

Road Profiler Users' Group 35<sup>th</sup> Annual Conference

# Key Findings Regarding Cross Correlation

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May 1, 2024



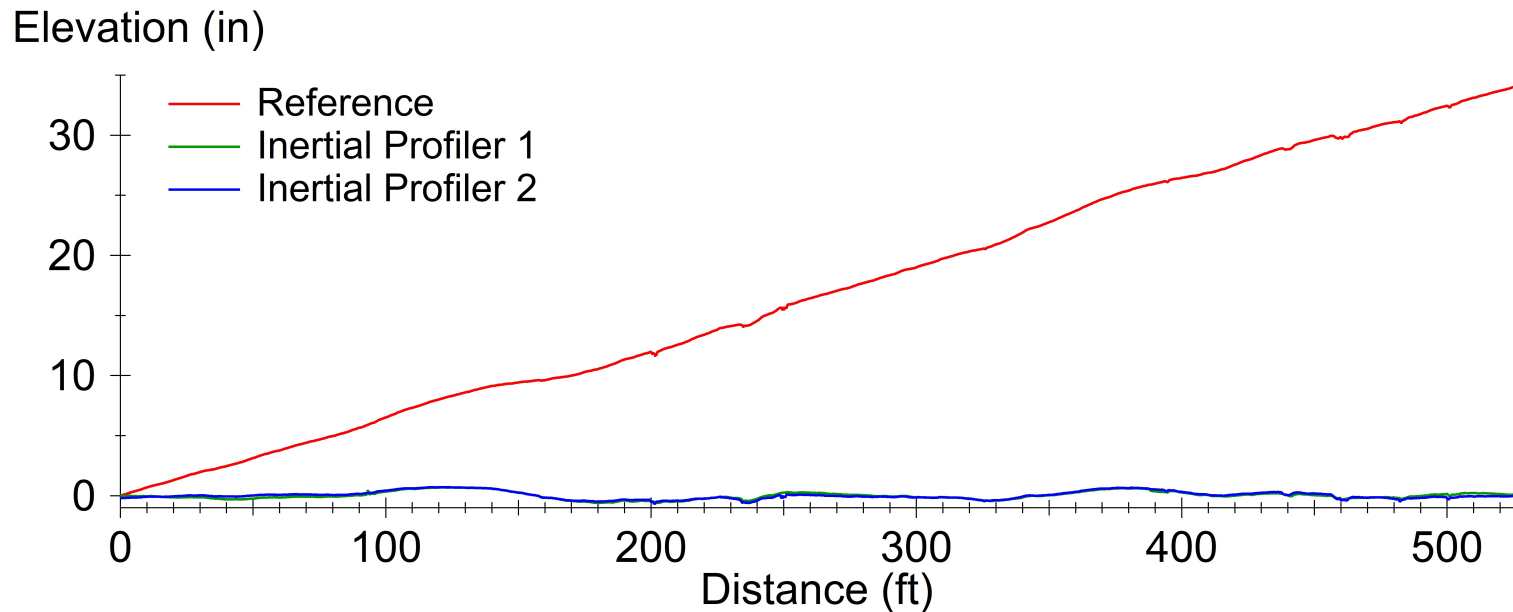
# Goals

- Provide background about cross correlation.
- Describe a specialized algorithm.  
(This includes things you'll have in ProVAL 4.0.)
- Discuss the influence of longitudinal distance measurement instrument (DMI) errors on agreement scores.
- Provoke a discussion about thresholds in AASHTO R56.

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# Reference Profile and Two Inertial Profiles



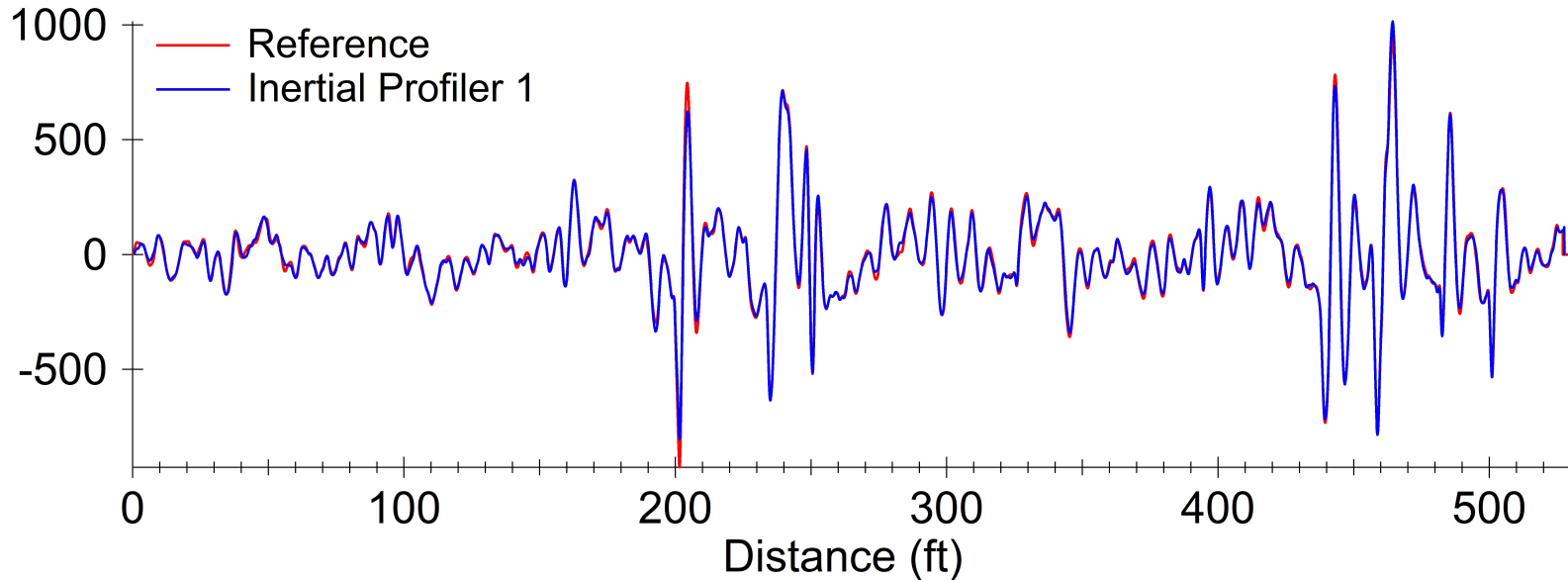
Reference IRI = 125.3 in/mi

Inertial Profiler 1 IRI = 123.5 in/mi

Inertial Profiler 2 IRI = 120.2 in/mi

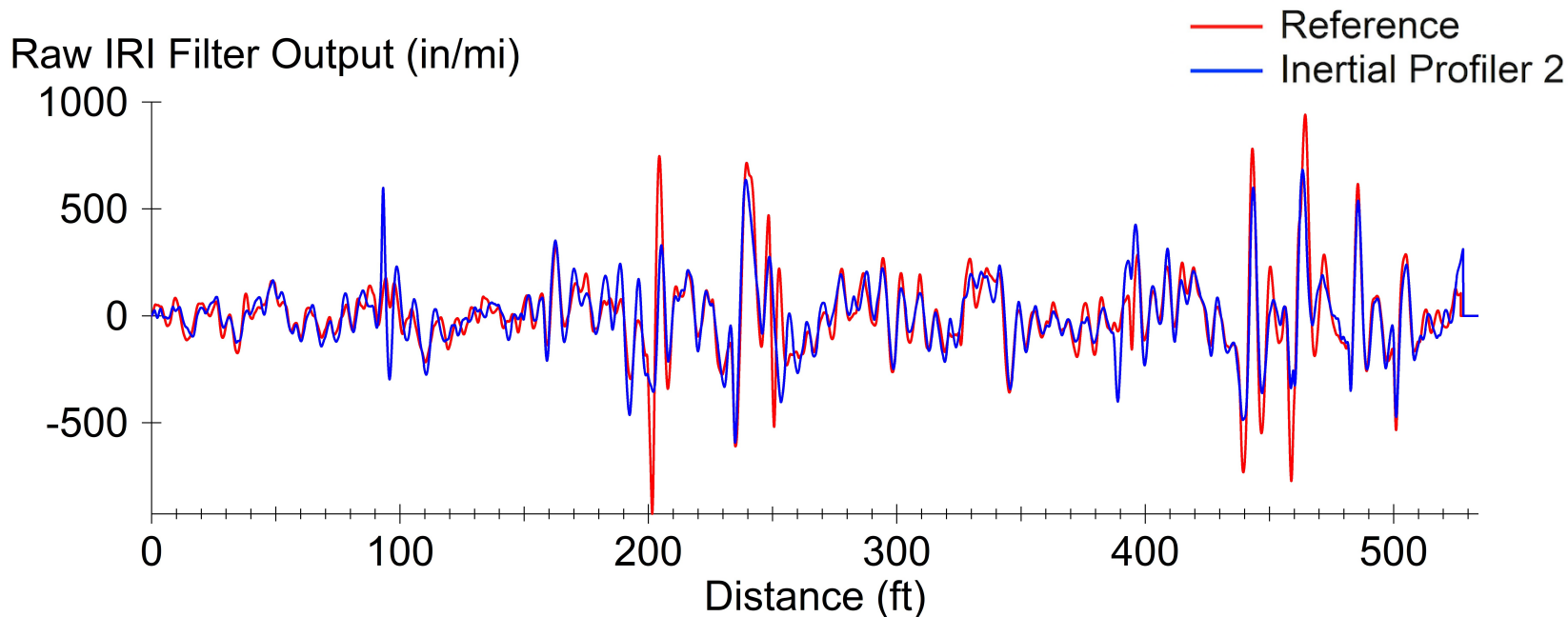
# Raw IRI Filter Output, Reference vs Inertial Profiler 1

Raw IRI Filter Output (in/mi)



Cross Correlation = 0.978

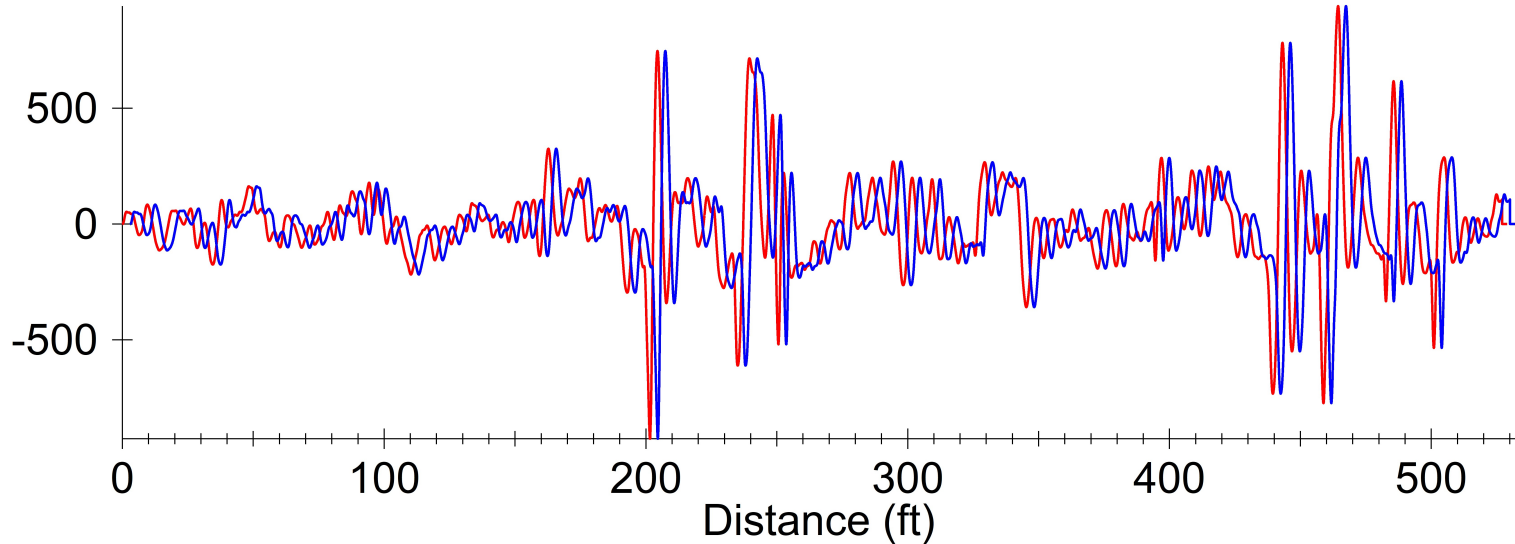
# Raw IRI Filter Output, Reference vs Inertial Profiler 2



Cross Correlation = 0.729

# Distance Offset

Raw IRI Filter Output (in/mi)

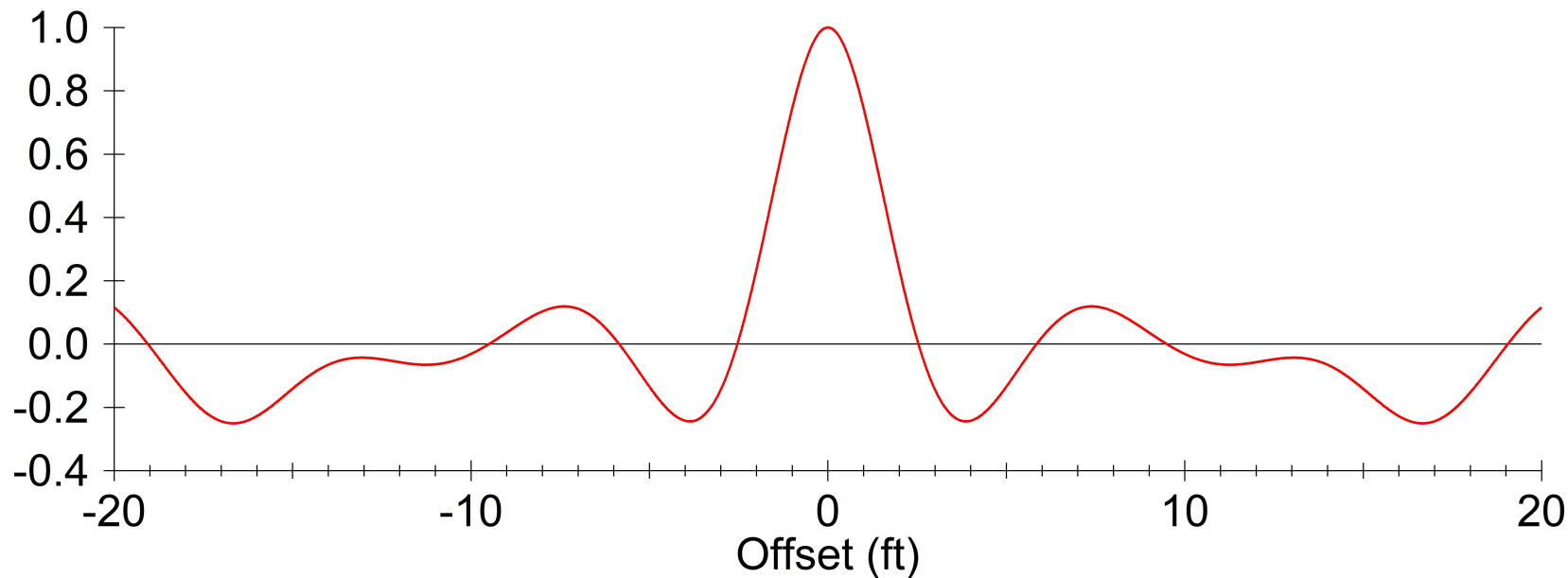


Offset = 3 ft (This is the AASHTO R56-14 limit.)

Cross Correlation < 0

# Cross Correlation versus Distance Offset

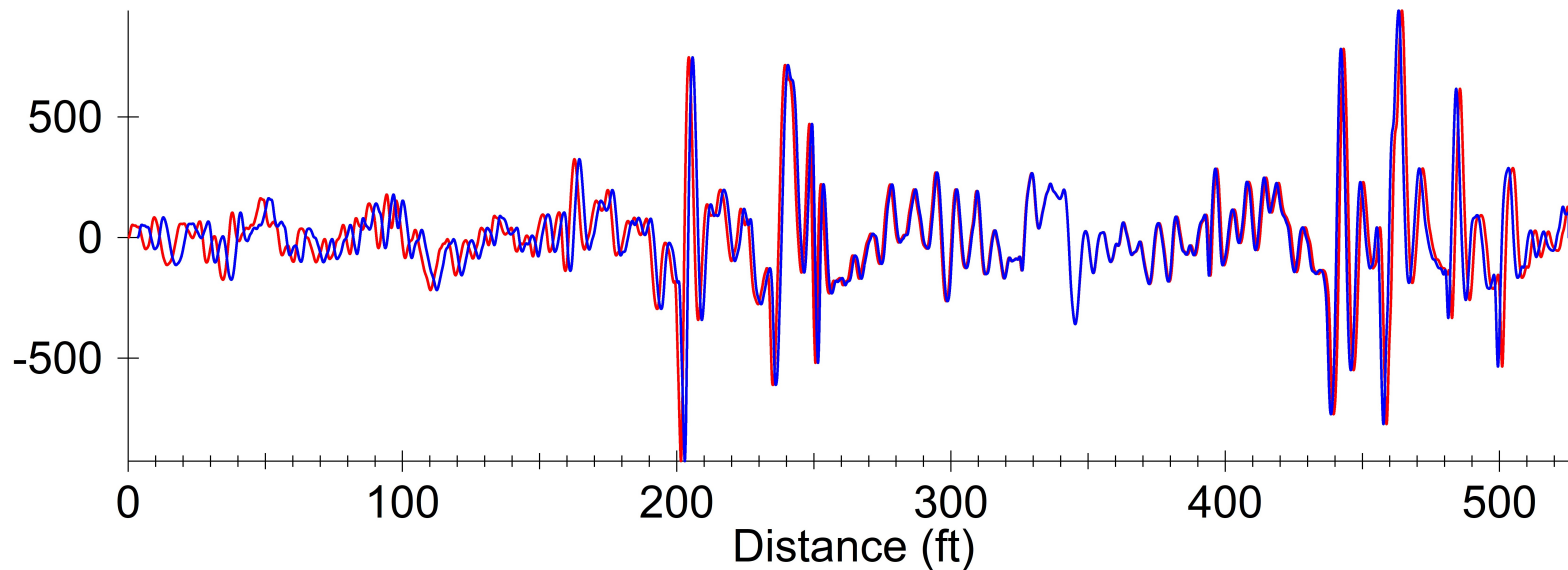
Cross Correlation (-)





# Longitudinal Distance Measurement Error

Raw IRI Filter Output (in/mi)



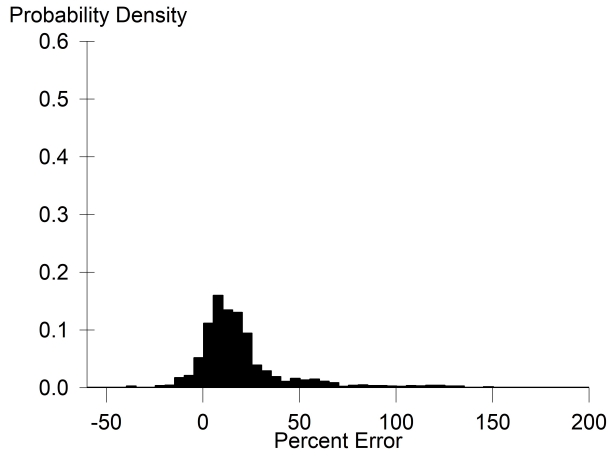
Distance Measurement Error 1 percent  
Cross Correlation = 0.647

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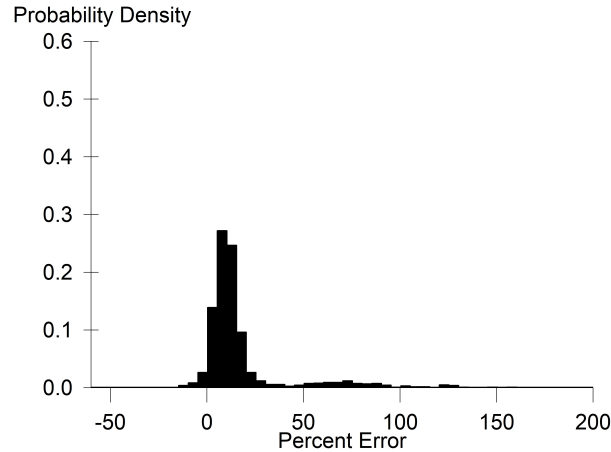
# Round-Ups (IRI Reproducibility)

1993



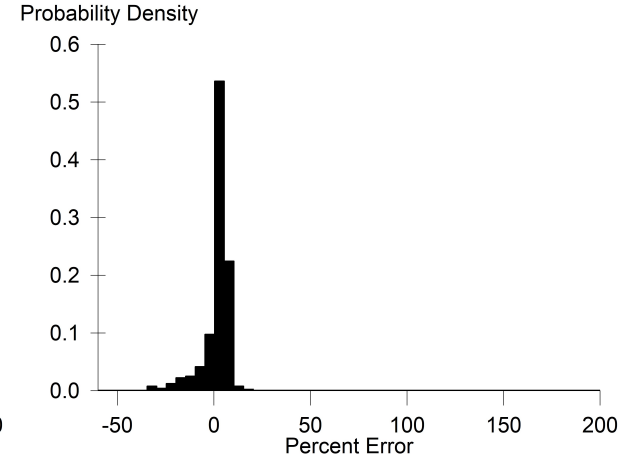
1993 RPUG Round-Up  
Network measurement  
(Perera and Kohn)  
30 test sections  
34 profilers  
129,812 comparisons

2004



2004 Round-Up  
Construction QA/QC  
(Karamihas with help)  
9 test sections  
68 profilers  
445,669 comparisons

2015



2015 Type Testing and  
Reference Testing  
(Perera and Karamihas)  
9 test sections  
16 profilers  
138,572 comparisons

# Specialized Procedure: Profile Reflection

Step 1: Reverse the profile horizontally and vertically.

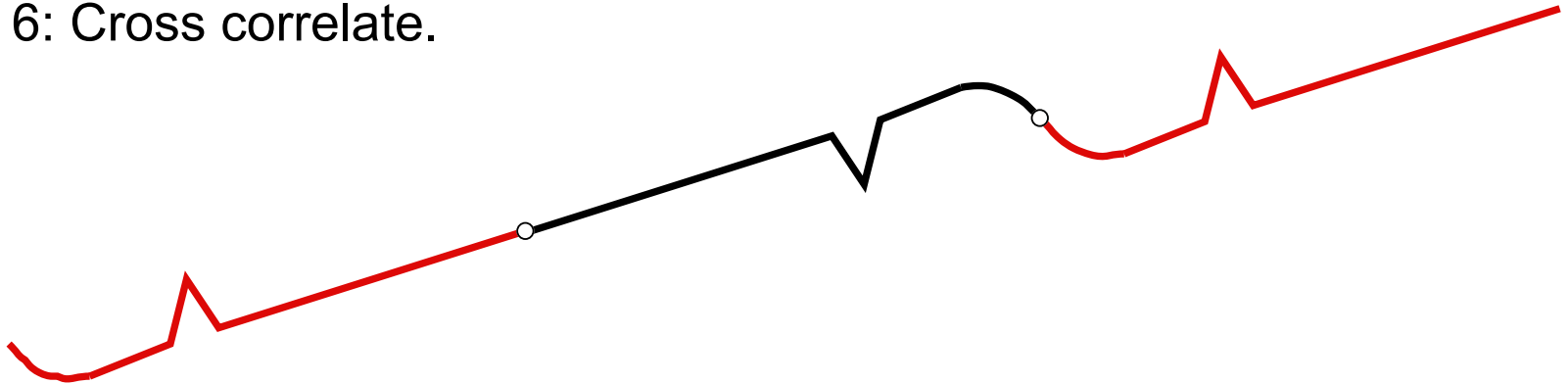
Step 2: Add the “reversed” version to the endpoints.

Step 3: Apply the filter.

Step 4: Crop to the original length.

Step 5: Resample.

Step 6: Cross correlate.



# Specialized Procedures

Step 1-4: Use padding (reflect, filter, crop).

Step 5: Resample to a common interval.

IMPORTANT: AASHTO R56 says resample to the interval of the reference profile. A change is needed.

Use of 5.08 mm is recommended.

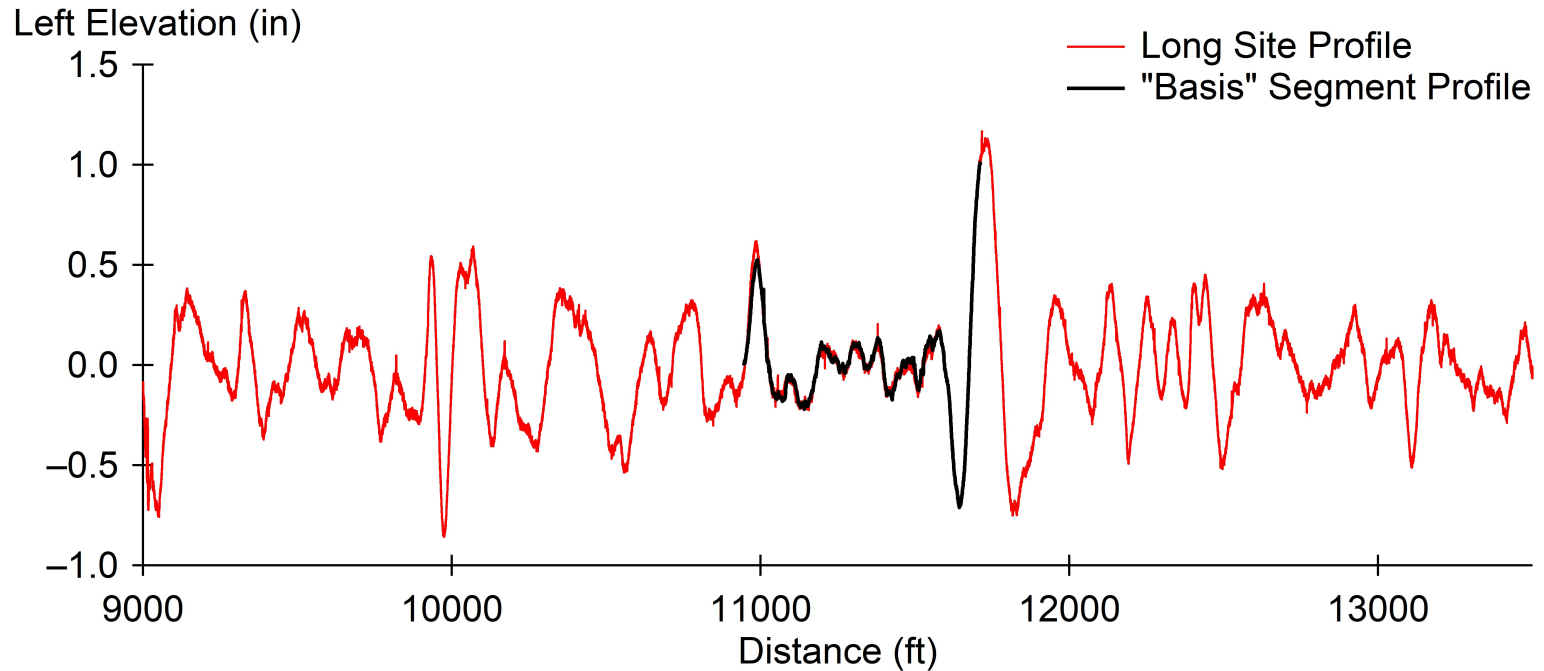
Step 6: Cross correlate, a lot.

Search for the DMI adjustment that produces the best score.

For each DMI adjustment, find the offset the produces the best score.

Report results for the best combination of offset and DMI adjustment.

# Extraction of Subsection Profiles

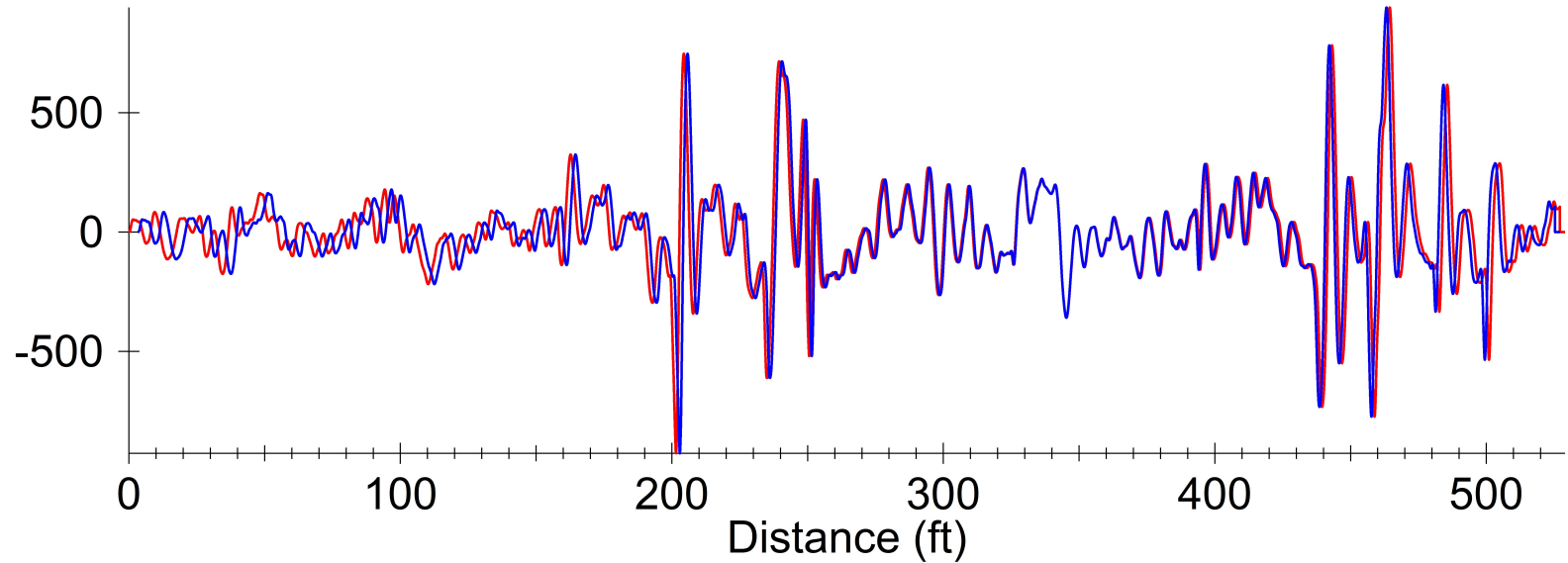


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# Rerun....

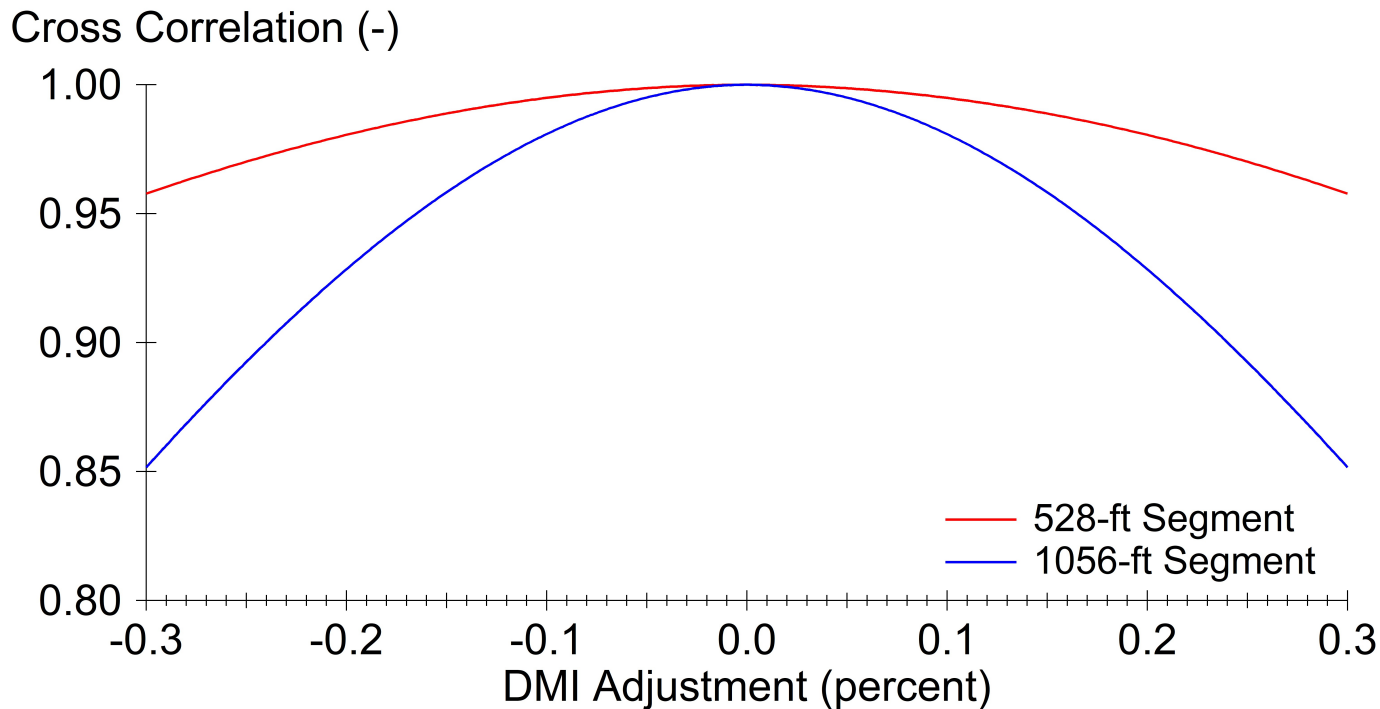
Raw IRI Filter Output (in/mi)



Distance Measurement Error 1 percent  
Cross Correlation = 0.647



# Longitudinal Distance Measurement Error



For 0.15 percent DMI error:

528 ft (0.989)

1056 ft (0.958)

# Certification Runs with DMI Error

Run	Accuracy Score	Accuracy Score with DMI Adj.	Difference	DMI Adj. (Percent)
1	0.933	0.951	0.018	-0.22
2	0.908	0.933	0.025	-0.24
3	0.901	0.941	0.040	-0.32
4	0.927	0.960	0.033	-0.28
5	0.908	0.956	0.048	-0.34
6	0.903	0.934	0.031	-0.28
7	0.910	0.952	0.042	-0.32
8	0.900	0.933	0.033	-0.28
9	0.905	0.936	0.031	-0.28
10	0.900	0.931	0.031	-0.28

## Repeatability Scores:

No DMI Adjustment  
0.973-0.995

With DMI Adjustment  
0.974-0.996

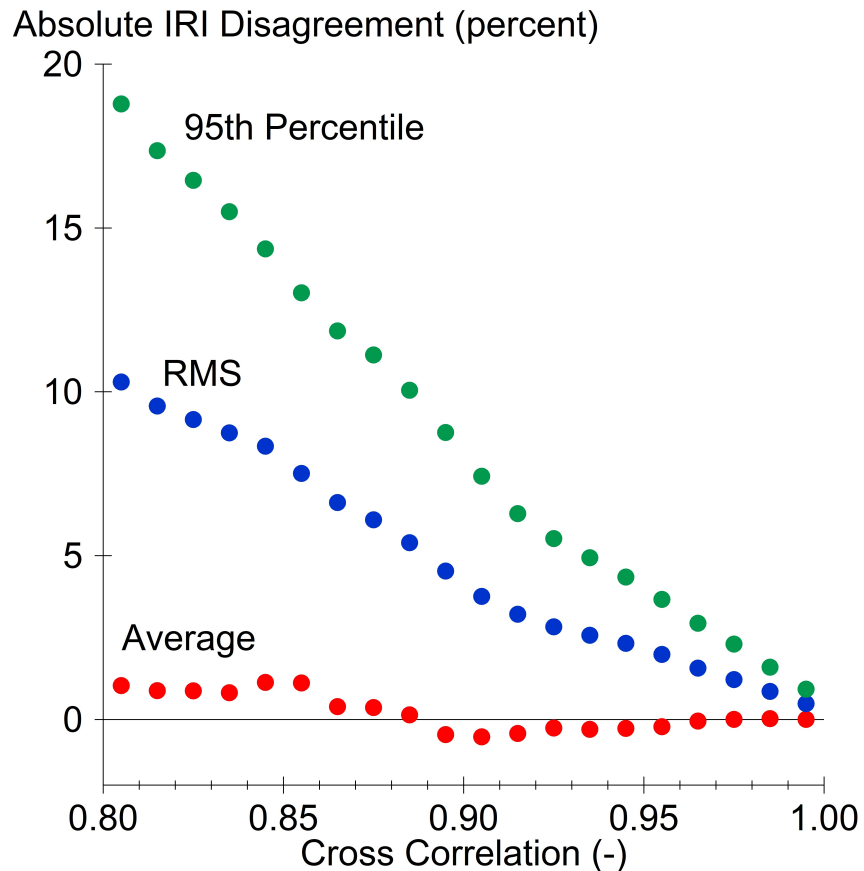
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# 2015 Round-Up, IRI Error versus Cross Correlation

Cross Correlation Range		Number of Comparisons	Error Level in IRI Measurement (Percent)				
From	To		Average	RMS	95th Percentile	Low	High
0.99	1.00	1305	0.01	0.48	0.93	-1.65	1.33
0.98	0.99	4538	0.03	0.86	1.60	-2.90	2.35
0.97	0.98	6128	0.01	1.22	2.31	-3.54	3.46
0.96	0.97	6725	-0.05	1.57	2.94	-5.15	4.88
0.95	0.96	7190	-0.22	1.99	3.67	-5.46	5.37
0.94	0.95	7590	-0.27	2.33	4.35	-6.49	6.31
0.93	0.94	7744	-0.30	2.57	4.94	-6.86	7.13
0.92	0.93	7795	-0.26	2.83	5.52	-7.69	8.40
0.91	0.92	7471	-0.43	3.21	6.29	-8.77	9.84
0.90	0.91	7006	-0.53	3.76	7.43	-9.90	10.71
0.89	0.90	7264	-0.46	4.53	8.76	-11.59	13.26
0.88	0.89	7518	0.14	5.40	10.05	-11.79	14.51
0.87	0.88	6569	0.37	6.10	11.13	-12.04	16.01
0.86	0.87	5826	0.40	6.62	11.86	-13.84	16.75
0.85	0.86	5260	1.12	7.51	13.02	-13.79	16.91
0.84	0.85	4747	1.13	8.34	14.36	-15.55	17.89
0.83	0.84	3964	0.82	8.75	15.50	-15.88	18.63
0.82	0.83	3275	0.88	9.15	16.45	-17.29	20.85
0.81	0.82	2866	0.88	9.57	17.36	-18.05	22.60

# 2015 Round-Up, Summary Results



## 2015

### CC Range

0.97-0.98

0.93-0.94

0.92-0.93

0.88-0.89

### 95 Percentile IRI Error

2.31

4.94

5.52

10.05

## 2004

### CC Range

0.97-0.98

0.92-0.93

0.81-0.82

### 95 Percentile IRI Error

2.00

4.80

10.00

# Discussion Items

- Should accuracy scores with DMI adjustment be used for profiler certification?
- Should we move to requiring accuracy scores of 0.94 and above?

Let me ask that another way:

- Do you want IRI value that are accurate to within 5 percent?