Machine Learning Applications in Design and Analysis of Transportation Infrastructures

“In God, we trust. All others must bring data.” - W. Edwards Deming

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Challenges for DOTs

In 2013, 38.2 millions tons of freight moved everyday (FHWA, 2015).

By 2040, It will increased to 51.5 millions tons per day (FHWA, 2015).

Between 2008 and 2012, number of permits increased by 50% (FHWA, 2015).

24% of the bridges in US are functionally obsolete (ASCE, 2013).

Dwelling maintenance and rehabilitation budgets.

To provide well maintained and functional infrastructures for safer mobility!

New challenge: Autonomous and Connected Vehicles!
High Tech Autonomous Vehicles...

**VIDEO CAMERA**
Mounted near the rear-view mirror, the camera detects traffic lights and any moving objects.

**LIDAR**
A rotating sensor on the roof scans the area in a radius of 60 metres for creation of a dynamic, three-dimensional map of the environment.

**POSITION ESTIMATOR**
A sensor mounted on the left rear wheel measures lateral movements and determines the car’s position on the map.

**DISTANCE SENSORS**
Four radars, three in the front bumper and one in the rear bumper, measure distances to various obstacles and allow the system to reduce the speed of the car.

*CARRIE COCKBURN/THE GLOBE AND MAIL*  // SOURCES: GOOGLE; ARTICLESBASE.COM; WHEELS.CA
Same Infrastructures…
Same Infrastructures...
Same Infrastructures...

I hate potholes!
Machine learning can capture complicated relations and variables...

Source: Forbes
Oversize and Overweight Vehicle Permit Fee

\[ W = 500 \left( \frac{LN}{N - 1} + 12N + 36 \right) \]

Source: http://www.heavyhaul.net
Overweight Vehicle Fee for Bridges

National Bridge Inventory → Bridge Conditions and Characteristics → Service Life (SL) Predictor → Scenario 1: With Damaging Trucks

- SL 1 (e.g. 48 Years)
- SL 2 (e.g. 40 Years)

Scenario 2: Without Damaging Trucks

- SL 1 (e.g. 48 Years)
- SL 2 (e.g. 40 Years)
Vehicle Weight Distribution Estimation Over Entire Network

Gaussian Mixture Models + Elastic-Net (LASSO and Ridge Regression)
Predicting structural responses within an airfield pavement
Mechanistic Empirical Pavement Design Approach

**Inputs**
- Traffic
- Environment
- Structure

**Mechanistic**
- Calculate Pavement Responses (Critical Strains)

**Empirical**
- Longitudinal Cracking
- Alligator Cracking
- Rutting
JFK Airport Instrumentation

- Temperature Gauges
- Strain Gauges
- Pressure Cells

Layers:
- Portland Cement Concrete (20”)
- Asphalt Stabilized Base (10”)
- Crushed aggregates base (12”)
- Subgrade

Dimensions:
- 10”
- 16”
- 19”
- 20”
Response Prediction

- **Objective:** Predict the response within pavement at various depths using pavement temperature data and climatic data.
Results
Summary

• We have proved the power of ML for addressing the problems in transportation infrastructure management.

• Use ML based models for new challenges:
  • Quantify the effects on CAVs on infrastructures
  • Use CAVs to improve transportation infrastructure management

• The ultimate goal: Help accelerating the adaption of CAVs
Questions?