Investigation of Pavement Maintenance Support Applications of IntelliDrive^{SM}

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ABSTRACT

The goal of the project is to assess the feasibility of using typical vehicle sensor information to evaluate pavement quality. Specifically, it is desired to estimate the international roughness index (IRI) of the road section and identify potholes or other bumps in the road. Multiple vehicles traveling a section of road way can provide their sensor data via dedicated short range communication (DSRC) or another form of wireless data transmission. The collected data can be evaluated using various algorithms to determine IRI or quantify the severity of bumps in the road. If DOT's have estimates of the pavement quality for the road sections in their jurisdictions they can better leverage their resources to more effectively manage the roadways.

MOTIVATION

Can common vehicle sensor information be used to asses pavement quality in an Intellidrive^{sm} deployment?

- Having estimates of the IRI for the roadways can help DOTs better leverage resources
- Limited vehicle sensor availability
- Estimate the International Roughness Index (IRI)
- Determine if any potholes are on a given road section

VEHICLE SENSORS

Sensors which can potentially measure road quality

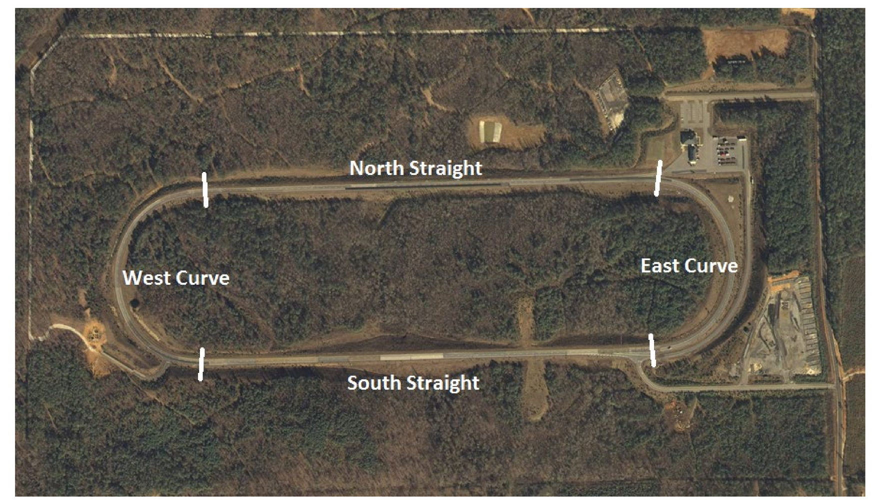
- Vertical accelerometer – used in SUV's for roll over detection
- Pitch rate gyroscope – uncommon in production vehicles
- Roll rate gyroscope – used for roll over prevention
- Suspension Deflection Sensors – active suspensions

Intellidrive^{sm} Deployment

- Passing vehicles broadcast their sensor data via DSRC
- Base station receives data and analyzes
- The roughness estimation will be more robust with more traffic
- Requires vehicles to store data for sections of road

TEST FACILITIES

National Center for Asphalt Technology Test Track



- 1.7 Mile Oval Track
- Track has pavement test sections from across the country
- Weighted trucks continuously drive around track
- A lifetime of pavement wear is compressed into a 2-year period

TESTING EQUIPMENT

2007 Infiniti G35

Road Profiling Van

Novatel PropakV3 GPS Receiver

Crossbow440 IMU

Kapsch MCNU

DATA COLLECTION

Track Roughness Data

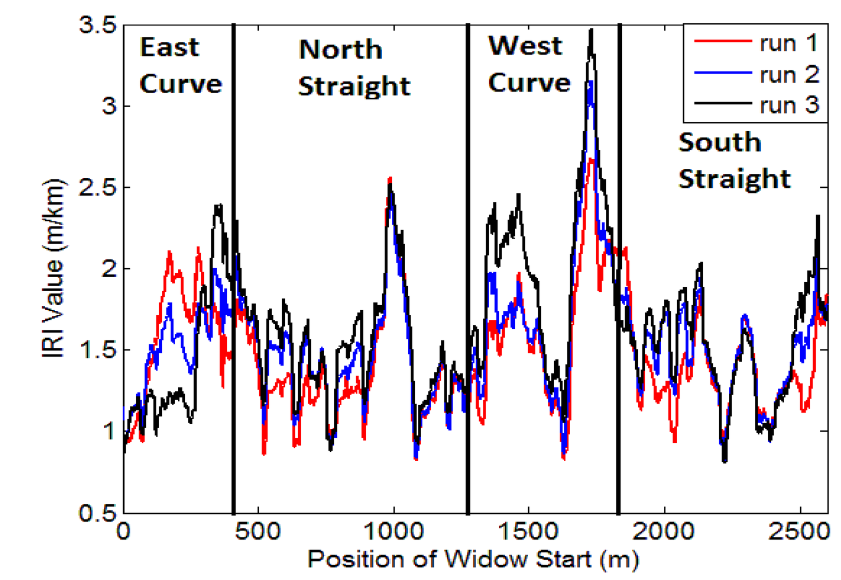
- NCAT profiling van was used to collect track profiles for right and left wheel path
- Three data runs were used
- IRI was calculated for each wheel path and the values were averaged (Mean Roughness Index)

Vehicle Sensor Data

- G35 driven around track at varying speeds 40-60MPH
- Data collection reset each lap based on GPS position
- Data can be broadcast using MCNU

IRI ESTIMATION

NCAT track IRI measurements

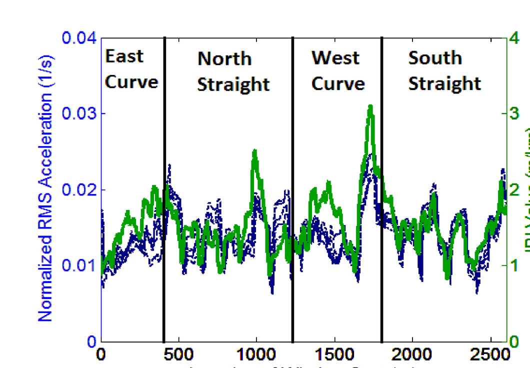


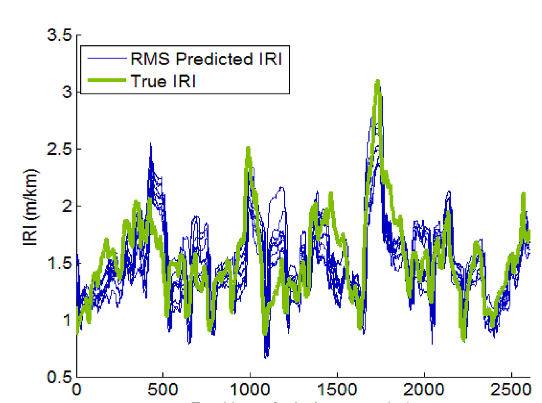
- 100 m sliding window for continuous calculation
- Variability in measurements
  - The bank on the turns can cause bias in data
- Average of three runs used as true IRI value

Root Mean Squared Vertical Acceleration

$$a_{z,rms} = \sqrt{\frac{1}{n}\sum_{i=0}^{n} {a_{z,i}}^2} \qquad a_{z,norm} = \sqrt{\frac{1}{n}\sum_{i=0}^{n}\left(\frac{a_{z,i}}{v_{x,i}}\right)^2}$$

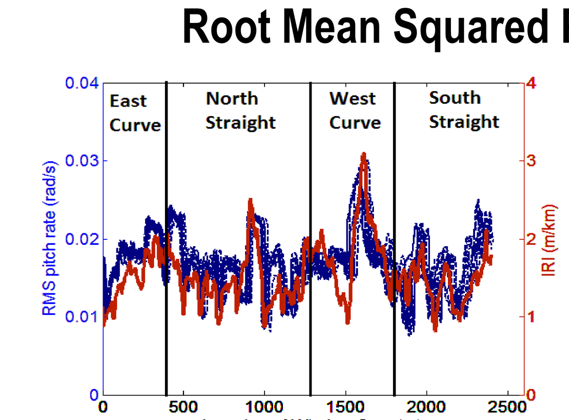
- RMS vert. accel. must be normalized to compensate for variation in vehicle speed

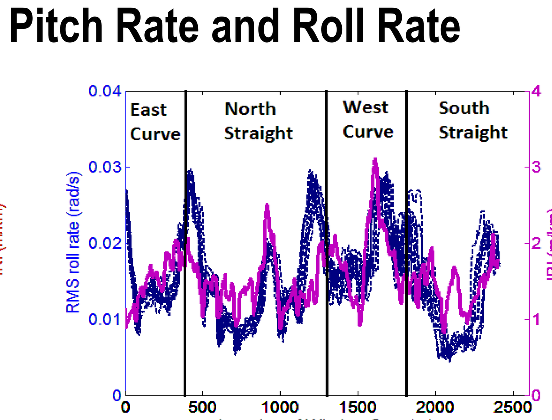




- Strong correlation between normalized RMS vert. accel. and IRI
- Normalized RMS vertical acceleration can be linearly mapped to IRI
- Estimate becomes biased when entering or exiting curves

Root Mean Squared Pitch Rate and Roll Rate





- Correlation exists between RMS pitch rate and IRI
- Entering and exiting the turns affects RMS roll rate correlation
- Roll rate sensor is more common but more easily corrupted

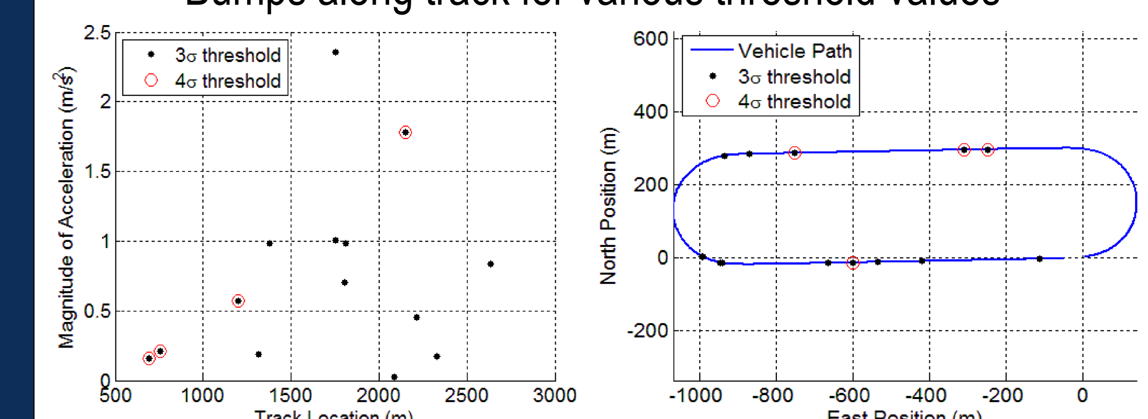
POTHOLE DETECTION

Wavelet Transform Based Algorithm

$$\psi_w(b,a) = \frac{1}{\sqrt{a}}\psi\left(\frac{x-b}{a}\right) \qquad C_{b,a}(x) = \int_{-\infty}^{\infty} f(x)\psi_w(b,a)dx$$

- Wavelet transform is effective for identifying discontinuities in a profile
- Acceleration profile is analyzed using wavelet transform
- Wavelet coefficients are calculated
- Standard deviation of coefficients is calculated
- Values above a threshold are classified as bumps

Bumps along track for various threshold values



- Detects the relative value of the acceleration to the rest of the acceleration profile
- Increasing the threshold value increases selectivity of algorithm

FUTURE WORK

- Test the methodology with other vehicles
  - Other sedans
  - SUV
- Collect data while broadcasting to a base station using DSRC radios
  - test real world feasibility
- Outfit test vehicle with linear potentiometers to measure suspension deflections
  - Investigate methods using deflections
  - Road profile estimation methods
- Pothole detection algorithm should be tested on city roads
- Deployment analysis

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