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Smart Highway Construction Site Monitoring Using Artificial Intelligence

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Introduction

The most important tasks of the construction industry are process monitoring and staying on schedule. However, conventional methods prove to be costly, time consuming, and inconsistent. This project developed a method to detect, classify, monitor, and track the equipment and other surrounding objects during the construction, maintenance, and rehabilitation of transportation infrastructure by using artificial intelligence and a deep learning approach.

It is known that conventional methods rely on manual observation and operation which include bias and can be confusing. For instance, on-site construction monitoring relies on cameras and sensors to automatically record data and take images and videos from the progress of a project. With AI, data can be taken without human interference and can replace traditional methods which are tedious and time-consuming. As AI models can monitor, evaluate, and predict potential risks, they can be suitable for the task of risk mitigation. Following the review of literature related to the use of AI and computer vision in construction monitoring, the following section discusses the goals and scope of the current project and a summary of approach to achieve the results.

The main research question in this project was "Can we detect and monitor various construction elements, including equipment, machinery, and workers by using videos captured during the construction, maintenance, and rehabilitation of transportation infrastructure projects and use the outcomes for process optimization, resource allocation, productivity analysis, improved work zone safety, and maximizing efficiency?" The proposed model employs Deep Learning (DL) and Computer Vision (CV) algorithms to increase the accuracy and speed of the object detection process in recorded videos.

Study Scope

This project developed and deployed a robust algorithm that can identify, detect, classify, and track different objects in the videos and images captured from the construction and rehabilitation sites, which were acquired from actual construction and rehabilitation projects in collaboration with Caltrans. The first portion of this study was focused on preparing a comprehensive database of annotated images for various classes of equipment and machinery that are commonly used in roadway construction and rehabilitation projects. The second part of the project focused on training the deep learning models and improving the accuracy of the classification and detection algorithms. The applications of the developed algorithms in this study include, but are not limited to, improving construction efficiency, advancing the construction monitoring process, and improving work zone safety measures.

Study Methods

The combination of an extensive dataset, increased training epochs, and accelerated processing capabilities led to significant improvements in our model's performance metrics. We observed notable enhancements in confidence scores, indicating the model's increased certainty in its predictions. Additionally, the accuracy of object detection showed marked improvement, with the model demonstrating a higher rate of correct identifications and classifications across various object categories and environmental conditions. To streamline our data management processes, we developed several specialized scripts. These tools were designed to automate and optimize various aspects of data preprocessing and organization. One key script focuses on mapping classes, ensuring consistent and accurate labeling across the entire dataset. This is particularly crucial when dealing with large-scale datasets where manual classification can be prone to errors or inconsistencies. Another critical script in our toolkit is designed to detect images lacking proper labels. This quality control measure is invaluable when working with datasets comprising thousands of images. By automatically identifying unlabeled or mislabeled images, we can maintain the integrity of our training data. This process helps prevent the introduction of noise or inconsistencies into the model training, which could otherwise lead to reduced performance or biased outcomes. The implementation of these automated scripts significantly enhanced our ability to handle and process large volumes of data efficiently. This scalability is crucial in the context of deep learning, where the quantity and quality of training data directly impact model performance. Our approach not only improved the accuracy of our dataset but also reduced the time and resources required for data preparation, allowing us to focus more on model development and optimization. We evaluated the performance of AI and deep learning algorithms to compare their performance in detecting and classifying the equipment in various construction scenes. Several edge-case scenarios with crowded scenes, where the target objects are occluded with other objects, were investigated. The detection accuracy and performance of the preliminary model were improved once we developed the image database. The developed model was able to detect and classify the most critical objects. Our goal was to find the optimized balance between the model capabilities in object detection and memory processing requirements.

Findings

The dataset collected and processed in this project is one of the most unique and specifically designed datasets that have been developed for the classification of highway construction machinery. The outcomes of the trained and improved deep learning classification model are promising in terms of the precision and accuracy of the model in detecting specific objects at a highway construction site. The model achieves high confidence scores, typically above 0.8, for diverse equipment including mobile cranes, dump trucks, and excavators. Lastly, the third set is performance from random images linked together. Our model also demonstrates robust performance in new scenarios, maintaining high confidence scores on unseen images (with all images meeting a floor of 0.8 and reaching highs of 0.95 for graders and compactors). Judging from the precision-recall curves, the model achieves both high precision and high recall simultaneously, suggesting excellent practical utility for construction equipment detection tasks that can improve safety and efficiency. It should be noted that the scope of this project was limited to the image and video data recorded from the ground level and cannot be extended to data captured by drones. Identification and detection of specific construction machinery from drone footage requires a separate dataset specifically curated for aerial imagery which can be pursued in the future.

Policy Recommendations

This study provides valuable insights into the potential of AI and deep learning to improve monitoring and enhance the efficiency of transportation infrastructure construction. Building upon these advancements, future research can focus on further refining the data processing pipelines and exploring more sophisticated model architectures. The focus will be to implement adaptive learning rates and advanced regularization techniques to push the boundaries of the model performance. Additionally, future research can investigate transfer learning approaches to leverage pre-trained models, potentially accelerating the training process for specific object detection tasks while maintaining high accuracy levels. The vision AI model developed in this study was able to extract valuable information from complex highway construction sites.

To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2336

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