THE COOPER UNION FOR THE ADVANCEMENT OF SCIENCE AND ART
ALBERT NERKEN SCHOOL OF ENGINEERING

Computer Vision for Vehicle Emission Estimation

By

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A thesis submitted in partial fulfillment of the requirements for the degree of
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Advisor

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This thesis was prepared under the direction of Carl Sable and has received approval. It was submitted to the Dean of the School of Engineering and the full Faculty, and was approved as partial fulfillment of the requirements for the degree of Master of Engineering.

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Abstract

Hello

Contents

1 Introduction

1.1 Motivation

Urban air pollution remains one of the most critical public health and environmental challenges of the twenty-first century. The World Health Organization (WHO) estimates that approximately 99% of the global population breathes air containing pollutant concentrations that exceed guideline limits [1], [2]. In 2023 alone, air pollution contributed to 7.9 million deaths worldwide, with 86% of these attributed to noncommunicable diseases such as cardiopulmonary conditions and lung cancer [2]. Beyond its immediate health impacts, atmospheric pollution catalyzes broader environmental degradation. Short-lived climate pollutants and greenhouse gases contribute to global warming, weather variability, and the intensification of the water cycle, which in turn threatens infrastructure and coastal settlements [3], [4].

Road vehicles are the central driver of both the climate and health aspects of this crisis. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report notes that direct greenhouse gas (GHG) emissions from the transport sector accounted for 23% of global energy-related CO_2 emissions in 2019 [5]. Of these, 70% originated specifically from road vehicles [5]. Without intervention, transport emissions are projected to double by 2050, driven by increasing vehicle ownership in developing economies [6]. In urban environments, these emissions are particularly consequential because they are released at ground level along the very corridors where people live, work, and commute, creating immediate exposure risks [3].

New York City (NYC) serves as a critical intersection of dense population, heavy traffic activity, and measurable health burdens. As of July 2024, there are 8.48 million residents in all five boroughs, with (x amount of people near major roadway/highway that is high risk exposure. ASK SABLE: should I try to find the number for this if I have the time? Like should I try to contribute as much as I can? I can't find a number past 2007) [7]. While the typical passenger vehicle emits approximately 411 grams of CO_2 per mile [8], it also releases pollutants toxic to human health, most notably fine particulate matter ($PM_{2.5}$). This pollutant is described by the NYC Department of Health and Mental Hygiene as "the most harmful air pollution for humans to breathe" as $PM_{2.5}$ penetrates deep into the lungs and enters the bloodstream, circulates throughout the body, and causes systemic inflammation [9].

The local impact of these emissions is quantifiable and severe. In New York City, $PM_{2.5}$ levels from all sources contribute to approximately 2,000 deaths and 5,150 emergency department visits annually [9]. 14% of local $PM_{2.5}$ is directly attributable to everyday car, bus, and truck traffic, resulting in an estimated 320 premature deaths and 870 hospitalizations each year [9]. In New York State, the combined health and climate costs attributable to passenger vehicles totaled approximately $7.9 billion in 2015, with health-related costs comprising two-thirds of that total [10].

Despite the well-documented impacts of transportation emissions, effective mitigation is hindered by the difficulty of accurate, timely measurement. Emissions from road vehicles are not distributed uniformly across space or time, but rather concentrated in specific "hotspots," vary by time of day, and depend heavily on vehicle composition. For instance, heavy-duty vehicles contribute disproportionately to nitrogen oxides (NOx) and particulate matter relative to light-duty cars [11], while congestion increases per-mile emissions through idling and stop-and-go driving. Consequently, understanding not only total vehicle counts but also the specific composition of traffic flows is critical for estimating localized emissions burdens.

Traditional emissions estimators, however, often rely on aggregate fleet statistics and modeled travel demand applied at coarse spatial scales. While indispensable for long-term planning, these methods often lack the granularity required to evaluate street-level exposure disparities. Similarly, fixed air-quality monitoring stations measure ambient concentrations but cannot directly attribute pollutants to specific vehicle classes or immediate traffic patterns. Furthermore, monitoring infrastructure is unevenly distributed globally. High-income regions typically possess denser monitoring networks, whereas many low- and middle-income countries lack adequate coverage, leaving large populations without reliable local air quality data [12].

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To address these limitations, this thesis proposes leveraging existing video infrastructure as a scalable monitoring tool. New York City maintains an extensive network of publicly accessible traffic cameras, offering a unique opportunity to generate high-resolution data without deploying new hardware. By applying computer vision techniques to identify vehicle classes and counts, combined with established emission factors, it is possible to generate spatially resolved estimates of traffic-related emissions. This approach does not replace traditional air-quality monitoring but complements it, providing a granular view of how traffic composition drives environmental health impacts. Moreover, this methodology offers a potential blueprint for regions with limited monitoring resources, suggesting that computer vision-based estimation could become an accessible, scalable tool for global environmental health monitoring.

2 Background Research

3 Dataset

4 Methodology

5 Experimentation and Results

6 Discussion

7 Limitations

8 Future Work

9 Bibliography

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