sense, the necessary requirements are fully satisfied. The presented works were published in the period 2020 — 2024. One of the publications is independent, and the other three are co-authored.

The results in this dissertation work have been reported at various scientific forums, such as:

- International Conference FedCSIS 2021, held online;
- FedCSIS 2022 September 4-7, 2022, Sofia;
- Conference on Environmental Protection and Disaster Risks 2020, held online with over 80 participants from Europe.

The abstract correctly reflects the content and main contributions of the dissertation. It is 55 pages long and contains 81 cited sources.

6. Critical remarks

I have some critical remarks and recommendations to the doctoral candidate:

- I would suggest a slight modification of the title of the dissertation to more accurately reflect the content and contributions in it, namely: "Modeling Ambient Air Quality: Health and Economic Implications". Then the title in English would be: "Modeling Ambient Air Quality: Health and Economic Implications" and would be better than the current English translation: "Modeling the State

of Air Quality based on Health and Economic Aspects". This recommendation is in case the doctoral candidate subsequently publishes the results of the dissertation in a book.

• I would recommend that an even more in-depth analysis be made of the existing optimization algorithms for tasks related to data processing, analysis and forecasting. Since the input data are measured with a certain accuracy, I recommend the use of Global Sensitivity Analysis. This would improve the reliability of the forecast.

• I have identified some inaccuracies in individual formulations, which, however, do not lead to misunderstanding or distortion of the meaning of the statements.

I would like to note that these notes/recommendations do not spoil the good impression of the doctoral students work and the work done, but require greater precision and attention on the part of the doctoral student.

7. Personal Impressions

I know Petar Zhivkov as a PhD student in the Department "Parallel Algorithms and Machine Learning with the Laboratory of Neurotechnology" of IICT-BAS and I have a good opinion of him as a researcher. He is motivated to carry out scientific work, persistent in his goals and possesses good organizational and communication skills.

8. Conclusion

The dissertation contains results that have scientific and applied scientific contributions in the field of professional field "Informatics and Computer Science" and most of them have been published in specialized international journals with SJR rank. The presented dissertation meets all the requirements of the Act on the Development of the Academic Staff in the Republic of Bulgaria (ADSRB), as well as the Regulations for the Implementation of the ADSRB, the Regulations on the Conditions and Procedure for Acquiring Scientific Degrees and for Holding Academic Positions at the Bulgarian Academy of Sciences and the Regulations on the Specific Conditions for Acquiring Scientific Degrees and for Holding Academic Positions at the Institute of Information and Communication Technology-BAS. The critical remarks in this review in no way belittle the results obtained in the dissertation.

The above gives me grounds for a positive assessment of the presented dissertation work, with which I propose to the Scientific Jury to award the educational and scientific degree "Doctor" to Petar Rumenov Zhivkov in doctoral program 4.6, professional field "Informatics and Computer Sciences".

27th of January 2025

Signature:

На основание
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