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Vehicle Terrain Performance Laboratory

Removing Drift from Inertial Navigation System Measurements

RPUG 2009

Robert Binns
Mechanical Engineering
Vehicle Terrain Performance Lab

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Outline

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Laboratory Overview

Vehicle Terrain Measurement System

Addressing the Problem

Correcting INS Drift in Terrain Measurements

Summary

Laboratory Overview

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Vehicles

- Passenger cars, commercial off-road, military vehicles, motorcycles (system level)
- Modeling and Simulation

Terrain

- Modeling
- **Measurement**

Performance

- Ride
- Handling
- Reliability
- Durability

Robert Binns
www.me.vt.edu/VTPL

Vehicle Terrain Performance Laboratory

Vehicle Terrain Measurement System

- Scanning Laser
  - Provides relative height measurement
- Inertial Navigation System
  - DGPS:
    - Establishes global coordinate system
  - IMU:
    - Mitigates low frequency body motion (<10 Hz)
  - Accelerometers
    - Mitigates high frequency body motion (>10 Hz)

Addressing the Problem

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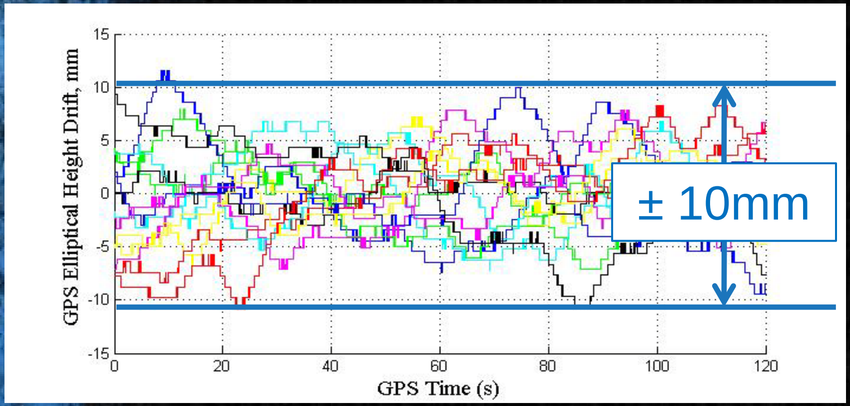
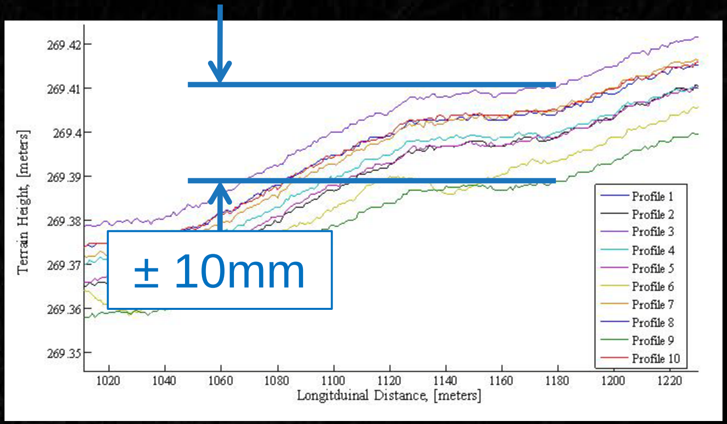
- INS is capable of a establishing a geodetic (latitude & longitude) position with 2cm accuracy with differential GPS
- Experimentation shows artifacts of “INS drift” in *height*
  - Max variation = +/- 10mm
- INS drift introduces run-to-run variation
- Negatively impacts IRI cross-correlation (~80%)





Addressing the Problem

Fundamental Question

How do we recognize and remove error contributions from INS drift only?

Correcting INS Drift

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Assumptions

- Neglect horizontal drift
- Elliptical height changes only in time
- Non-deformable terrain only
- INS treated as “black box” – combining DGPS + IMU

Correcting INS Drift

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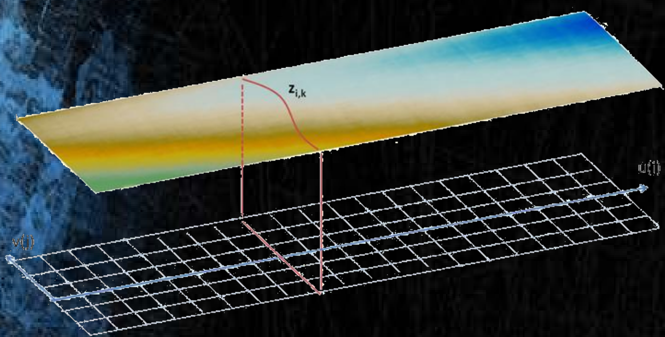
Each measurement represents the sum of three "sub-surfaces"

Measured Surface



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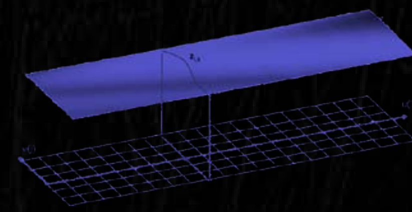
Noise



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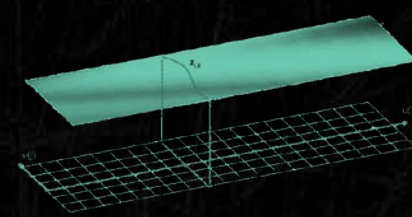
INS Drift



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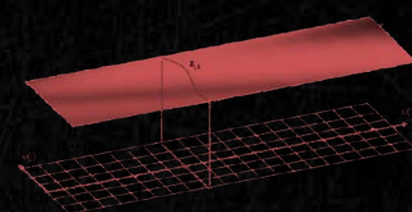
"True" Surface

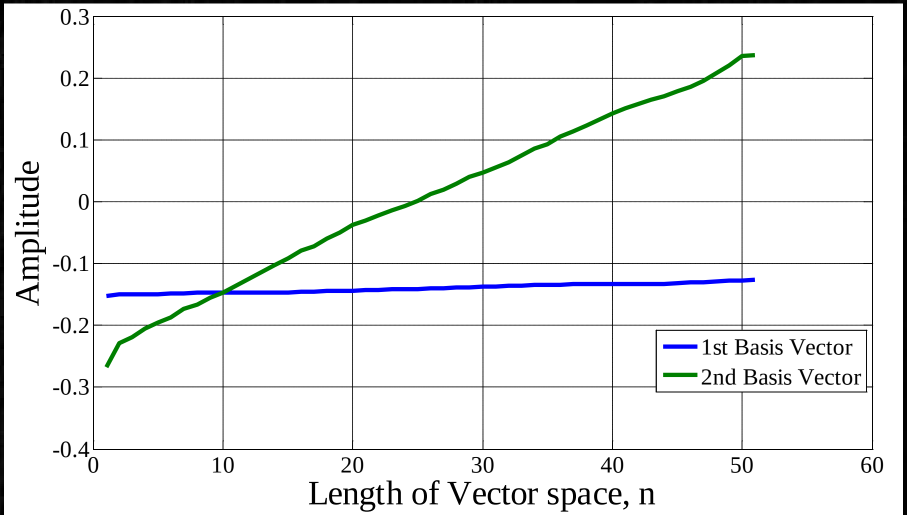


"Total" Error

Correcting INS Drift

The "Total" error must be separated into INS drift and noise.

- Singular Value Decomposition – determine contributions from different "shapes" to the error
- Noise must be zero-mean and is not correlated to the INS drift



Correcting INS Drift

Proof of Concept

- MnRoad Test Facility, Albertville, MN
- 160m section of asphalt
- 10 total measurements (alternating directions)
- Vehicle Velocity ~ 10 m/s
  - 10mm Longitudinal Spacing
  - 20mm Transverse Spacing

Correcting INS Drift

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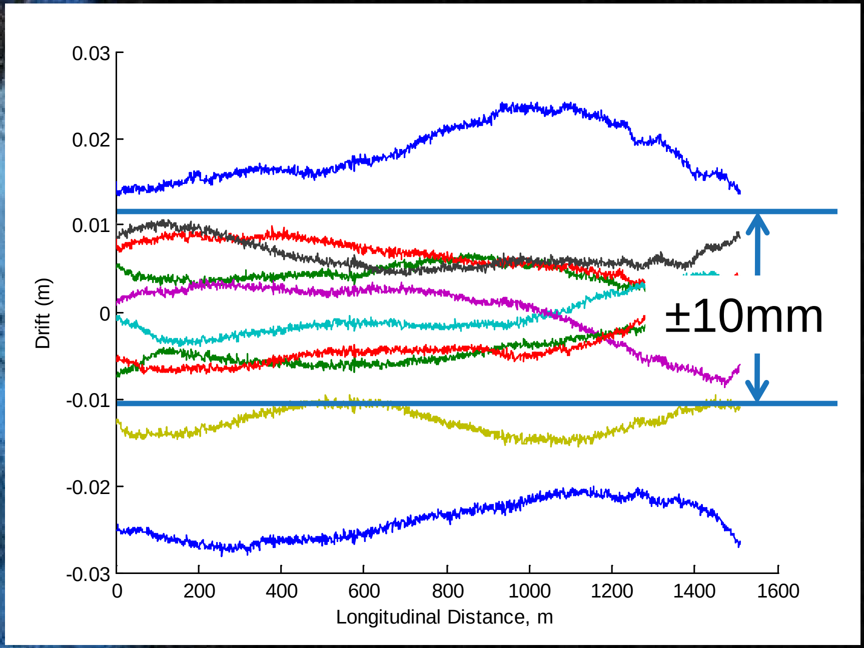
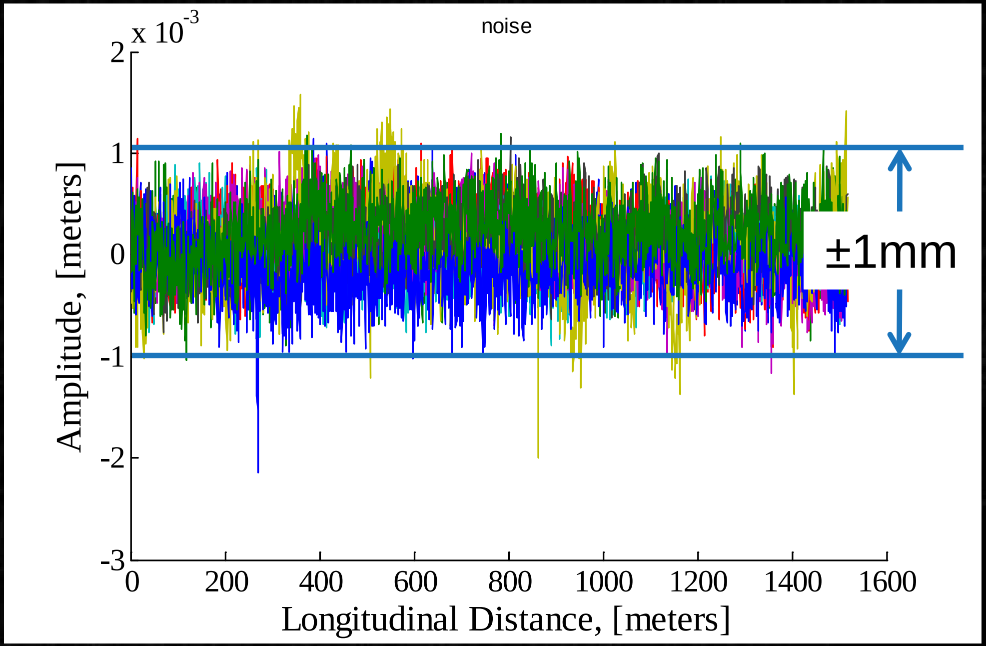
Drift



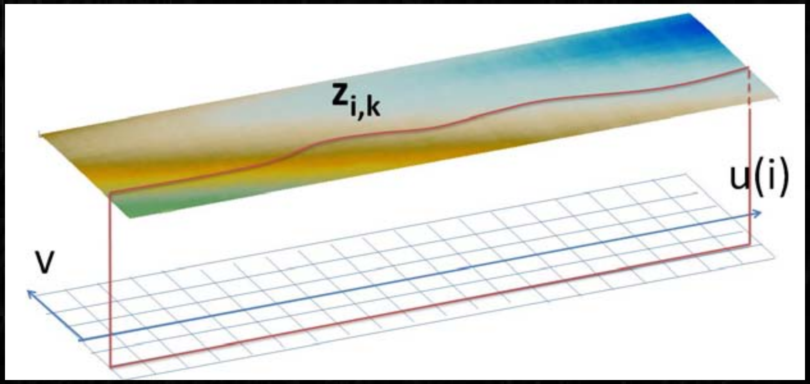
Noise



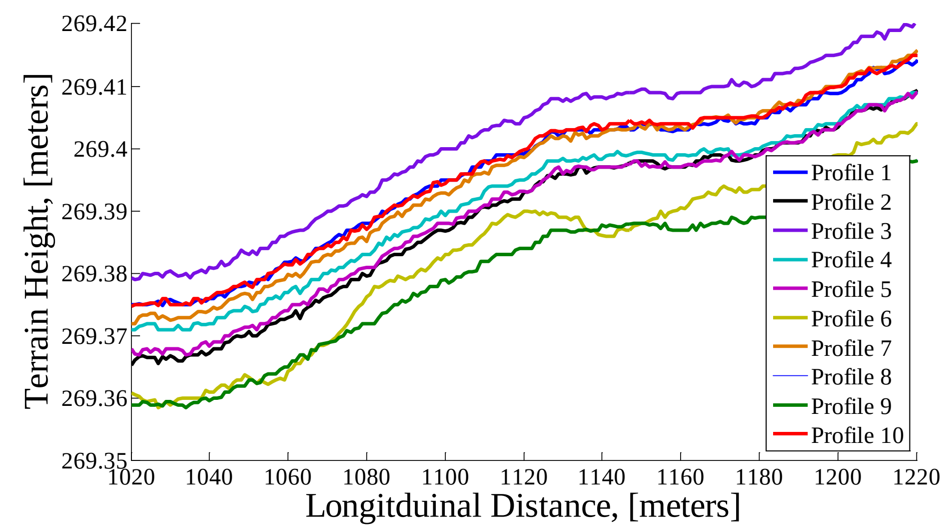
Correcting INS Drift

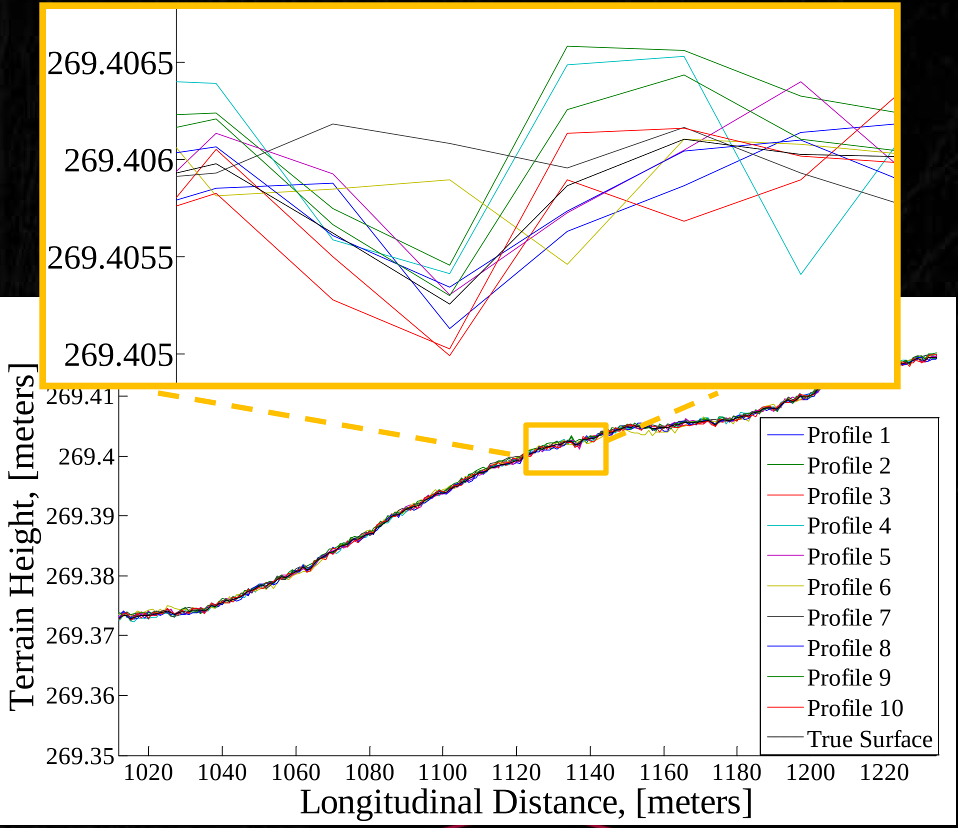
Proof of Concept

- Longitudinal view of terrain surface



No INS Drift Correction





Summary

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- INS Drift sufficiently characterized and removed
  - Error contribution due to precision (noise) remains
- IRI cross-correlation improved to 98%
- Autocorrelation improved to 99%
- Future Work:
  - Research effects on different road geometries (bank, grade, crowning, rutting)

Vehicle Terrain Performance Laboratory

Large High-Resolution Display for Terrain Visualization

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Haeyong Chung
Computer Science
Vehicle Terrain Performance Lab

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Terrain Visualization

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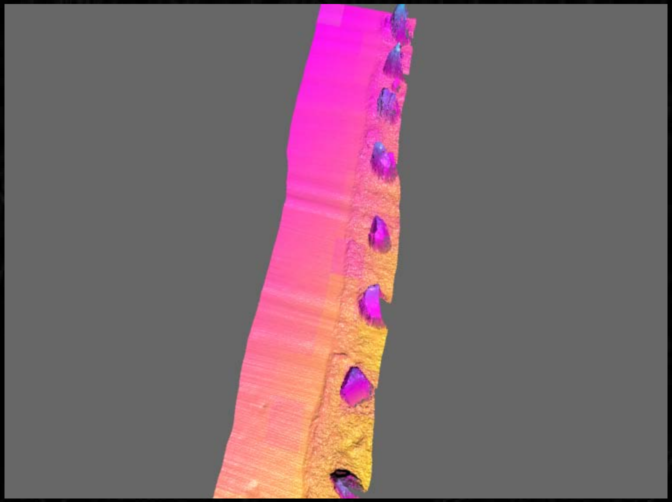
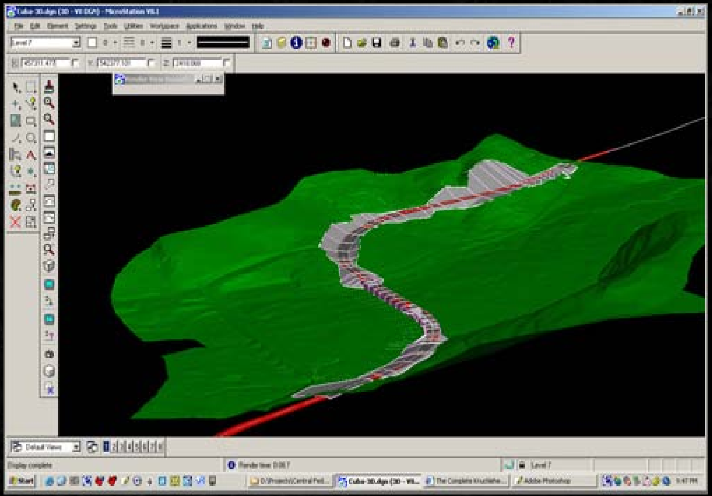
- Improve user's subjective understanding of the terrain data
- Have been used in various engineering simulations
- Industry is making use of terrain visualization in designing and planning





VTMS Data Visualization

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- A single dataset includes several millions of points.
- Difficult to visualize multiple VTMS datasets in small displays and desktop systems
- Massive amounts of computing power are required to render the high-fidelity terrain data.
- The resolution of the VTMS datasets is easily beyond the capability of current computer display and graphics systems.

Haeyong Chung
www.me.vt.edu/VTPL

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Large High-Resolution Display (LHRD)

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- Much higher DPI
- Wider field of view to terrain data
- Terrain visualization on a scale comparable to real life
- Terrain rendered in parallel
- Collaboration

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VEHICLE TERRAIN PERFORMANCE LABORATORY

Possible Applications for LHRD Visualization

- Data analysis of terrain data and simulation results
- Visualization of vehicular simulation
- Visual inspection of pavement health
- Planning and designing of roads
- Effective communication tool for stakeholders and public

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Visualization Prototypes

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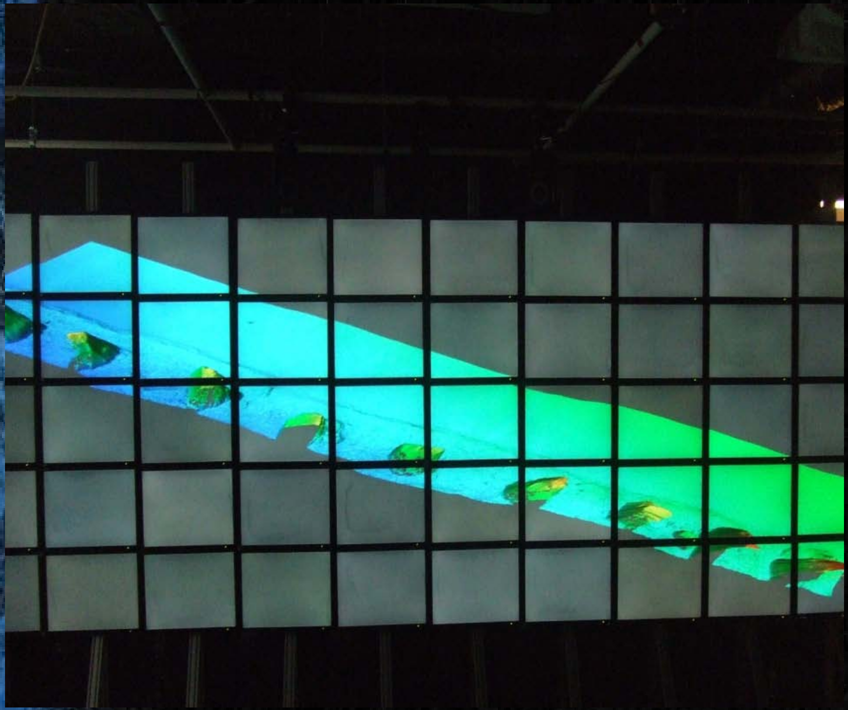

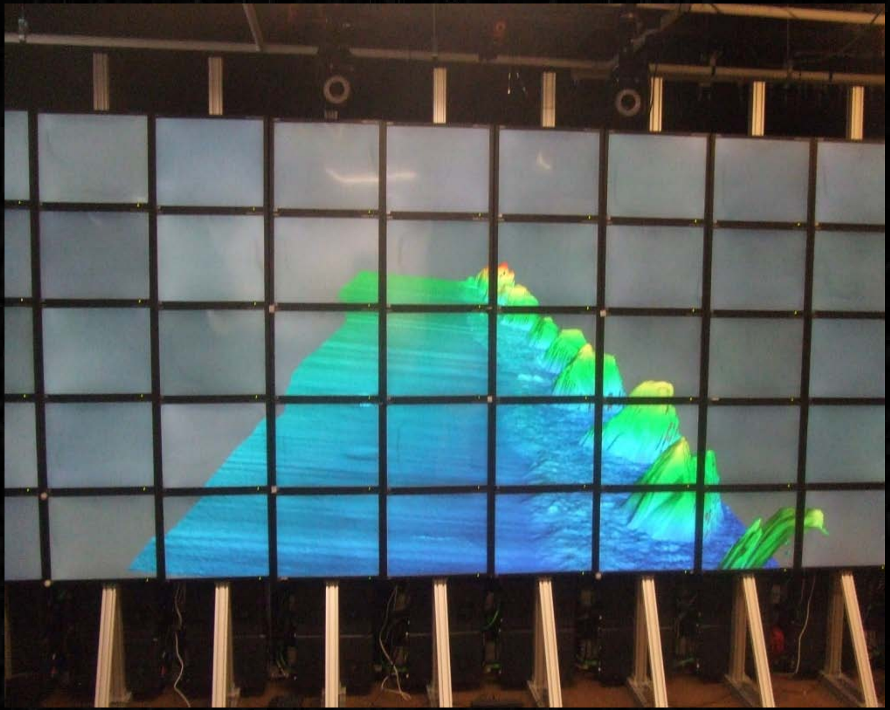

Visualization Prototypes

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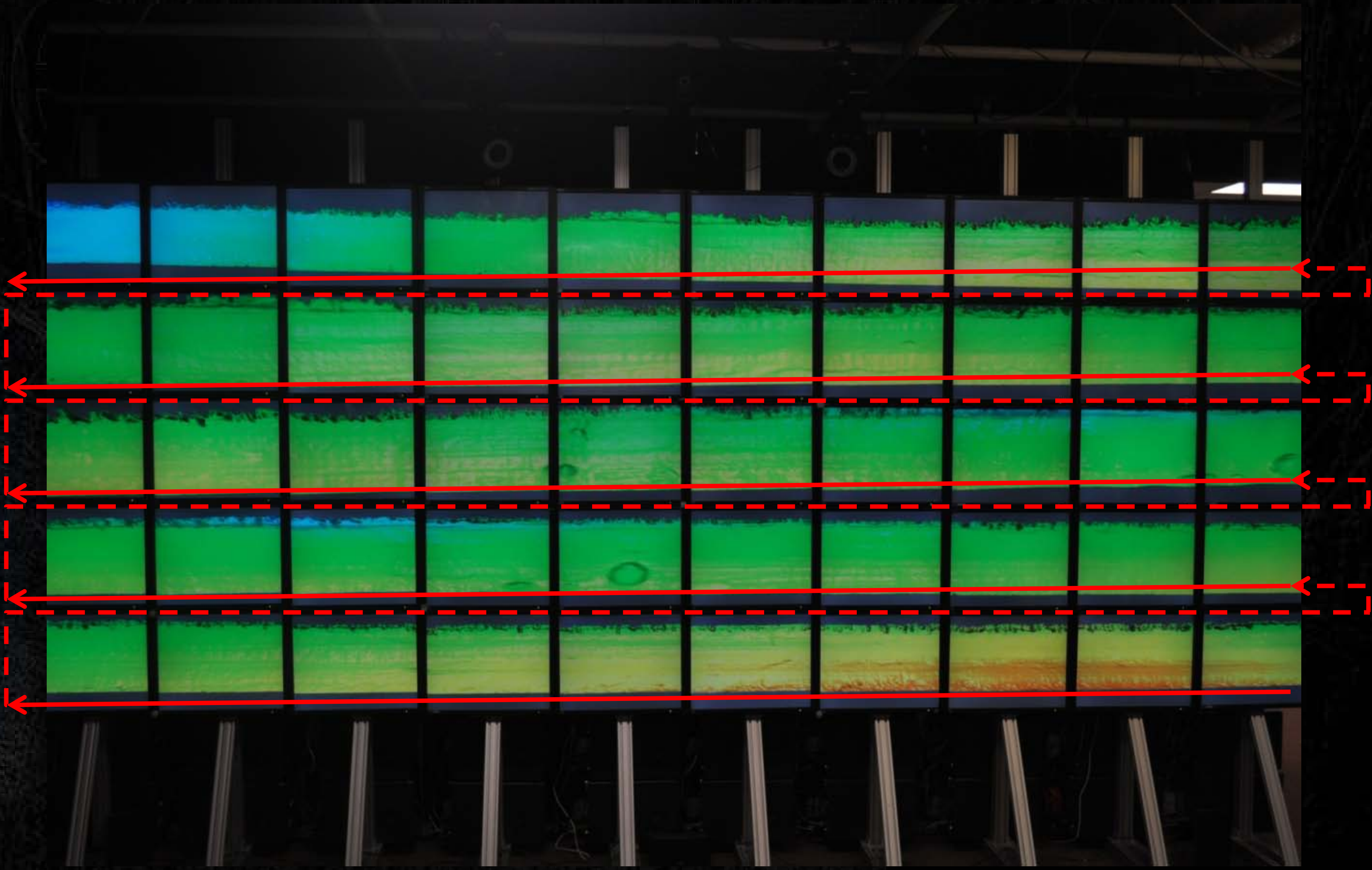

Haeyong Chung
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Summary

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- LHRD provides a novel platform to interactively visualize high-fidelity terrain data
- Terrain features can be displayed at a life-size scale
- Potential applications span both vehicle simulation and pavement communities