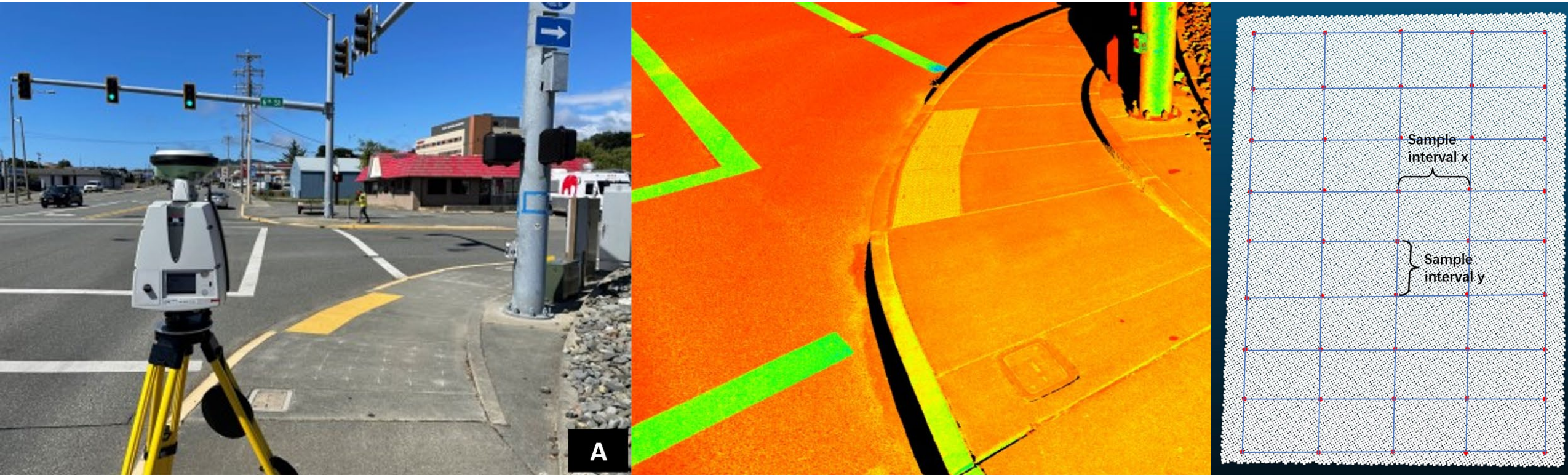


Virtual Curb Ramp Assessment from Lidar Data



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Oregon State University

Disclaimer

- Drs. Olsen and Che have financial interests in the company EZDataMD LLC, a tech transfer company spun out from OSU. The conduct, outcomes, or reporting of this research could benefit EZDataMD LLC and could potentially benefit us.
- Tech Transfer of Geomatics Research at OSU
 - Exclusive IPs for point cloud processing:
 - **RoME**: road marking extraction and evaluation
 - **Vo-Norvana**: point cloud segmentation
 - **Vo-SmoG**: ground filtering
 - **EZPC**: point cloud data management toolkit
 - **EZVox**: point cloud data processing toolkit
 - **EZFeat**: feature extraction toolkit
 - **RAMBO**: slope stability/terrain modeling/change analysis
 - And MANY MORE!
- Provides a wide range of services
 - Licensing software
 - Consulting services
 - Custom development



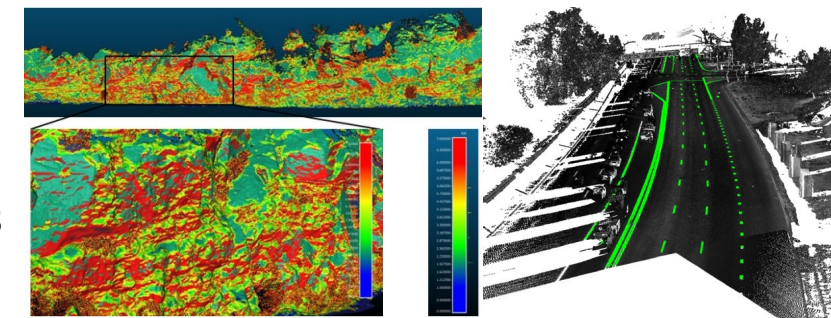
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Michael Olsen



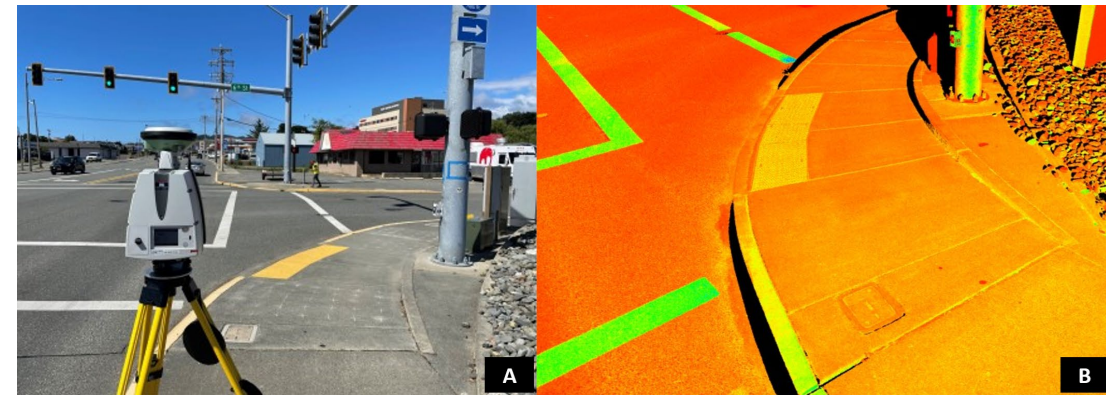
Ezra Che



Smart Level vs Lidar



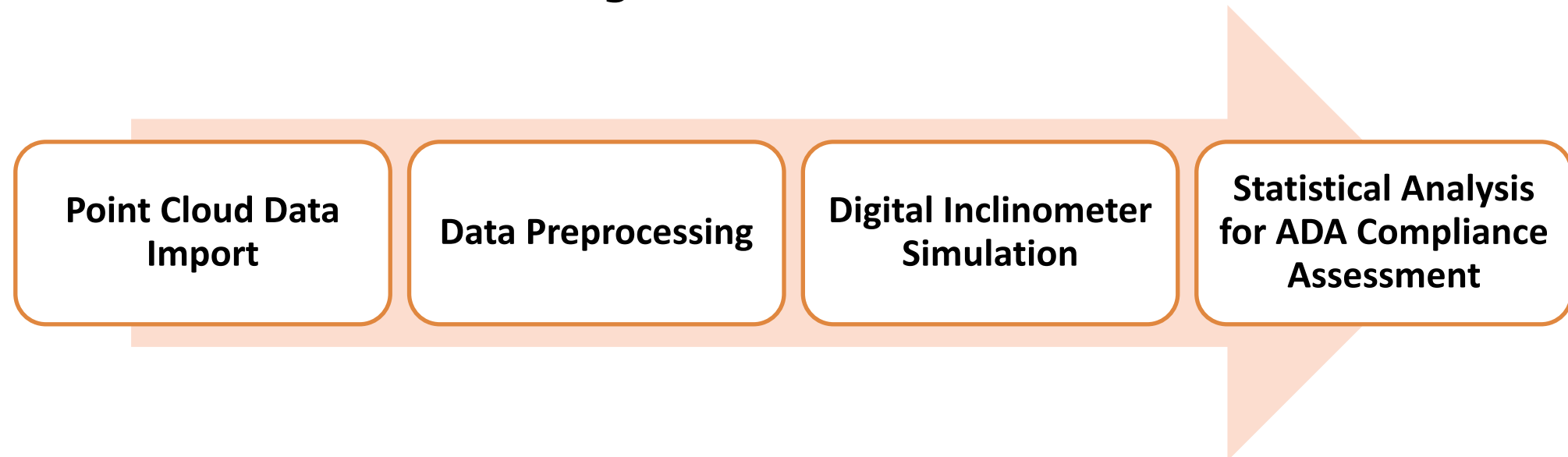
- Smart Level
 - Easy to operate
 - High Accuracy (0.2%, 1-sigma)
 - Current standard
- Lidar
 - High Accuracy (sub-cm)
 - High resolution (cm)
 - Surrounding environment



Objectives



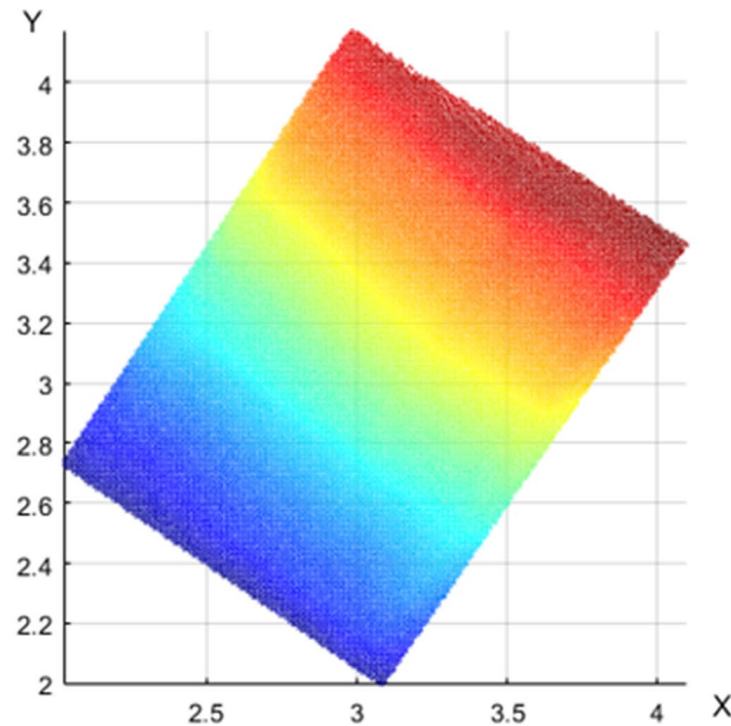
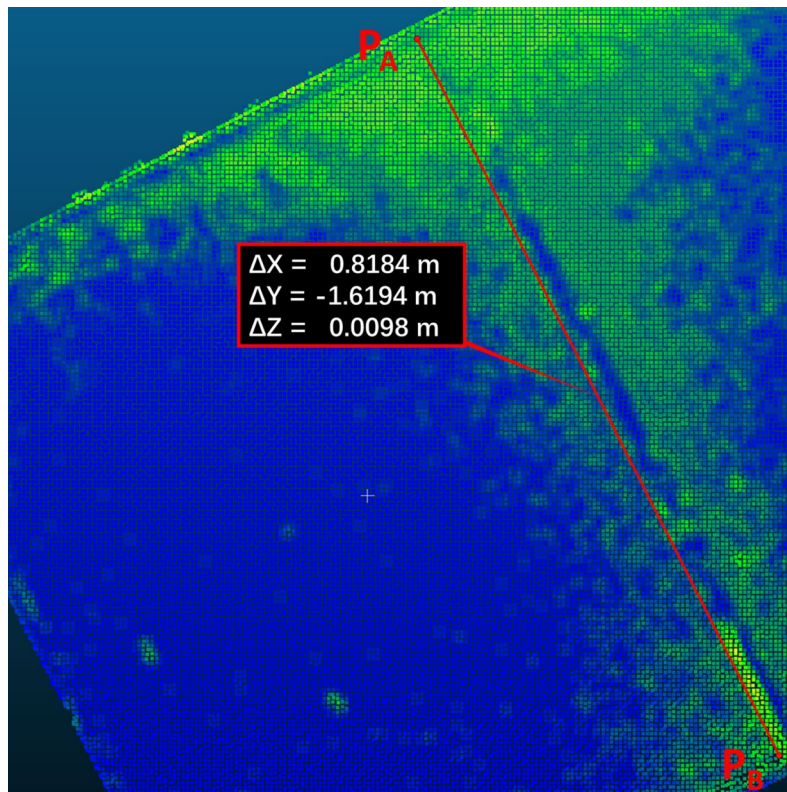
- Workflow for slope measurement using lidar:
 - Consider context of ADA compliance assessment.
 - Align with field equipment and procedure
 - Minimize user intervention
 - Consider surface roughness



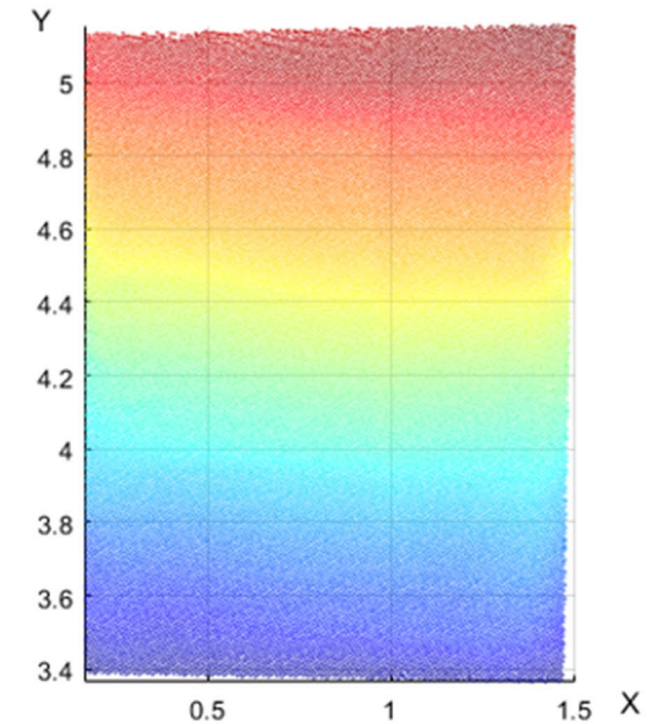
Data Preparation



- Crop the point cloud
- Define ramp orientation



Point cloud data before rotation

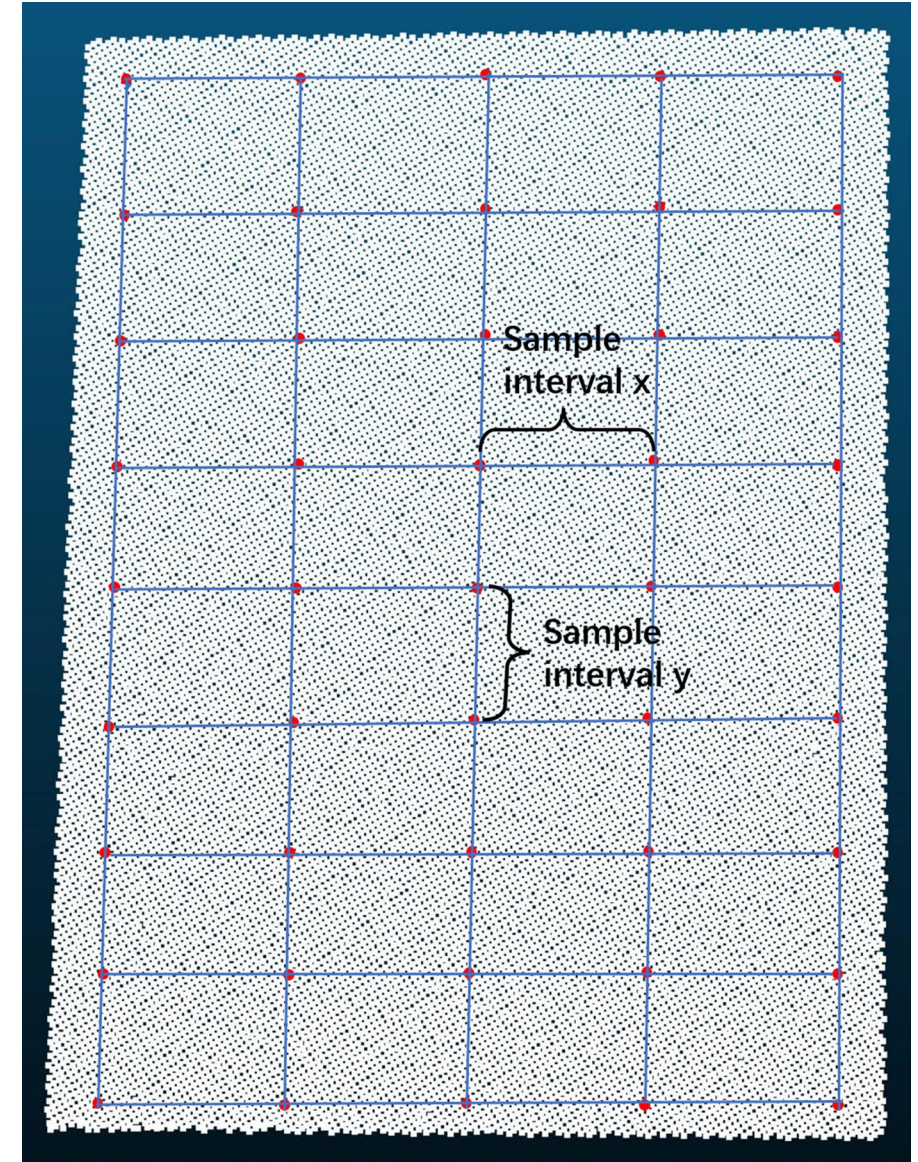
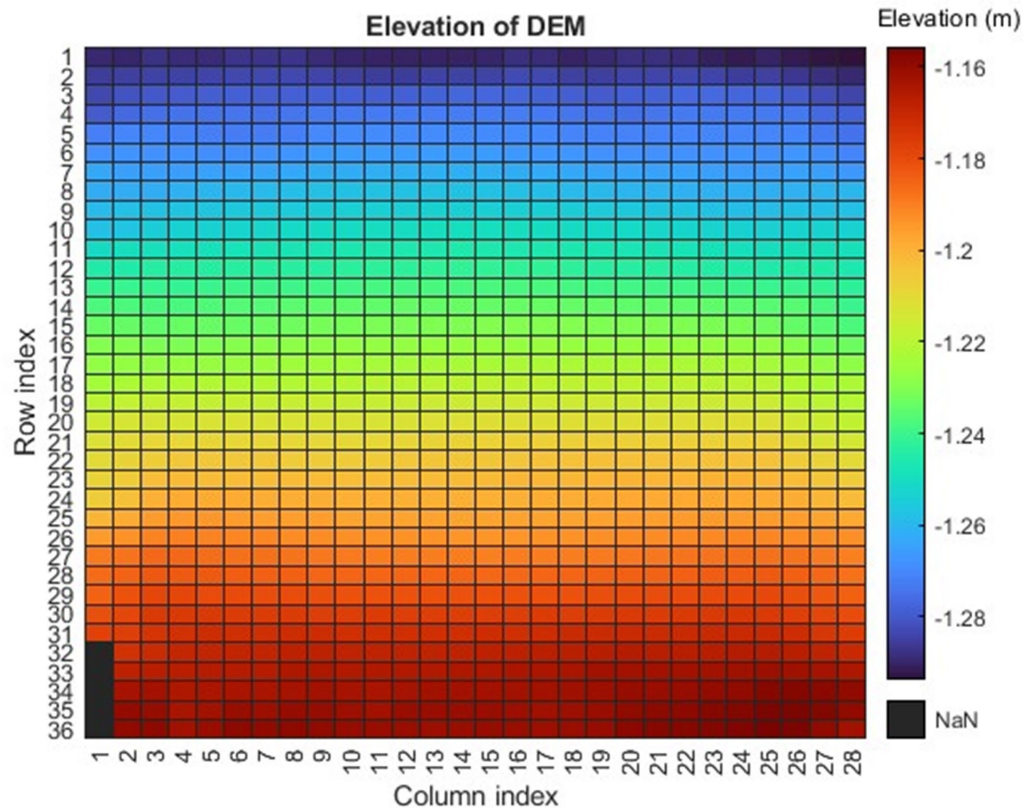


Point cloud data after rotation

DEM & Sampling



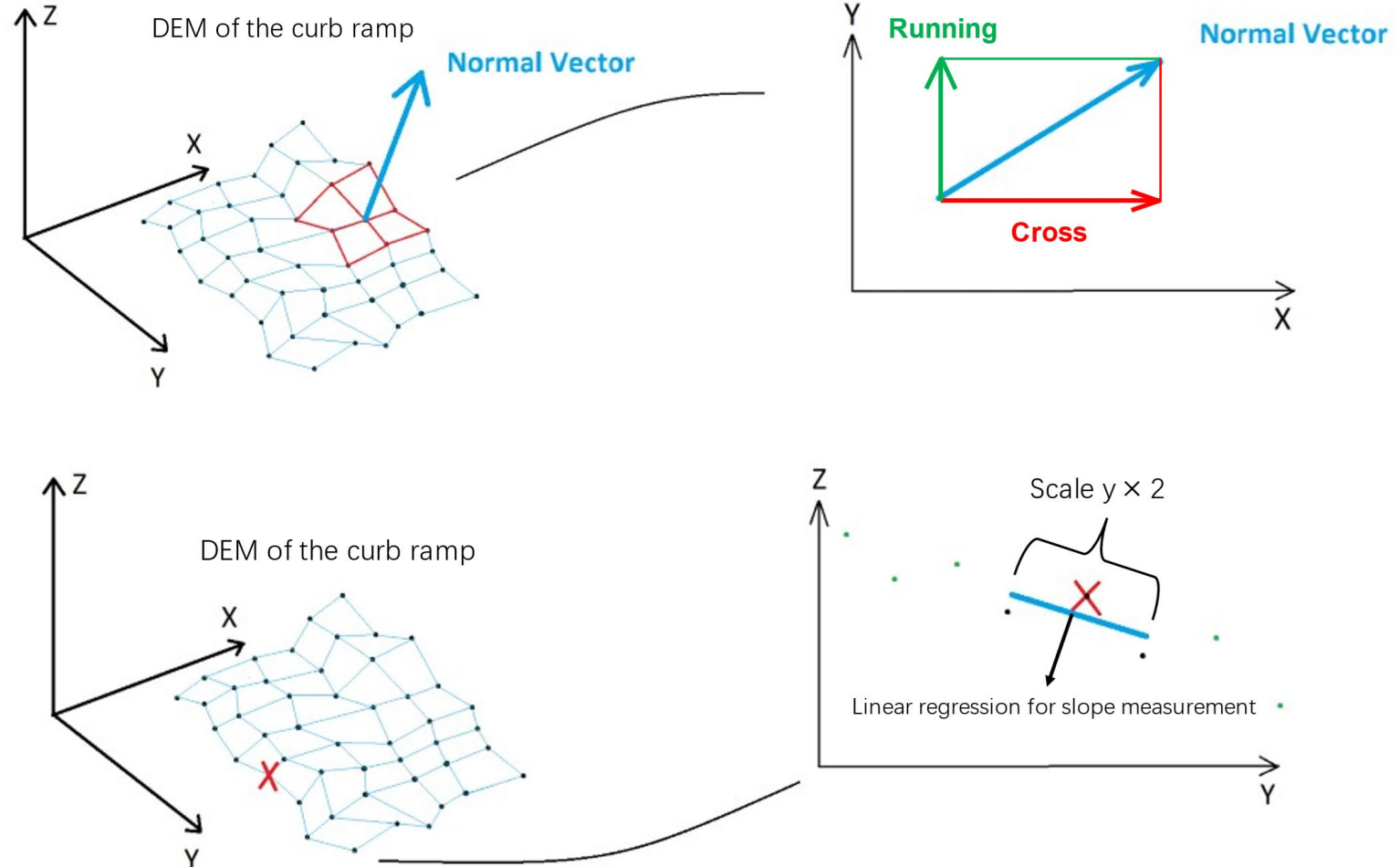
- Generate DEM
- Define sampling locations



Slope measurement



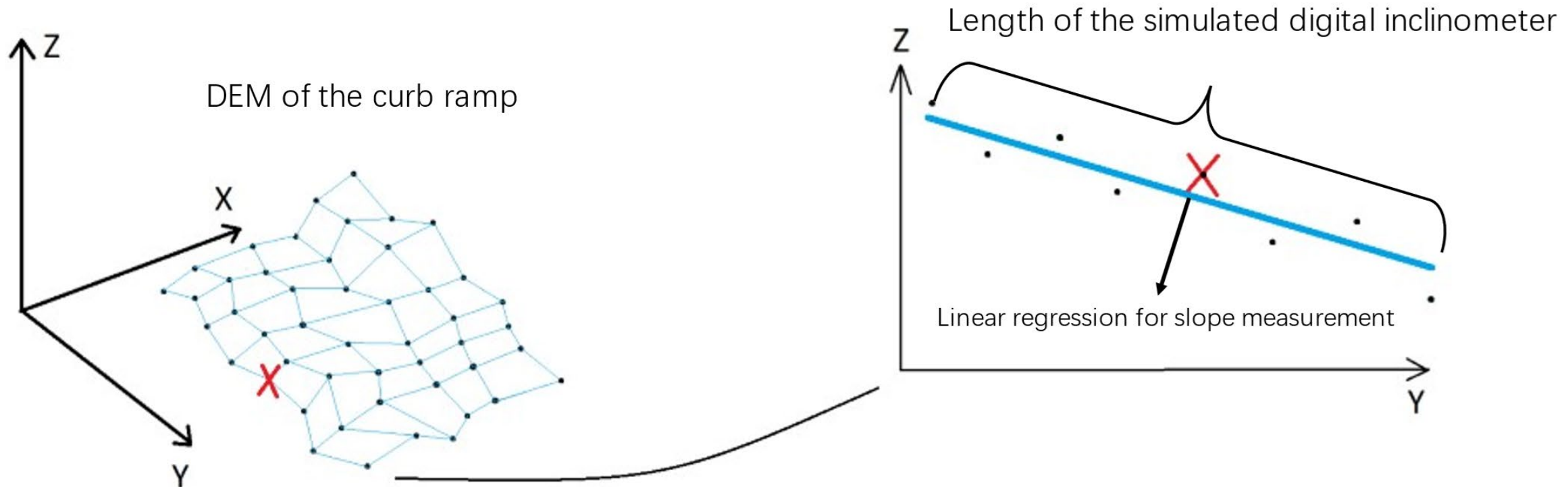
- Surface Normal (SN)
- Linear Regression (INLR)
 - Immediate neighbor used
 - Sensitive to noise
 - Do not match smart level's measuring scale (length).



Slope measurement (cont.)



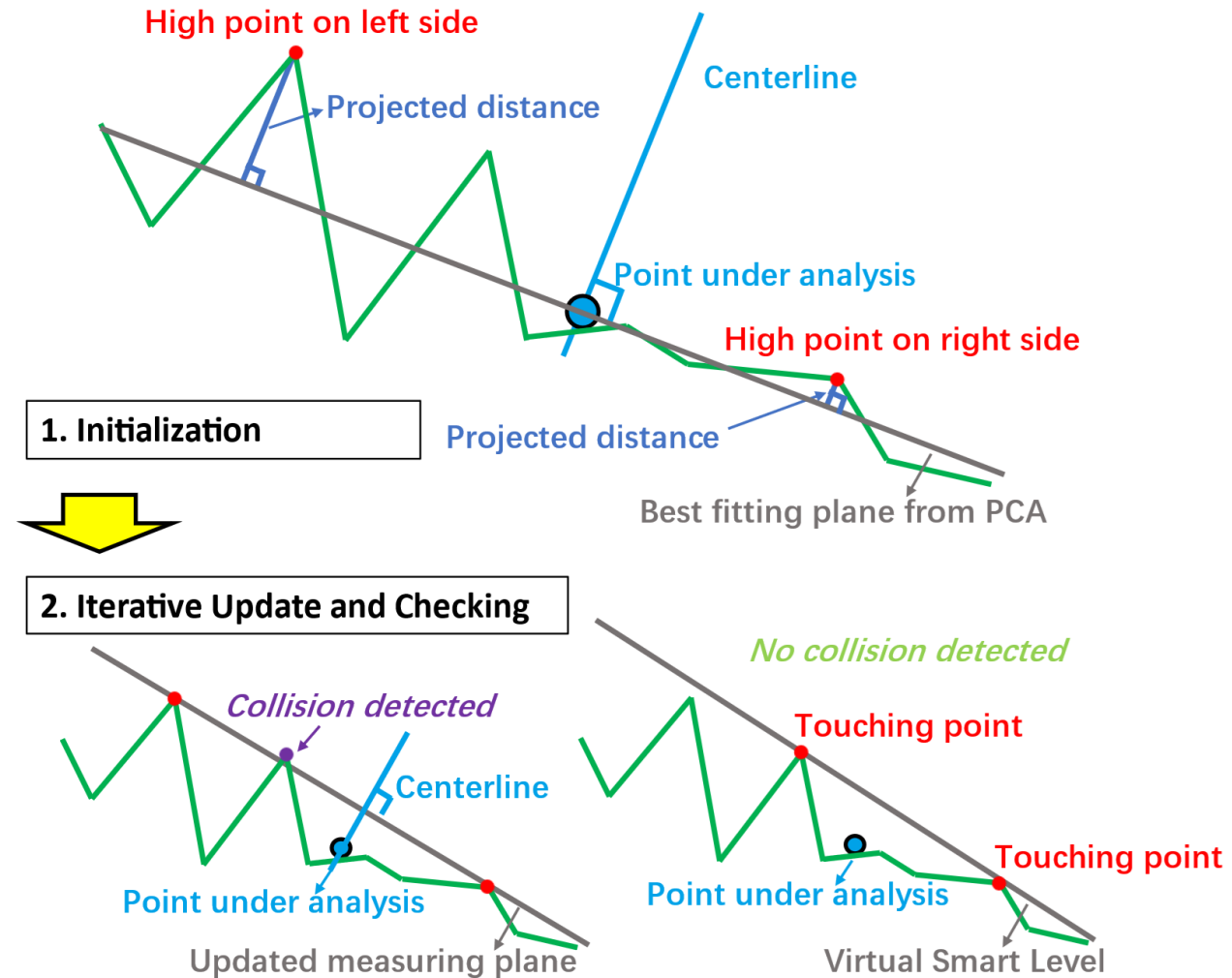
- Scaled Neighbor Linear Regression (SNLR)
 - Match the size of a smart level (0.6 m, 2 ft)
 - Still assume the surface to be smooth.



Touching Point



- Criteria:
 - There is one touching point on each half of the virtual smart level.
 - The entire virtual device is above the ground (DEM).
- Advantages:
 - Considering both the measuring scale and surface roughness.



Testing Dataset

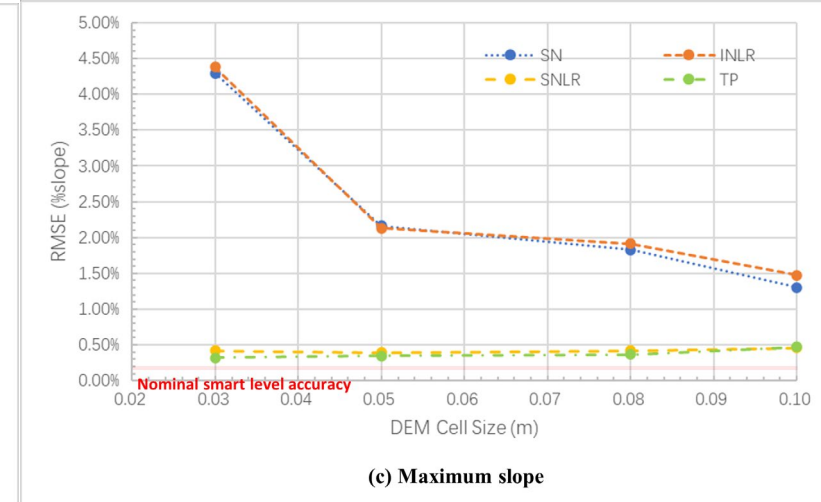
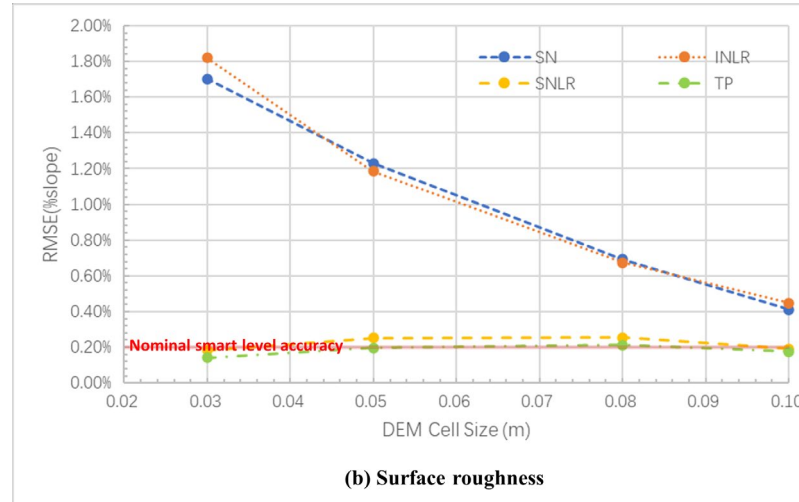
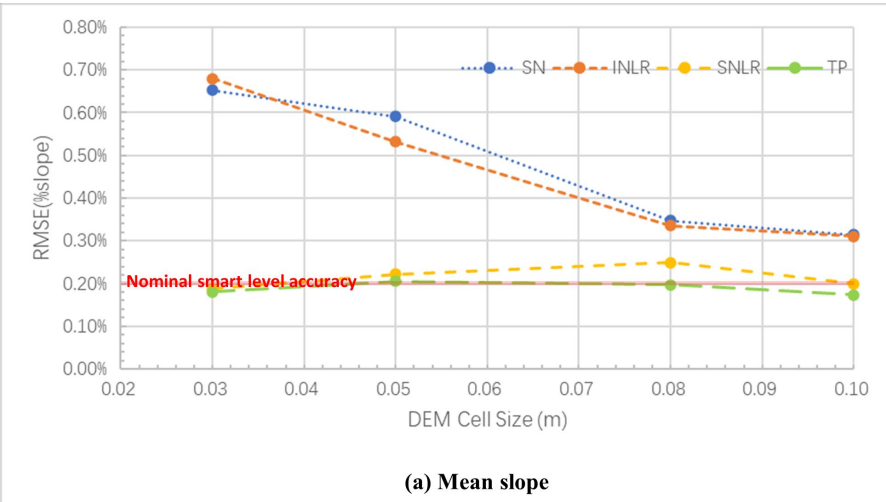


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- Slope metrics
 - Mean Slope: general trend of the ramp surface.
 - Slope Std. Dev.: roughness of the ramp surface.
 - Maximum Slope: current standard for assessment.



Accuracy Assessment



Optimized Cell Size = 0.03 m (matches the width of a smart level!)

RMSE of mean slope	SN	0.65%
	INLR	0.68%
	SNLR	0.19%
	TP	0.18%

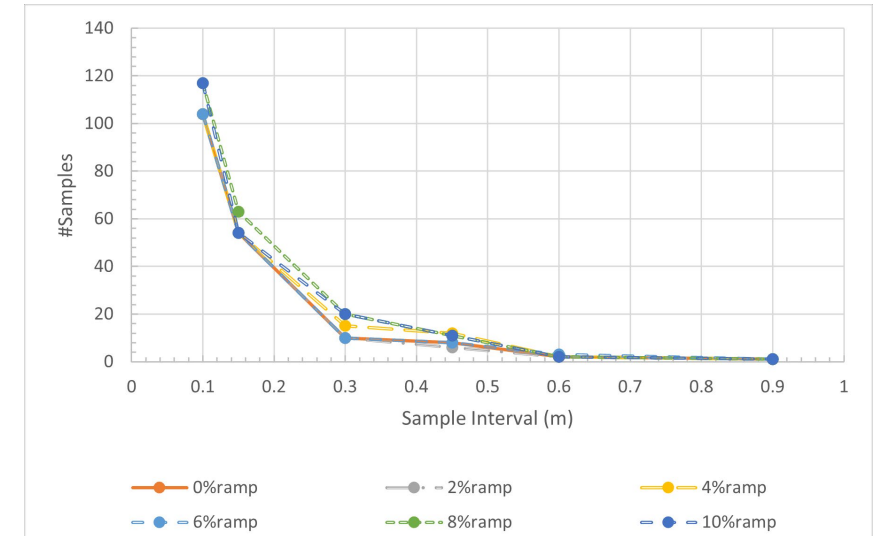
RMSE of surface roughness	SN	1.70%
	INLR	1.82%
	SNLR	0.18%
	TP	0.14%

RMSE of maximum slope	SN	4.29%
	INLR	4.38%
	SNLR	0.42%
	TP	0.32%

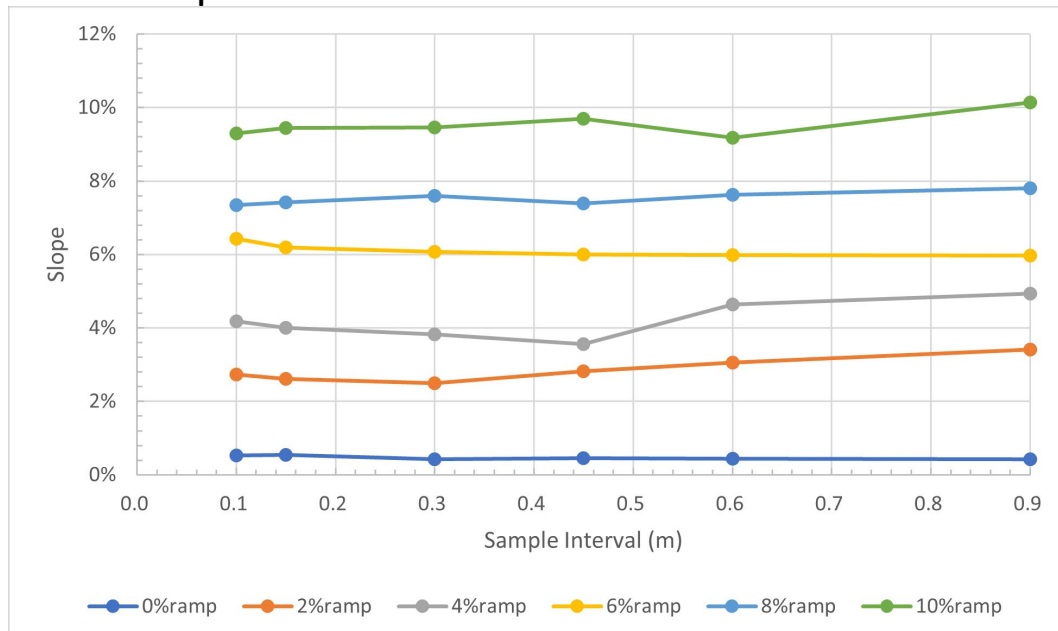
Application Example



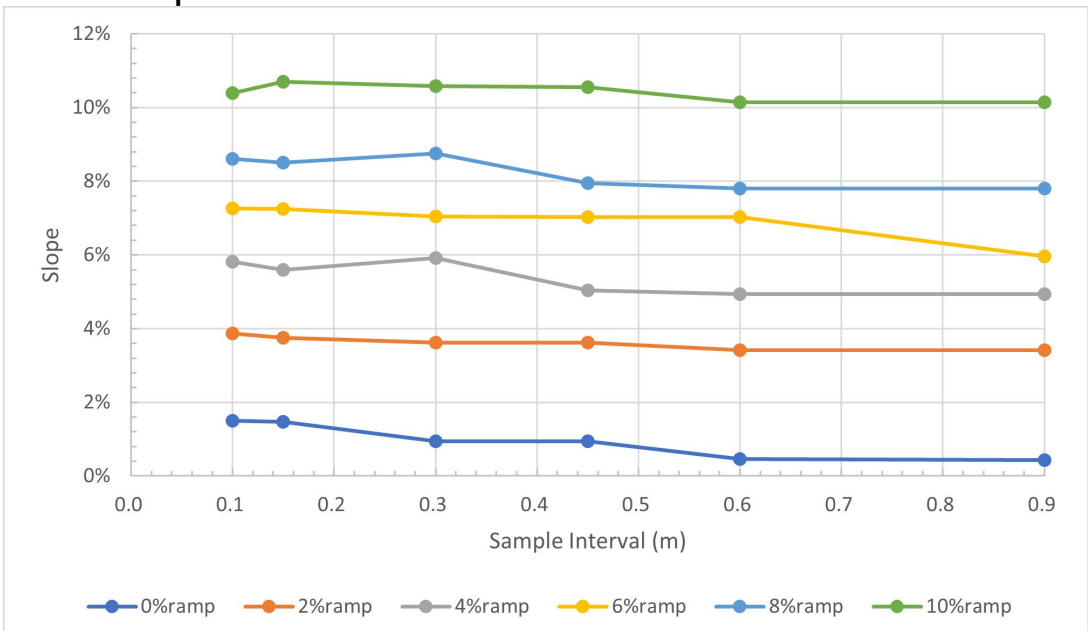
- Virtual sensitivity analysis
 - Sampling Interval
 - Number of samples



Mean Slope



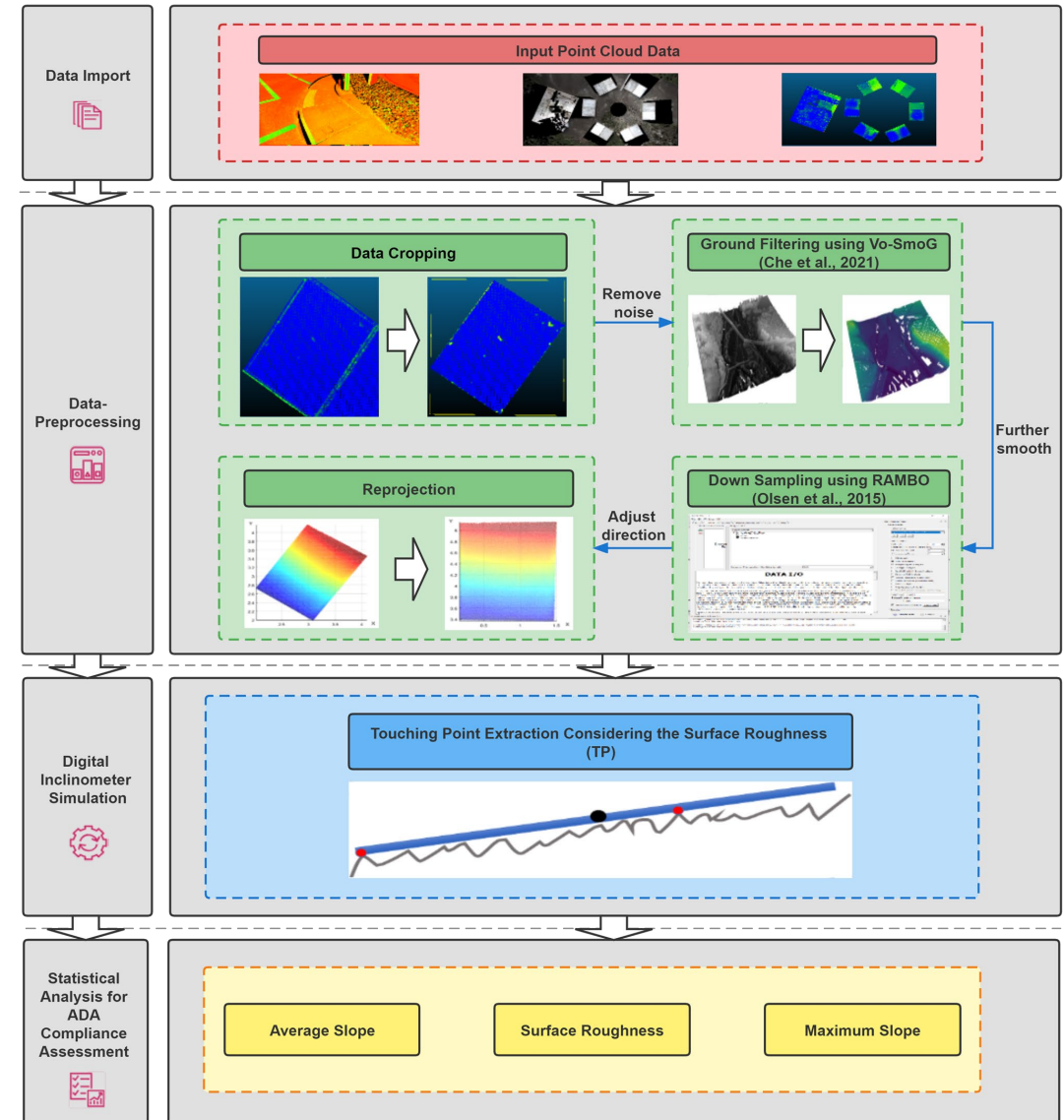
Max Slope



Conclusion



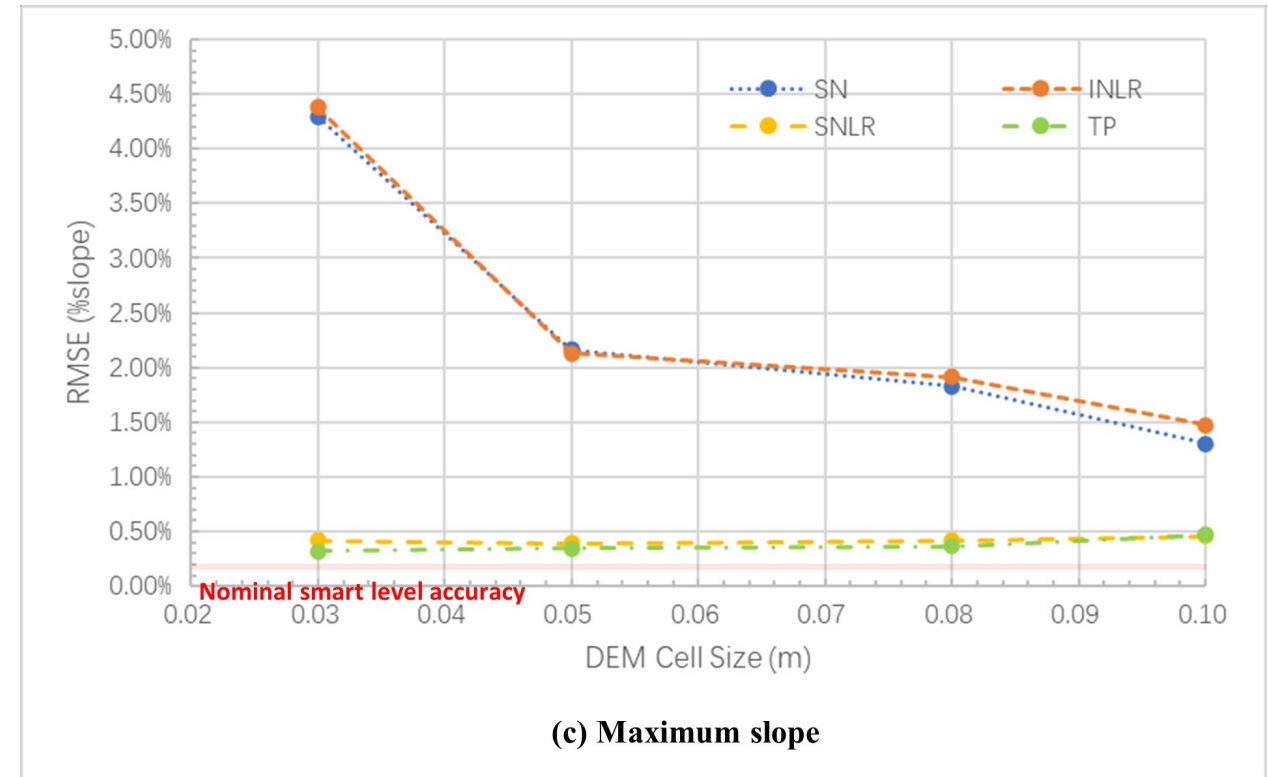
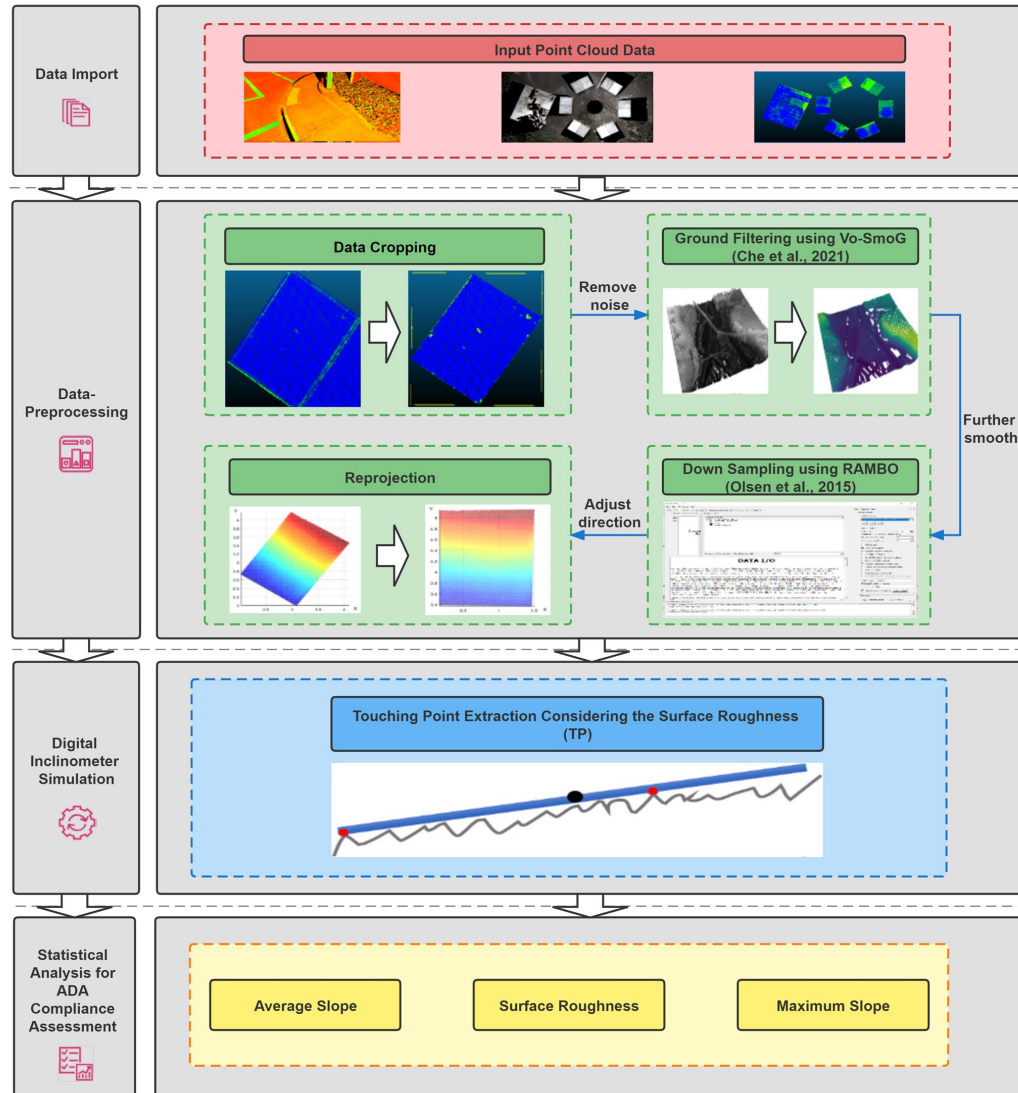
- Accuracy
 - Mean slope: 0.18%
 - Roughness: 0.14%
 - Max slope: 0.32%
 - Smart Level: 0.2%
- Consistency
 - Inspectors: 0.5% (max slope)
- Flexibility
 - Adjustable sampling distance
- Efficiency
 - Save field time



THANK YOU!



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ODOT standard for curb ramp design.



Characteristic	ODOT standard
Running slope	5.0% to 7.5%
Cross slope	1.5% maximum
Counter slope	4.0% maximum
Clear width	54 in (1.4 m), 66 in (1.7 m) (island)
Flares	10% maximum
Landing slope	1.50%
Landing dimension	54 in (1.4 m)
Gutter cross slope	1.50%
Turning space	54 in or 1.4 m minimum and 66 in or 1.7 m minimum when the back is constrained, 1.5% maximum slope

Test results obtained with the proposed approaches for the 0% slope curb ramp (cell size: 0.03 m).



Nominal Slope: 0%							
Method	Ramp ID	Slope Metrics (% slope)					
		# of samples	mean	std	min	max	median
SN	A	19	1.41%	1.15%	0.08%	3.94%	1.11%
	B	17	1.52%	1.21%	0.06%	3.42%	1.08%
INLR	A	19	1.51%	1.41%	0.00%	4.33%	1.00%
	B	20	1.54%	1.17%	0.17%	3.58%	1.21%
SNLR	A	8	0.44%	0.40%	0.01%	1.33%	0.33%
	B	12	0.63%	0.63%	0.09%	1.88%	0.43%
TP	A	8	0.45%	0.26%	0.06%	0.94%	0.41%
	B	12	0.55%	0.62%	0.01%	1.89%	0.29%
Smart level	A	9	0.56%	0.43%	0.05%	0.15%	0.55%
	B	9	0.58%	0.67%	0.10%	1.95%	0.30%

Difference values (Δ) between the different approaches and smart level on the ramps with a nominal slope of 0% (cell size: 0.03 m).



Nominal Slope: 0%						
Method	Ramp ID	D (% slope)				
		mean	std	min	max	median
SN	A	0.85%	0.72%	0.03%	3.80%	0.56%
	B	0.94%	0.54%	-0.04%	1.47%	0.78%
INLR	A	0.95%	0.98%	-0.05%	4.19%	0.45%
	B	0.96%	0.50%	0.07%	1.63%	0.91%
SNLR	A	-0.12%	-0.03%	-0.04%	1.19%	-0.22%
	B	0.05%	-0.04%	-0.01%	-0.07%	0.13%
TP	A	-0.11%	-0.17%	0.01%	0.79%	-0.14%
	B	-0.03%	-0.05%	-0.09%	-0.06%	-0.01%

Statistical summary of the mean slopes for all ramps (cell size: 0.03 m, unit: % slope).



Method	Statistics of the mean slope (from 0% to 10%)					
	avg	std	min	max	median	RMSE
SN	0.23%	0.64%	-0.53%	1.41%	0.16%	0.65%
INLR	0.17%	0.69%	-0.52%	1.44%	-0.06%	0.68%
SNLR	-0.06%	0.19%	-0.27%	0.32%	-0.08%	0.19%
TP	-0.10%	0.16%	-0.38%	0.18%	-0.10%	0.18%

Accuracy of the curb ramp metrics for each approach with variant DEM cell sizes



DEM cell size		0.03 m	0.05 m	0.08 m	0.10 m
RMSE of mean slope	SN	0.65%	0.59%	0.35%	0.31%
	INLR	0.68%	0.53%	0.34%	0.31%
	SNLR	0.19%	0.22%	0.25%	0.20%
	TP	0.18%	0.20%	0.20%	0.17%
RMSE of surface roughness	SN	1.70%	1.23%	0.69%	0.41%
	INLR	1.82%	1.19%	0.67%	0.45%
	SNLR	0.18%	0.25%	0.25%	0.19%
	TP	0.14%	0.20%	0.21%	0.18%
RMSE of maximum slope	SN	4.29%	2.16%	1.83%	1.31%
	INLR	4.38%	2.13%	1.92%	1.47%
	SNLR	0.42%	0.39%	0.42%	0.46%
	TP	0.32%	0.34%	0.37%	0.47%