Transverse Profiles Applications: Rutting, Crowning & Cross Slope

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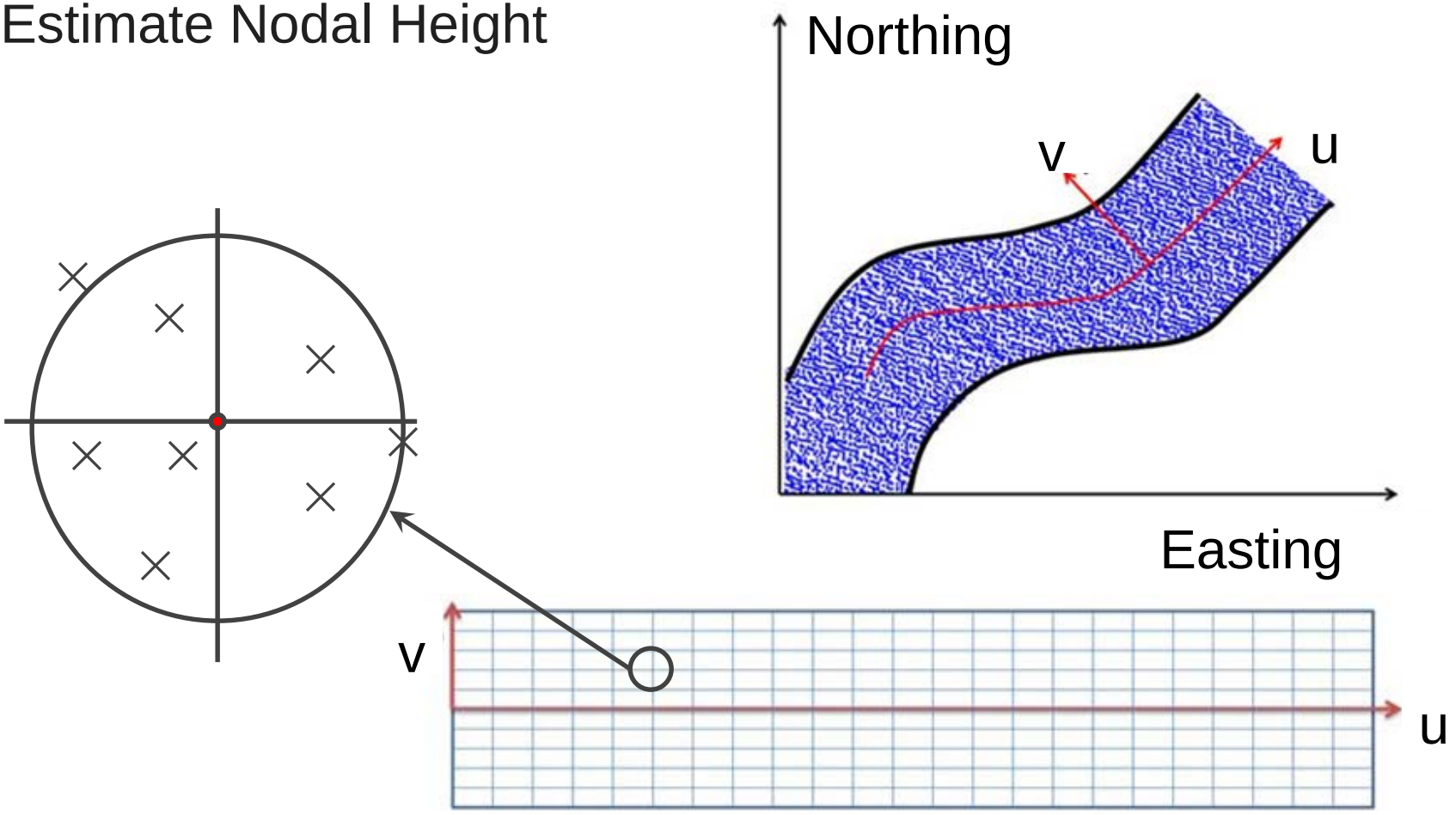
Outline

- Measurement and Gridding
- Issues with rut measurement (as an example)
- Galerkin projection of transverse profiles onto orthonormal basis of discretised Legendre polynomials
  (read: curve fitting)
- Research Need

Measurement and Gridding

Estimate Nodal Height



Measurement and Gridding

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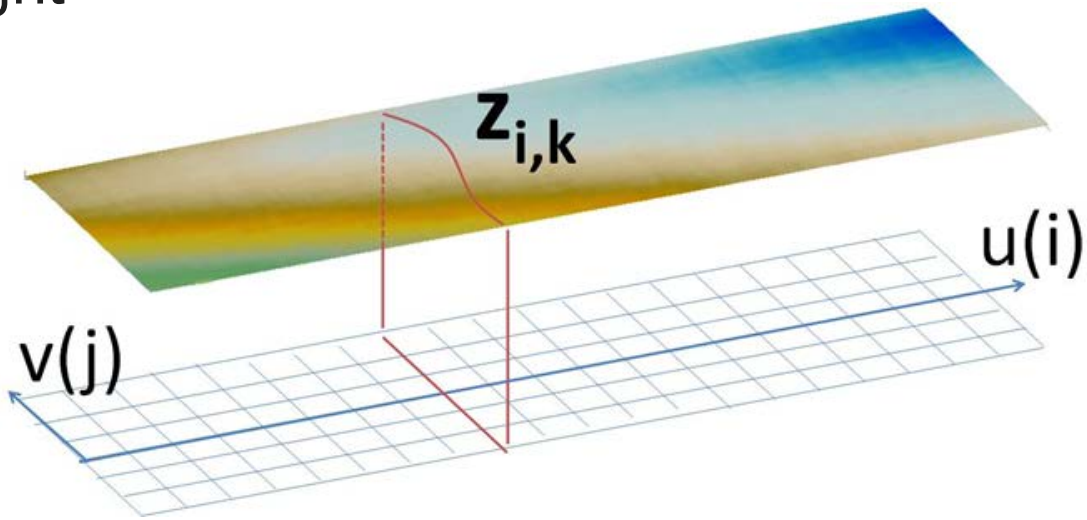
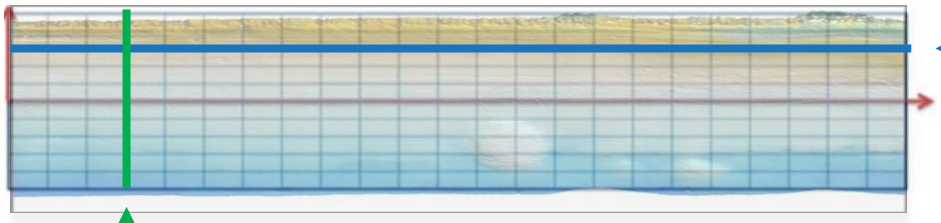


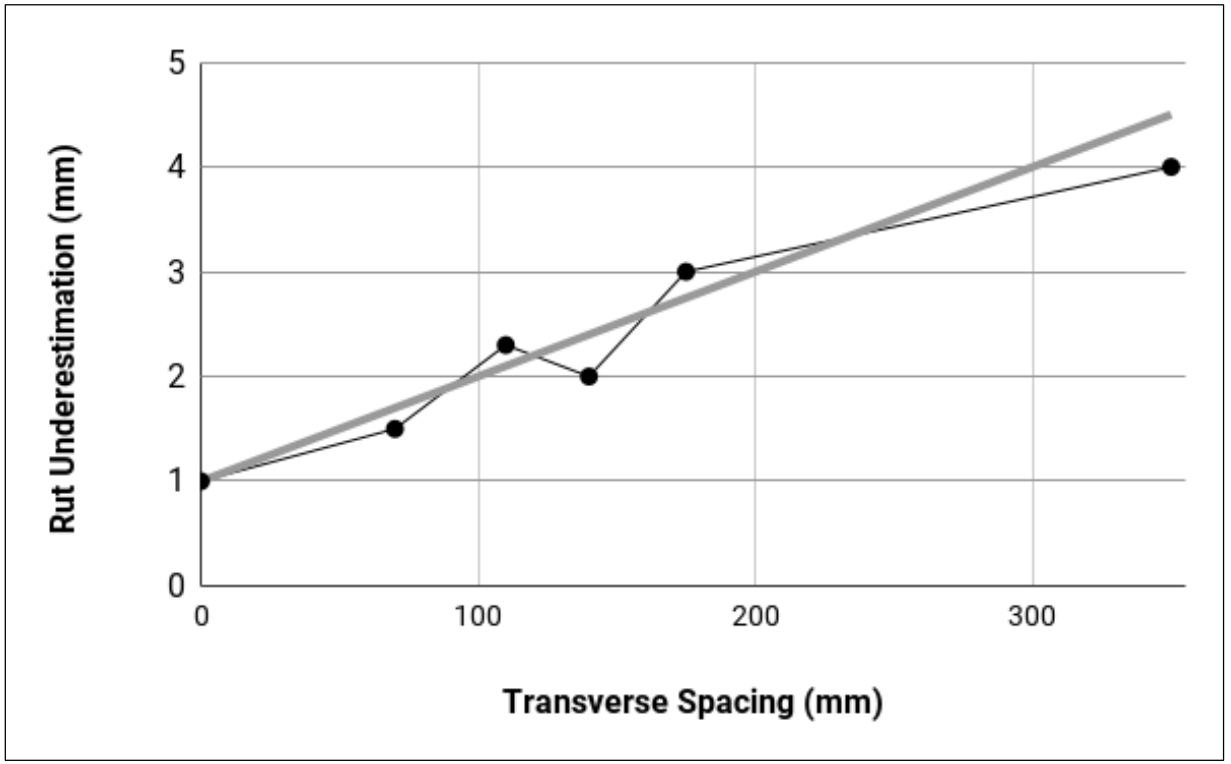


Longitudinal Profile

Transverse Profile

Rutting Issues

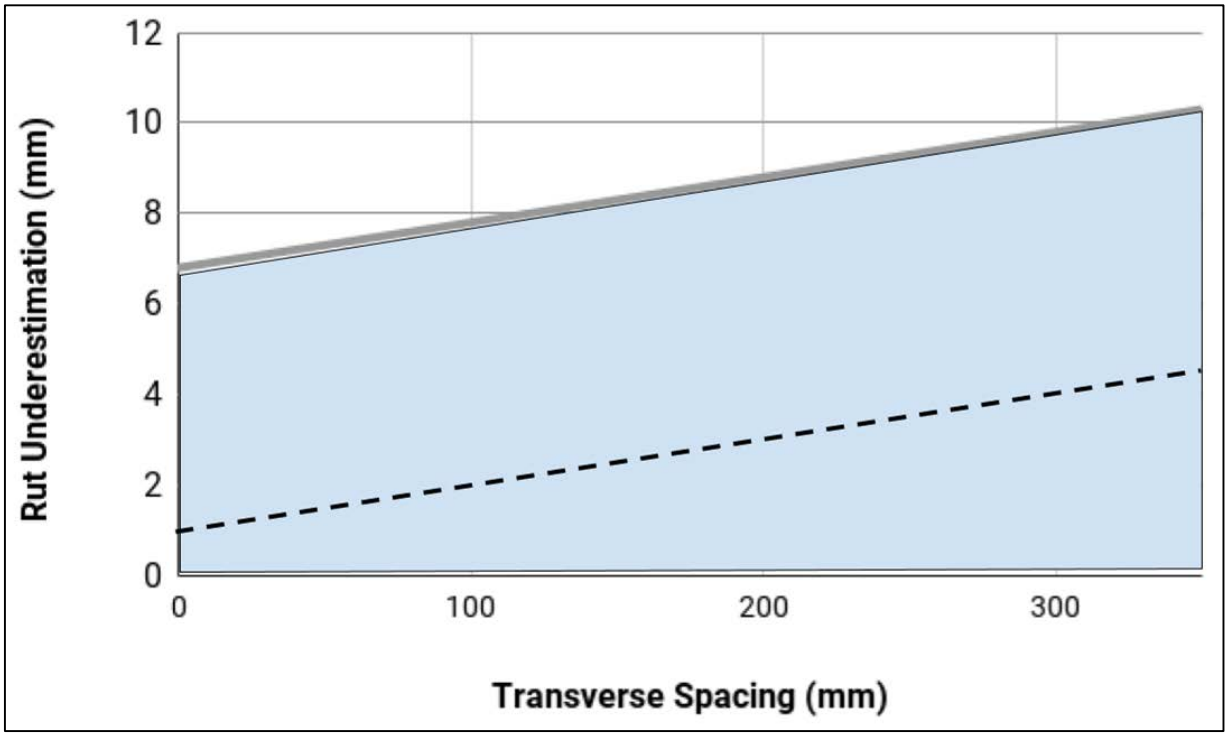
Rut depth underestimation *bias*
(*no variation or wander*)



Rutting Issues

Variation (*rough* estimates) due to

- Standard error: 1 - 4 mm
- Wander: $\lesssim$ 6.4 mm



Rutting Issues

Why *underestimation*?

Statistical implication of using extrema as a measure

→ *Extremely sensitive to outliers*

6 sets of 10 Random Samples from *same* Normal Distribution, σ = 2 mm

Range of values = 3.5 mm

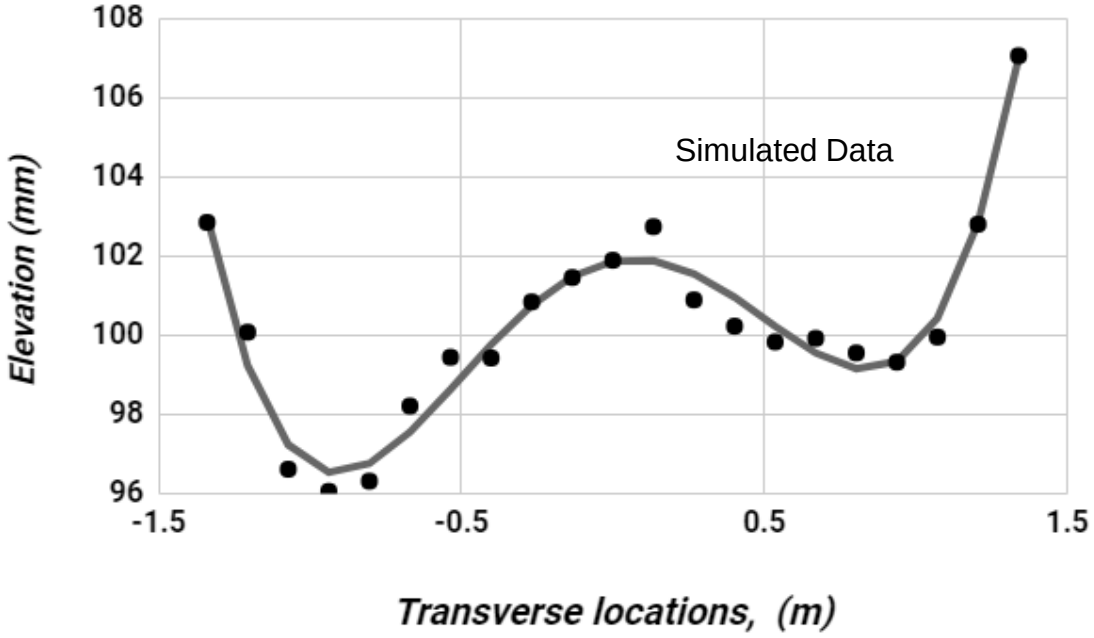
	2.112	-2.640	1.513	1.046	-1.348	2.668
	-2.477	2.302	-0.593	0.946	3.677	-1.488
	-0.032	-1.802	-1.895	-0.677	-0.037	1.306
	3.493	-0.228	1.924	4.208	-3.472	5.627
	-1.982	-0.451	1.245	0.996	-0.339	0.036
	2.218	-1.999	-0.322	2.810	4.992	-0.008
	0.792	-0.995	4.414	-1.342	2.227	1.528
	-1.708	1.570	2.263	4.383	1.689	-1.919
	2.844	1.681	1.041	2.336	-2.291	-0.146
	1.473	1.102	-0.324	2.060	1.110	2.742
Max	3.493	2.302	4.414	4.383	4.992	5.627
Min	-2.477	-2.640	-1.895	-1.342	-3.472	-1.919
Max - Min	5.970	4.942	6.308	5.725	8.464	7.545

Curve Fit

Rejects outliers
Least-squared-error fit

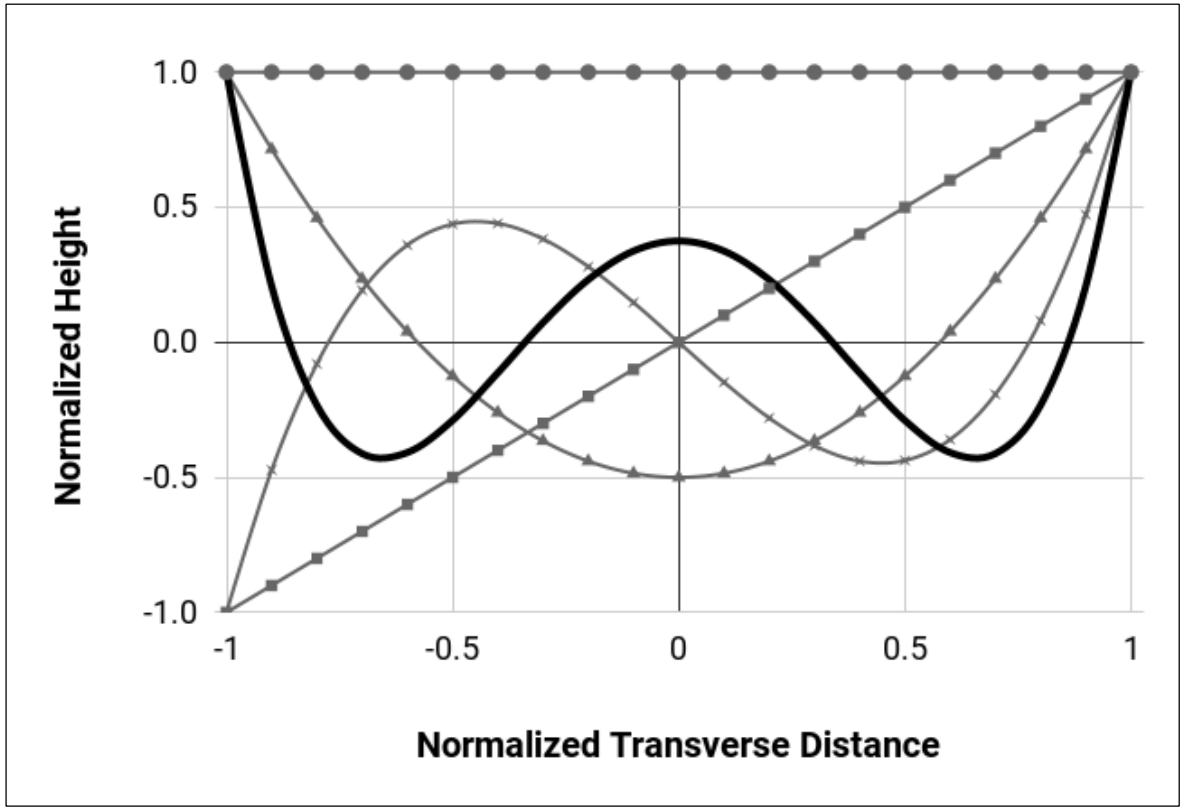
But…
needs to capture surface characteristics

- Elevation
- Cross-slope
- Crowning
- Rutting



Curve Fit

Consider a set of Legendre Polynomials



- ● Elevation
- ■ Cross-Slope
- ▲ Crown
- X Asymmetry
- — Rutting

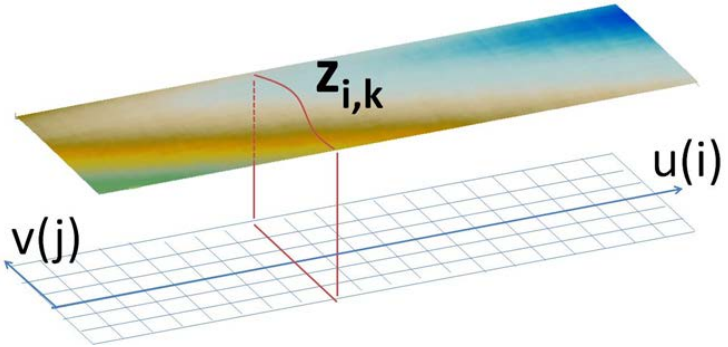
Curve Fit

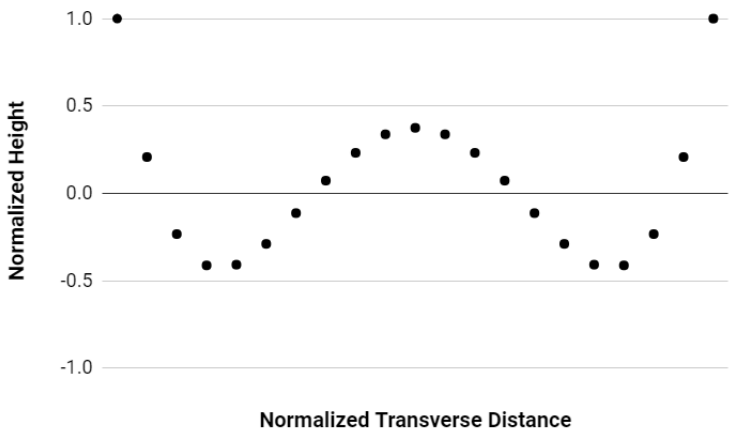
Recall Transverse spacing, v(j)

Discretize the polynomials

- according to spacing v(j)
- ex: Rutting

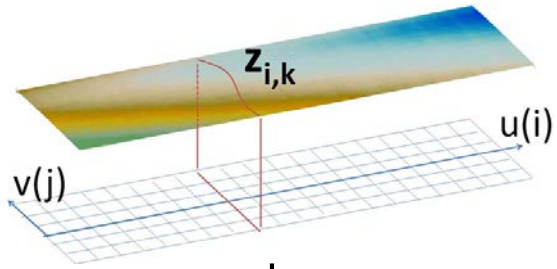
Orthonormalize each discretized polynomial (e.g., Gram-Schmidt)
→ Orthonormal basis vectors

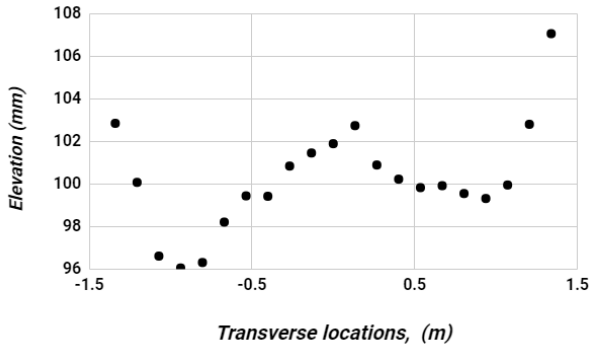


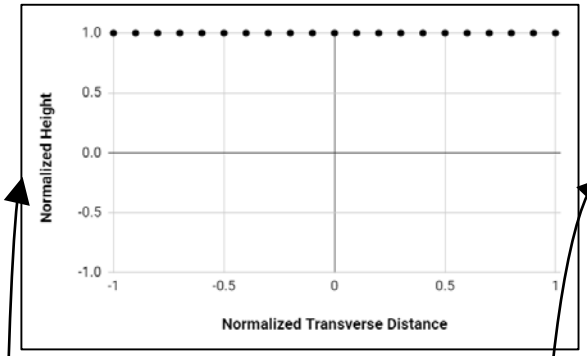


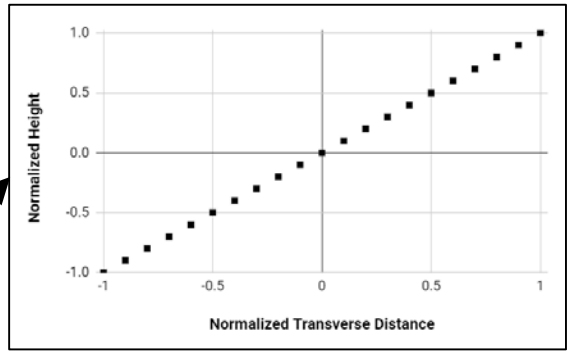
Curve Fit

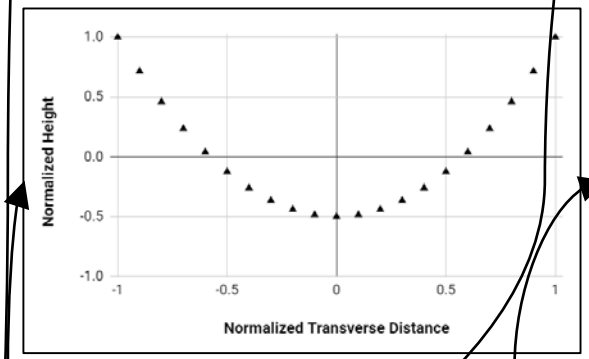
Project transverse profile onto each basis vector

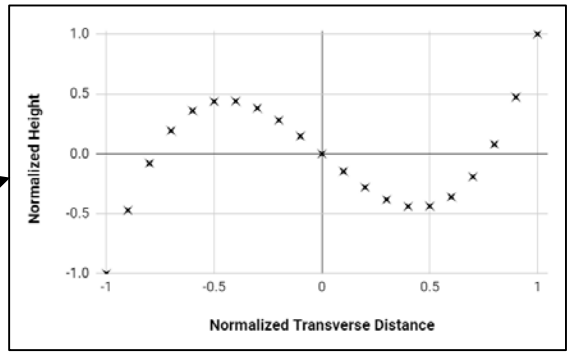


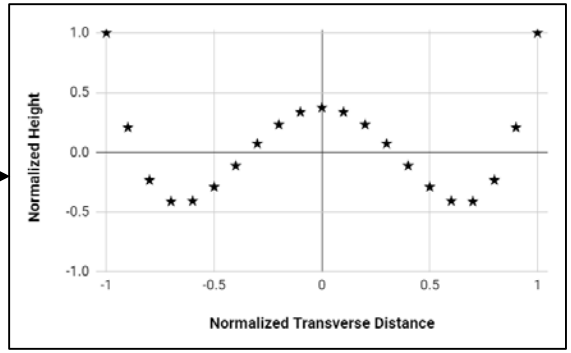










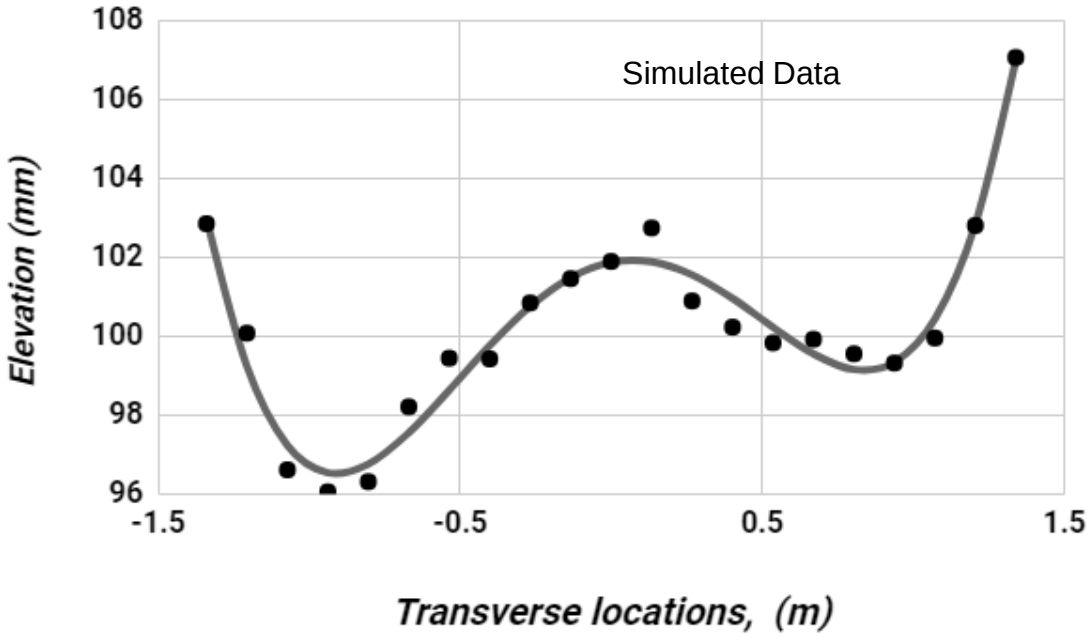


Curve Fit

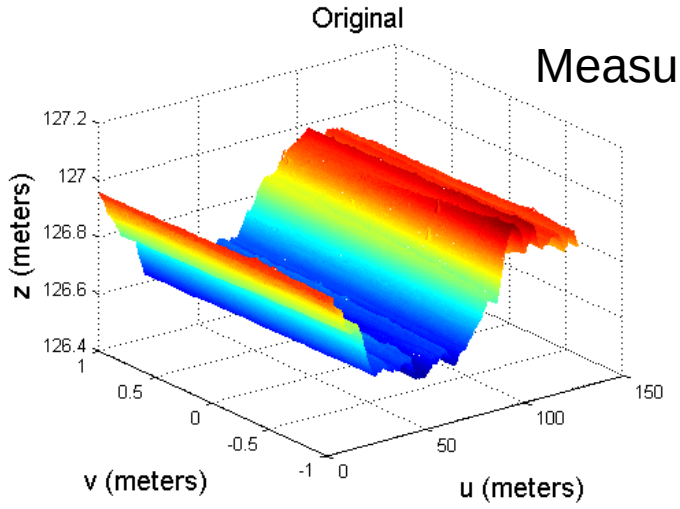
Example:

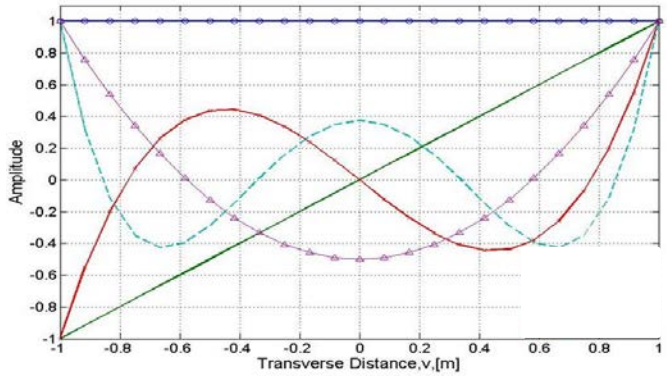
100 * Elevation +
2 * Cross-Slope +
0 * Crowning +
0 * Assymmetry +
5 * Rutting

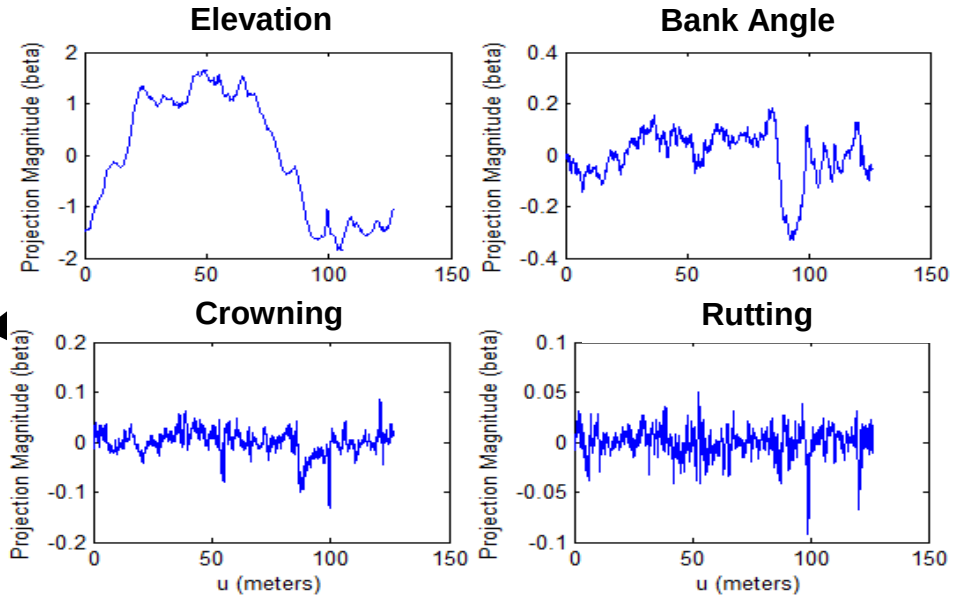
Can find these projections for all longitudinal locations



Curve Fit

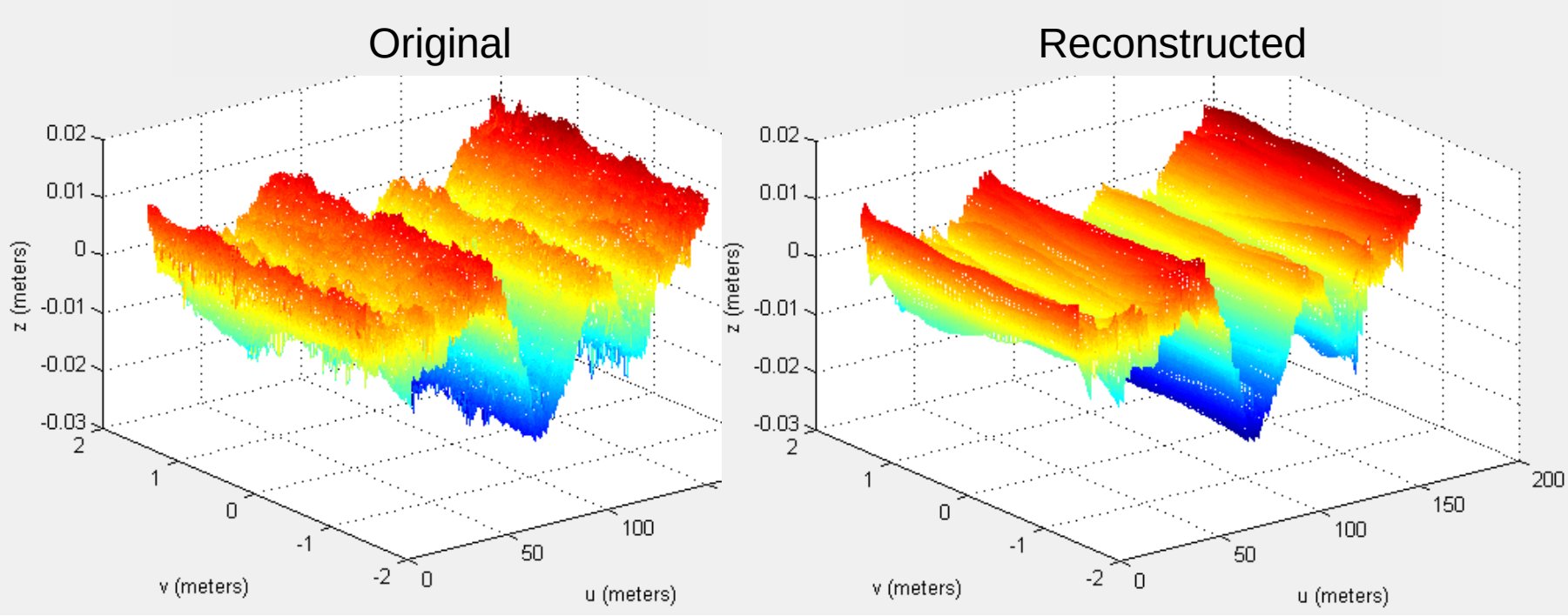

Original
Measured Surface
z (meters)
v (meters)
u (meters)


Amplitude
Transverse Distance,v,[m]


Elevation
Bank Angle
Crowning
Rutting
Projection Magnitude (beta)
u (meters)

Curve Fit

Using 5 polynomials to fit measured surface

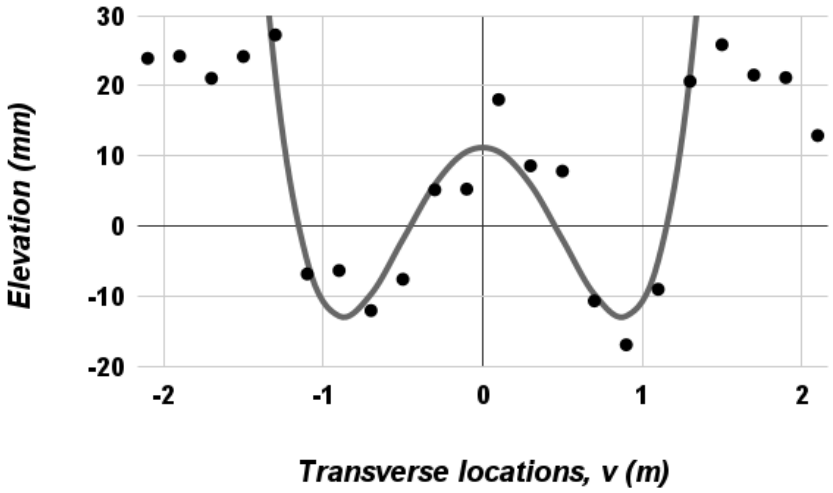


Research Need

GREAT!

So… we're done, right?

If we match "ruts" in Legendre polynomial
→ does not fit entire width of road



Research Need

Projecting trans. profiles onto orthonormal basis vectors

- Smooth and precise measures of transverse profile characteristics in that the squared error is minimized
- Provides unambiguous measures of elevation, cross-slope, crowning, and rutting

Future Work

- Identify more appropriate basis vectors

Questions?