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Recognizing Construction Equipment Activities Using a Smartphone

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-David Engelhaupt, Civil Engineering

Introduction

The purpose of this research is to develop a smartphone based system to continually analyze construction equipment activity (e.g. a skid loader moving forward, side-ways, or raising its bucket) using a variety of different sensors and give feedback to the equipment operator or the supervisor. Such a system could detect inefficiencies in construction operations and provide valuable information to project managers.

Related Work

Research in this field has been growing a lot in recent years. Vision based tracking has been a very popular avenue to track movements of construction equipment, but has many limitation especially in regards to mobility. On-board diagnostic systems are by far the most popular within the industry but it is hindered by its high costs and compatibility issues with older machines. RFID and GPS approaches are also popular and inexpensive in comparison, although it lacks the ability to sense stationary movements.

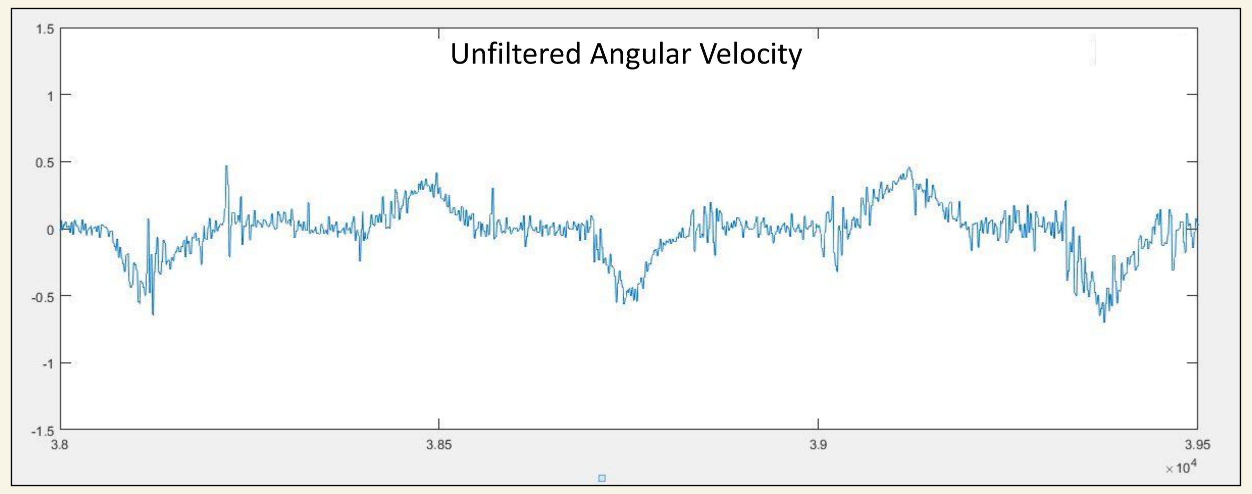
Data Collection

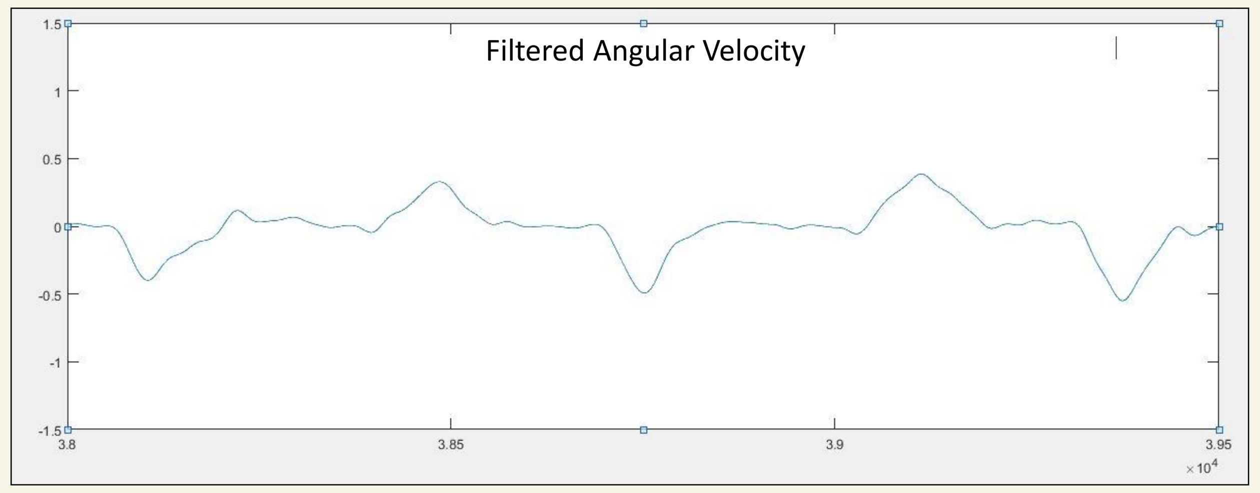
All data was collected by the smartphone. In our experiments we utilized the accelerometer and gyroscope sensors in all three dimensions of movement (x, y, z). These sensors were the ones utilized to detect the machine's movements. The gyroscope gave us information about the machine's orientation, for example if it is on an incline this would measure the degree of the slope. The three-axis accelerometer served the purpose of a vibration sensor.

Analysis & Classification

After data collection was completed, it was analyzed in the lab. The video data was time-stamped at one second intervals of the activity that the construction equipment was performing. The time-stamped data was then fed into a machine learning algorithm and data classifier program known as Weka.

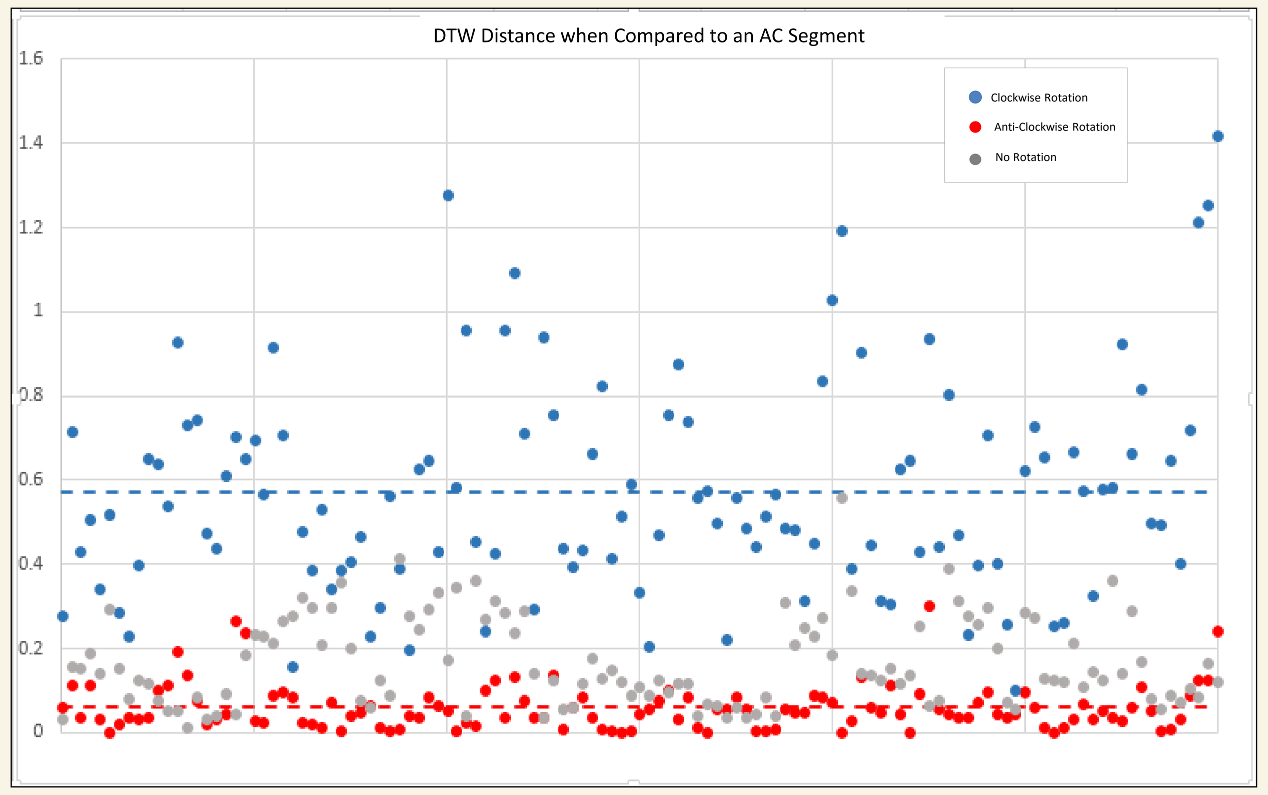
Since the smartphone may be placed in the cab at any orientation, the data must be re-oriented to match the axis of the construction equipment. This is done by detecting the acceleration due to gravity and calculating a rotation matrix to apply to the data. After re-orientation a 4th order low-pass filter is applied to reduce noise.

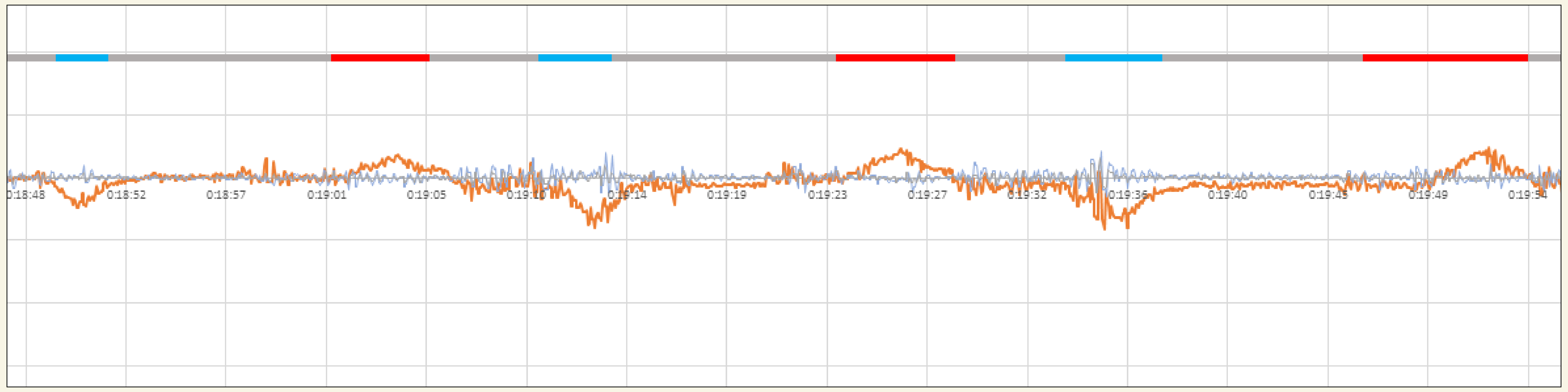




Several key features are calculated from the oriented and filtered data and used by Weka to classify the activities. Since the acceleration and gyroscope readings are highly time-series dependent, dynamic time warping (DTW) is used as a feature. Dynamic time warping measures the similarity between two segments that may be warped in time. DTW is very effective at distinguishing between clockwise and anti-clockwise rotation but has not been effective at determining if rotation is occurring. This may be improved by accurate segmentation.

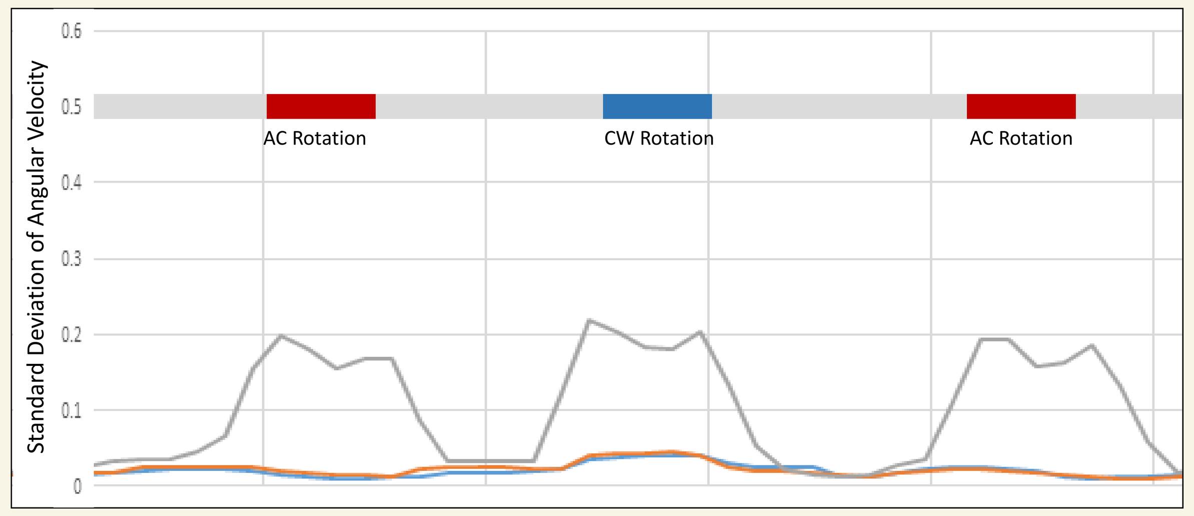
In order to compute distances by DTW the data must first be segmented. Segmenting based on a fixed window was attempted but did not provide sufficient accuracy. Segmenting based on changes in standard deviation is being tested.





Results

The results have demonstrated that DTW is effective at identifying typical rotation patterns. It has been less effective for slow rotations over long duration or very fast rotations with short durations. The accuracy of DTW is improved when the data is accurately segmented. Use of standard deviation to segment the data is very promising. Current work involves determining the most effective window to calculate standard deviation on, and an appropriate threshold value to use for segmentation.



Implications

This project can provide improvements in environmental conservation, economic efficiency, and safety on the job site. Construction equipment has been largely ignored in the pursuit of fuel economy and emissions reduction. It is essential to reduce carbon dioxide emissions because of the growing threat of climate change. The application that is created from this research could be used by contractors to mitigate the environmental impacts of construction by allowing them to keep track of the use of their equipment, its efficiency, and operator habits. Tracking operator habits has the potential to decrease equipment-related safety accidents, which account for 17% of fatalities in construction (Bureau of Labor Statistics, 2012). This could be done by watching for unsafe driving practices or reviewing the data from the multi-sensor hub after an accident occurs to analyze the situation that caused it. To achieve these goals a lot more work needs to be done but this research is step in the right direction and has the potential to revolution construction equipment use and efficiency.

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