Pavement Evaluation 2010

Determine Localized and Homogeneous Rutting Sections Using Shortest Path Algorithm

Presented by

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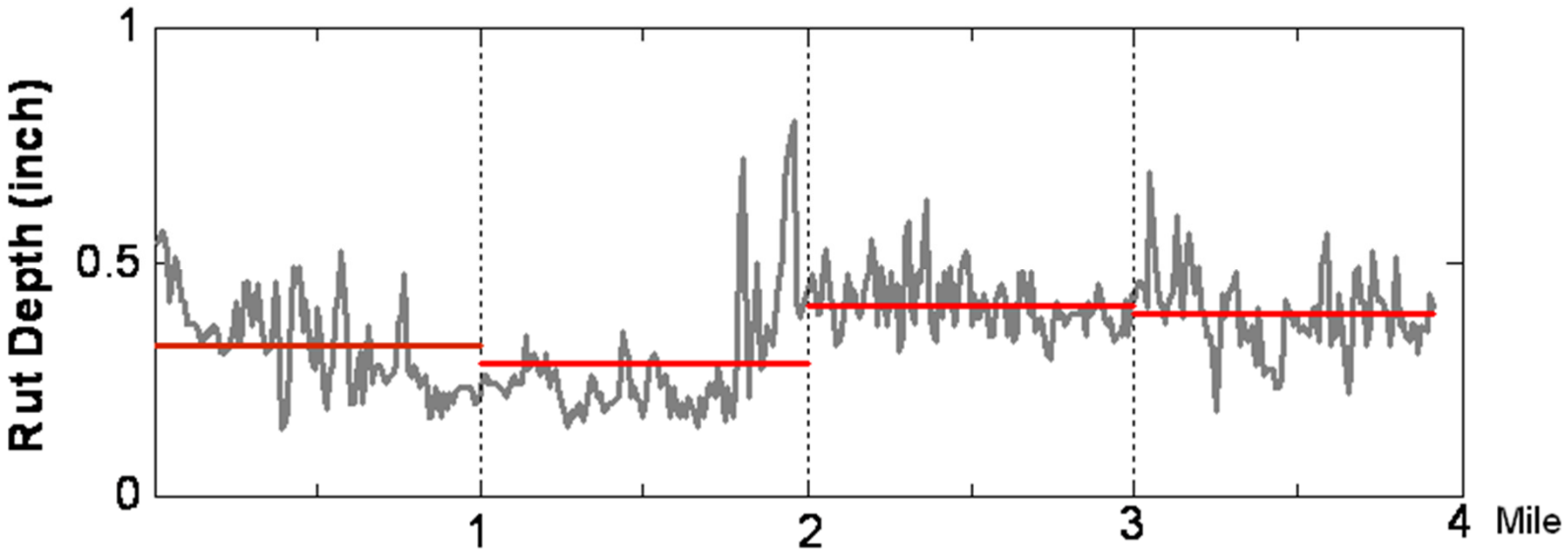
  - Yiching Wu, Research Engineer

Outline

- Background
- Objective
- Proposed methodology (1-D approach)
- 3-D Approach - rut volume estimation using 3D continuous transverse pavement profiles
- Conclusions and future research

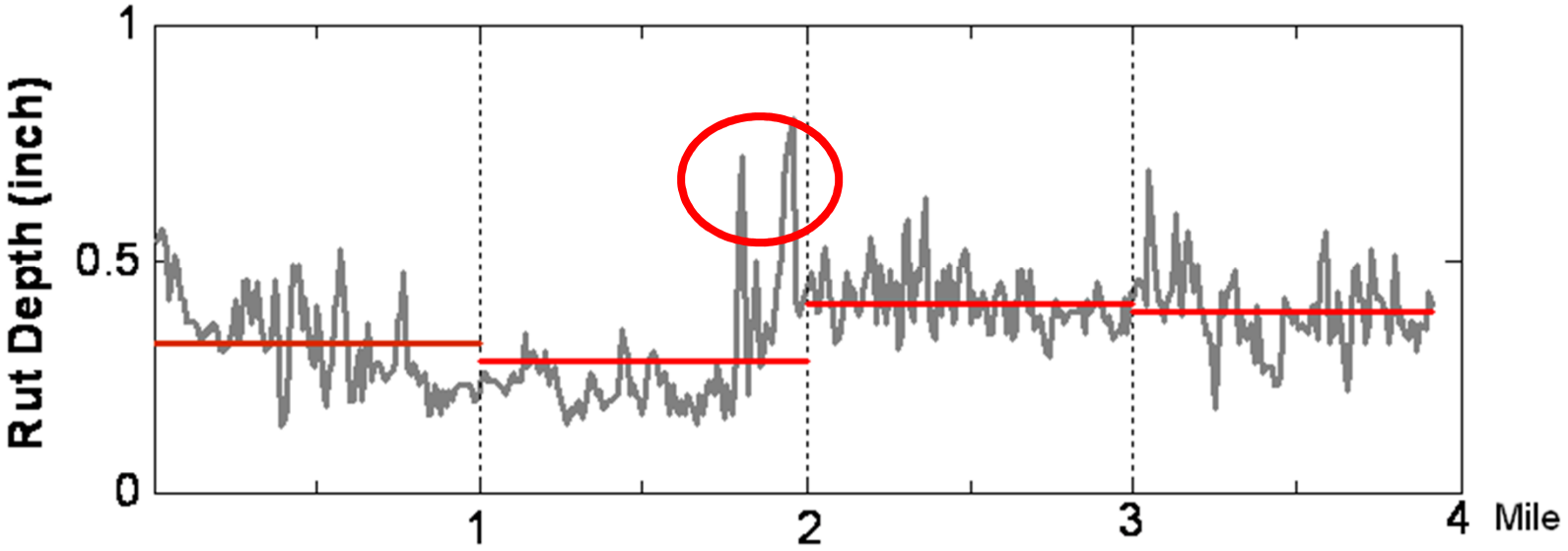
Background

- Pavement rutting increases the potential for a vehicle to hydroplane and loss of vehicle control (safety concern).
- Pavement rutting is often reported (aggregated) using a fixed interval (e.g. 1 mile or 0.1 mile).



Background (Cont.)

- Localized rutting is often not identified in current reporting method.
- It is difficult to determine homogeneous rutting sections from the rutting data that has large variations.



Objective

- To propose a method that can determine homogeneous rutting sections optimally using the rutting data with variations.
- To propose an effective way to reduce the data while preserving important rutting information.

Proposed Methodology

- Formulate the problem into an optimization problem (a constrained segmentation problem - CSP)
- Convert CSP to a network flow problem
- Solve the network flow problem by employing a shortest path algorithm

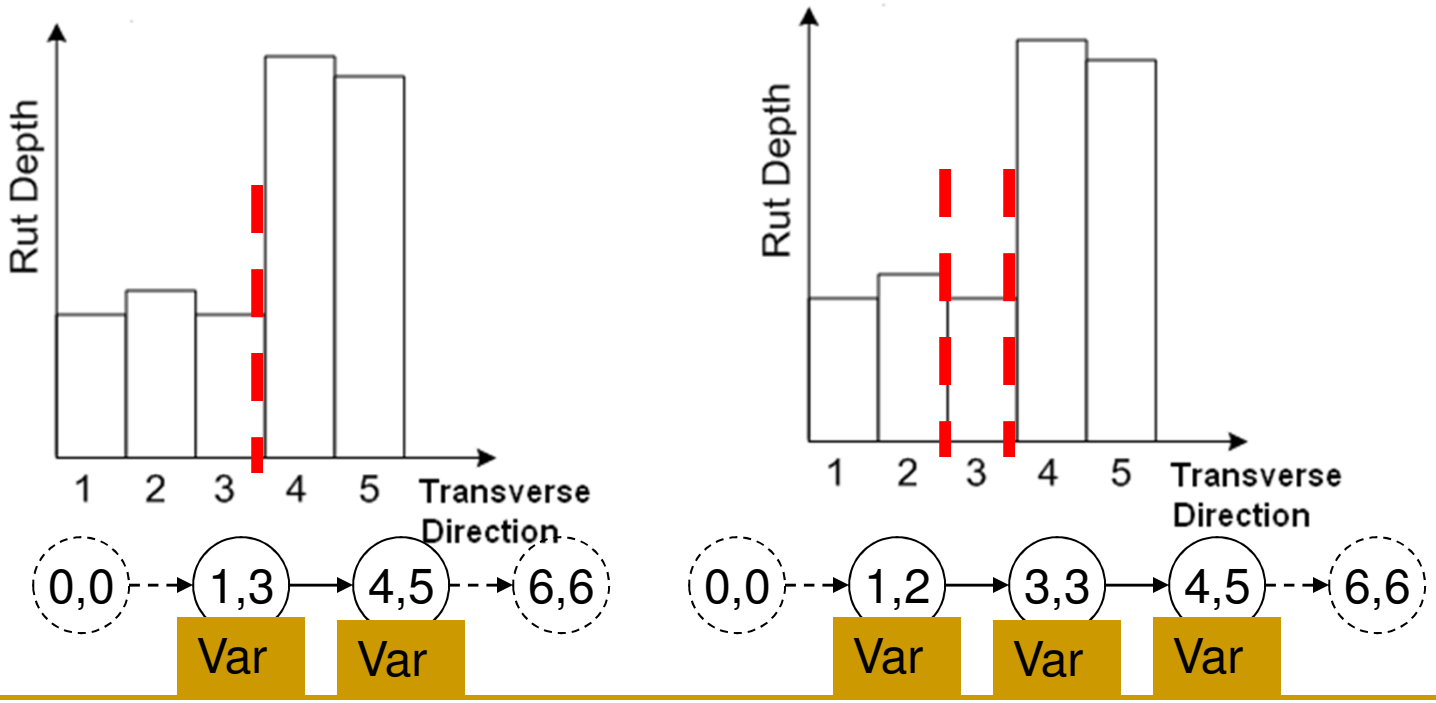
Topological Ordering based Segment Clustering (TOSC) Method

Constrained Segmentation Problem (CSP)

- Objective
  - To group *m* rut depth measurements into *n* clusters in a way such that the total variation is minimized
- Given
  - *m* rut depths r_i {1,2,…,*m*}
- Constraints:
  - Measurements have to be clustered consecutively
  - A cluster is required to contain at least *L* measurements
    - e.g. contains at least *L*=2 measurements
  - The mean rut difference between adjacent clusters should be greater than *D*

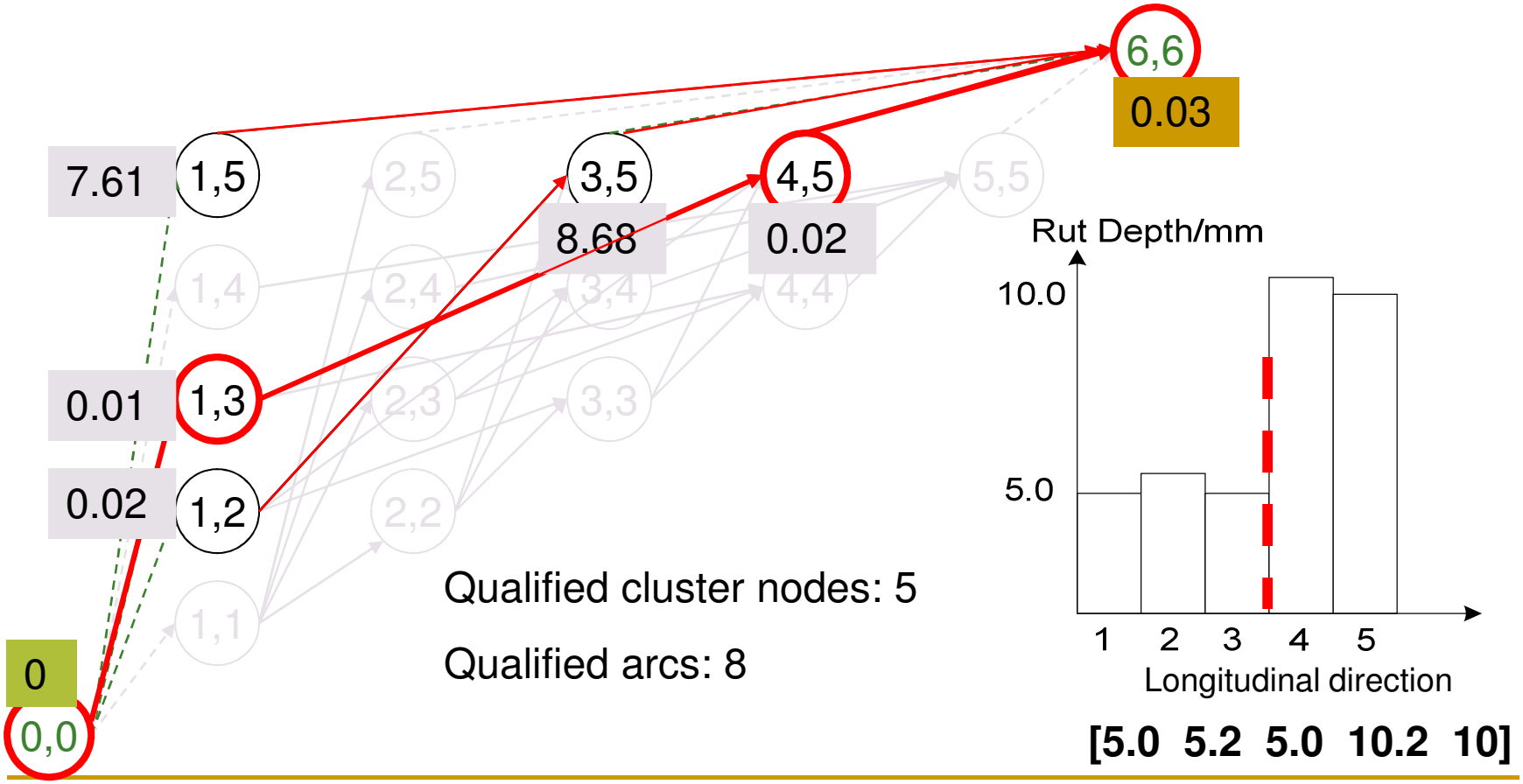
Convert into a Shortest Path Problem

- CSP can be converted to a network flow problem according to the continuity constraints
- Each cluster corresponds to a node in the network model
- Each combination of clusters corresponds to a path from the dummy source node to the dummy sink node in the network model
- The variation of each cluster is the distance to walk through the corresponding node



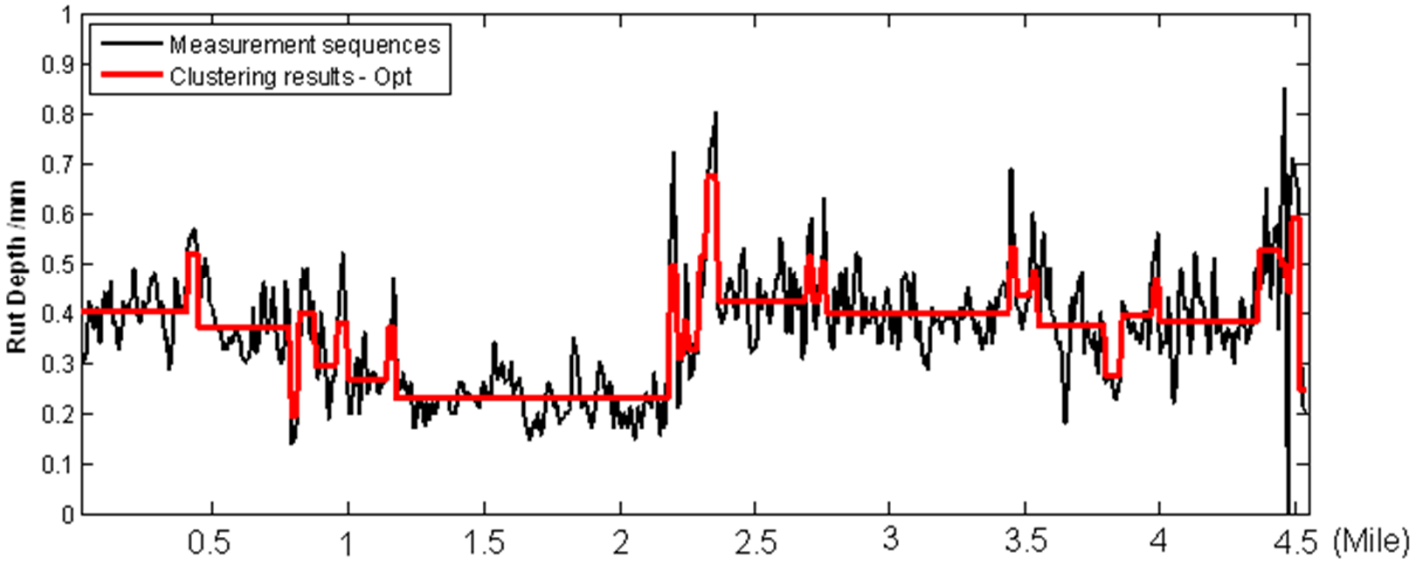
TOSC Method (Cont.)

- Solve the Network Flow Problem (L=2 & D=0)



Test Results Using Real Data

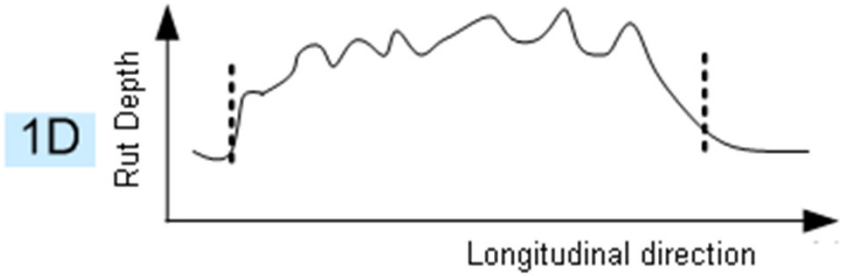
- Data: Rut depth data from the Louisiana DOT (0.01mile)

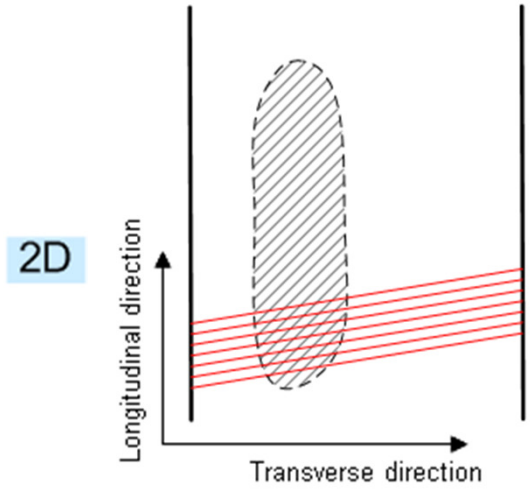


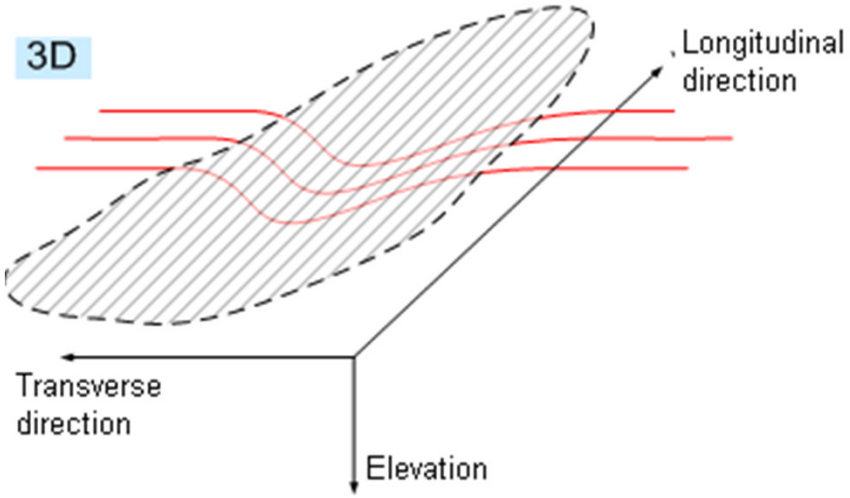
Min length: 0.02mi; Min depth: 1/8 inch

A total of 34 homogeneous sections in a 4.5-mile section.

Extend to 2D and 3D

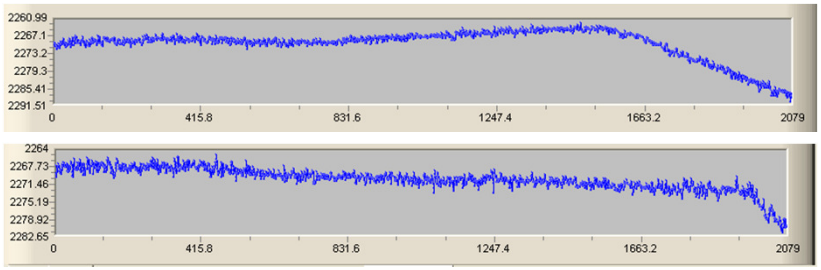


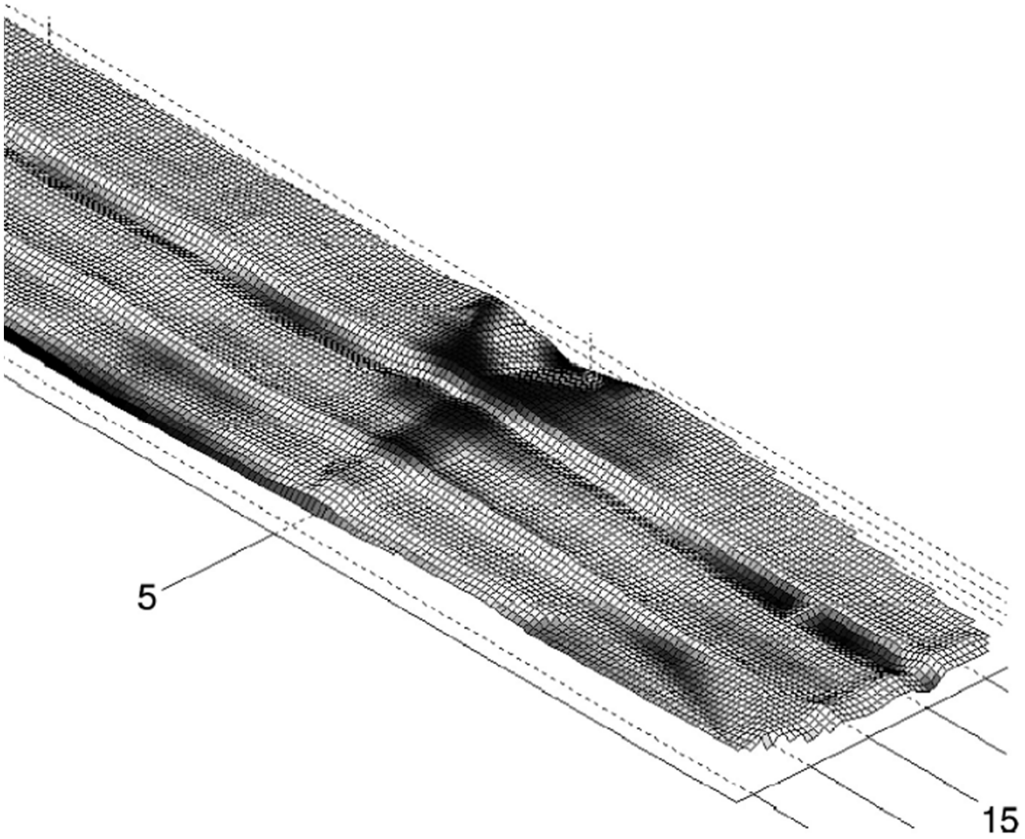




3D Rut Volume Estimation - A Preliminary Study

3D Continuous Transverse Laser Profile





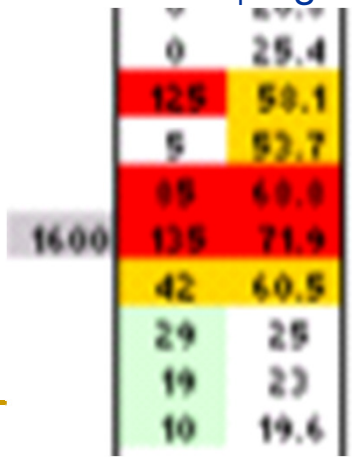
- Transverse direction: 1 mm
- Longitudinal direction: 1 – 5 mm
- More than 2.3 million points per second

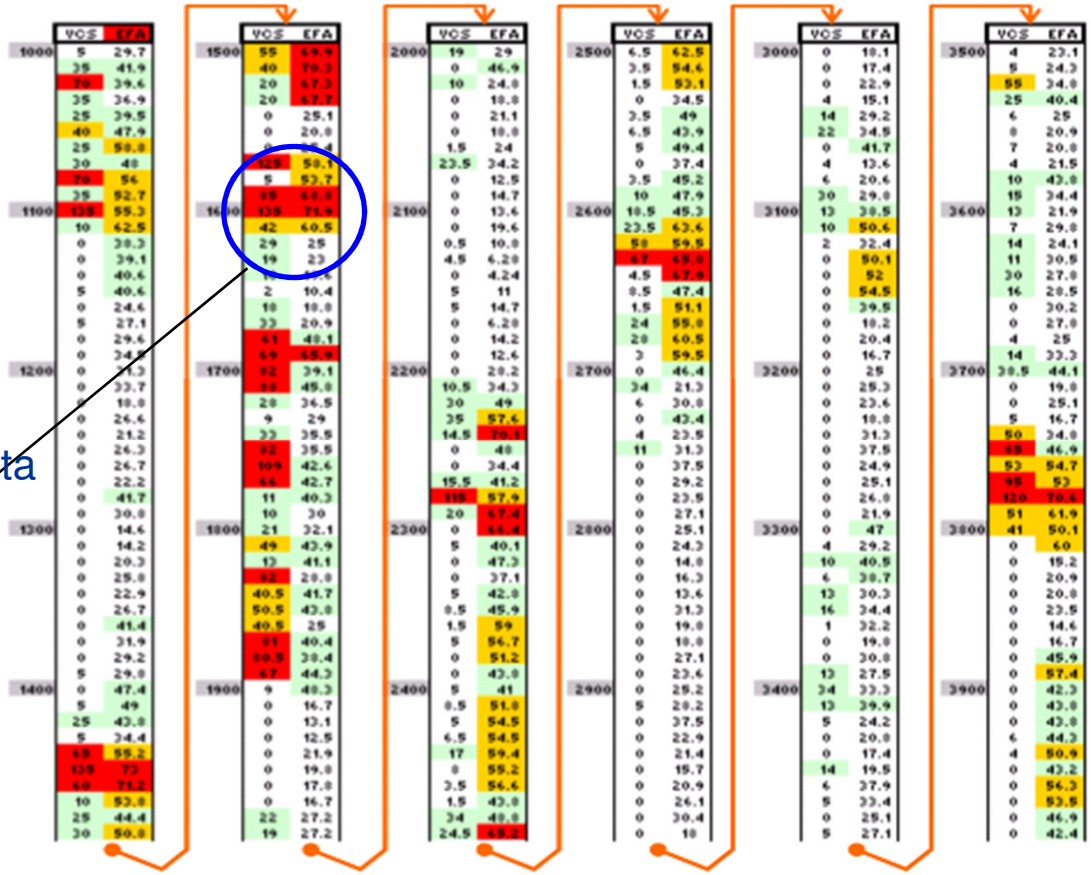
(Source: Laurent, et. al., 2008)

Validate the Algorithm for Spot Rutting Detection

- Process, analyze and cluster data for identifying spot rutting (localized ruts)

Reference data | Algorithm data

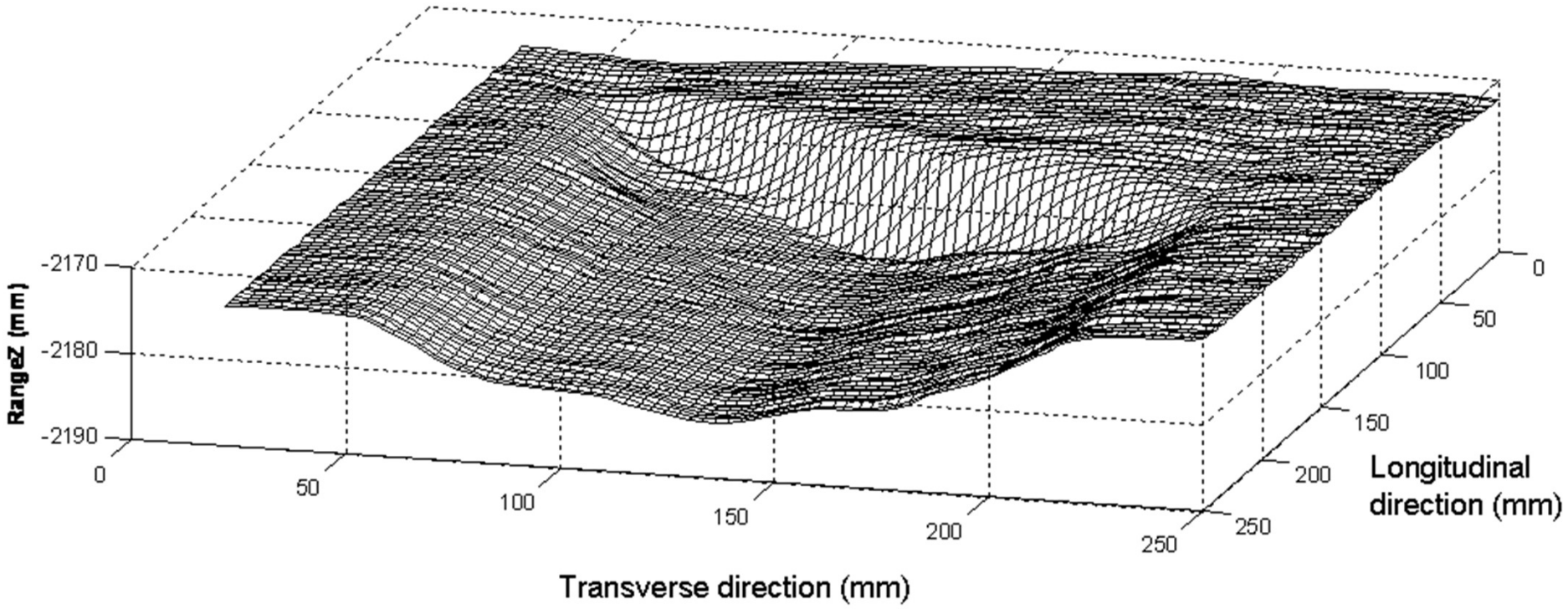




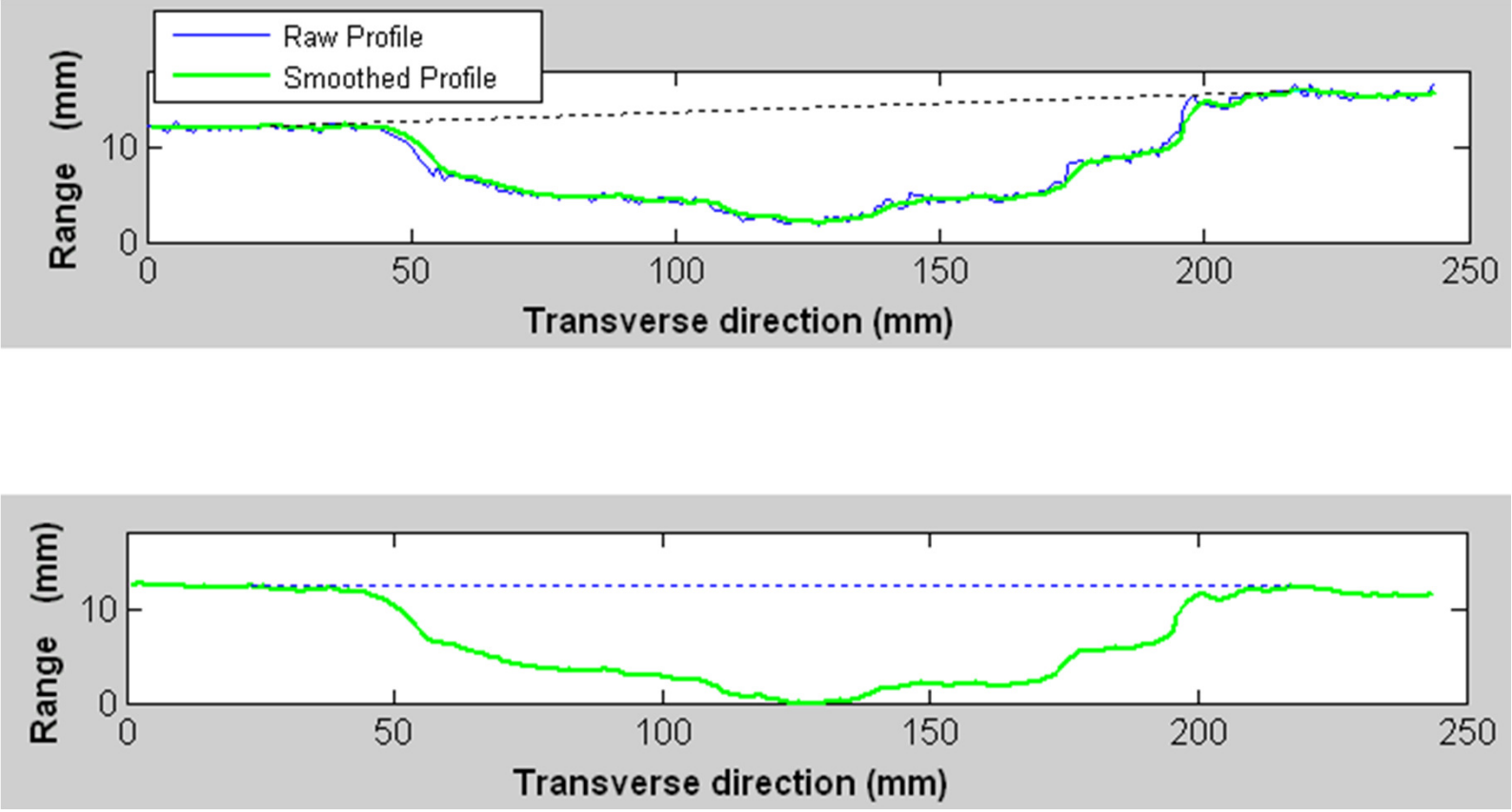
(Scott et. al., 2008)

3D View of Rutting

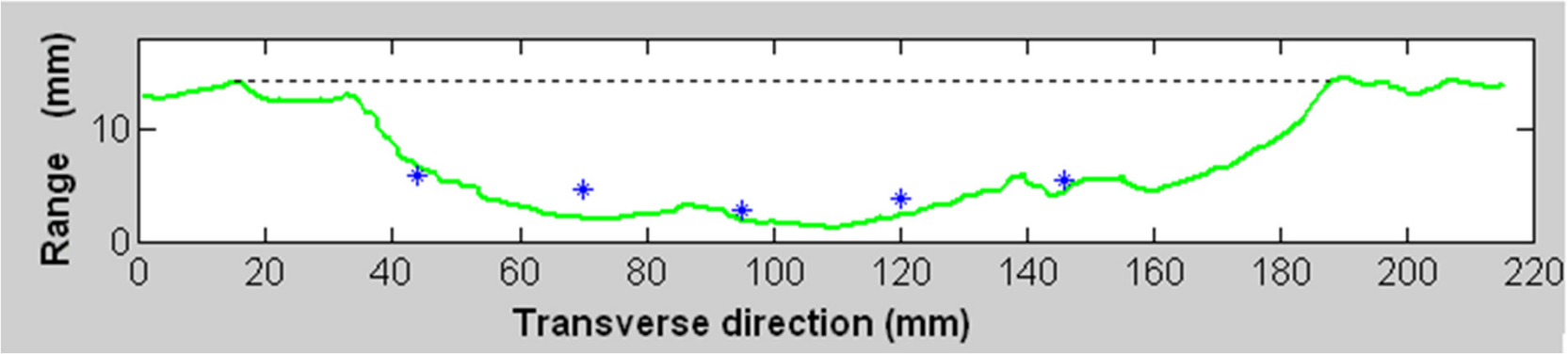
- Rut sample (depth ½ in.)
- 3D continuous laser profile
  - Transverse direction: 1 mm
  - Longitudinal direction: 1 mm

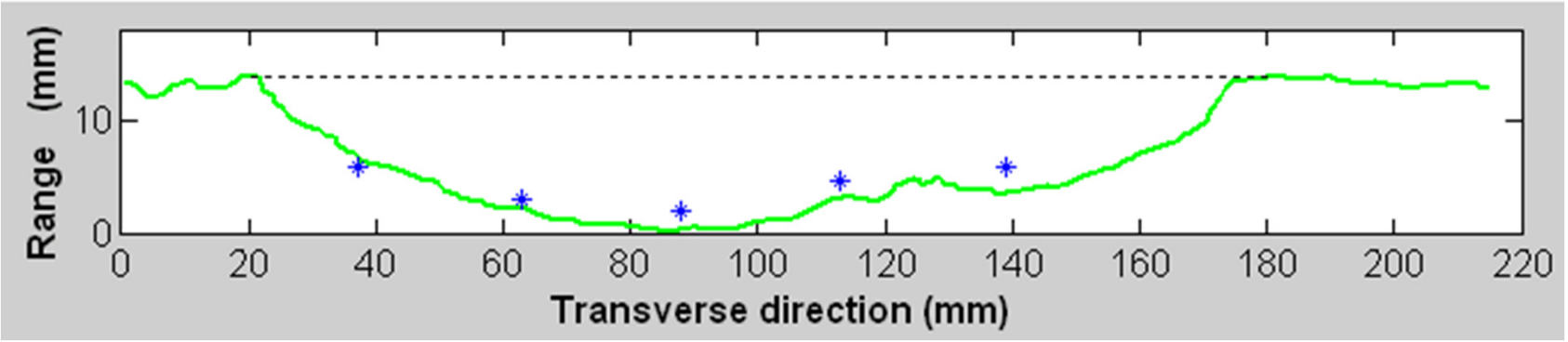


Smooth and Level Profile



Validate the Profile

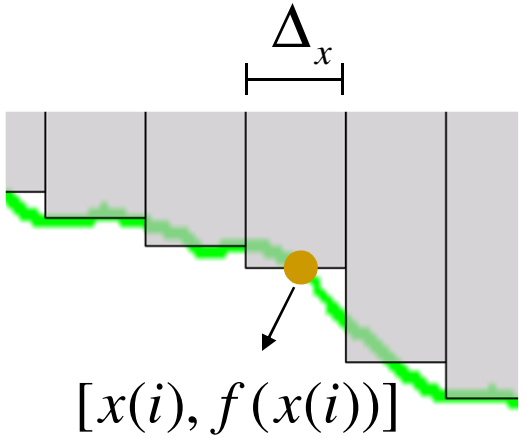




Compute Rut Area and Volume

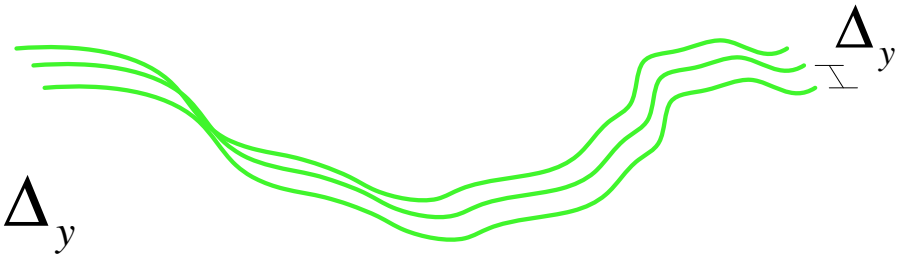
- Compute rut area

$$A = \int_{x=0}^{L_x} f(x)dx \approx \sum_{i=1}^{L_x} f(x_i) * \Delta_x$$



- Compute rut volume

$$V = \int_{y=0}^{L_y} A(y)dy \approx \sum_{i=1}^{L_y} A(y_i) * \Delta_y$$



Conclusions

- The **Topological Ordering based Segment Clustering (TOSC)** method is first time proposed to optimally determine homogeneous rutting sections, and it produces good outcomes
- The TOSC method is demonstrated to be able to
  - Determine homogeneous rutting sections for the rutting data with variations
  - Make a flexible segmentation by adjusting constraints (L and D) to meet following purposes:
    - Network level analysis
    - Project level analysis, e.g. localized rutting identification
- The method has a promising potential to reduce the huge amount of rutting data and store only the boundaries of homogeneous rutting sections that are important to engineers
- The method can be applied to determine homogeneous sections of other pavement condition data (e.g. IRI)

Future Research

- Test more cases using data collected from real roadways (e.g. a road section with verified localized rutting) and evaluate the results quantitatively.
- Compare the TOSC method with other methods, such as cumulative difference approach (CDA).
- Develop methodology to identify rut location and estimate the volume.
- Develop methods to remove the signal noise and non-rut distresses (e.g. crack).

Thanks

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Questions?

Agenda

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- Objective
- Proposed methodology (1-D approach)
- 3-D Approach - Rut volume estimation using 3D continuous transverse pavement profiles
- Future research