Strain Response Shape Classification for Bridge Weigh-in-Motion Applications

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Introduction

Why Weigh Trucks?

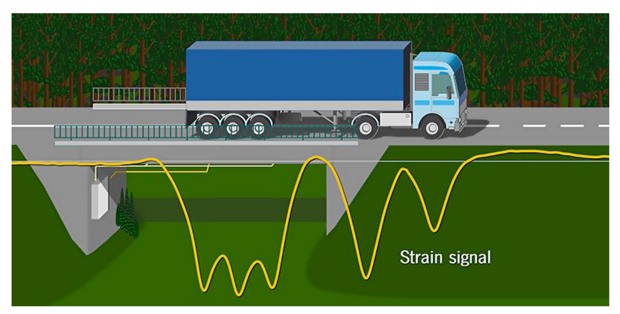
Due to their heavy load, trucks are predominantly responsible for the structural requirements of transportation infrastructure. Collecting data about these vehicles allows for improved…

- Load estimation for design
- Maintenance planning
- Enforcement of vehicle load limits

What is Bridge Weigh-in-Motion?

- A non-intrusive alternative to traditional static weigh stations
- Typically utilizes strain data collected during the passing of a vehicle over a bridge
- Can be used to determine data such as gross vehicle weight, axle weights, and vehicle classification

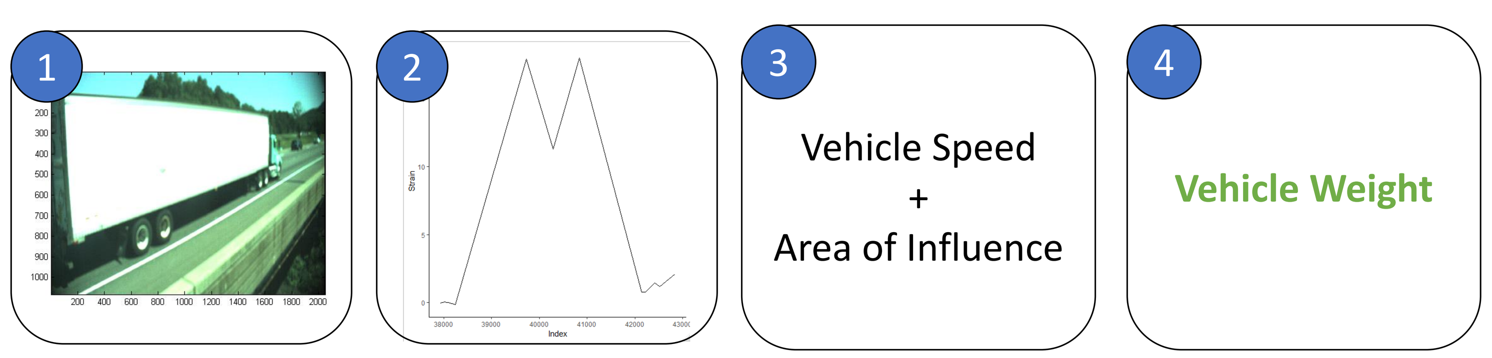
- Expensive to operate
- Interrupts traffic flow
- No continuous monitoring



+ Non-intrusive
+ Cost effective
+ Continuous data collection

BWIM Research in Connecticut

A substantial amount of BWIM research in Connecticut has been conducted using an apparatus installed on a highway bridge in Meriden, CT. This research evaluates raw strain readings from this system in addition to the output of a previously implemented, typical BWIM algorithm (Kolev). The graphic below provides a visual representation of the algorithm.



****Entire weight calculation is dependent on strain response****

Classification of the Strain Response

Motivation for the Classification of Strain Response Shape

A BWIM algorithm's performance is dependent on the strain response, the characteristics of which are determined by a vehicle's weight and axle configuration. The response shape is a high level descriptor that can contextualize algorithm output during analysis.

Procedure for Developing a Classifier for Strain Response Shape

Annotating the data is necessary to develop a classifier, however it is prohibitive to do so manually as…

- Each "truck event" is a sequence of strain readings, not an individual data point
- The response shape is often ambiguous

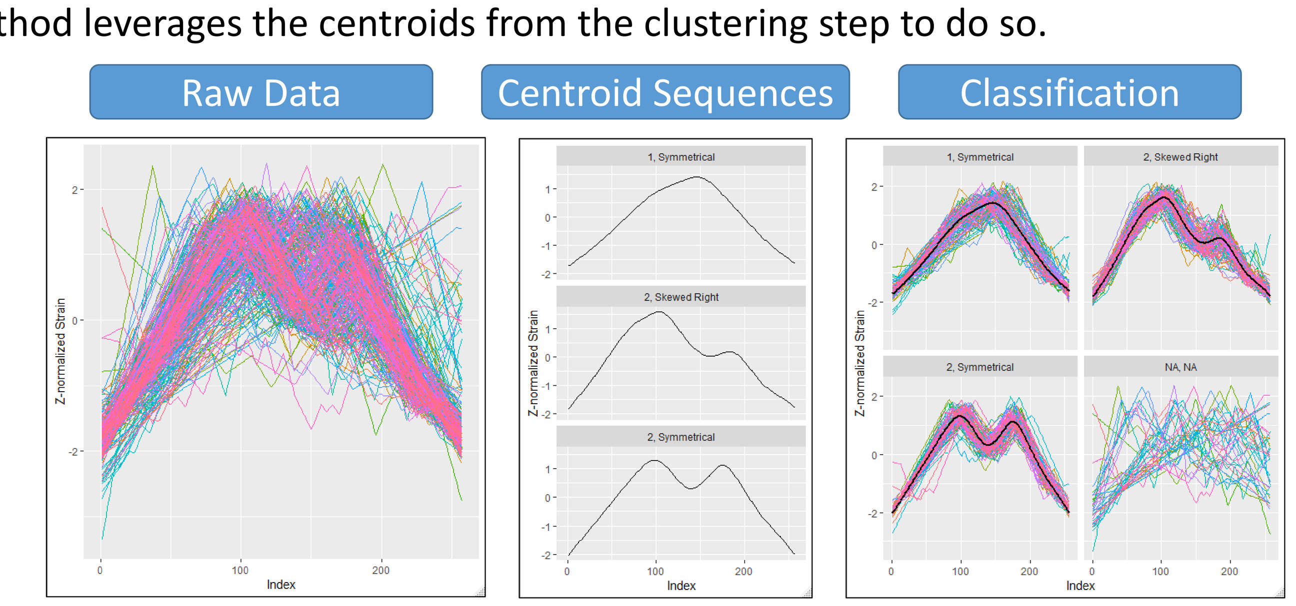
In other words, it is difficult to correctly and consistently identify the most relevant patterns within the data. For this reason artificial intelligence is leveraged.

1. Sampling Raw Data
80% of the total sequences are sampled to develop the classifier

2. Shape-Based Clustering
The k-Shape algorithm (Paparrizos and Gravano) is applied to cluster the sequences with similar shapes. The algorithm…

- Is partitional, meaning that the number of target clusters is predetermined
- Utilizes a "shape-based-distance" that identifies similarity regardless of phase and (or) scale distortion
- Returns centroid sequences, artificial sequences of readings that are representative of their respective cluster

3. Classification
A 1-nearest-neighbor classifier is implemented to classify unlabeled query sequences. This method leverages the centroids from the clustering step to do so.



****80% Classification Accuracy****

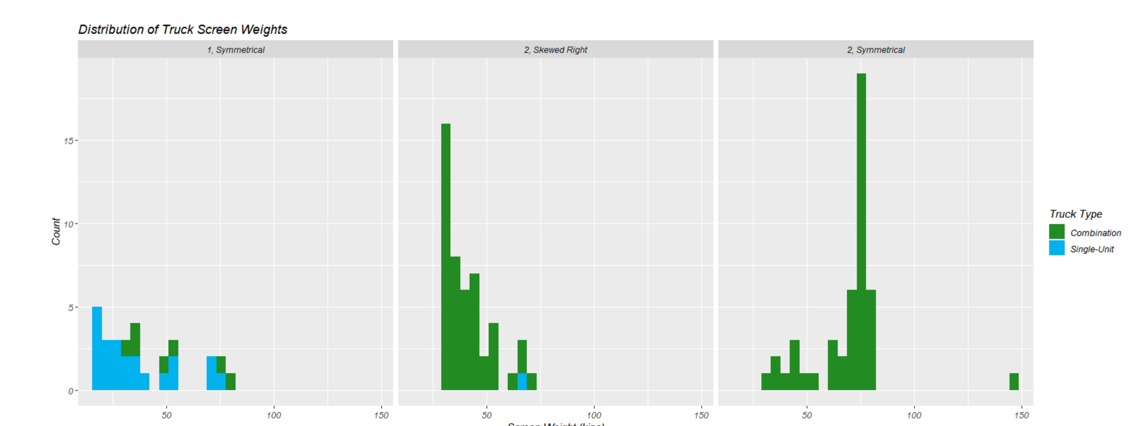
Results

Association with Physical Truck Characteristics

159 of the truck events in the data set had corresponding pictures of the vehicle which allowed for classification using the FHWA 13-Category system. 129 of the truck events had corresponding screen weights. Analysis indicates that…

Vehicle Type	Response Shape: 1, Symmetrical	Response Shape: 2, Skewed Right	Response Shape: 2, Symmetrical
Single Unit	30	1	0
Combination	10	56	57

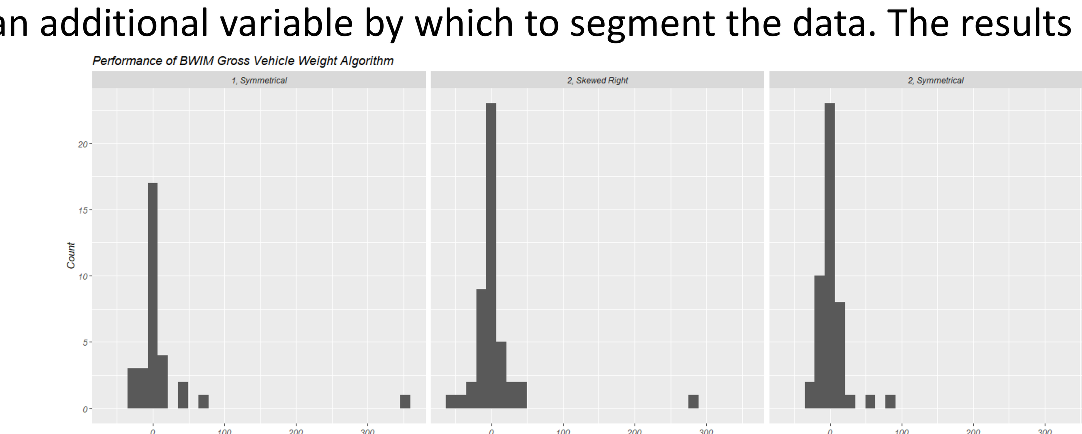
The number of peaks differentiates between single-unit and combination vehicles



The two peaked shapes correspond to partially and fully-loaded combination vehicles

Evaluation of a Typical BWIM Algorithm

The performance of the typical BWIM algorithm was evaluated using classification of strain response as an additional variable by which to segment the data. The results indicate that….



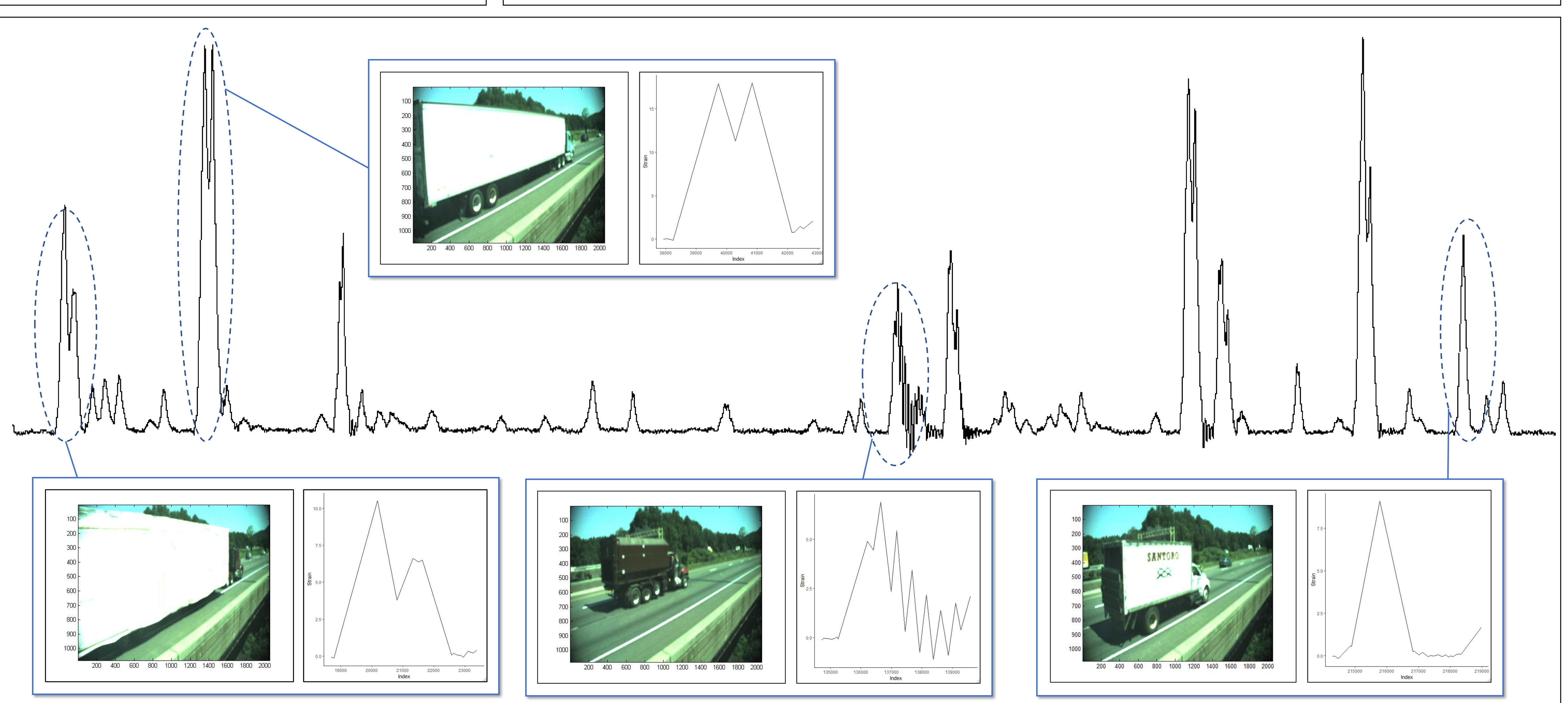
The algorithm's performance is uniform across the entire domain

Data Sample

The data set for this project was collected over a period of four days . 452 distinct "truck events" were detected during this period. The figure to the right is a 2 minute sample of the data set. This sample contains…

- Strain responses of varying magnitude
- Strain responses of varying shape
- Multiple of truck types

These observations demonstrate the variability of strain response within the domain and the association between vehicle type and strain response.



Conclusions

This research demonstrates that the proposed procedure can successfully classify strain response shape. The classification is relevant to BWIM applications as it provides insight into the underlying strain response and properties of the vehicle which enacted said response without requiring the entire sequence of strain readings to be stored. The evaluation of the typical BWIM algorithm's performance demonstrates the merit of applying the procedure as it allowed for the algorithm to be validated across the entire domain.

Acknowledgments

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Citations

Kolev, V. I. Bridge Weigh-in-Motion Long-term Traffic Monitoring in the State of Connecticut. Master's Theses, 2015. 838.
Paparrizos, J. and L. Gravano. k-shape: Efficient and accurate clustering of time series. Proceedings of the 2015 ACM SIGMOD International Conference on Management of Data, 2015. 1855-1870.