Deep Learning-based Framework for Smart Sustainable Cities: A Case-study in Protection from Air Pollution

Nagarathna Ravi, Thiagarajar College of Engineering, Madurai, India
Vimala Rani P, Thiagarajar College of Engineering, Madurai, India
Rajesh Alias Harinarayan R, Thiagarajar College of Engineering, Madurai, India
Mercy Shalinie S, Thiagarajar College of Engineering, Madurai, India
Karthick Seshadri, National Institute of Technology, Andhra Pradesh, Tadepalligudem, India
Pariventhan P, Thiagarajar College of Engineering, Madurai, India

ABSTRACT

Pure air is vital for sustaining human life. Air pollution causes long-term effects on people. There is an urgent need for protecting people from its profound effects. In general, people are unaware of the levels to which they are exposed to air pollutants. Vehicles, burning various kinds of waste, and industrial gases are the top three agents of air pollution. Of these three top agents, human beings are exposed frequently to the pollutants due to motor vehicles. To aid in protecting people from vehicular air pollutants, this article proposes a framework that utilizes deep learning models. The framework utilizes a deep belief network to predict the levels of air pollutants along the paths people travel and also a comparison with the predictions made by a feed forward neural network and an extreme learning machine. When evaluating the deep belief neural network for the case study undertaken, a deep belief network was able to achieve a higher index of agreement and lower RMSE values.

KEYWORDS

Air Pollution, Deep Belief Network, Deep Learning, Health, IoT Sensors, Restricted Boltzmann Machine, Smart City, Smart Environment

INTRODUCTION

Contamination of nature’s resources that are very much necessary for the sustenance of flora, fauna and microbes on Earth is termed as pollution. There are several types of pollution namely: air pollution, water pollution, land pollution, sound pollution, light pollution, radiation pollution, thermal pollution etc. Out of these various types of pollution, air pollution leads to deaths of millions of humans each and every year across the world (Donahue, 2017). Air pollution is nothing but degradation of quality of air. Activities of humans are the major reason for the degradation of air quality. Air is said to be polluted when it is adulterated by a mix of particulate matter like particulate matter 2.5 (PM2.5) (particles that have size less than 250nm), particulate matter 10 (PM10) (particles that have size less than 1000nm) and other gases like sulphur dioxide (SO₂), nitrogen oxides (NOₓ), ozone (O₃), carbon monoxide (CO), etc. (Babadjouni et al., 2017). The pollutants can be in any of three forms.

DOI: 10.4018/IJIIIT.2019100105

Copyright © 2019, IGI Global. Copying or distributing in print or electronic forms without written permission of IGI Global is prohibited.
like gaseous, droplets and particle matters. Pollutants are also categorized as primary and secondary based on whether the pollutant is a direct result of human related activities or not emitted directly. Both the type of pollutants is hazardous in their own way. Kids, aged people and people with chronic diseases are affected by acute health issues when exposed to high levels of atmospheric pollutants (Bogdanovic et al., 2017).

Atmospheric pollution is known to create a hike in the rate of morbidity and mortality, thereby reducing the life expectancy (Delpont et al., 2018). There are various studies that substantiate the positive correlation between the exposure to atmospheric pollutants and cancer, death due to stroke and the triggering of stroke (Delpont et al., 2018). Smog has also been evident in playing a role in cardiovascular diseases such as heart failure, atherosclerosis, cardiac arrest and arrhythmias (Mishra, 2017). Also, there are research studies that have found positive correlation between diabetes and NO\textsubscript{x} (Renzi et al., 2018). There also exists a significant association between the diabetes in women of age less than 50 years and the secondary air pollutant O\textsubscript{3} (Renzi et al., 2018). Various classes of diseases that affect the respiratory system, digestive system, blood circulatory system, ophthalmological system, connective tissue, musculoskeletal, system of metabolism and genitourinary system have been associated with the primary air pollutants like PM2.5, PM10 and NO\textsubscript{x} (Chen et al., 2017). Even the primary air pollutant SO\textsubscript{2} has a strong association with mental disorders in people (Chen et al., 2017). It is also found that seasons play a vital role in diseases because of exposure to air pollutants (Chen et al., 2017). For instance, positive correlations between the mental disorder and the air pollutants was relatively lesser in cold seasons when compared to warm seasons (Chen et al., 2017). Exposure to primary pollutants also leads to cognitive dysfunction in children as well as elderly persons and other neurodegenerative conditions like Parkinson’s and Alzheimer’s diseases (Babadjouni et al., 2017). There has also been evidence that when pregnant ladies are exposed to air pollutants persistently, it leads to miscarriage (Ha et al., 2017). Exposure to PM2.5 not only affects health, but also leads to increase in psychological distress (Sass et al., 2017). Air pollutants also leave its footprints on climatic system by bringing about changes in the pattern of weather and temperature, which ultimately leads to loss in the crops (Ravina et al., 2017). This subsequently leads to a market equilibrium shift in the food supply chain (Sun et al., 2017).

Health hazards related to air pollutants are not in general taken up seriously or given importance except in major incident cases such as leakage of gases from the chemical industries, Chernobyl radioactive fallout incident, Bhopal explosion and other incidents that required immediate action and has turned out to be cases of public concern (Black et al., 2017). Air pollution and its effects are by nature invisible and there is a need to protect people by minimizing their exposure to air pollutants. Air pollution is high in places where the traffic density is higher (Woodward et al., 2015). There are studies that show that reduction in vehicular pollutants will significantly reduce the air pollution (Kishimoto et al., 2017). It is obvious that the air pollutant levels are higher in roads and outdoor than in indoor region. Hence, it is necessary to protect commuters from being exposed to air pollutants.

Due to the applicability of the wireless sensor network (WSN) nodes in effectively monitoring or sensing a region and the cooperation of WSN in the transmission of sensed data, WSN finds its application in environmental care (Sasirekha et al., 2017). Moreover, it is necessary to provide cognition to the system in order to be effective in addressing the problem. Of the variety of machine learning algorithms that are capable of providing intelligence to the system, deep learning has the capability of extracting hidden information in huge data space and aids in making decision. So, we have proposed the usage of deep learning and Internet of Things, (which is a form of WSN) in order to protect Indian people from getting exposed to high levels of air pollutants.

The next section provides an overview of the various related research works; the third section describes in detail the proposed framework; the fourth section provides the results of the evaluation of the proposed framework applied on Madurai, India and the final section provides a conclusion and possible future extensions to the framework.