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Automated Measurement of Heavy Equipment Greenhouse Gas Emission: The Case of Road/Bridge Construction and Maintenance

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Road/bridge construction and maintenance projects are major contributors to greenhouse gas (GHG) emissions such as carbon dioxide (CO2), mainly due to extensive use of heavy-duty diesel construction equipment and large-scale earthworks and earthmoving operations. Heavy equipment is a costly resource and its underutilization could result in significant budget overruns. A practical way to cut emissions is to reduce the time equipment spends doing non-value-added activities and/or idling. Recent research into the monitoring of automated equipment using sensors and Internet-of-Things (IoT) frameworks have leveraged machine learning algorithms to predict the behavior of tracked entities. In this project, end-to-end deep learning models were developed that can learn to accurately classify construction equipment activities based on vibration patterns picked up by accelerometers attached to the equipment. Additionally, relationships were studied between the equipment activities and the emissions that they generate.

Study Methods

Data was collected from two types of real-world construction equipment, both used extensively in road/bridge construction and maintenance projects: excavators and vibratory rollers. The validation accuracies of the developed models were tested of three different deep learning models: a baseline convolutional neural network (CNN); a hybrid convolutional and recurrent long short-term memory neural network (LSTM); and a temporal convolutional network (TCN).

Findings

It was seen, across all of the measurements taken, that the new TCN model is competitive with the previous reigning champion, DeepConvLSTM. In fact, it beats DeepConvLSTM in terms of validation accuracy every time, yet it is faster to train and simpler to explain. The most notable differences in performance occurred in the two excavator experiments, which are challenging datasets because they include many activities that sometimes occur together to such a degree that the authors could only label the activity during such instances as Various. In the first excavator experiment, DeepConvLSTM managed a validation accuracy of 77.6%, with its mistakes largely coming from confusion related to the Various label. Eliminating the Various label from consideration and rebalancing the data set by adjusting the remaining number of Idle labels allowed its accuracy to rise to 82.5%, but the TCN managed to achieve 83.4% validation accuracy regardless of whether the Various label was present. In the second excavator experiment, we see a similar trend. It seems that DeepConvLSTM tended to get confused by the Various label, but the TCN fared much better. The TCN achieved a validation accuracy of 78.8%.

Cut the carbon footprint and fuel use of heavy equipment in road/bridge projects through deep learning models.

Policy/Practice Recommendations

Using deep learning methodologies can significantly increase emission estimation accuracy for heavy equipment and help decision-makers to reliably evaluate the environmental impact of heavy civil and infrastructure projects. Reducing the carbon footprint and fuel use of heavy equipment in road/bridge projects have direct and indirect impacts on health and the economy. Public infrastructure projects can leverage the proposed system to reduce the environmental cost of infrastructure project.

About the Authors

Dr. Reza Akhavian is an Assistant Professor at the Department of Civil, Construction, and Environmental Engineering at San Diego State University (SDSU) and was formerly an Assistant Professor of Construction Management at the School of Engineering, California State University East Bay (CSUEB). Dr. Akhavian's research interests are in the areas of information technology, data analytics, machine learning, and automation and robotics for different civil engineering and infrastructure management applications.

To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/1852.

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