European Road Profile Users' Group 2023

Better use of data and smarter analysis

Comprehensive Analysis of Walkway Pavements: Opportunities and Challenges of 3-D Measurement and User-based Evaluation

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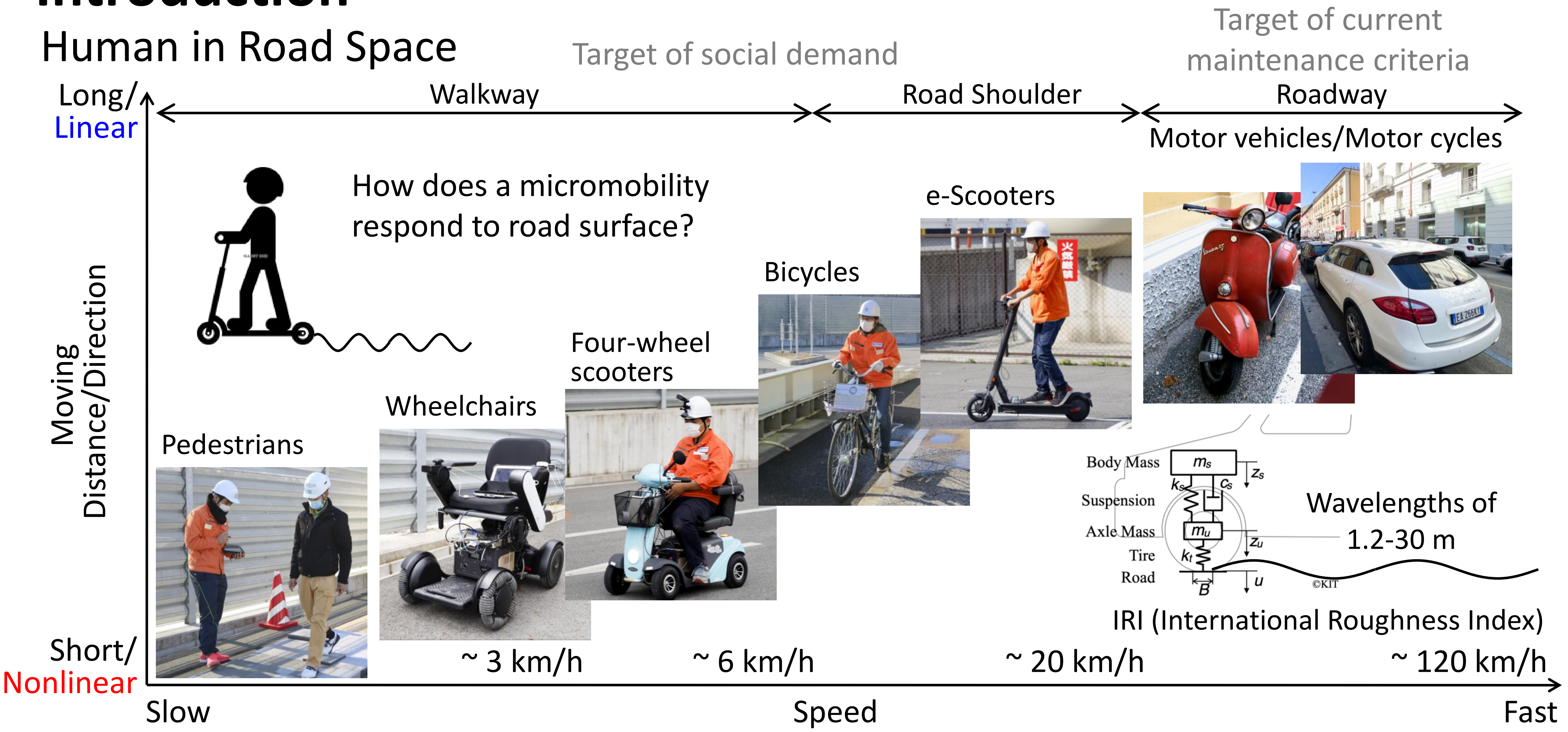
Introduction

Human in Road Space

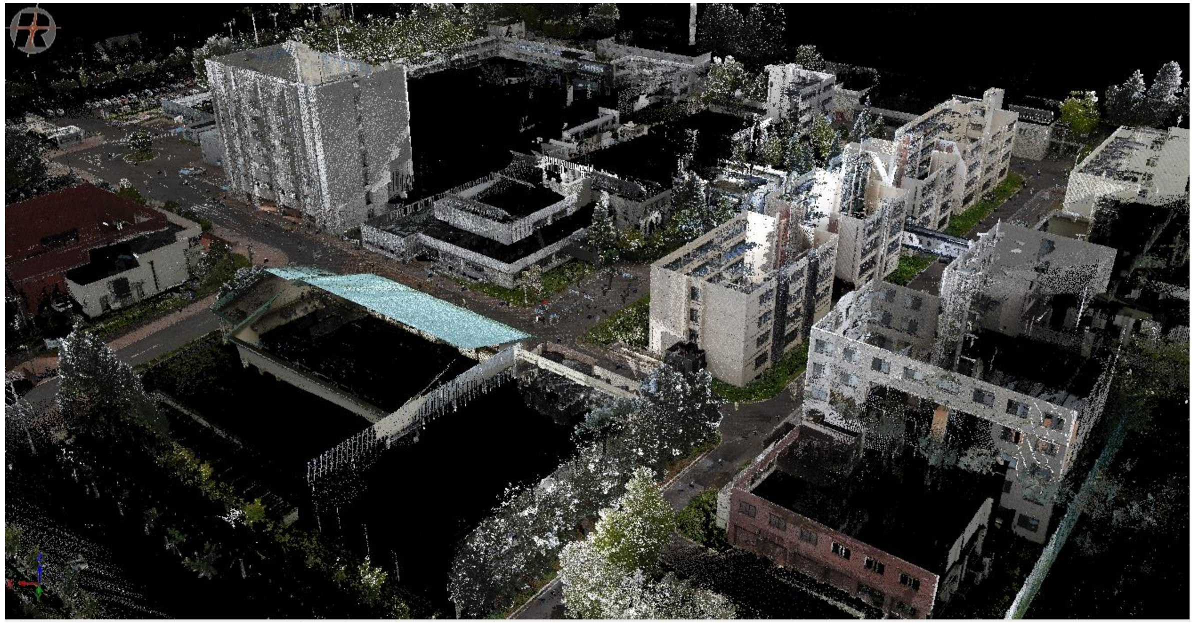


Introduction

Potential of 3D Measures

- ✓ include much information
- ✓ detect localized irregularities
- \- identify the information required
- \- associate physical surface properties

Mathematical analysis with
DTCWT: Dual-Tree Complex Wavelet Transform

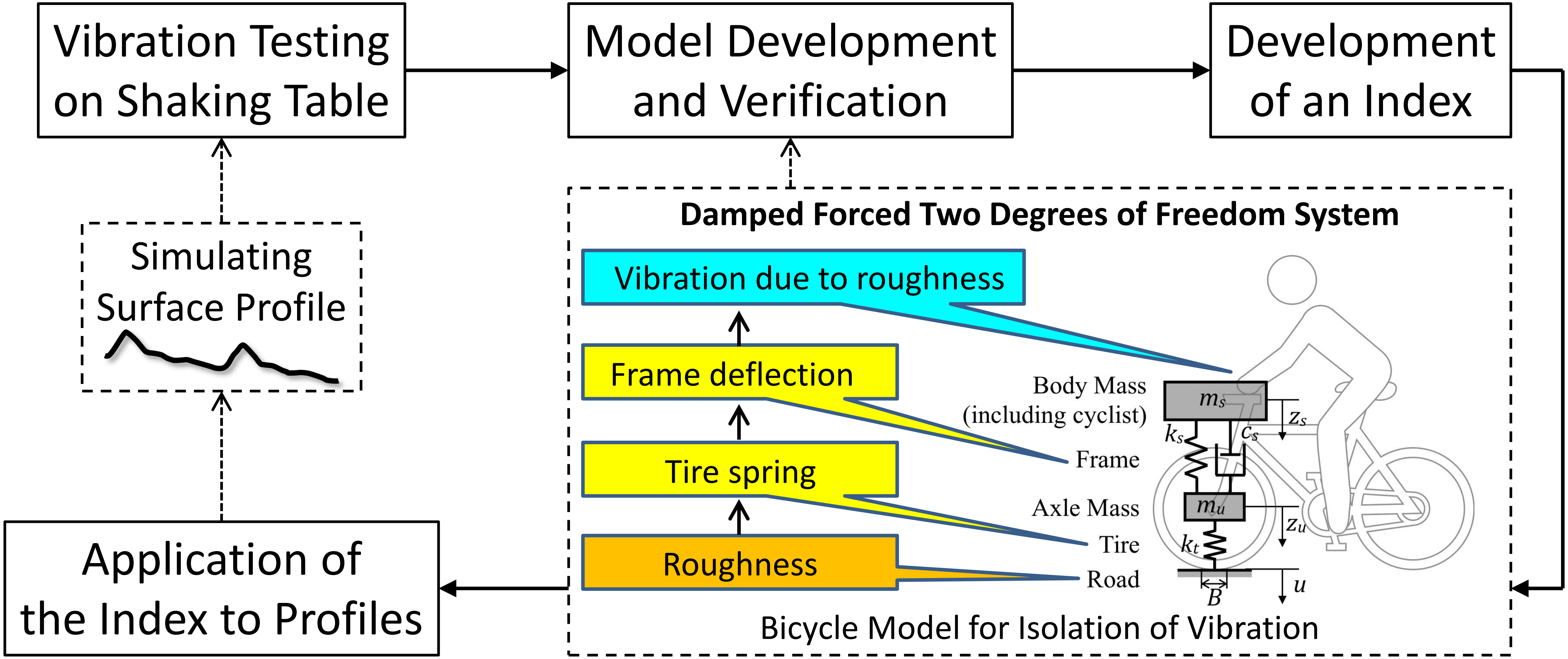


3D Point Cloud of KIT Campus

- ☐ Effective and efficient data processing for 3D measurements (**nonlinear**)
- ☐ Diagnostic identification of wavelength, location, and direction (**functional**)
- ☐ Clear and theoretical evidence for the analysis (**theoretical**)

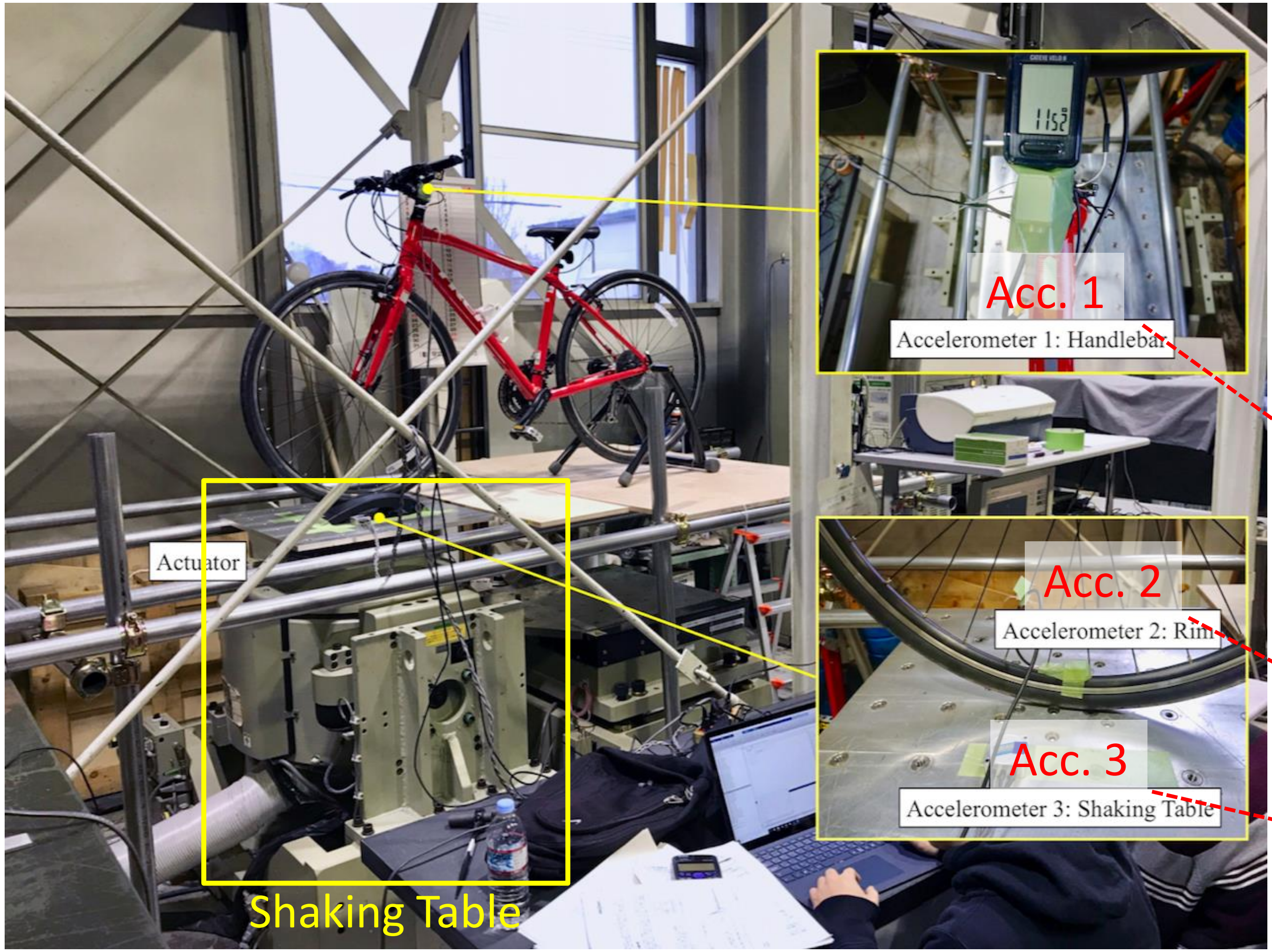
Analysis of Vehicle Motion (Bicycle)

Research Flow



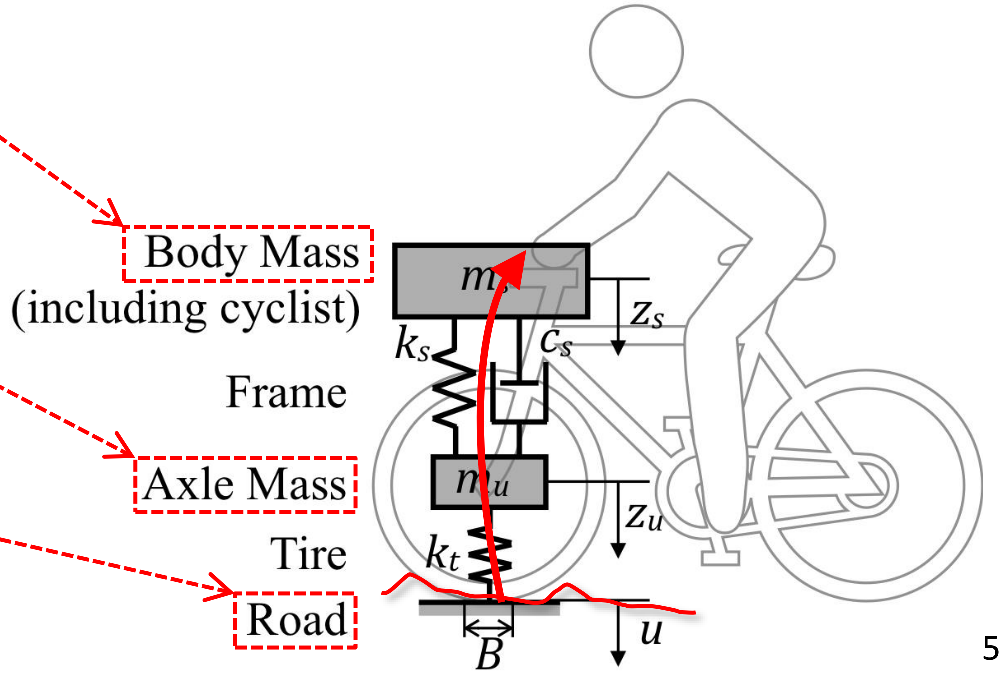
Analysis of Vehicle Motion (Bicycle)

Shaking Table and Accelerometer Setup



Acc. 1, 2: body and axle masses
Acc. 3: input oscillation

Sampling interval of acceleration: 1000 Hz (1 msec)



Analysis of Vehicle Motion (Bicycle)

Parameter Estimation Result

Masses (corresponding to the ration of two resonance frequencies):

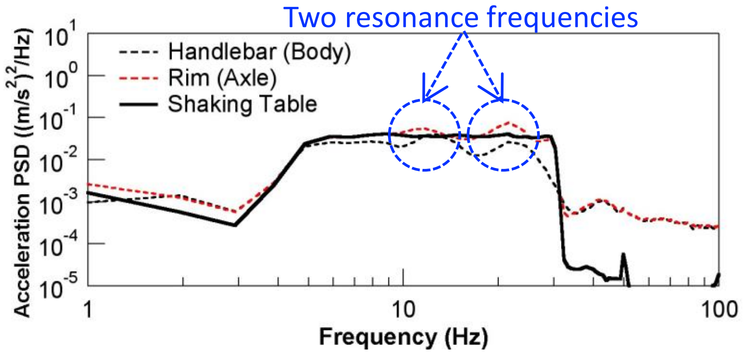
- body mass m_s: 27 kg
- axle mass m_u: 13 kg

Elastic Coefficients

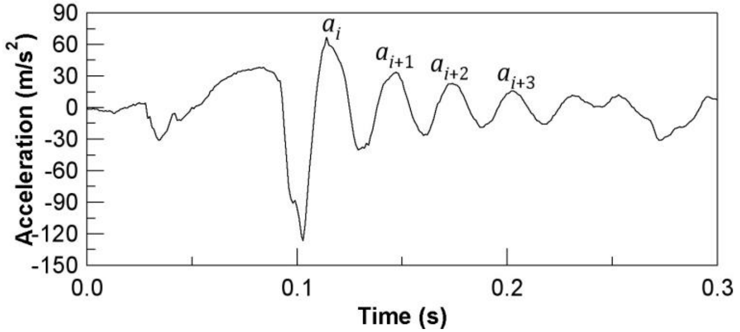
- body mass k_s: 107 kN/m
- axle mass k_u: 205 kN/m

Viscoelastic Coefficients

- body mass c_s: 271 N*s/m
- axle mass c_u: 0 N*s/m



Vibration Response of Bicycle



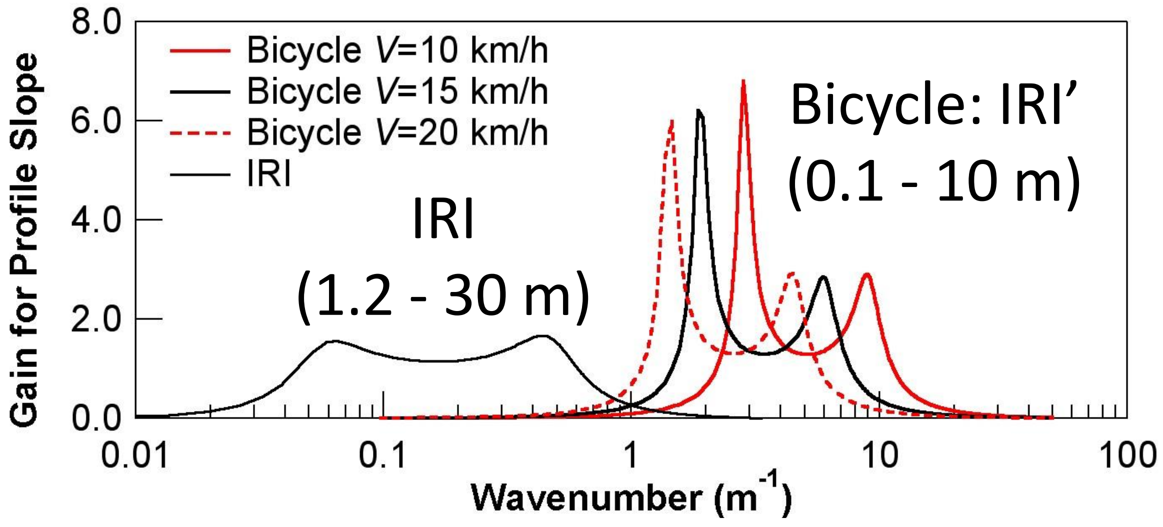
Ride Over Hump Test for Estimating Damping Ratio

Measurement of Tire Envelope Length (150 mm)

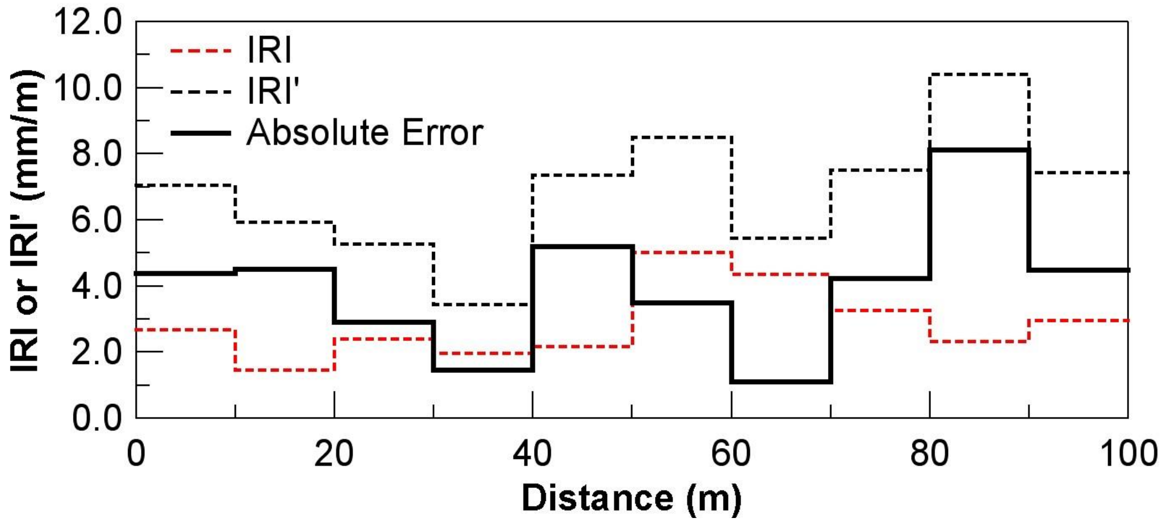
Analysis of Vehicle Motion (Bicycle)

Potential Index

A profile can be rectified and summarized as same as IRI: $\mathrm{IRI} = \frac{1}{L}\int_0^{L/V} |\dot{z}_s - \dot{z}_u|\,dt$



Response of each simulation model



An Example of the Application of Roughness Indices

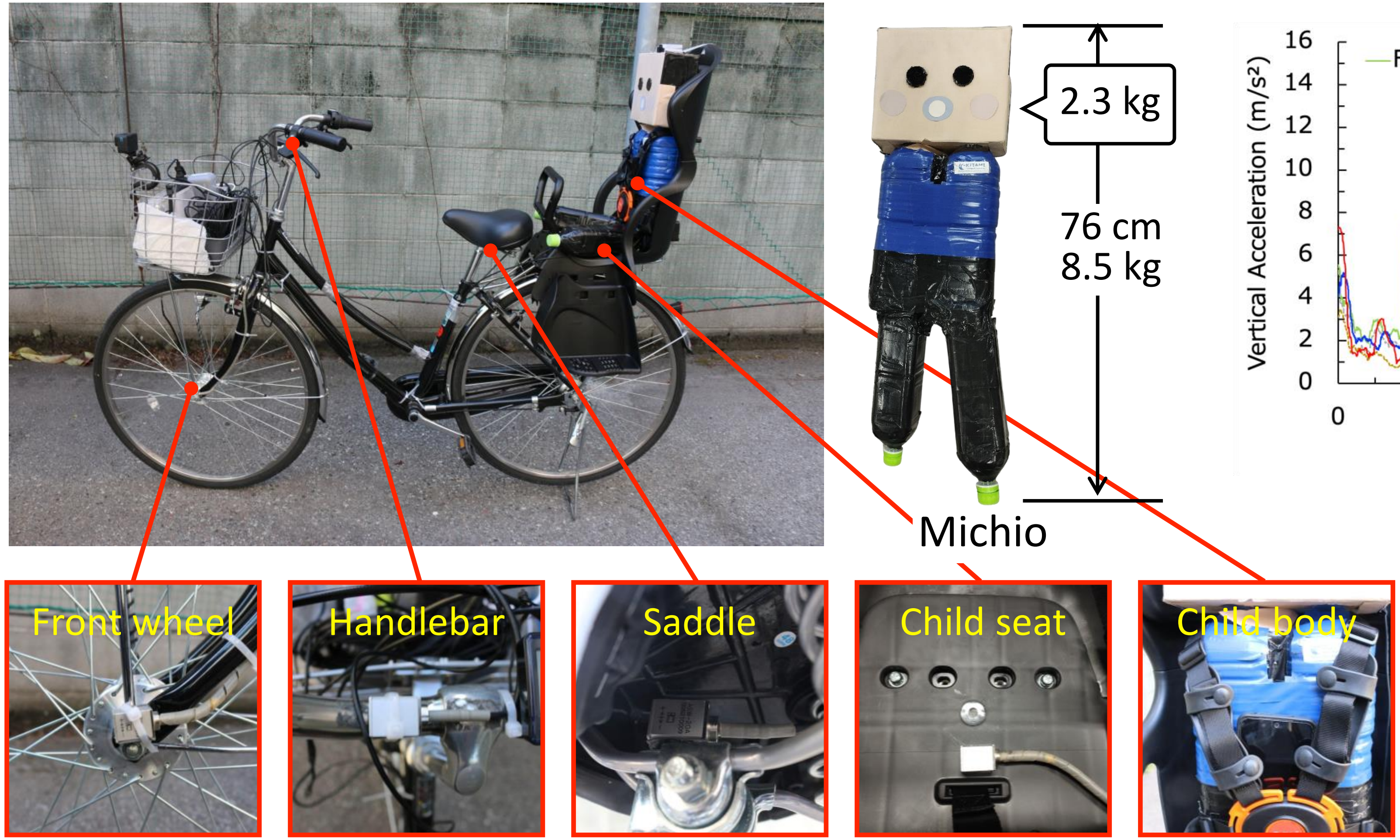
The bicycle model is more sensitive to surface roughness

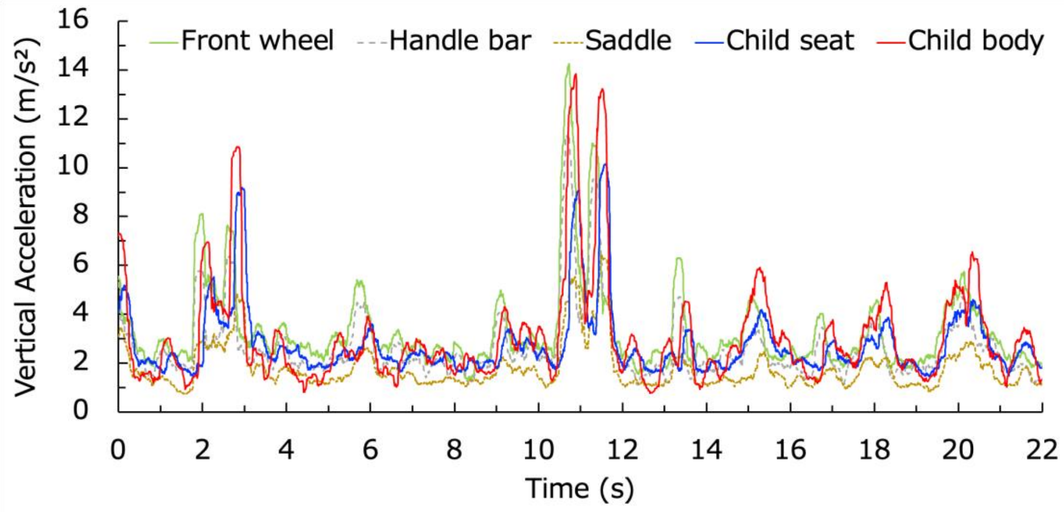
(The bicycle has no suspension systems unlike motor vehicles)

Challenges: speed, bicycle type, road Categories

Analysis of Vehicle Motion (Bicycle)

With Child Seat



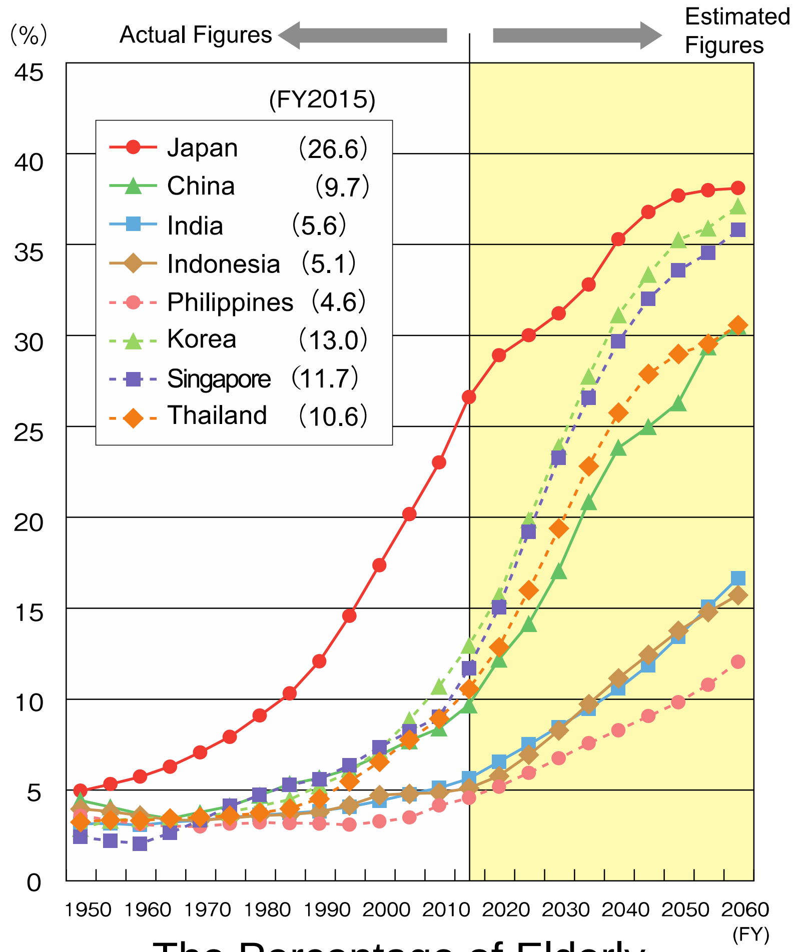


Acceleration Observed

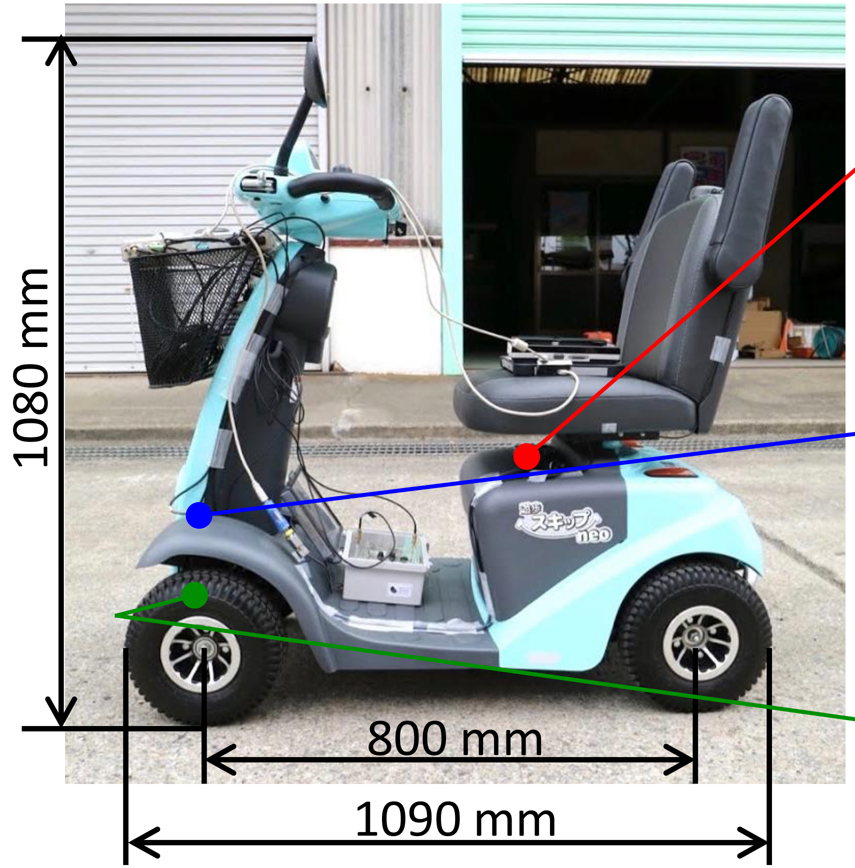
Children on bicycle are exposed to the same vibration level with the front wheel…

Analysis of Vehicle Motion (Four-wheel scooters)

Population aging in Japan



The Percentage of Elderly
(Source: Cabinet Office, Japan)



Specifications of an EMS

CG.
- seat vibration
- ride quality
- whole-body vibration

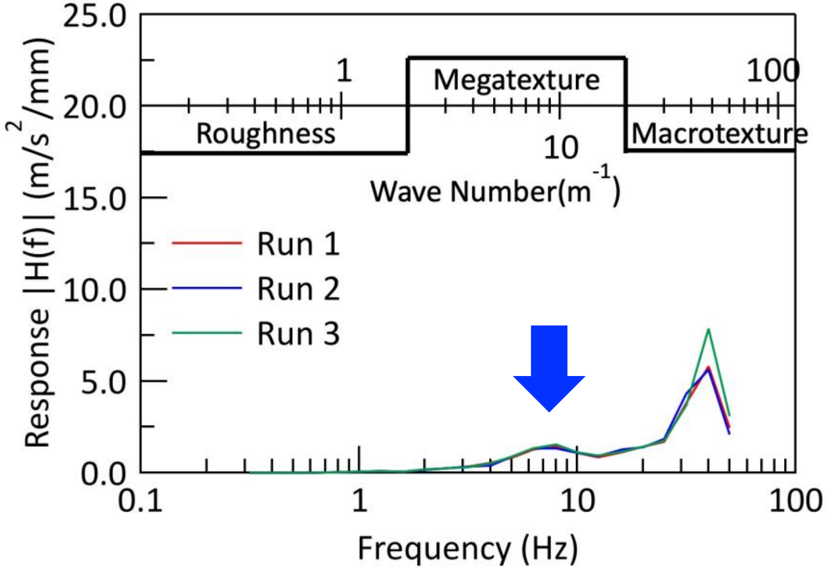
Sprung mass
- body vibration
- ride quality

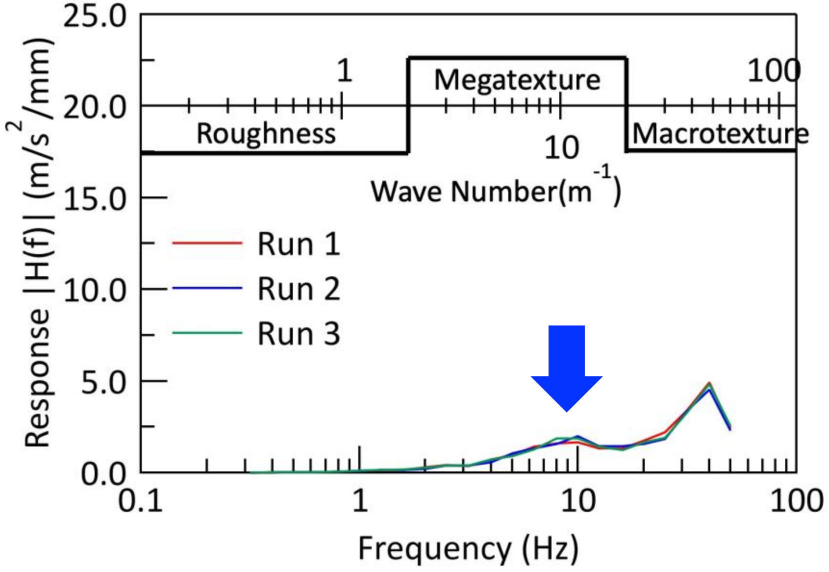
Unsprung mass
- roughness input
- texture evaluation

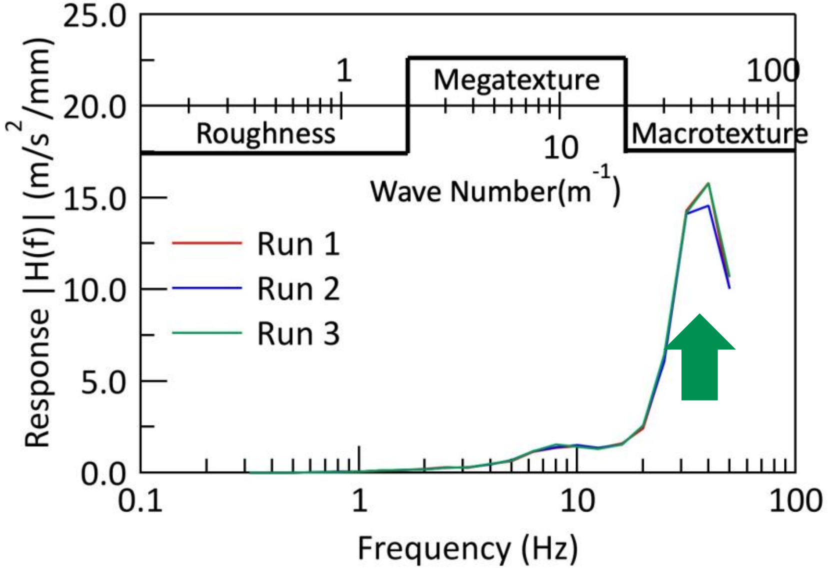
Measuring Vertical Acceleration

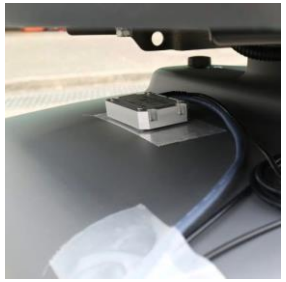
Analysis of Vehicle Motion (Four-wheel scooters)

Vibration Response









CG.
Freq. 8 Hz

Sprung mass
Freq. 8 Hz

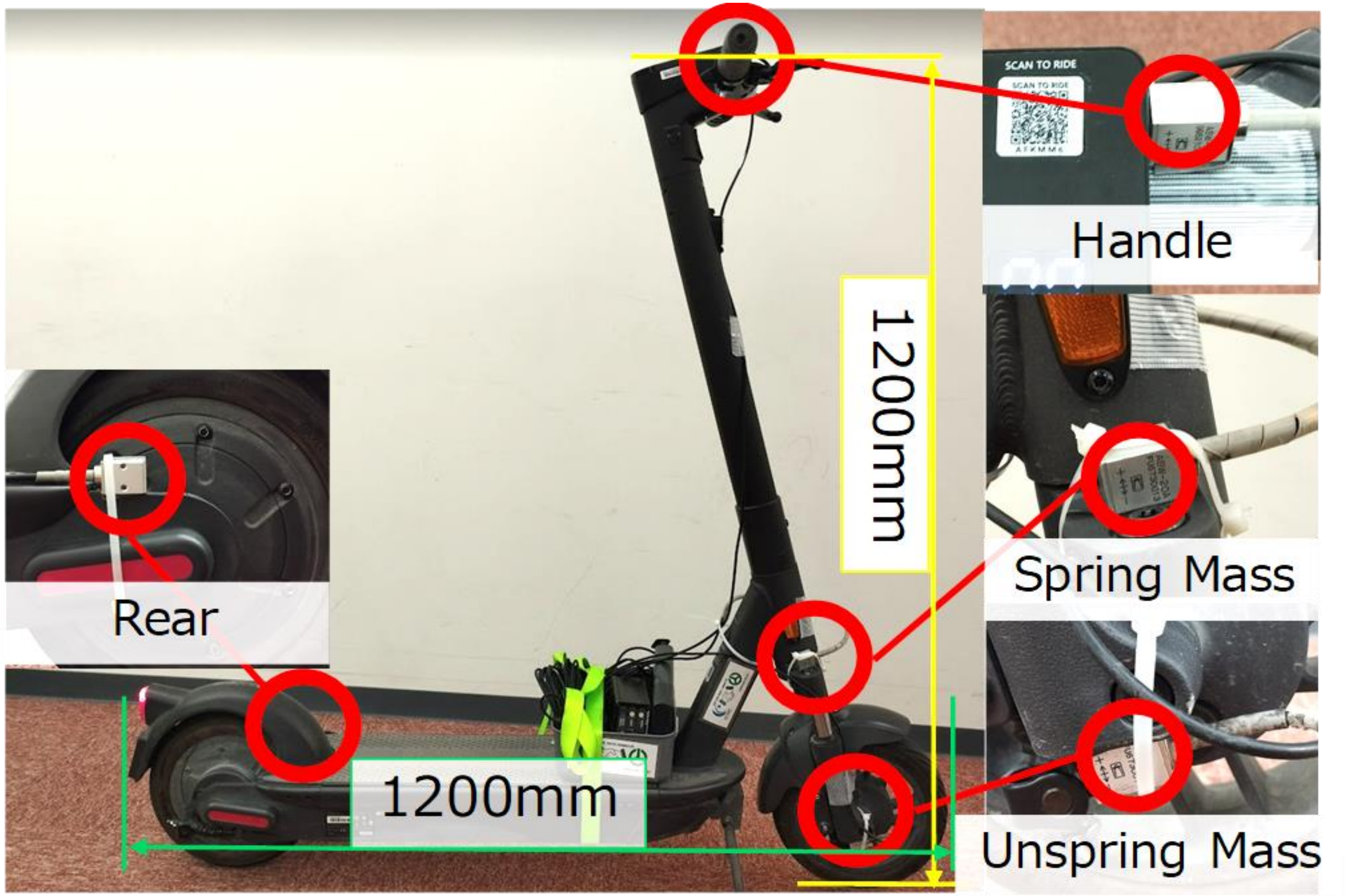
Unsprung mass
Freq. 30 Hz

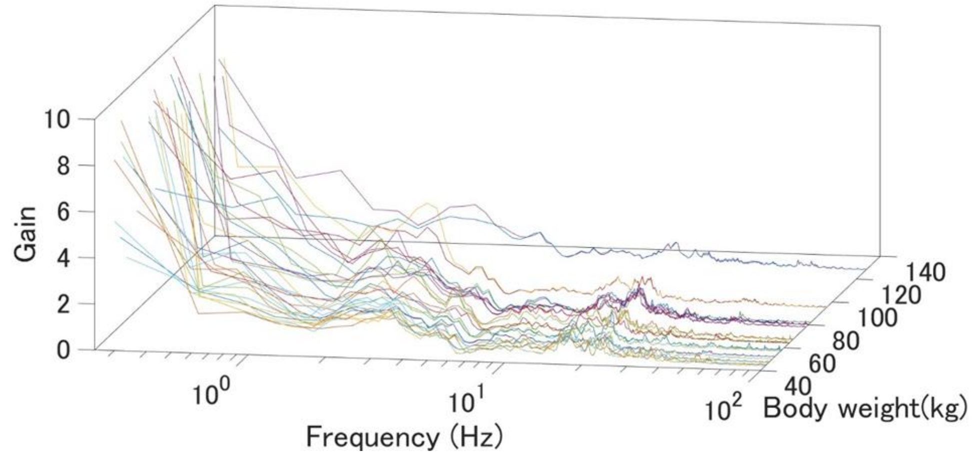
Megatexture & Ride comfort

Macrotexture

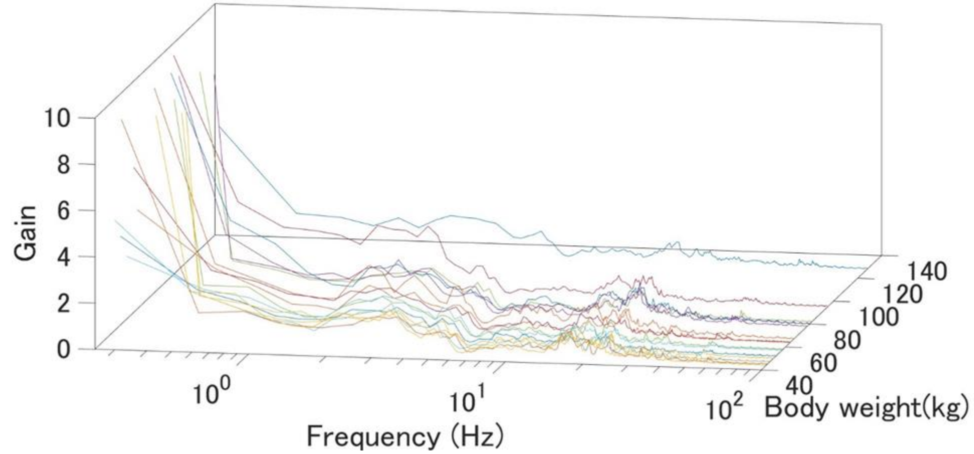
Analysis of Vehicle Motion (e-Scooters)

Vibration Response



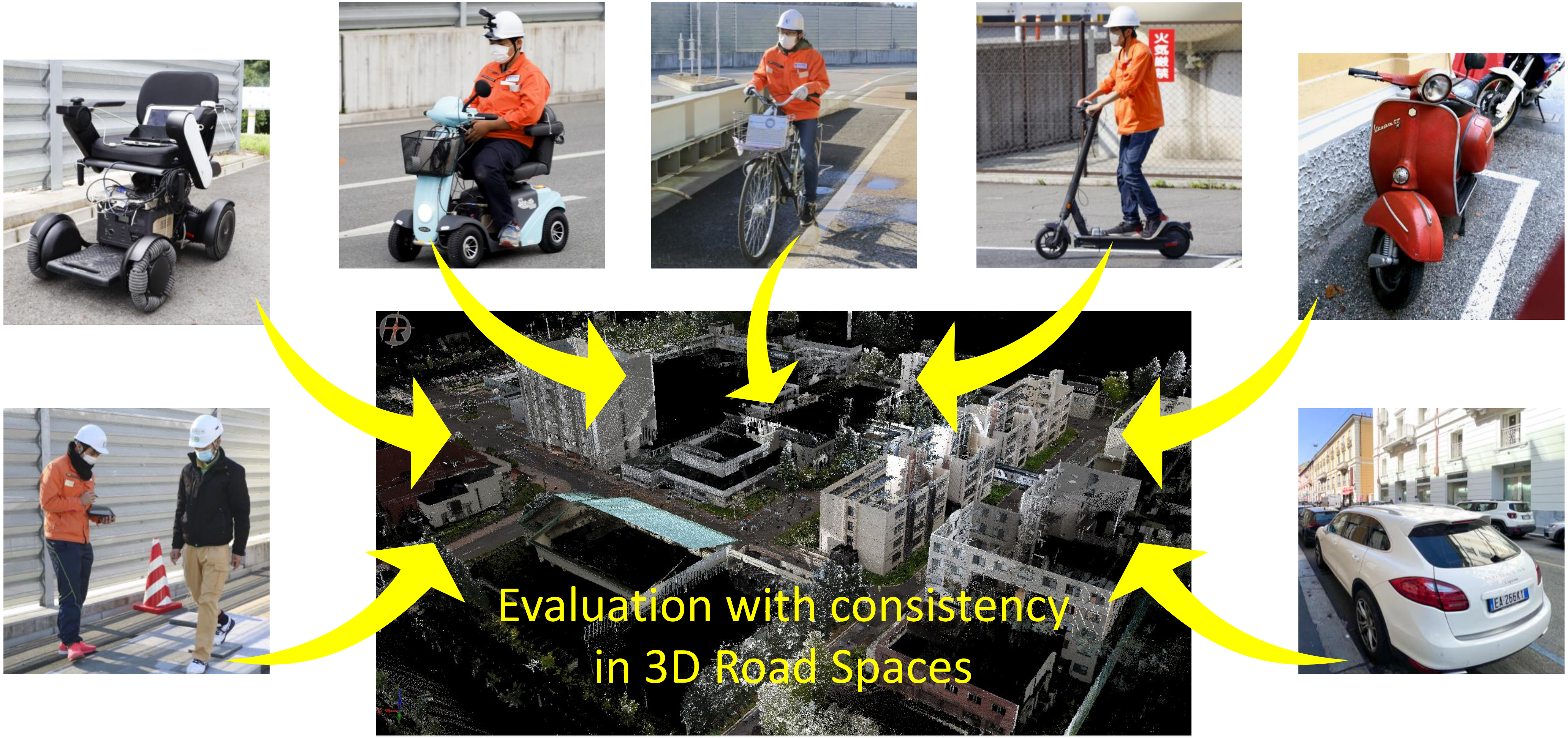


Sprung mass@10km/h



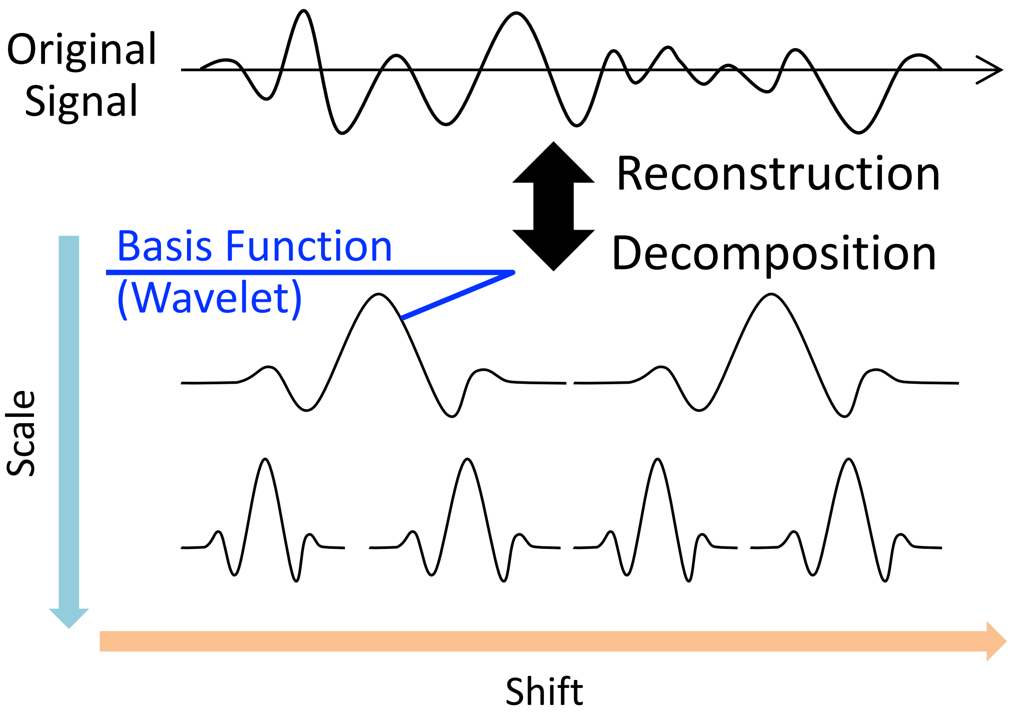
Unsprung mass@10km/h

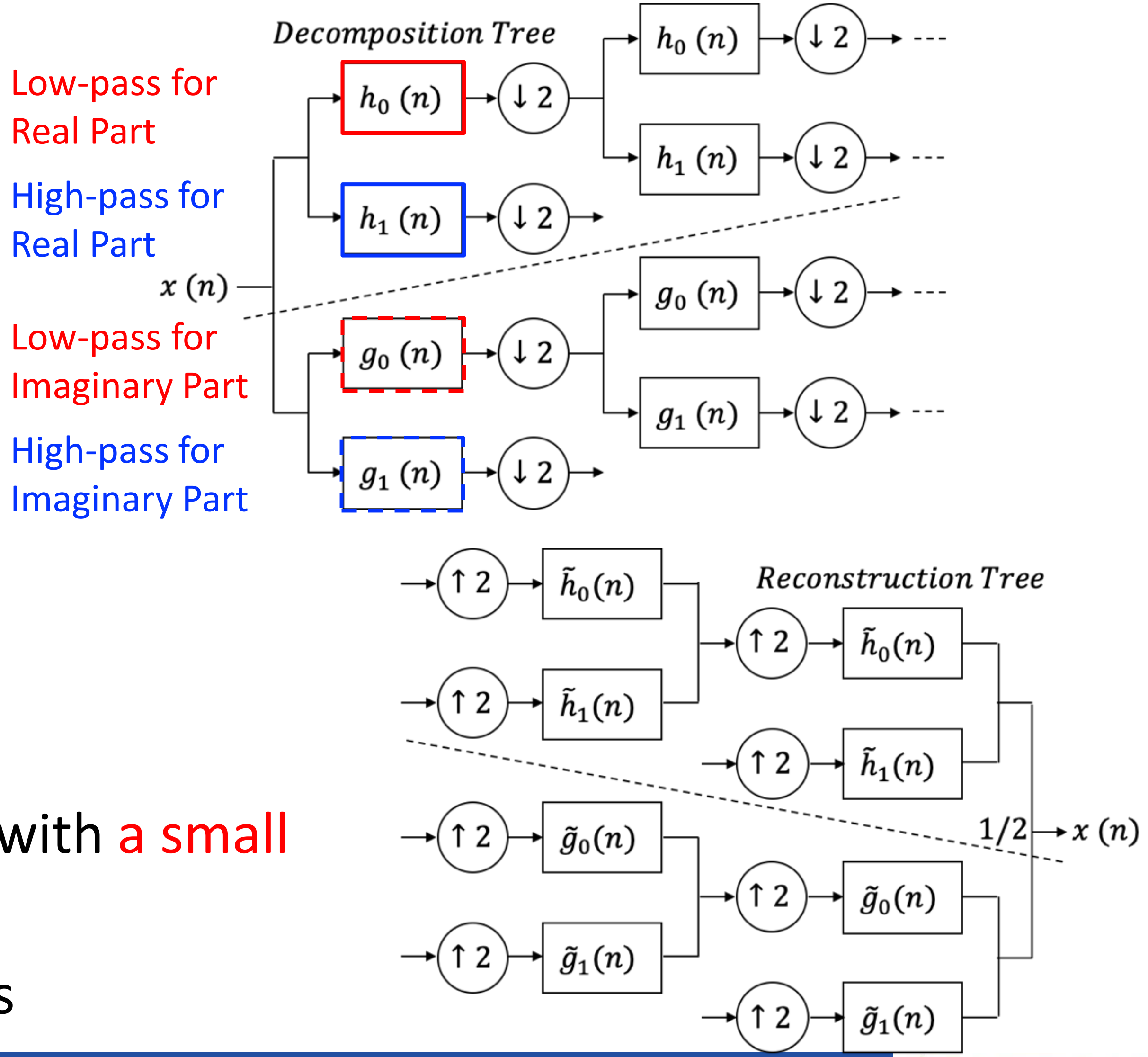
Opportunity for Comprehensive Evaluation



Dual-tree Complex Wavelet Transform (DTCWT)

Idea of Wavelet

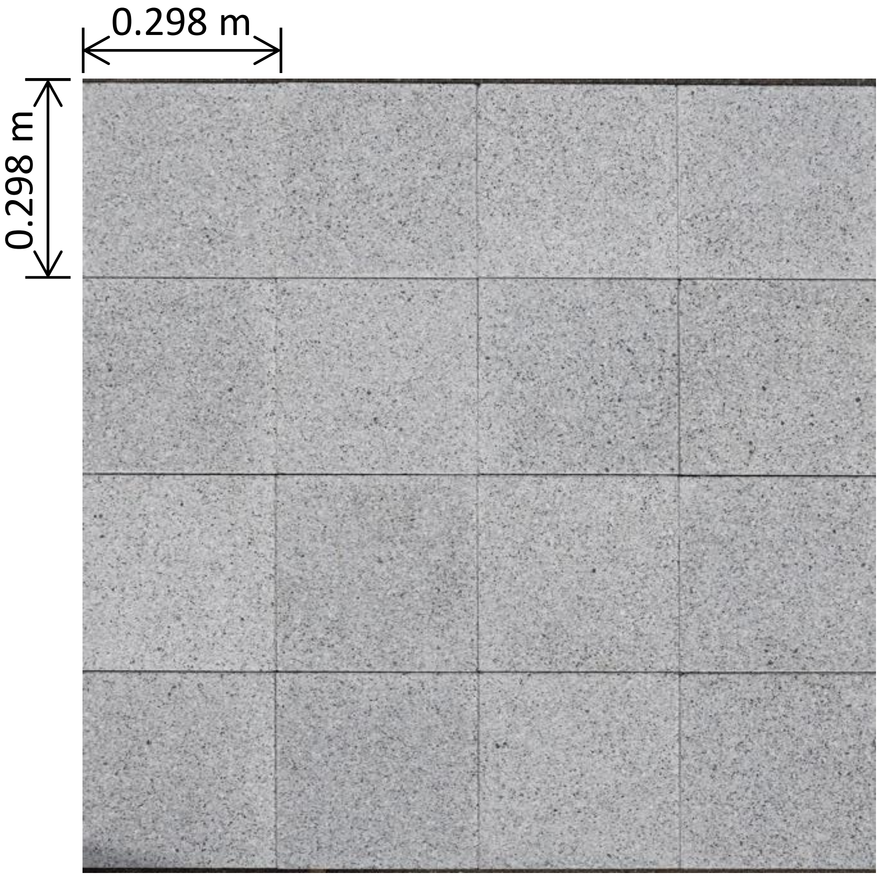




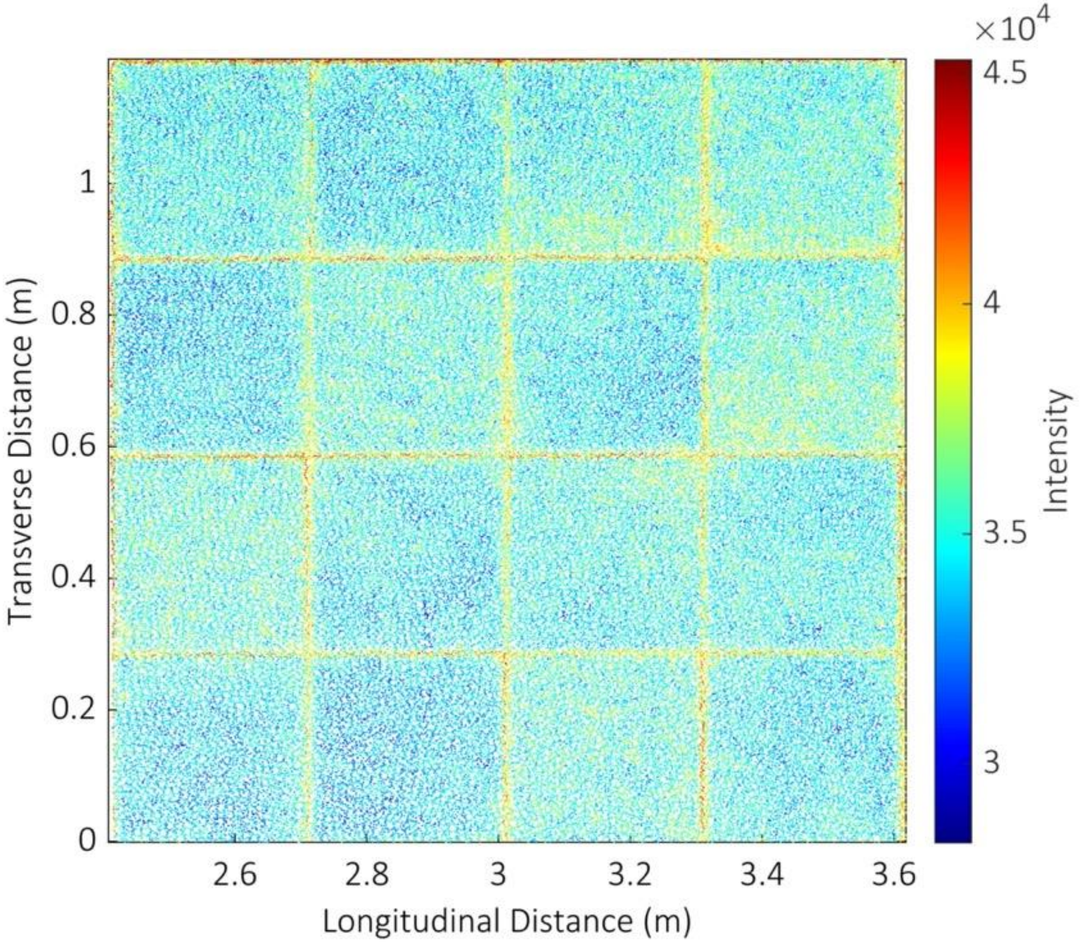
- ✓ Analyze non-stationary wave by correlating with a small localized wave (wavelet)
- ✓ Implement spatial-spatial frequency analysis

DTCWT Multiresolution Analysis

Measured Point Cloud



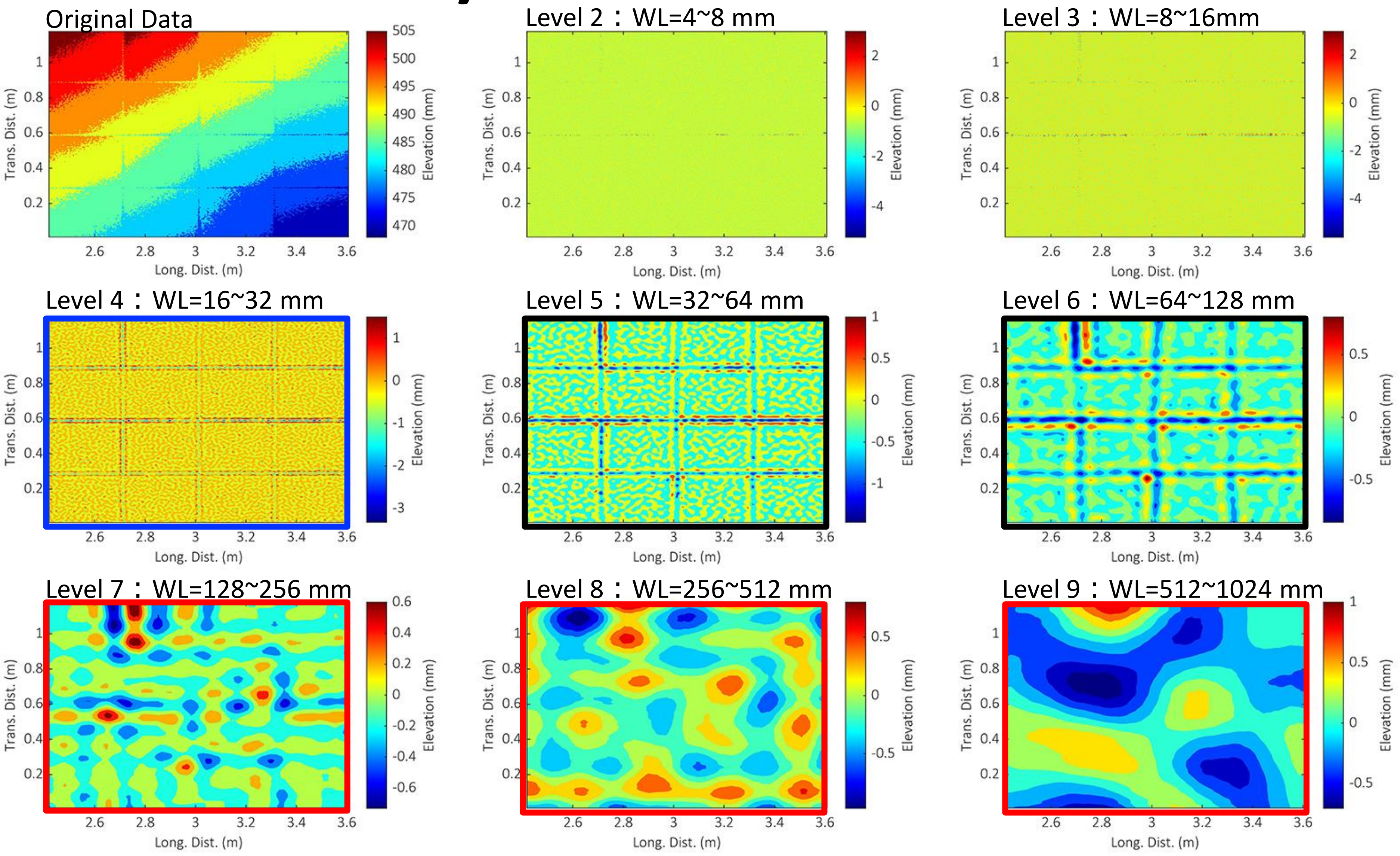
Overview
(Arranged precast concrete tile block)



Measured Point Clouds (Laser intensity view)

DTCWT Multiresolution Analysis

Omnidirectional Decomposition into Detail components (high-pass filter)



Diagnostic View

- Level 4 -> Edge Deterioration
- Level 5 to 6 -> Joint (Fault)
- Level 7 to 9 -> Unevenness

DTCWT Multiresolution Analysis

Diagnostic Points

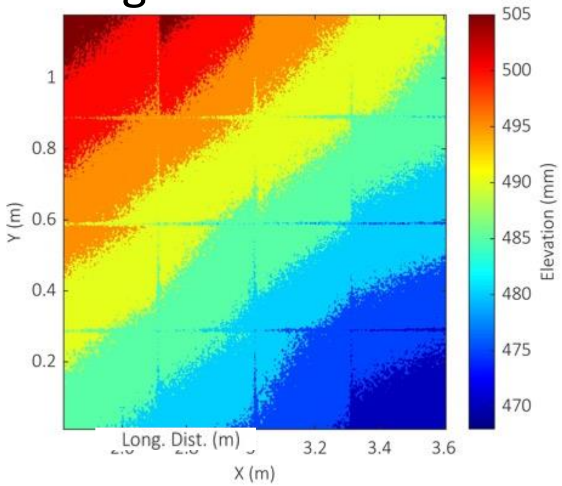
- Level 4 -> Edge Deterioration
- Level 5 to 6 -> Joint fault
- Level 7 to 9 -> Unevenness

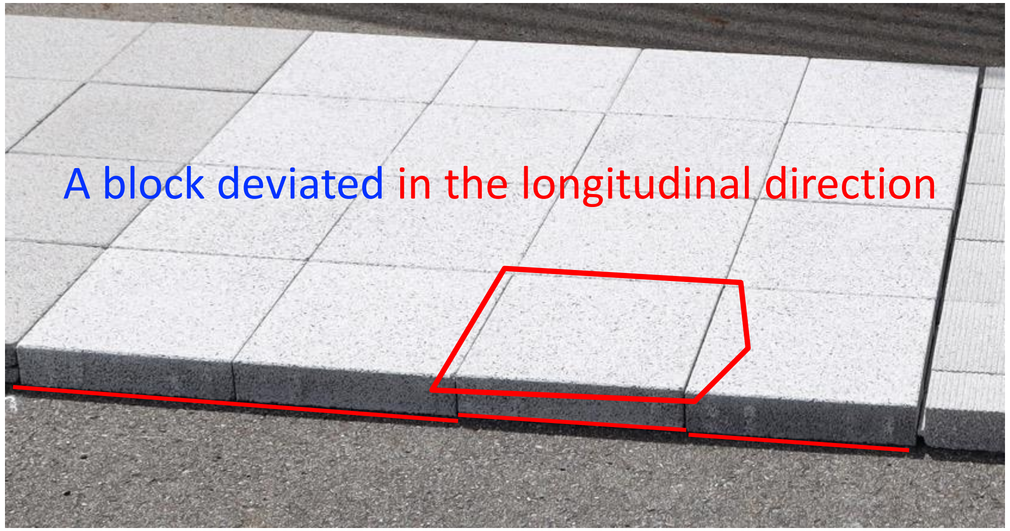
Integration of **Level 4** and **Level 7 to 9**

⇩

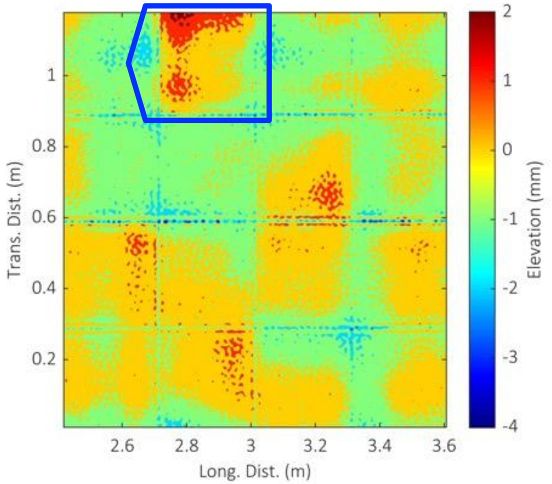
Functional Evaluation

Original Data

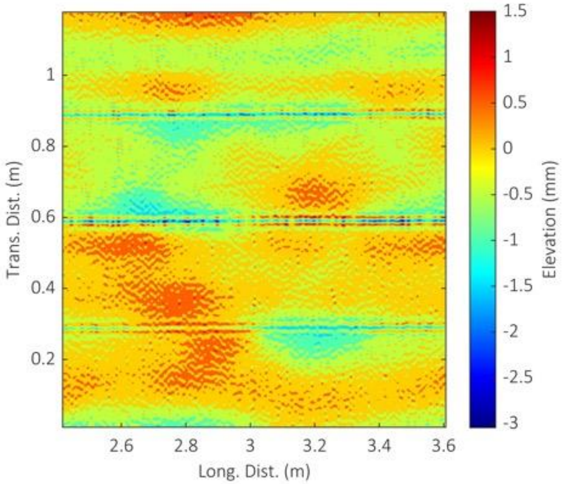




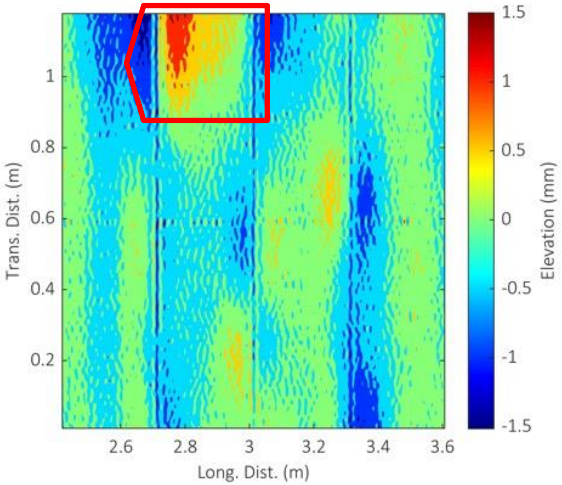
Omnidirectional



Transverse direction



Longitudinal direction



Conclusions

- A wide variety of mobilities in a road space
  - needs to identify corresponding surface characteristics
  - improvement of pavement M & R by use of 3D technologies

- Evaluation of mobility interaction with surface properties
  - different responses of mobilities to surface in terms of ride quality
  - challenges for consistent evaluation of pavements in road spaces

- Application of DTCWT for Pavement Diagnosis
  - understanding deterioration modes in terms of the wavelength
  - area-based quality assurance and fault identification
  - functional assessment of pavement condition corresponding to mobilities

Thank you for your kind attention
Question?

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