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VEHICLE TERRAIN PERFORMANCE LABORATORY

Transitioning from Profiles to Surfaces

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Outline

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Motivation

Background

Developing a Compact Model

Conclusions

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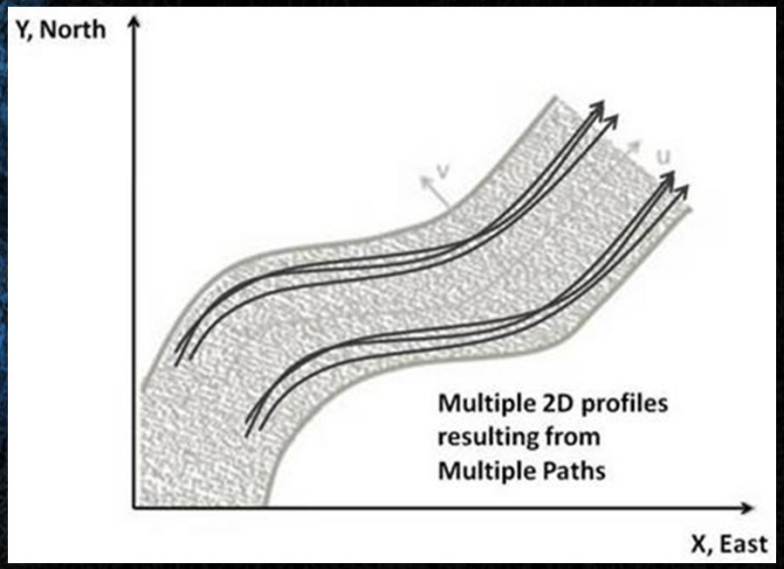
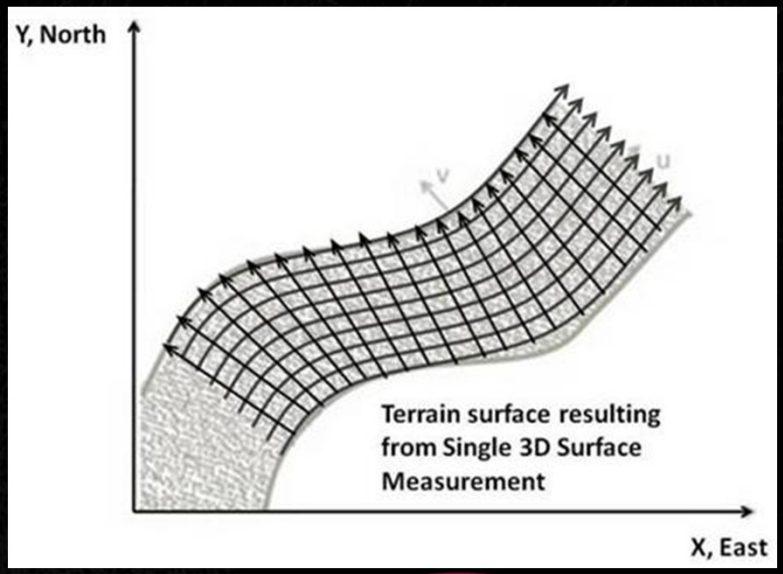
Vehicle Terrain Performance Laboratory

Motivation

- Various measurement systems available
  - Point Lasers
  - Scanning Lasers
- Sample terrain surface at discrete locations





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Background: Vehicle Terrain Measurement System

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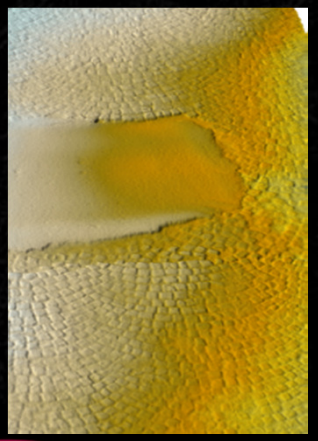
Scanning Laser

- Provides relative height measurement

Inertial Navigation System

- Differential GPS + Inertial Measurement Unit
- Establishes global coordinate system
- Mitigates body motion



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Background: Coordinate System

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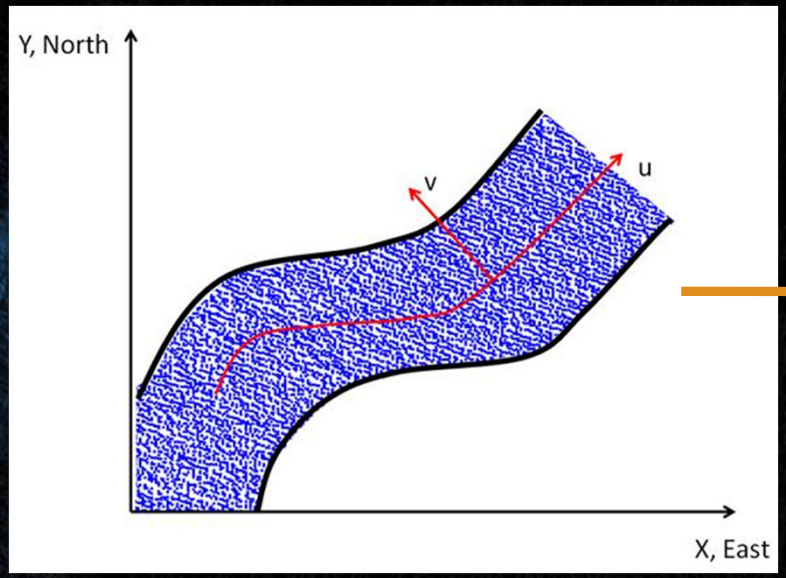
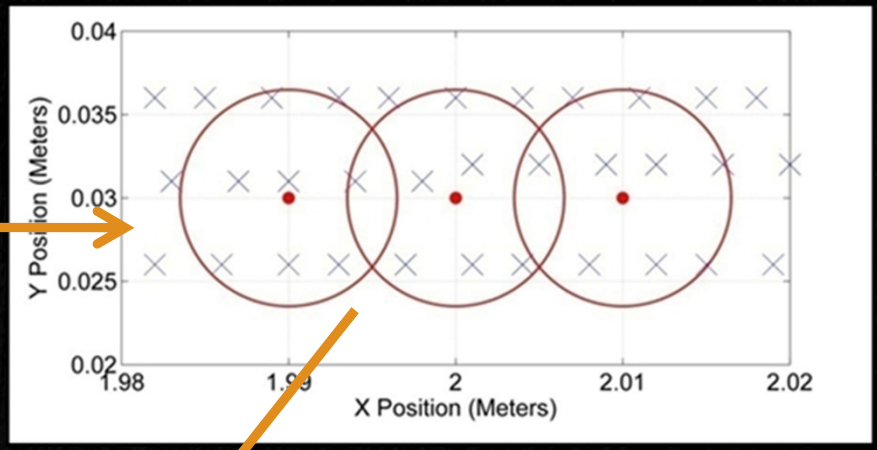
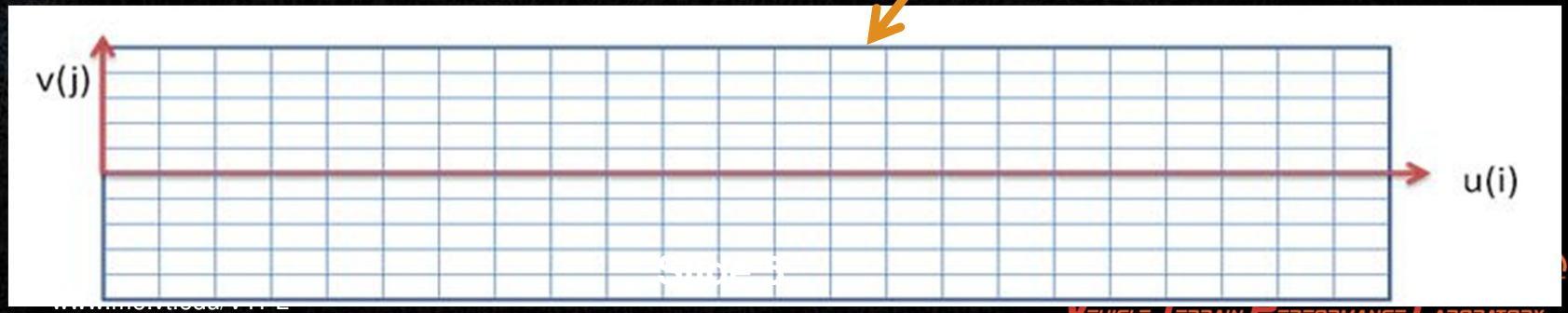
Horizontal Plane

- Map point-cloud data to uniform grid → Defined by Vehicle Path (u)







Background: Coordinate System

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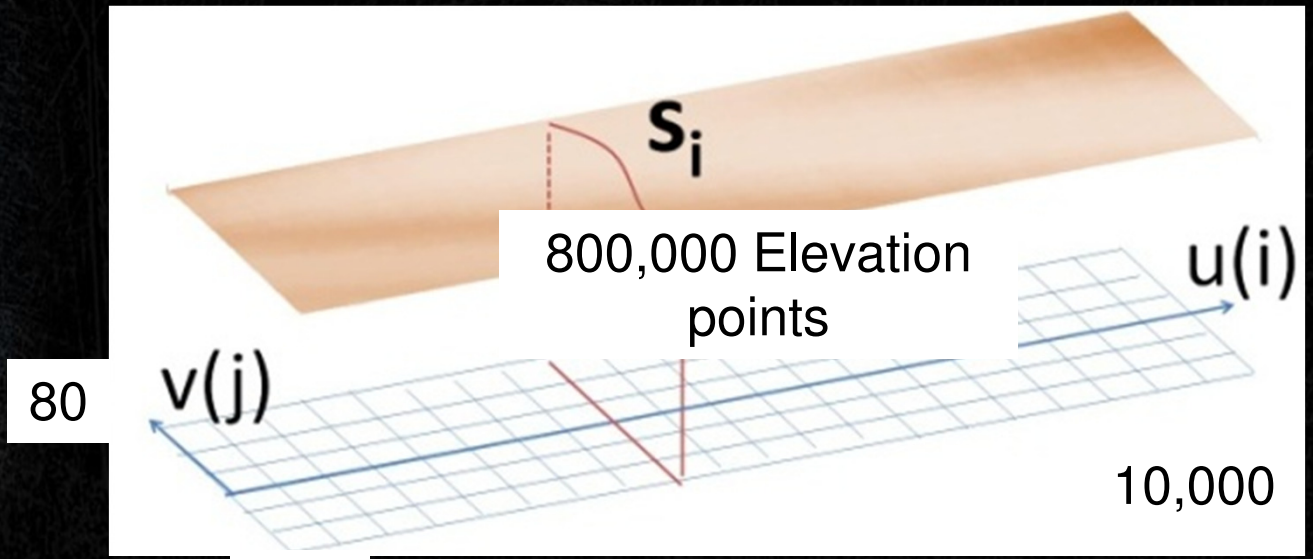
True Surface

- i: longitudinal location of transverse profile, where $i \in \{0,1,\ldots,m\}$
- j: transverse location of longitudinal profile, where $j \in \{0,1,\ldots,n\}$



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Developing a Compact Model

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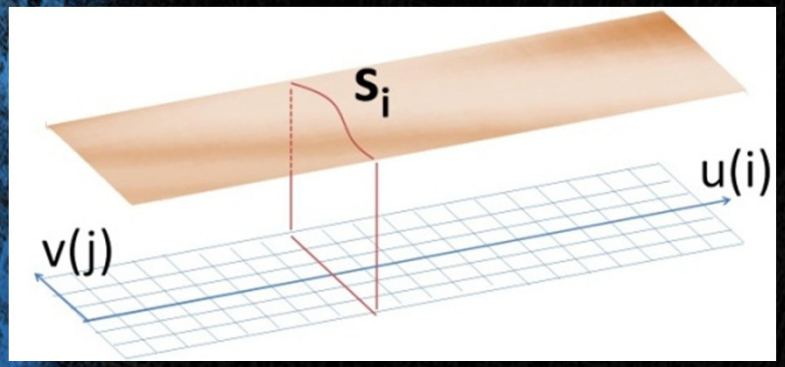
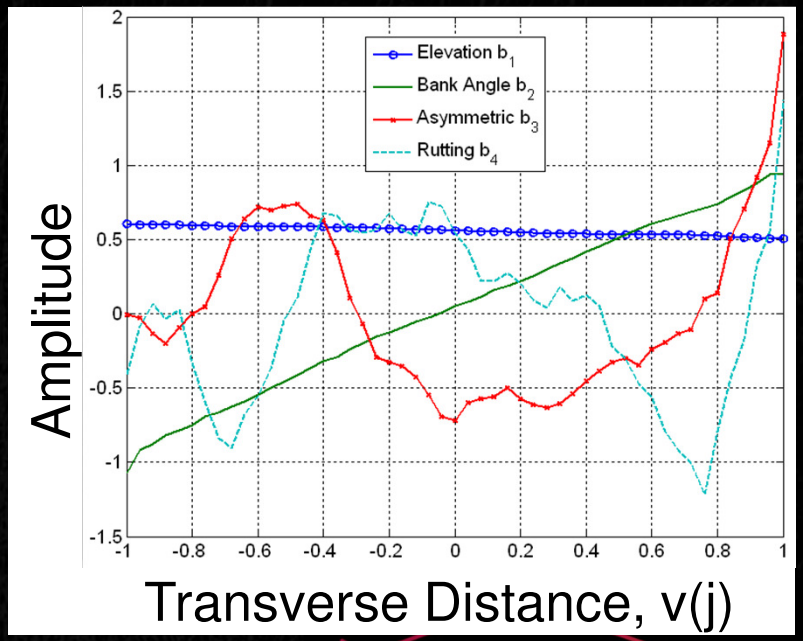
Empirical Basis Vectors

- Singular Value Decomposition
- Principal directions = Primary terrain characteristics:
  - Elevation
  - Bank Angle
  - Rutting





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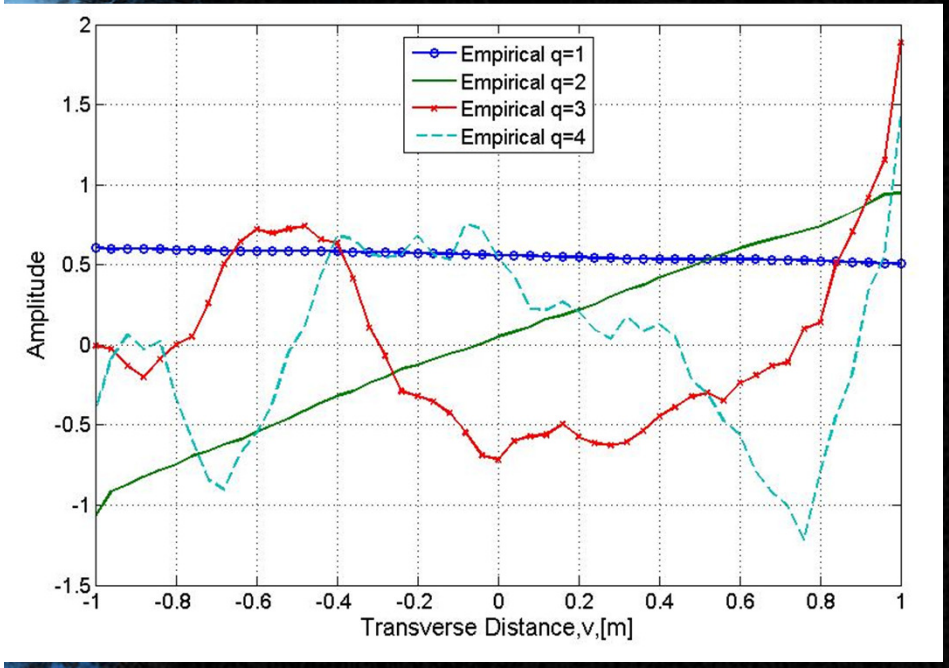
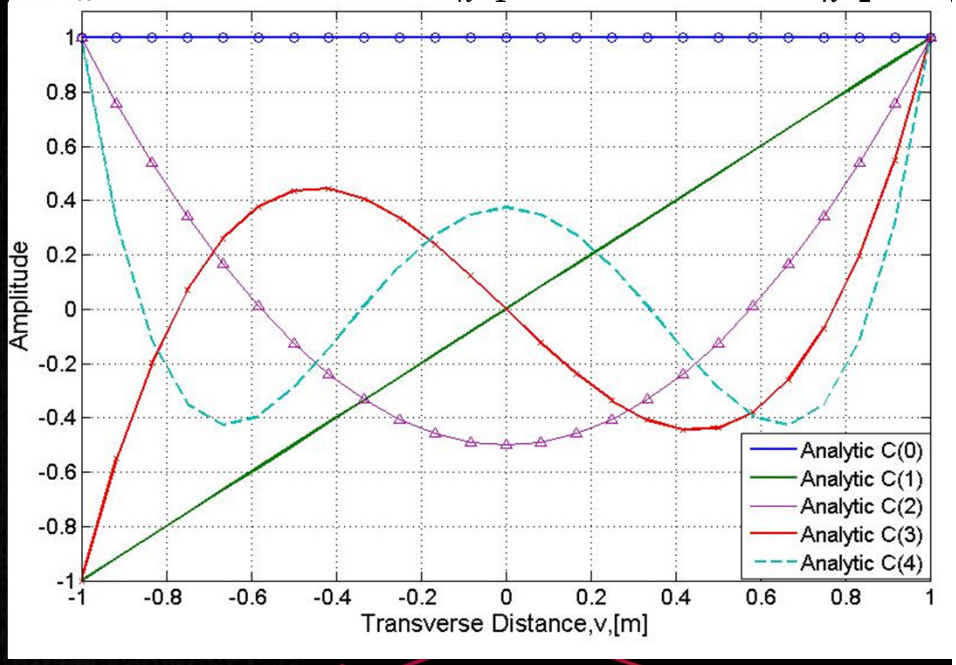
Developing a Compact Model

- Basis vectors of paved surfaces exhibit consistent shapes
- **Goal**: Portable and compact method to represent terrain surfaces



$$nC_n^{(\lambda)}(x) = 2(n+\lambda-1)xC_{n-1}^{(\lambda)}(x) - (n+2\lambda-2)C_{n-2}^{(\lambda)}(x)$$



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Developing a Compact Model

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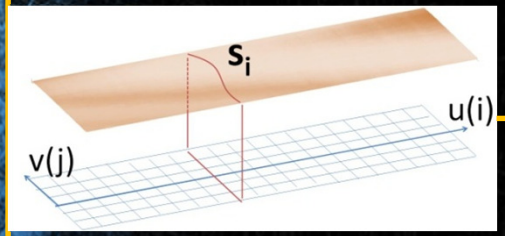
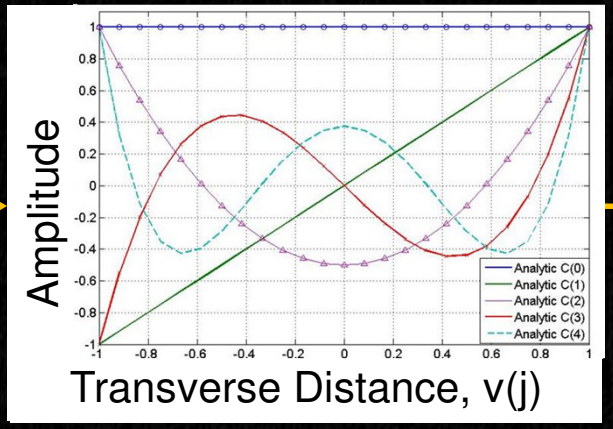
Surfaces vs. Profiles

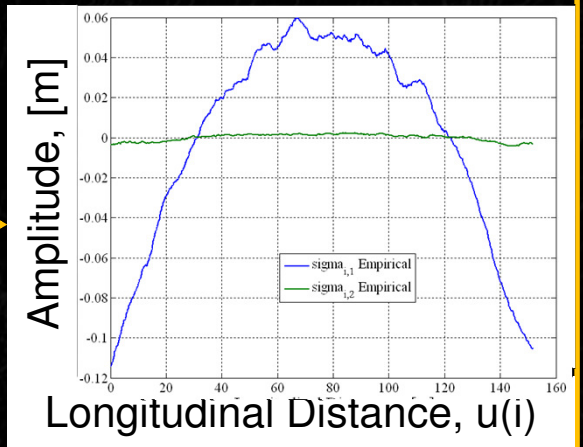
Surface Approach



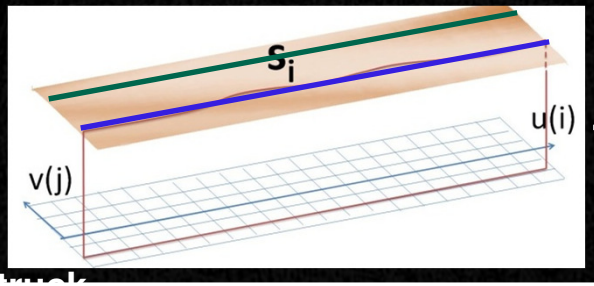
Basis Vectors: p_l

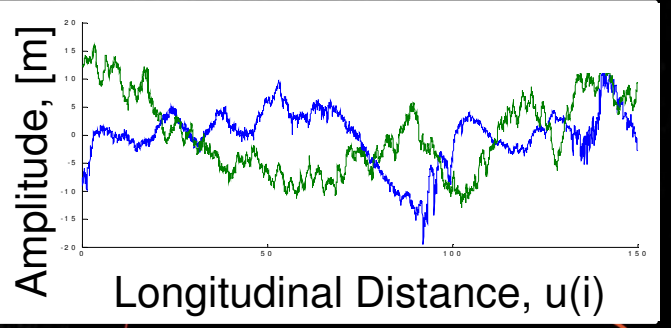


Terrain Components: $\sigma_{i,l}$



Profile Approach





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Developing a Compact Model

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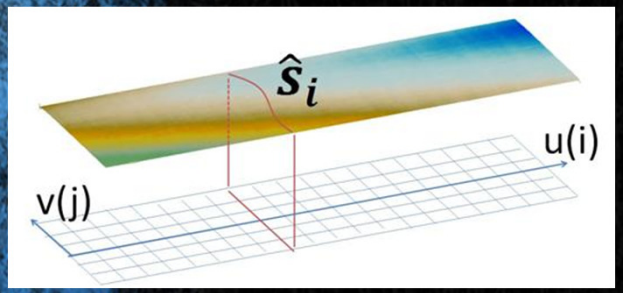
Defining the Truncated Surface

- Summation of $\sigma_{i,l}$ multiplied by a truncated set of basis vectors

$$\hat{s}_{trunc(i)} = \sum_{l=1}^{t \le q} \sigma_{i,l}\, p_l$$



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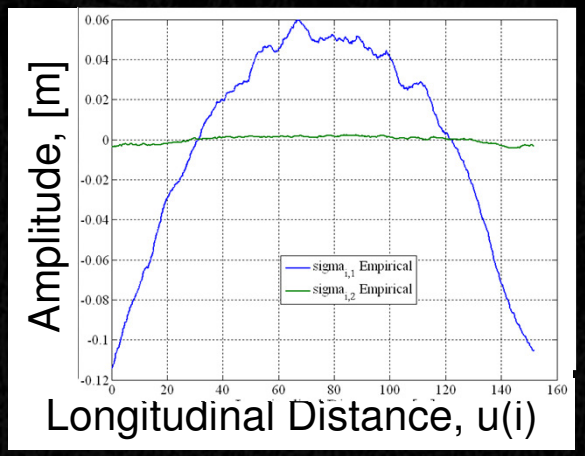
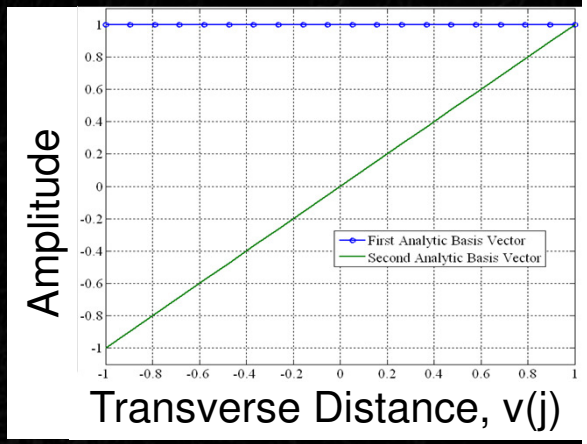


X



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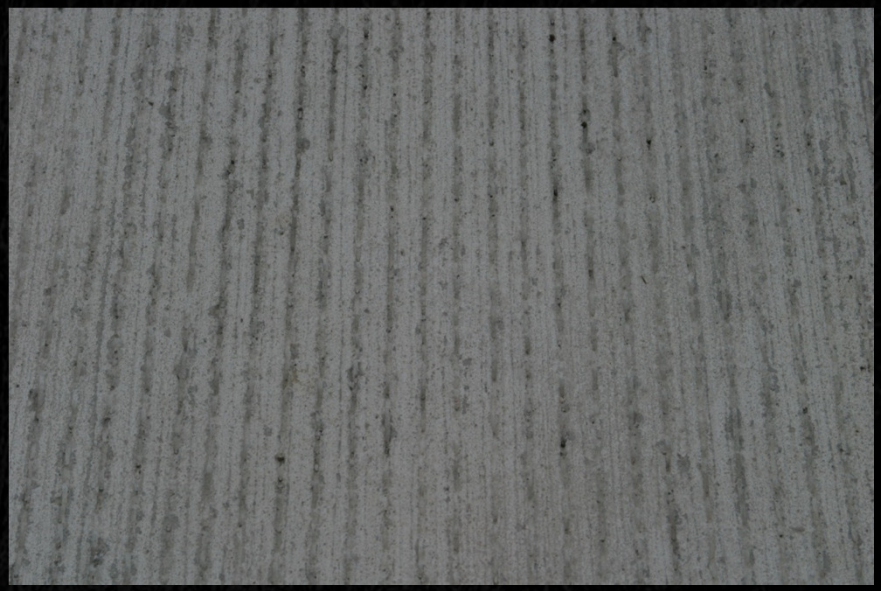
Proof of Concept

- Longitudinally tined jointed concrete: MnRoad, MN



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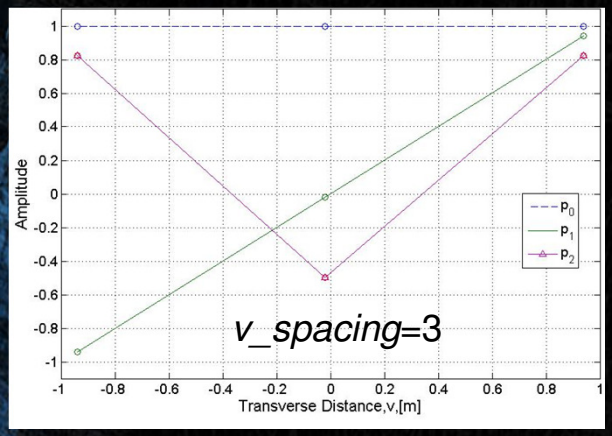
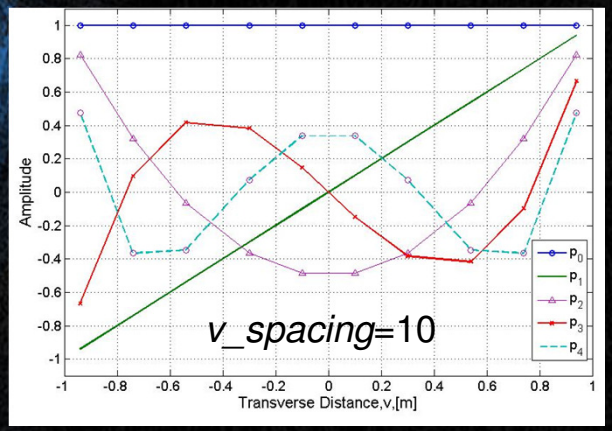
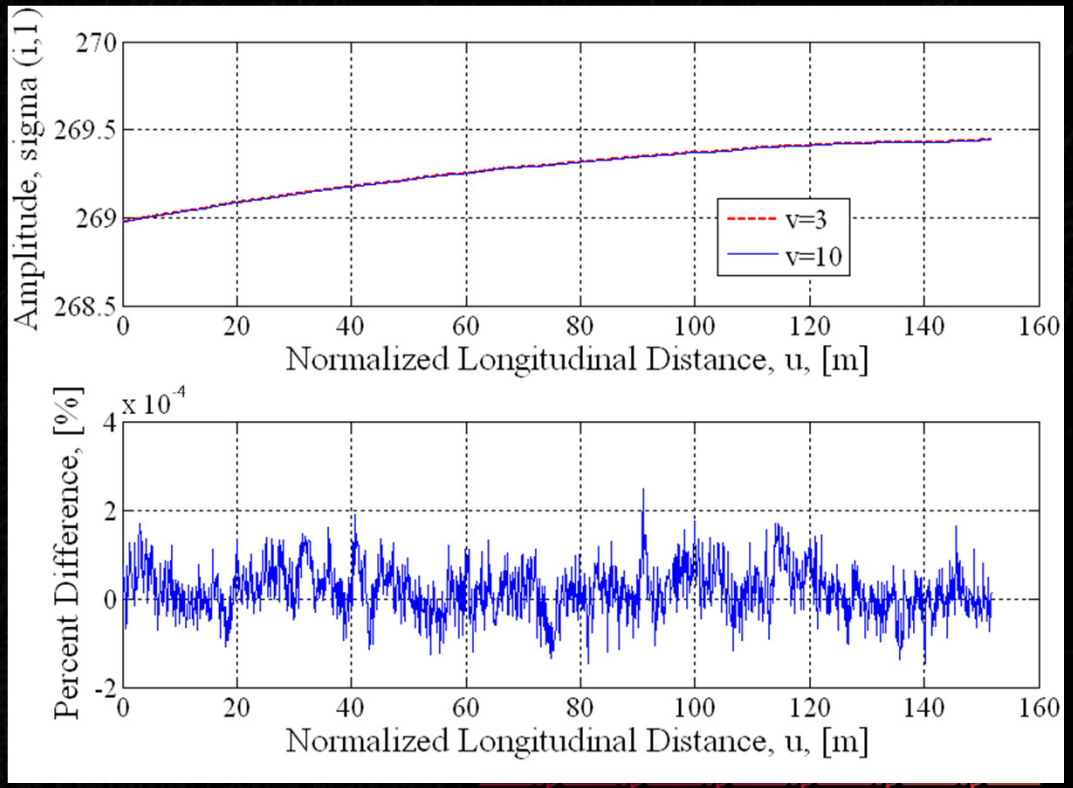
Insensitivity to number and location of discrete samples

- 0.0255% difference between components of terrain







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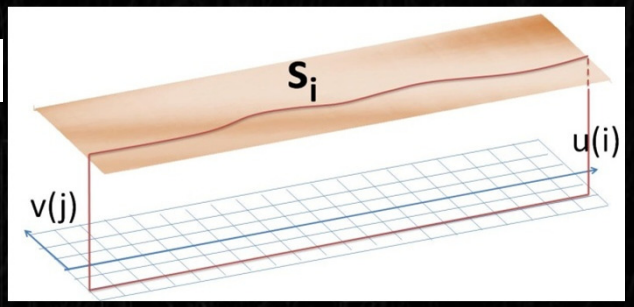
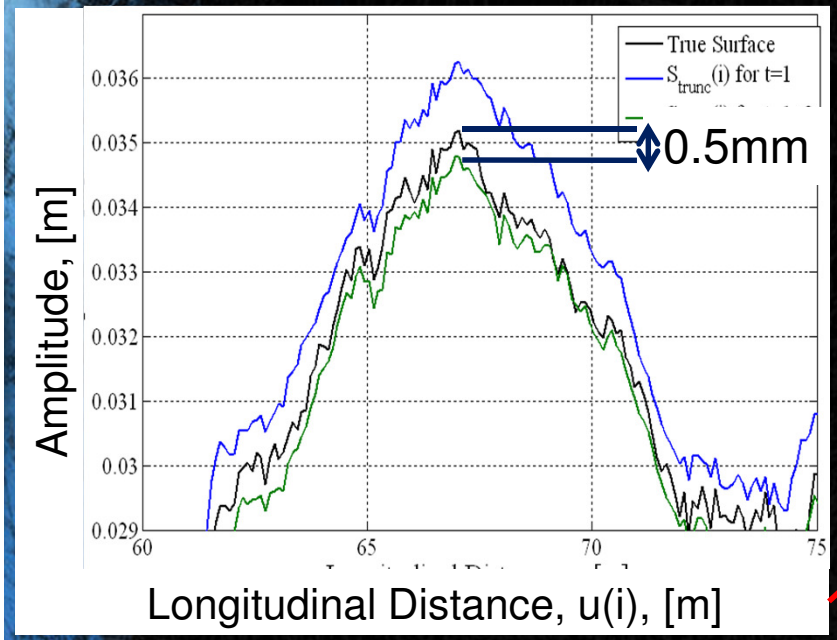
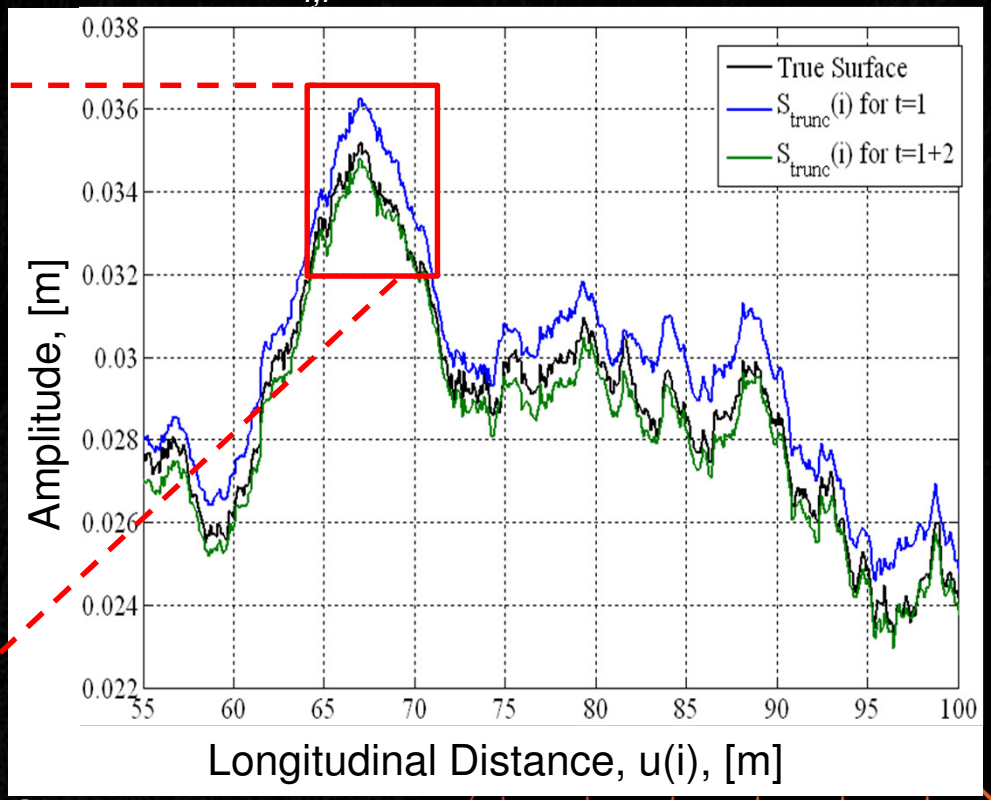


Proof of Concept

- Truncated surfaces for $\sigma_{i,l}$ 1 and 2
- Converges to true terrain surface if all $\sigma_{i,l}$ are deterministic





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International Roughness Index

- 0.138% difference between *mean of wheel paths* and *elevation component of terrain*
- ~1.5% difference between wheel paths

	IRI
Elevation Component of Terrain	0.5756
Left Wheel Path Longitudinal Profile	0.5680
Right Wheel Path Longitudinal Profile	0.5848
Mean of Wheel Paths	0.5764

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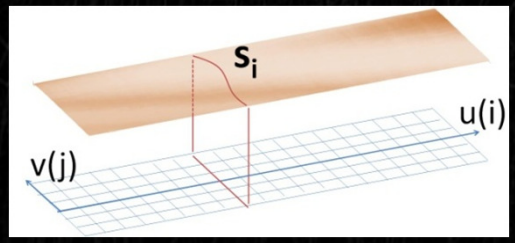
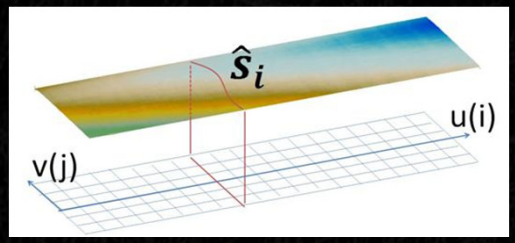
Conclusions

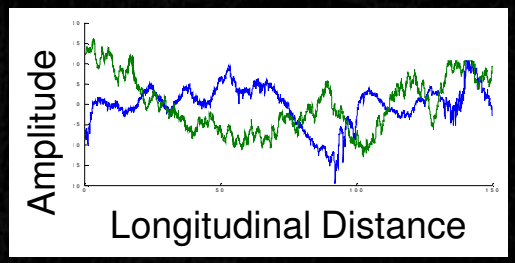
800,000 points



2 basis vectors + 2 terrain components → 20,000 points



Ref: 2 terrain profiles → 20,000 points



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Conclusions

Terrain surfaces can be compactly represented

- Empirical basis vectors (describe principal direction)
- $\sigma_{i,l}$ (captures the contribution of each basis vector in the surface)

Principal Directions can be discretized according to measurement system

IRI more representative of roughness of surface when based on *elevation component of terrain*

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