CTIPS Center for Transformative Infrastructure Preservation and Sustainability

USDOT Region 8 University Transportation Center

Artificial Intelligence and Mobile Phone-Based Pavement Marking Condition Assessment and Litter Identification

CTIPS-007 – Full Project Description

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Research Needs

Pavement marking, as a critical transportation infrastructure and asset, aims to effectively convey regulations, guidance, or warnings to road users to ensure safety (FHWA, 2009). As a result of wear and tear exacerbated by heightened traffic demands, inclement weather conditions, and snowplow operations, pavement markings are bound to experience degradation issues, including either faded or complete loss of markings (Sassani et al., 2021; Xu et al., 2021). Hence, pavement markings typically only have a short service life of only 0.5-3 years (Alzraiee et al., 2021). Degraded markings are a serious issue for drivers and pedestrians, easily leading to accidents (Kawano et al., 2017; Sassani et al., 2021). To ensure road safety, pavement markings need to be assessed and fixed periodically. However, traditional pavement marking inspections either rely on manual efforts, which are subjective, labor-intensive, and time-consuming, or need professional inspection devices, e.g., retroreflectometer (Pike et al., 2011; Wei et al., 2021). Due to the low efficiency and high cost, manual inspection cannot be carried out on a large scale and frequent basis. For these reasons, a lightweight, efficient, and low-cost approach is critically needed to inspect pavement markings.

Another issue in the daily management of roadways is litter (Chamberlin et al., 2021), such as construction debris, vehicle debris, food containers/wrappers, plastics, and leaves, strewn across the street roads, which easily lead to blockage of the roadside drainage system (Karimi & Faghri, 2021; Mullaney & Lucke, 2014) and posing significant hazard to road users by introducing traffic accidents. A research report by the AAA Foundation for Traffic Safety indicates that, over the year of 2011-2014, an estimated average of 50,658 police-reported crashes in the US were attributed to road debris, resulting in approximately 9,800 injuries and 125 fatalities annually (Tefft, 2016). Therefore, maintaining a clean and hygienic pavement is an important task for traffic safety and municipal works (Ramalingam et al., 2021). Similar to pavement marking issues, current practices for identifying litter on the roadside rely on the manual process, which is repetitive and laborious (Gómez et al., 2022). Hence, there is a pressing demand for an intelligent and efficient way to identify the litter on the roadways.

One way to develop an efficient and automated approach to inspect pavement marking and identify litter is the utilization of artificial intelligence (AI), such as computer vision and deep learning algorithms. The advancement of AI has enabled automatic inspection of transportation assets through object detection and classification with high accuracy and at a nearly real-time speed (Krizhevsky et al., 2017; Redmon et al., 2016). An example of this application is the identification of pavement distresses, such as cracks and potholes (Du et al., 2020; Ghosh & Smadi, 2021; Majidifard et al., 2020). A few studies focused on the recognition and extraction of pavement markings for automated driving assistance (Kawano et al., 2017; Liu et al., 2017; Park et al., 2023). However, less attention has been devoted to assessing the condition of pavement markings and identifying litter on the roadways.

Research Objectives

Based on the practical needs mentioned above, this project aims to propose a lightweight, efficient, and automated approach to inspect the condition of pavement markings and identify the litter on the roadways, with the assistance of a mobile phone and artificial intelligence. An AI toolkit for inspecting transportation assets will be developed in this research project, including the following capabilities:

1) Auto-identifying the pavement marking issues and the litter on the roadways.
2) Auto-counting the number of identified issues;
3) Auto-geolocating the identified issues;
4) Visulizing and demonstrating the detected results, including issue type, location, and condition.

Research Methods

To achieve the above research objectives, Artificial Intelligence algorithms (e.g., deep learning) will be developed to inspect pavement marking conditions and identify litters on the roads. Deep learning has demonstrated remarkable capabilities of accurate and efficient identification of objects in images and videos. Also, object tracking and counting algorithms, involving continuously counting objects across frames in a video sequence, will be developed. These advanced AI models facilitate identification of pavement marking issues and litters on the roadways, as well as quantification of these identified issues from recorded videos.

Specifically, we will first review existing techniques and practices in inspecting transportation assets. Next, a mobile phone mounted on a vehicle will be utilized to collect the image data of the pavement, covering the object of interest. Based on the collected images, deep learning models (e.g., YOLO, R-CNN) will be customized for identifying marking issues and litter on the roads. Additionally, object tracking and counting algorithms (e.g., DeepSORT) and GPS tracker will be used to facilitate counting and locating the identified issues (i.e., pavement marking issues and litter) in different road sections under inspectation. The performance of the developed models will be validated and evaluated in different sections of highways, leveraging accuracy metrics in algorithm development.

Relevance to Strategic Goals

Pavement, as a critical transportation asset, needs to be inspected and maintained regularly, including repainting of pavement markings and cleaning litter on the roadways, to ensure its proper functioning and provide a safe environment to road users. The proposed work introduces an effective, cost-effective, and lightweight approach to inspect the condition of pavement markings and identify the litter on the roadways automatically, which would facilitate a larger-scale, more frequent, and more cost-efficient pavement inspection and maintenance. The proposed AI models in this project can serve as a valuable tool to enable effective pavement maintenance and preserve the existing pavement system in decent and safe conditions.

Educational Benefits

One PhD student from the Department of Civil & Environmental Engineering at the University of Utah will be involved in this project to develop AI models to inspect pavement markings and identify litter. Also, the research results will be shared in the graduate and undergrad courses of transportation and construction in the department to broaden the project impacts and demonstrate the capability of AI techniques for improved infrastructure maintenance practice.

Outputs through Technology Transfer

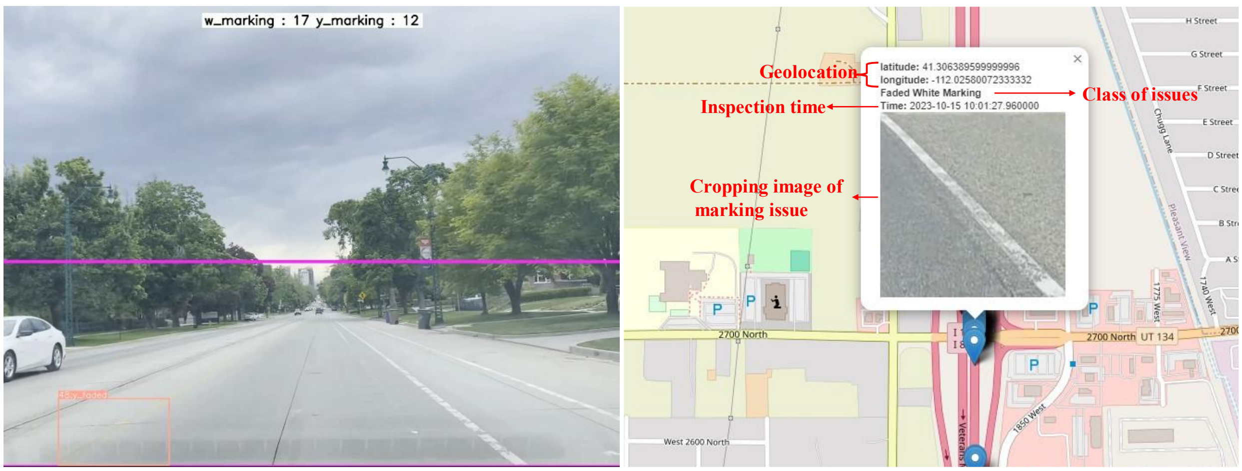
The developed models in this study provide an efficient, lightweight, and affordable solution to inspect pavement markings and pavement cleanliness. These works will be directly utilized in the practice of UDOT road asset maintenance. Meanwhile, the project outcomes will be documented and shared in conferences held by UDOT, the Transportation Research Board Meeting, and other journals in relevant fields. Also, the project impact will be broadened through YouTube videos the team will make and publish on the website to facilitate the technology transfer.

Expected Outcomes and Impacts

The expected outcomes of the project will be validated AI algorithms for auto-inspecting pavement marking conditions and auto-identifying litters on the roads without boot on the ground. The demonstration to identify the faded marking issues and litter on the roadways are presented in Figure 1. Also, the developed models can count the identified issues in a road section (as shown in Figure 2 (a)), which is critical information to determine to severity of these identified issues in this road section or if there exist any urgent maintenance needs. Besides, the developed models are able to locate the identified issues (as demonstrated in Figure 2(b)), informing specific locations that need maintenance in practice.

(a) Faded white dot lane marking (b) Black litter on the freeway

Figure 1 Identified Pavement Marking Issues and Litters



(a) Counting pavement marking issue (b) Locating identified pavement marking issue

Figure 2 Examples of Counting and Locating Identified Pavement Marking Issues

The developed models can be applied to infrastructure inspection. Once successfully deployed, the lightweight and affordable approach can be employed in the DOT vehicle fleet to help assess the conditions of pavement markings and pavement cleanliness efficiently and periodically, hence, contributing to enhanced road safety.

Work Plan

The major tasks involved in this project are listed as follows. The expected duration of the project is 15 months, and the project timeline is demonstrated in Table 1.

1) **Literature review**: review existing technologies and current practices in inspecting transportation assets (3 months).
2) **Data collection**: record road videos through mobile phones on the highways and local street roads (10 months).
3) **Identification of faded markings and litters**: develop and validate a model for pavement marking condition assessment and litter identification (8 months).
4) **Counting of identified issues** (faded pavement markings and litter): develop and validate a model to quantify the number of detected issues in a road section (2 months).
5) **Geolocation of identified issues**: develop and validate a model to locate where the identified issue is (2 months).
6) **Visualization of identified issues**: develop a visualization tool to demonstrate the identified issues, e.g., issue type, location, and inspection time (2 months).
7) **Project report preparation**: prepare the final project report (2 months).

Table 1 Project Schedule Timeline

Project Schedule (month)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Task 1: Literature Review	■	■	■												
Task 2: Data Collection			■	■	■	■	■	■	■	■	■	■			
Task 3: Issue Identification			■	■	■	■	■	■	■	■					
Task 4: Issue Counting										■	■				
Task 5: Issue Geolocation											■	■			
Task 6: Visualization												■	■		
Task 7: Final Project Report														■	■

Project Cost

Total Project Costs:	$100,000
CTIPS Funds Requested:	$ 50,000
Matching Funds:	$ 50,000
Source of Matching Funds:	Utah Department of Transportation

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