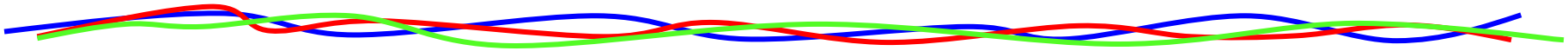
Road Cracking Detection by Using Smartphone Accelerometer



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Outline

Previous Study

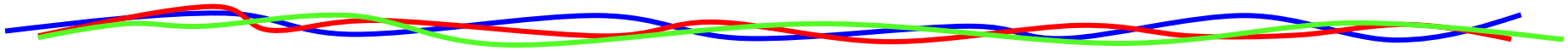
- ✓ Roughness measurement method by using smartphone.
- ✓ It is easy, convenient, low cost, and good reliability.

Challenges

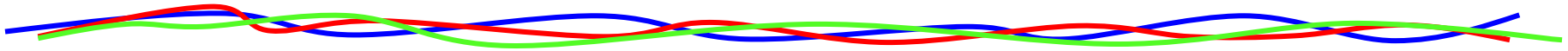
- ✓ To evaluate road conditions, not only roughness, but also cracking and rutting is required.
- ✓ Try to develop cracking detection method, by using smartphone accelerometer and GPS.
- ✓ This is an early report of this trial.

Detecting Target : Cracking

Previous Study Roughness Measurement by Smartphone

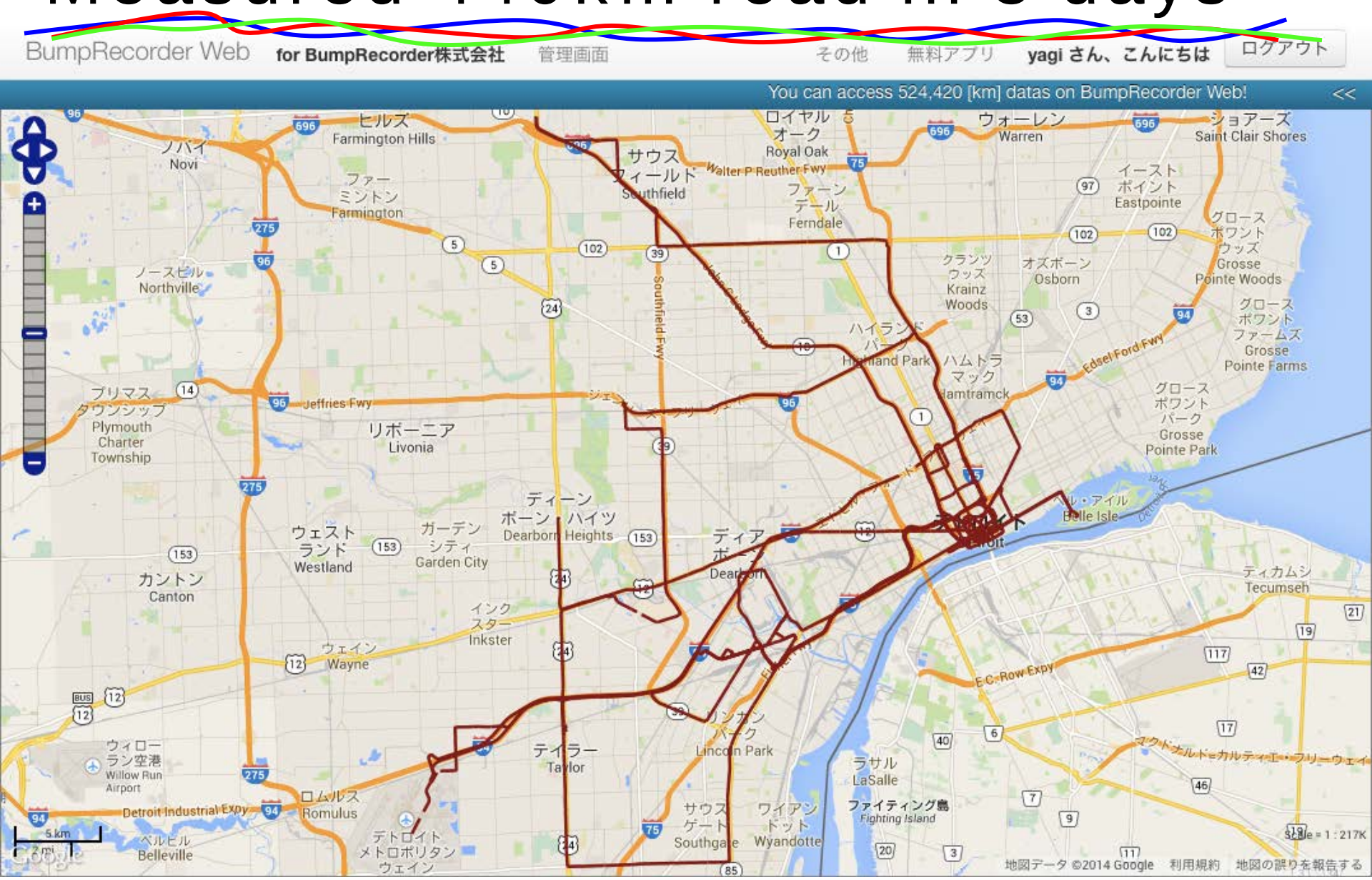


It is easy to measure.



Measured at Detroit Road

Measured 440km road in 3 days



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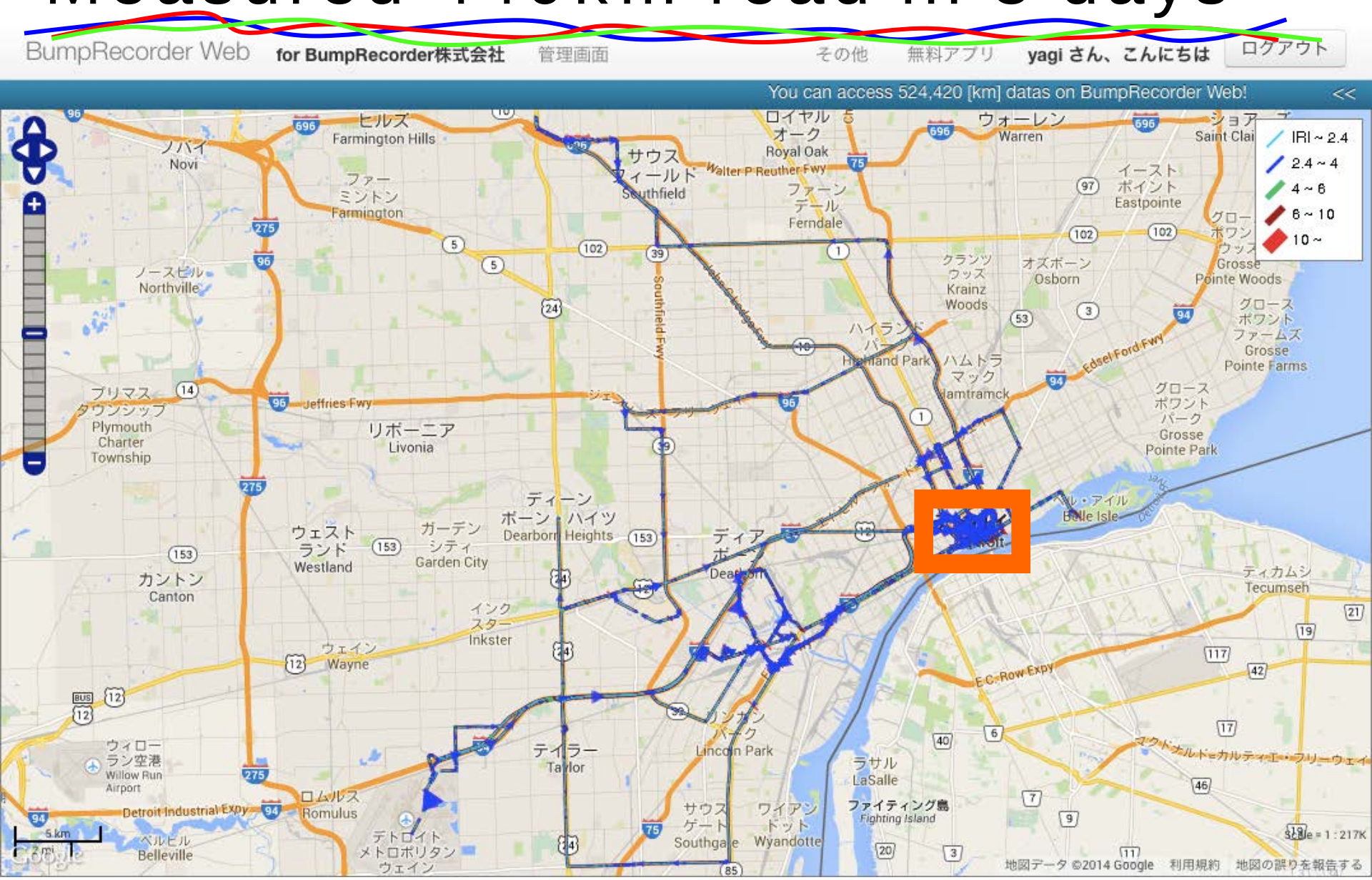
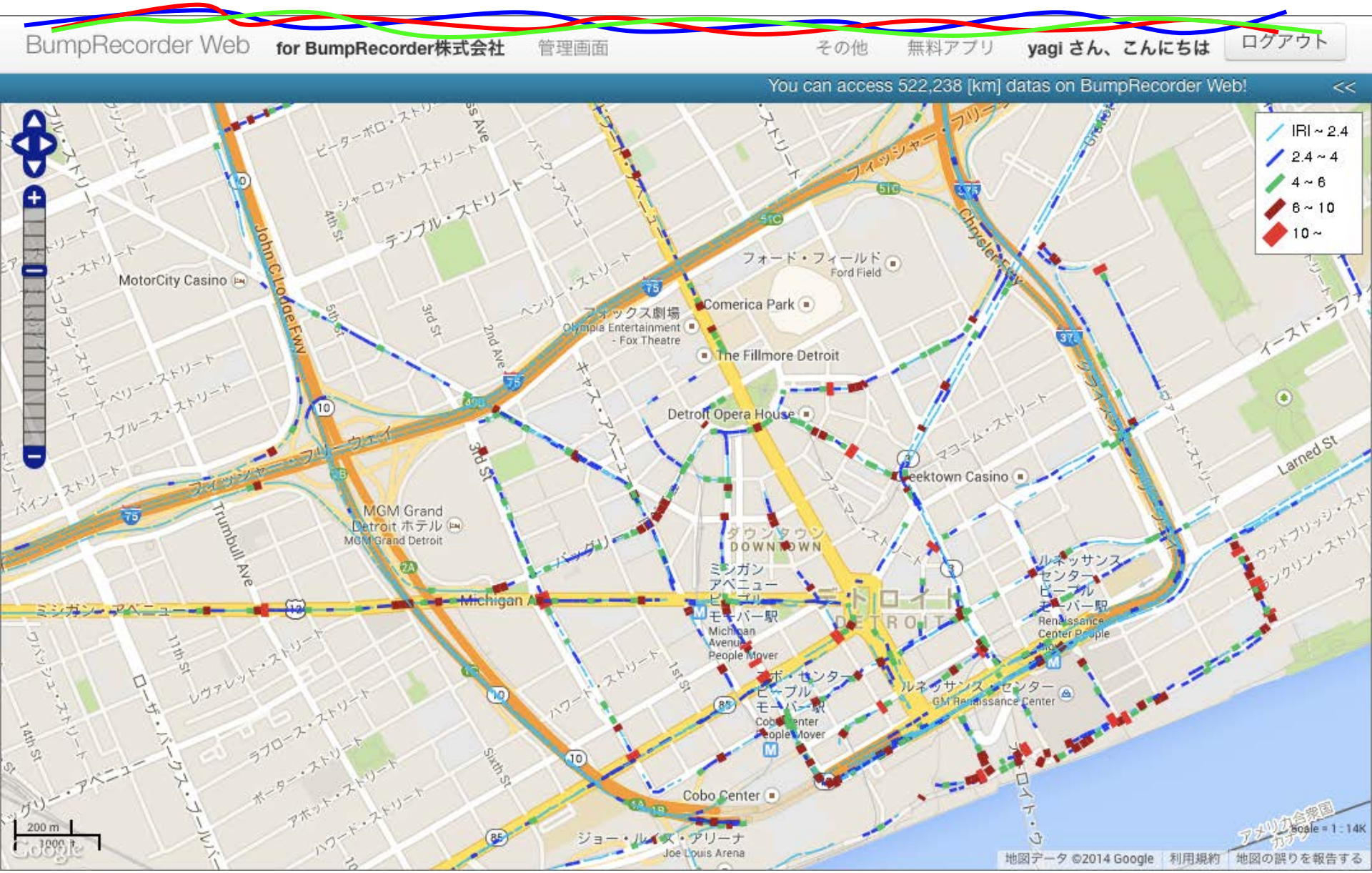
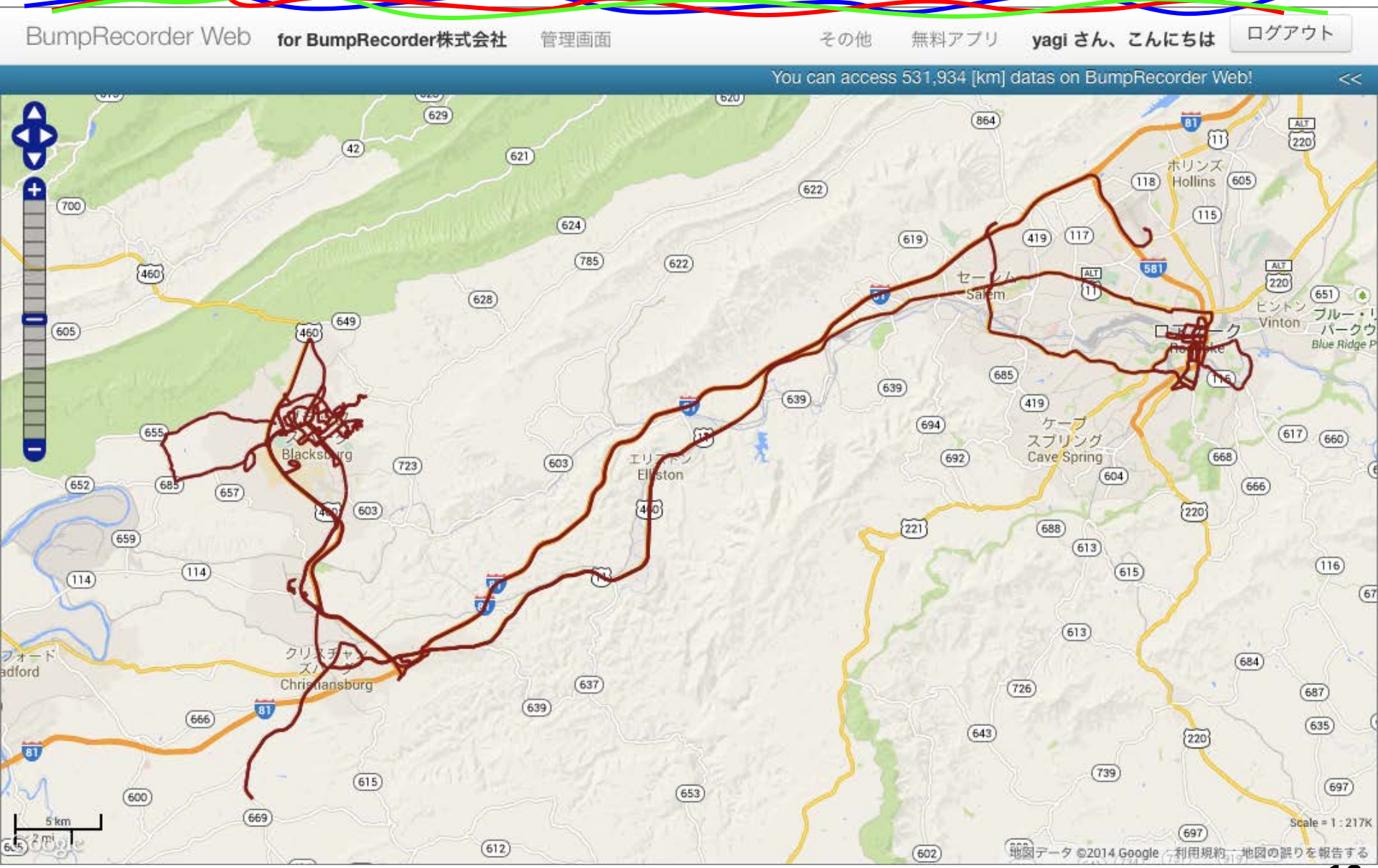


Measurement at Detroit

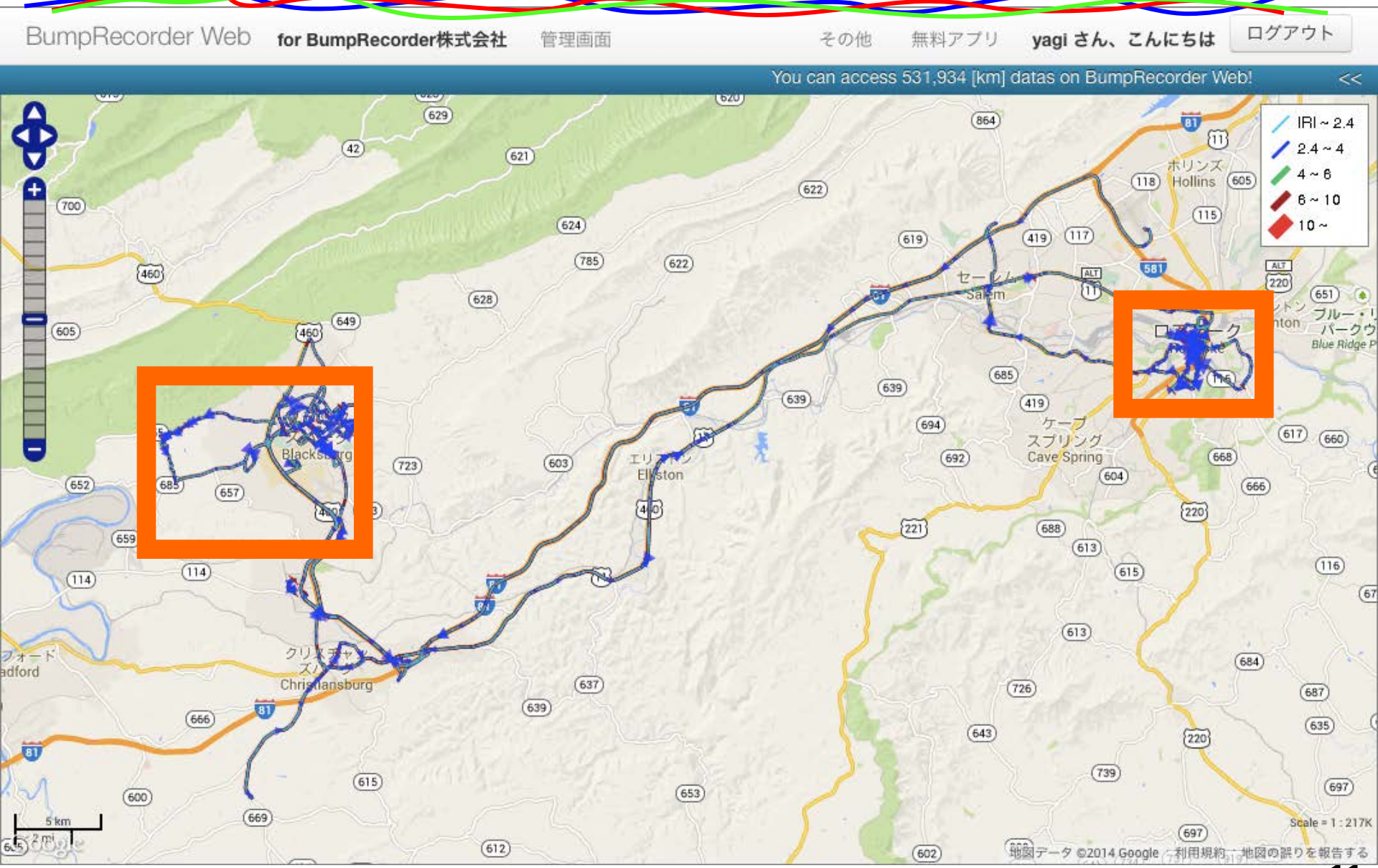


Measurement at Detroit

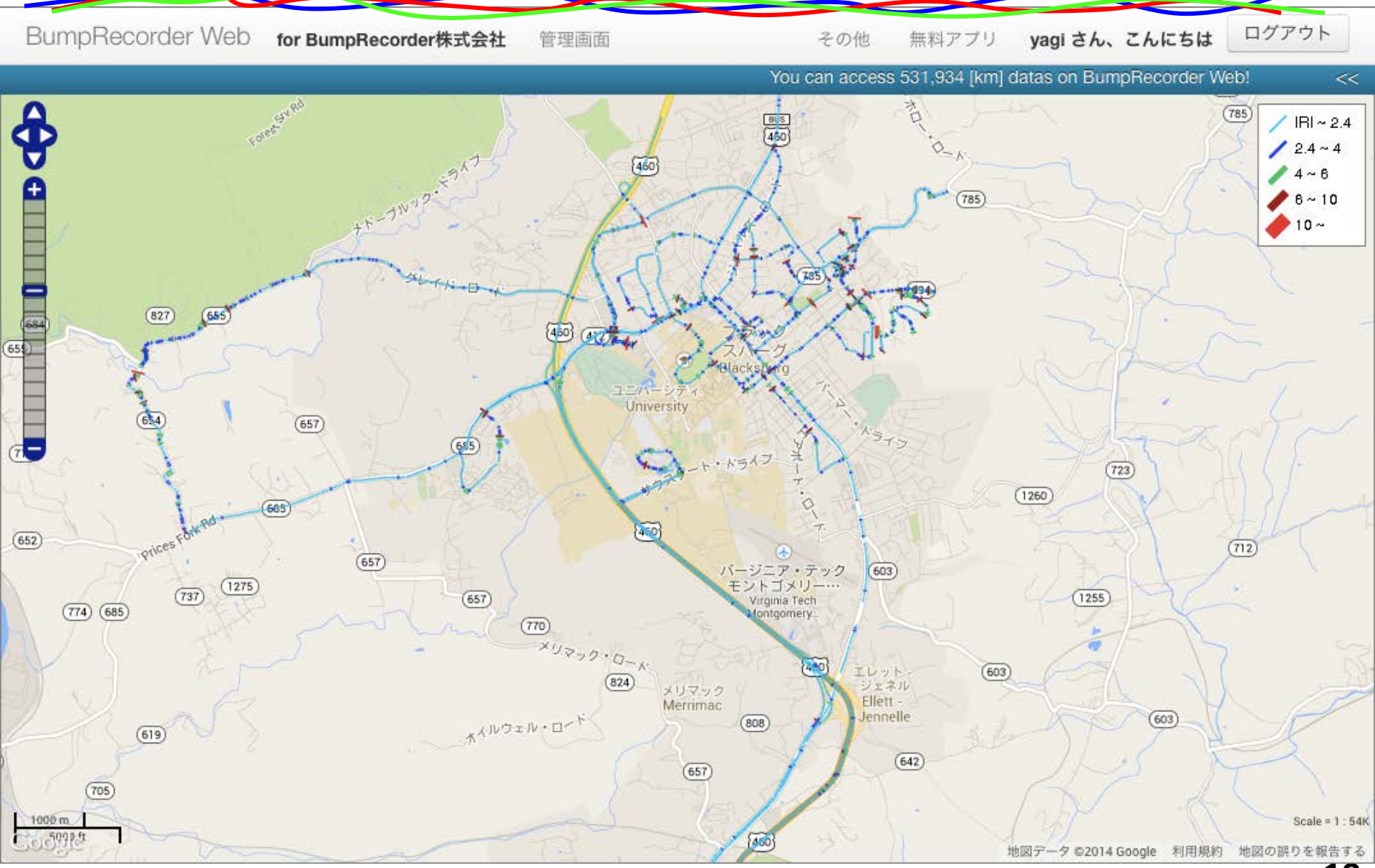
Measured 450km road in 4 days



Measured 390km road in 3 days



Measurement at Blacksburg



Measurement at Roanoke

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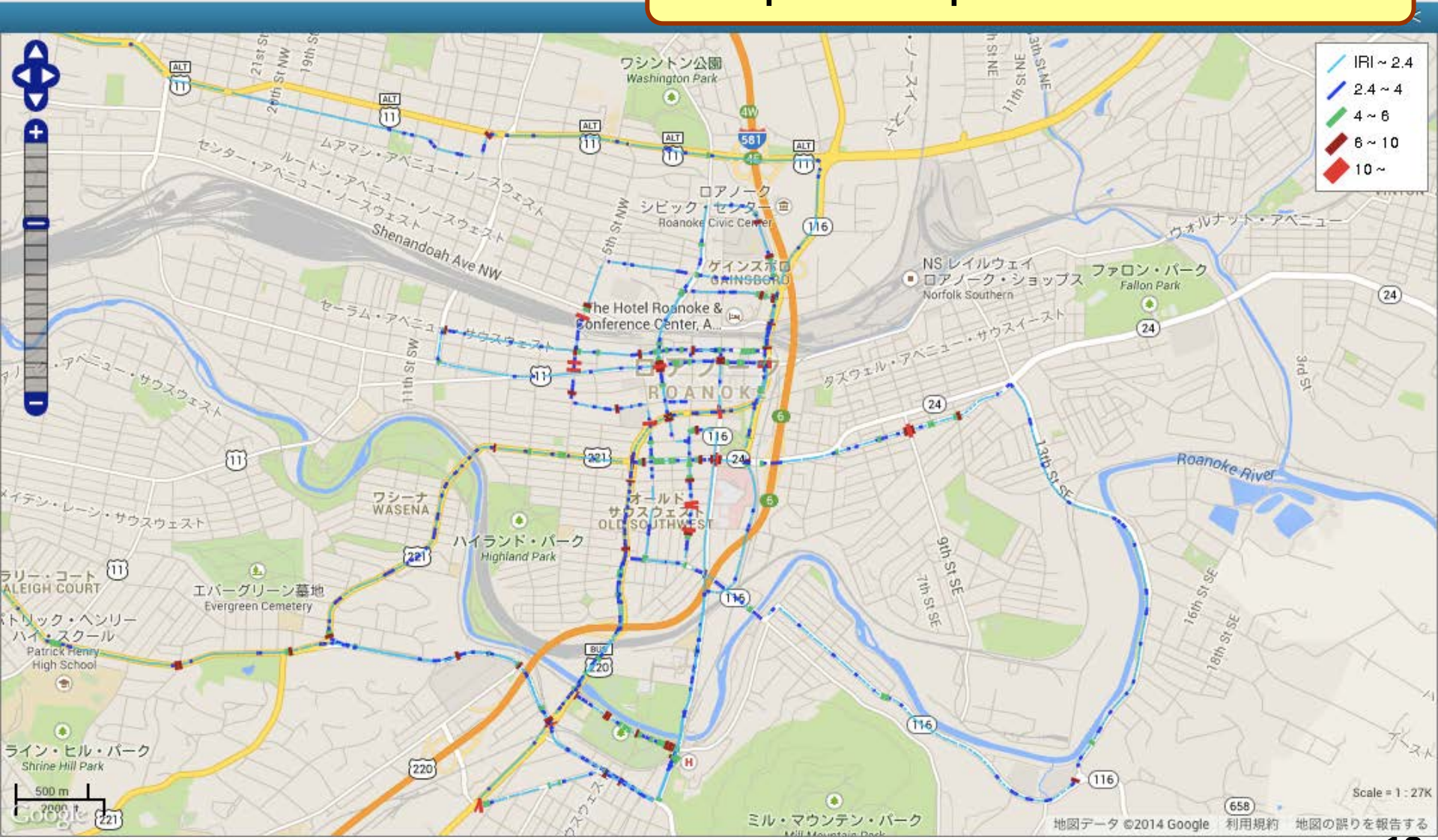
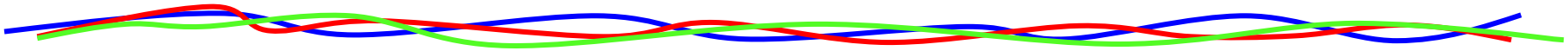
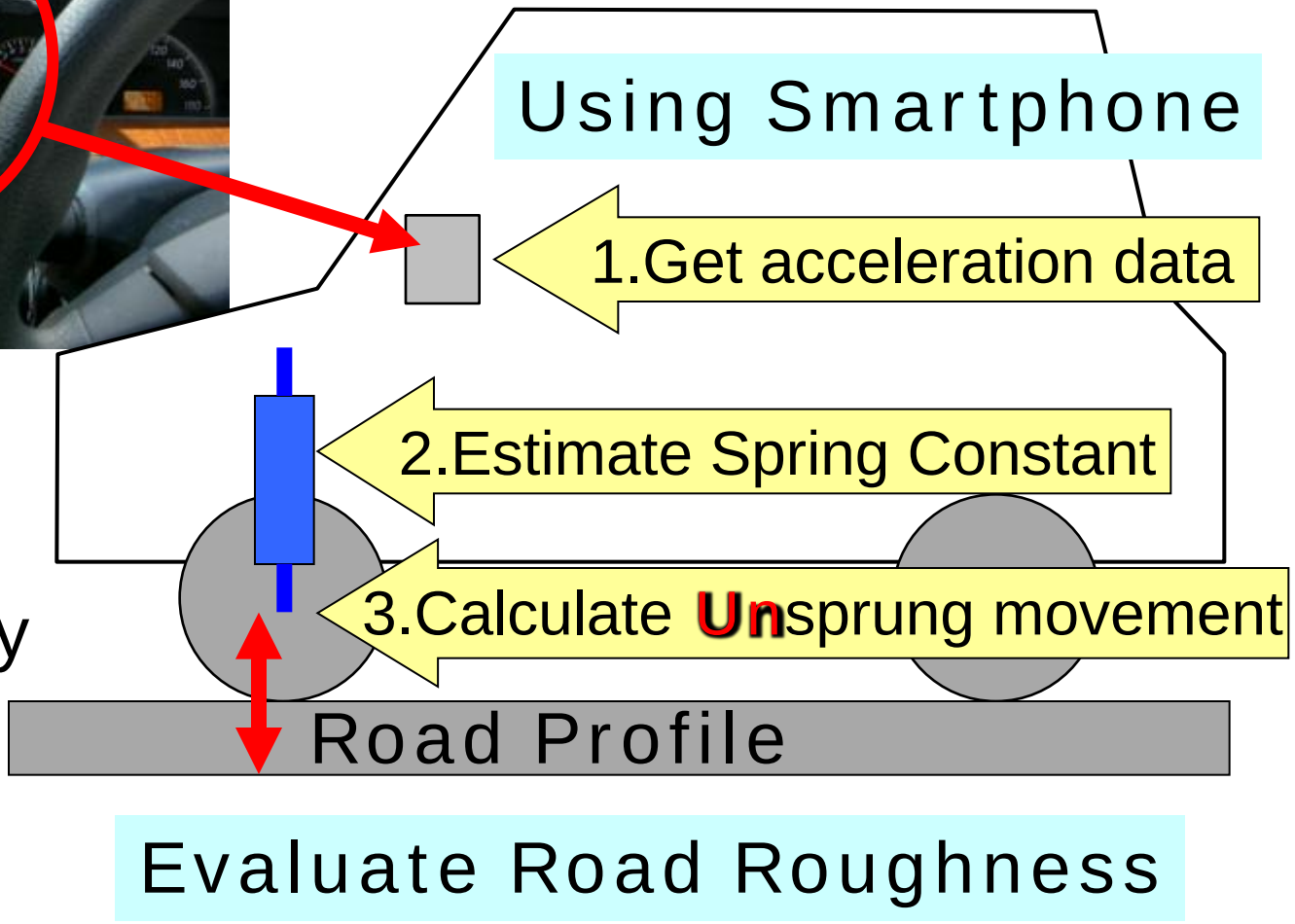


Previous Study
Technical Side of Roughness Measurement Method



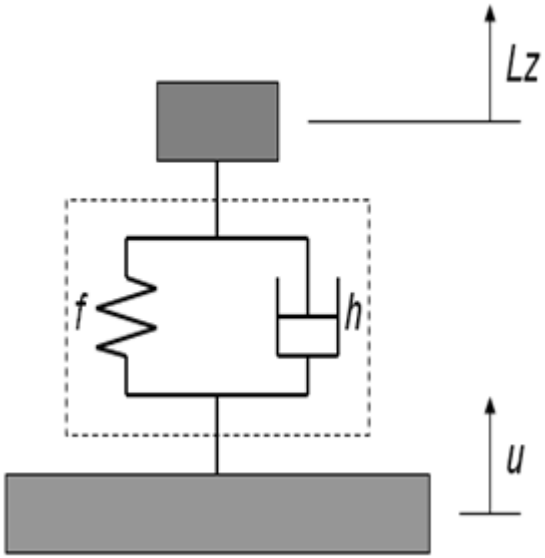
Roughness Measurement

All process proceed automatically



Evaluate Road Roughness

Calculate equation of motion



Suspension Spring Constant : f

FFT for vertical acceleration data

Picking up resonant frequency around 1.5Hz

Damping Ratio : h

Using FFT result and half-width method

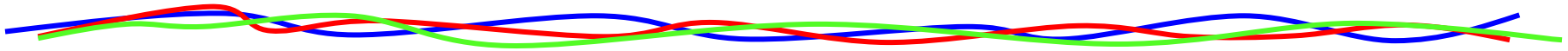
Calculate equation of motion for 1 mass spring model to get Unsprung movement "u" by using sprung movement "Lz"

$$\ddot{Lz} + 2h\omega(\dot{Lz} - \dot{u}) + \omega^2(Lz - u) = 0$$ Equation of motion

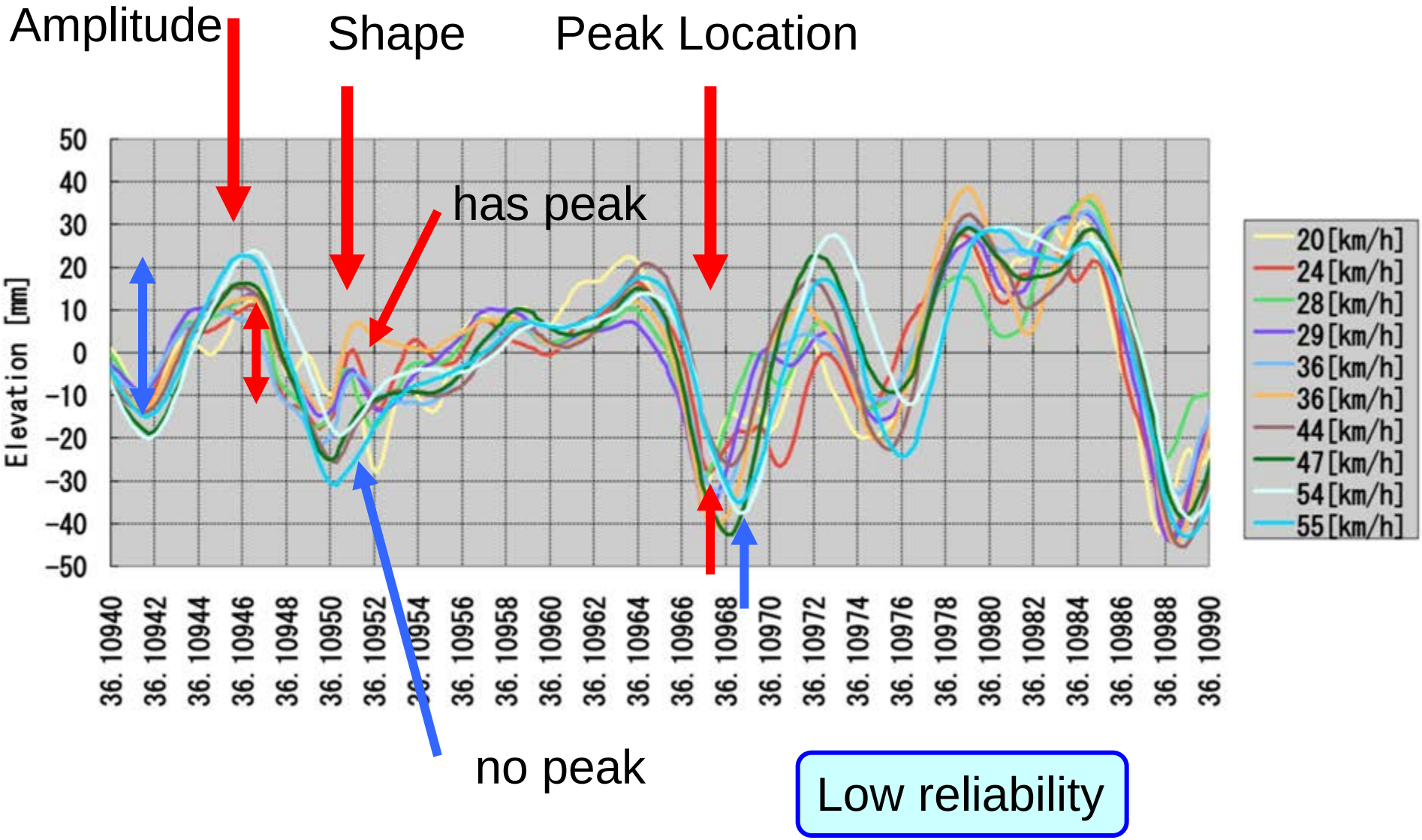
$$\omega = 2\pi f$$ Angular frequency

$$u(i) = u(i-1) + \frac{\dot{u}(i) + \dot{u}(i-1)}{2N}$$ Sum (Integlal)

Efficiency of Unsprung Estimation



Sprung movement



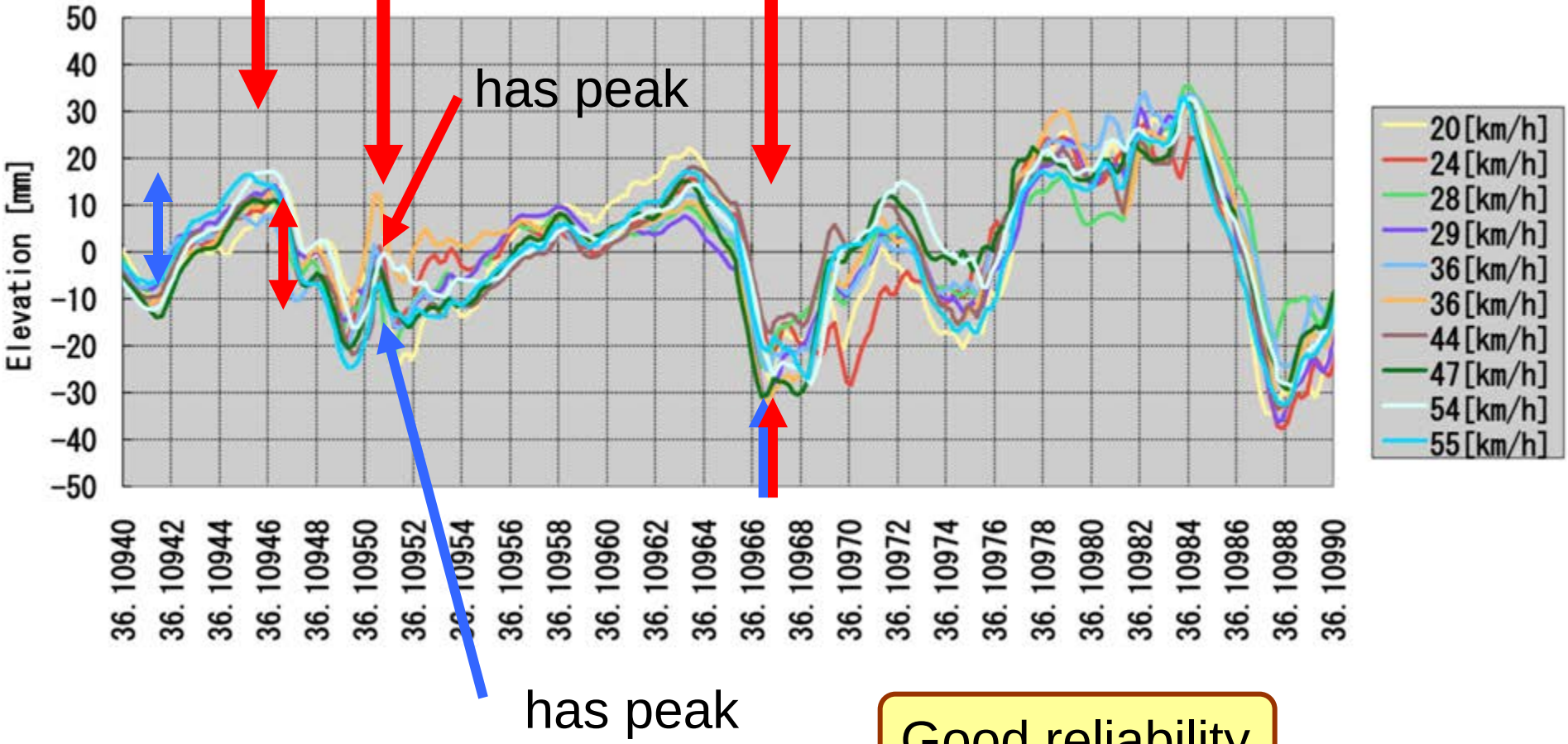
Low reliability

Unsprung elevation

Amplitude

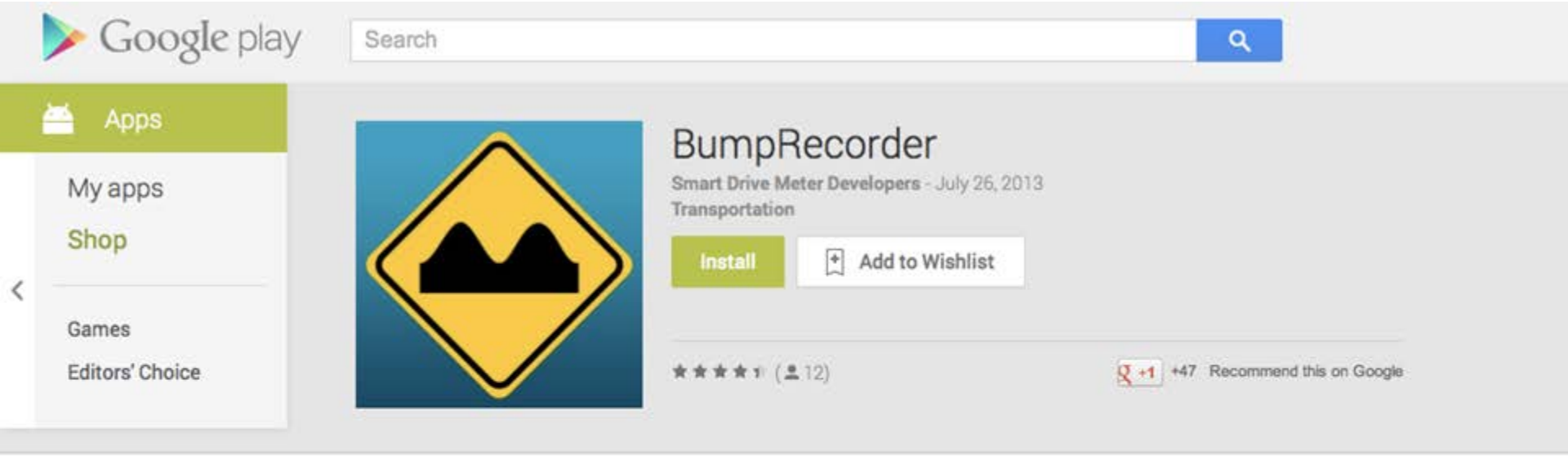
Shape

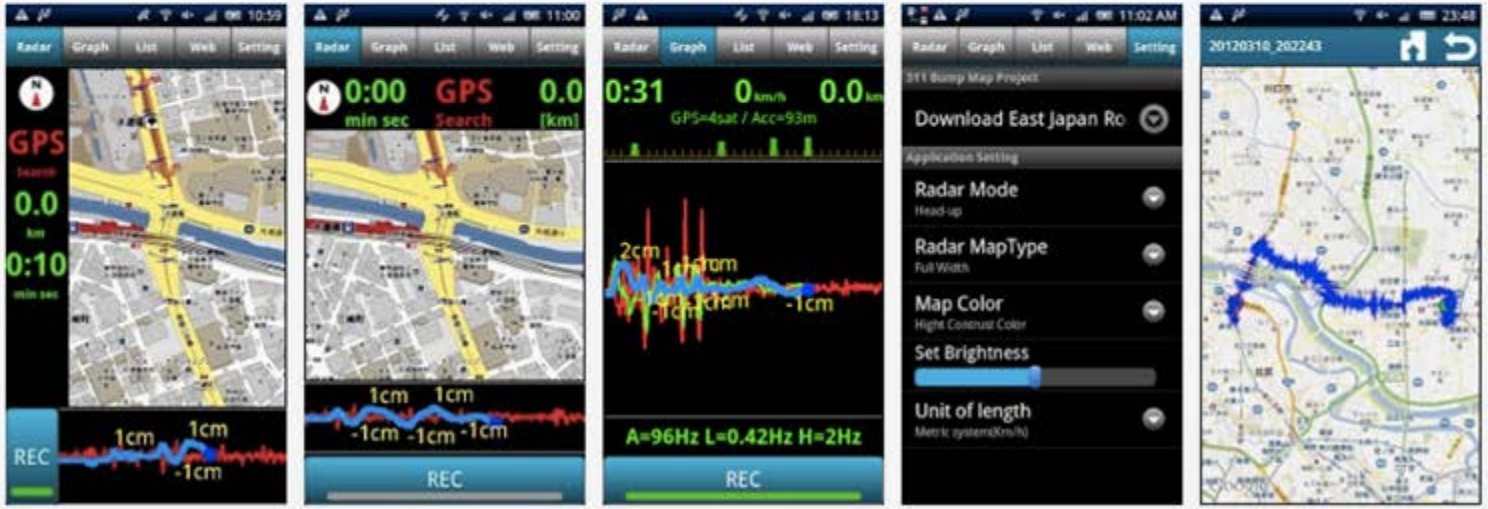
Peak Location



Good reliability

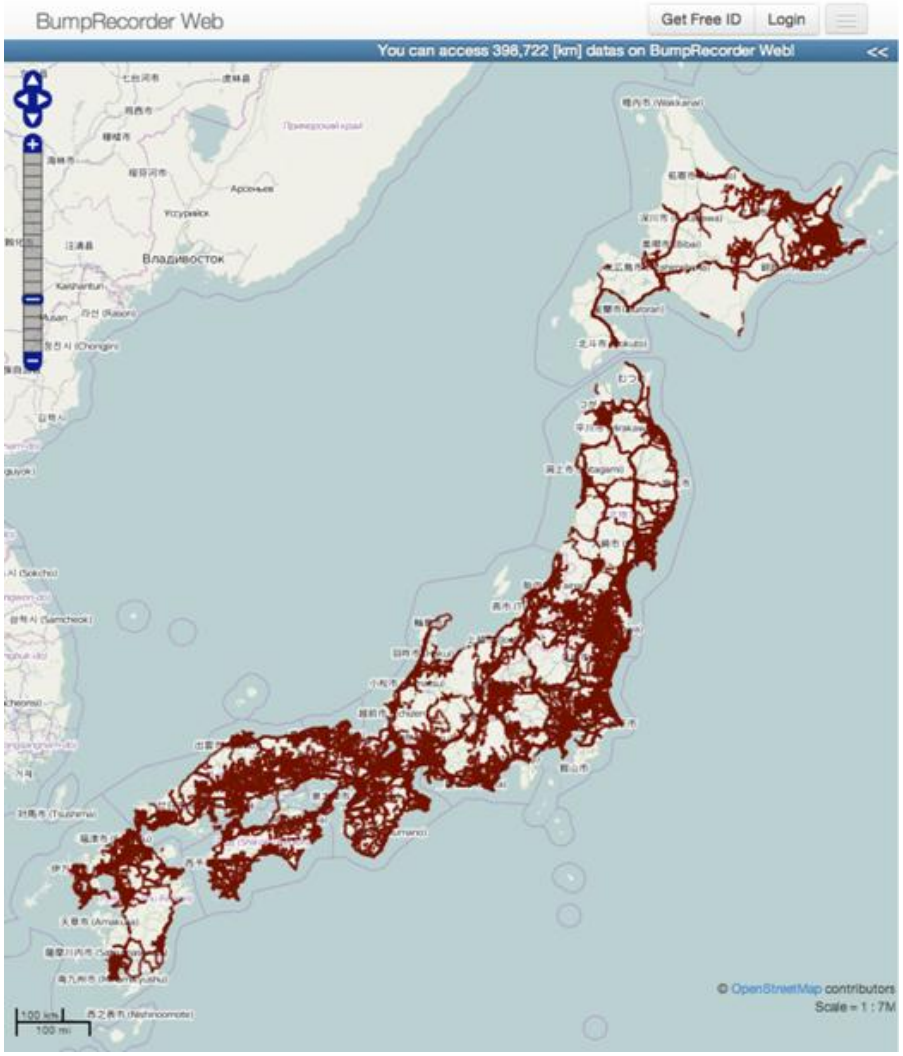
Smartphone App is Free





Collecting Data in Japan

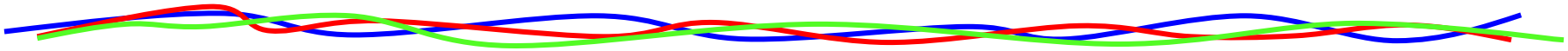
Already collected over 530,000km Pavement Bump Data.



Data collection is cooperating with GLOBAL SURVEY CORP.

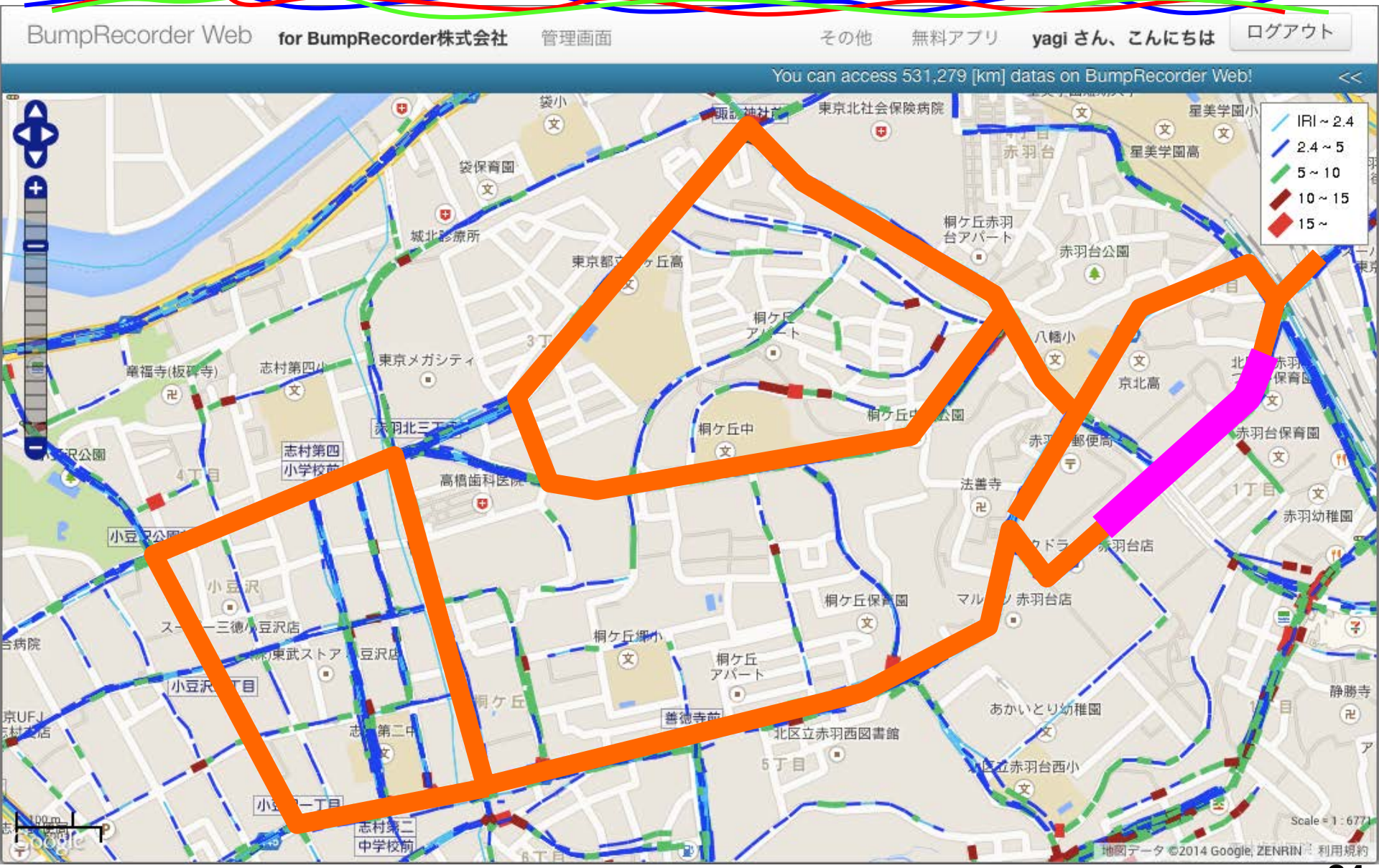
Smartphone approach is so convenient. You can get data anytime, it can be use for screening.

Challenges
Cracking Detection

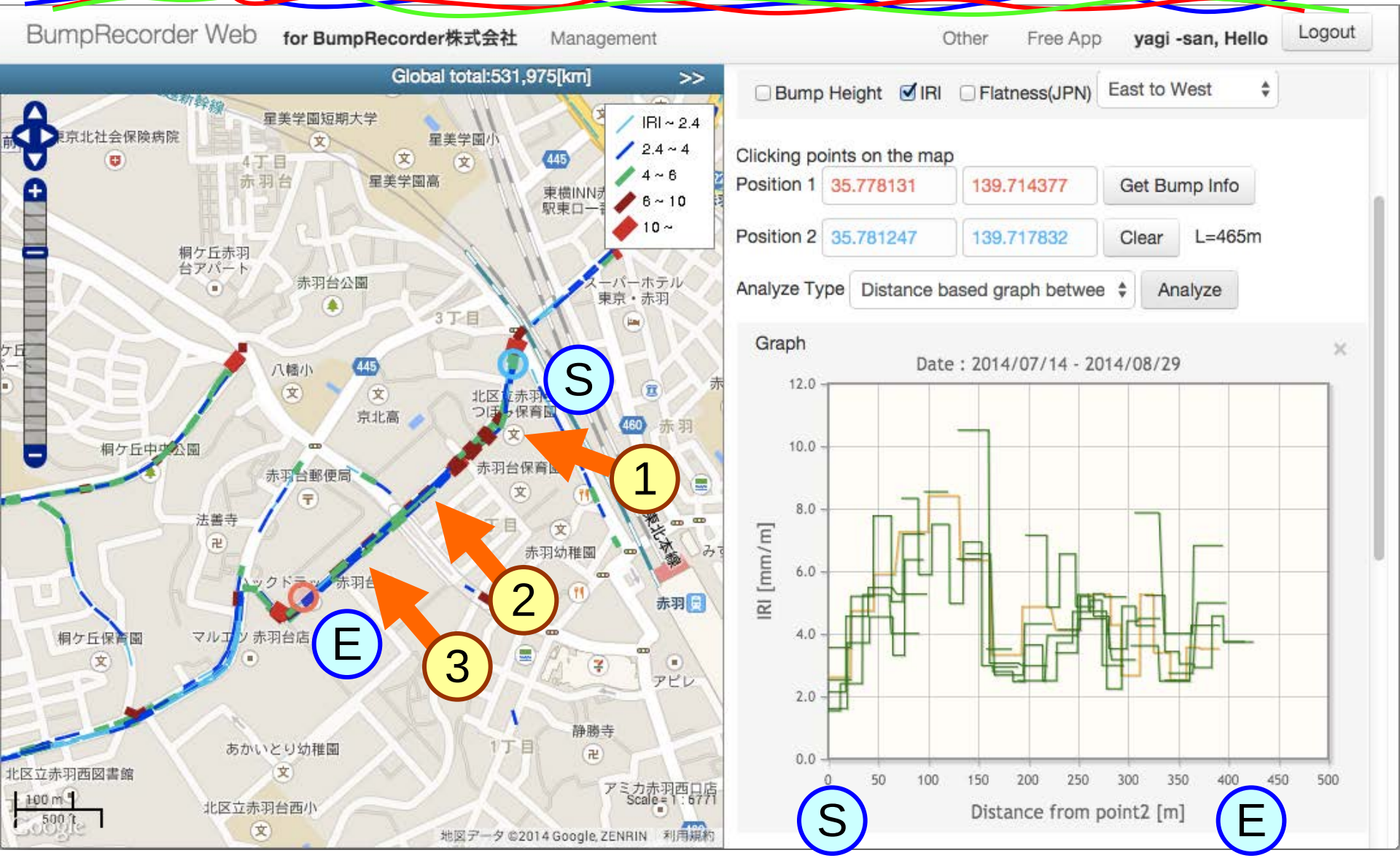


Tested Smartphone

Test Road and IRI



Test Road and IRI



Cracking point 1

Cracking point 2

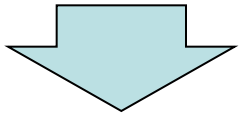
Cracking point 3

Detection Ideas

for example

Driving Speed : 36km/h = 10m/s
Sampling Cycle : 100Hz
1Cycle = 10cm

Cracking size is about 20cm



Cracking is appeared in 20ms=50Hz
on an acceleration data.

Frequency analysis will be done in short period.

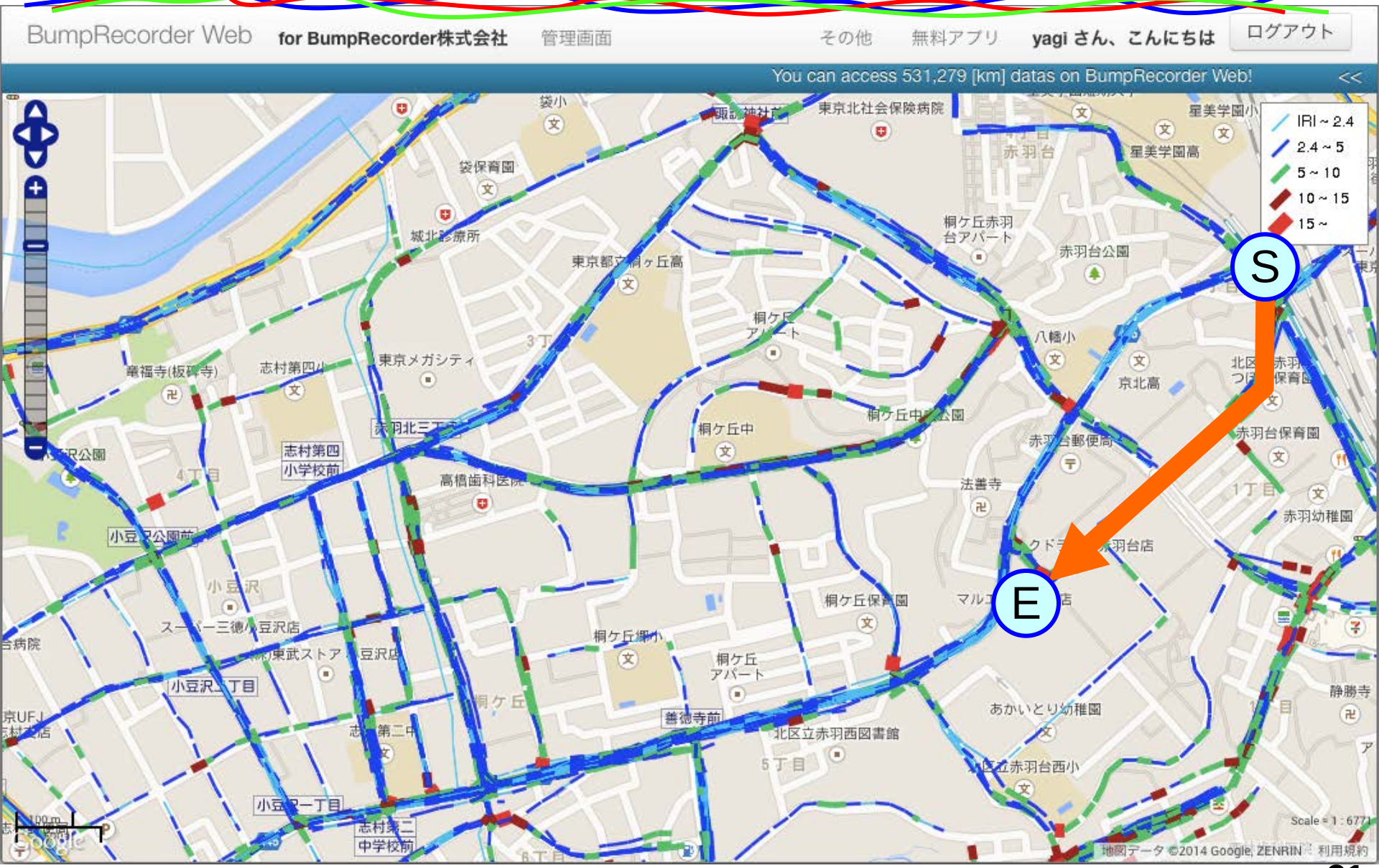
Detection Ideas

FFT will be done
at short time window less than 1 second.

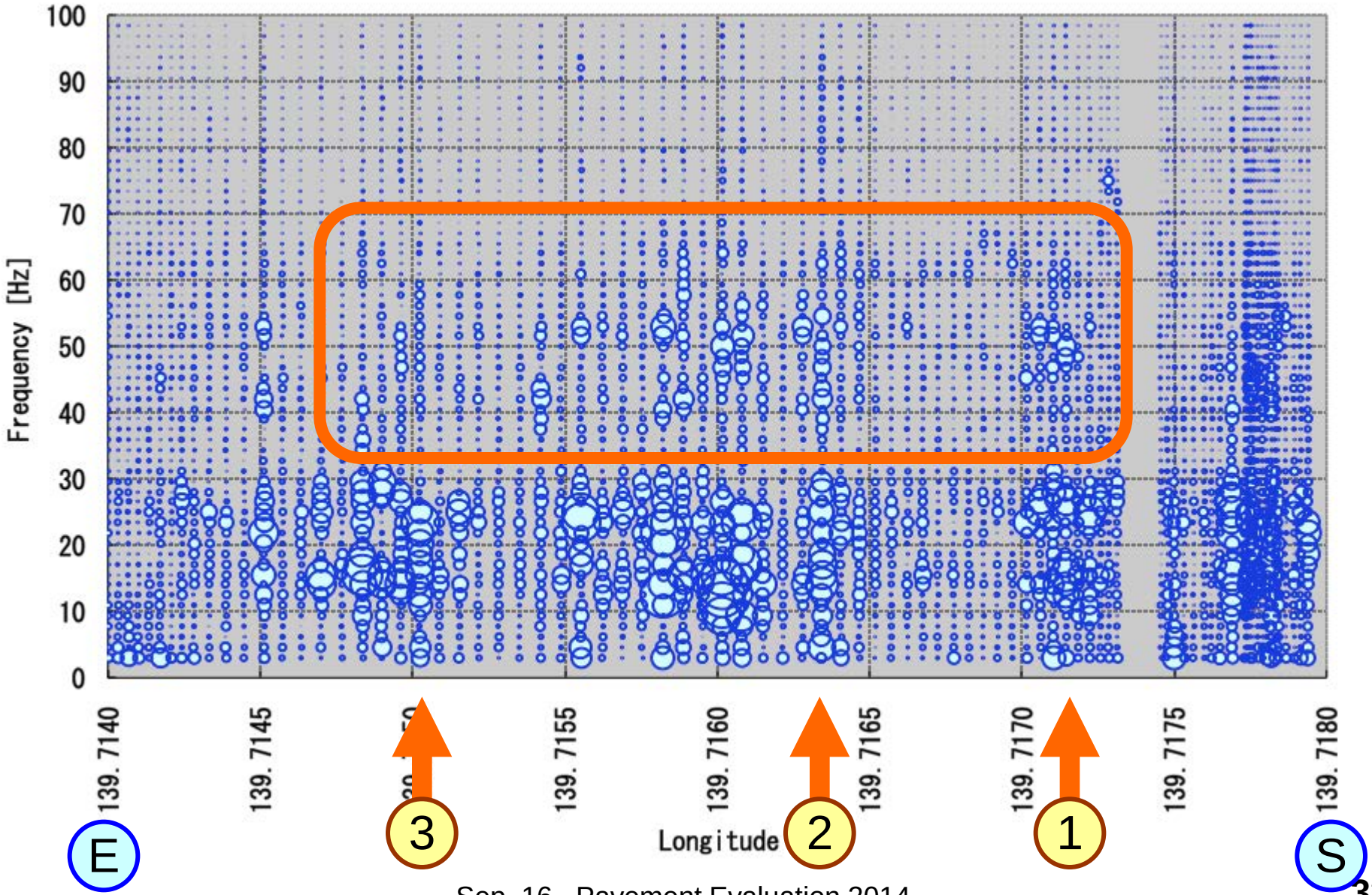
FFT data length must be powered by 2.

Acceleration sampling cycle	FFT length
200Hz	128
100Hz	64
50Hz	32

Testing Road



FFT Analysis : 200Hz



Cracking Index

When a high frequency is detected,
it may be cracking.

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Weighted Average of Frequency

$$f_{ave} = \frac{\sum_i f(i) \times a(i)}{\sum_i a(i)}$$

FFT result
f(i) : frequency
a(i) : amplitude

Cracking Index

When a high frequency is detected,
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Weighted Average of Frequency

$$f_{ave} = \frac{\sum_i f(i) \times a(i)}{\sum_i a(i)}$$

FFT result
f(i) : frequency
a(i) : amplitude

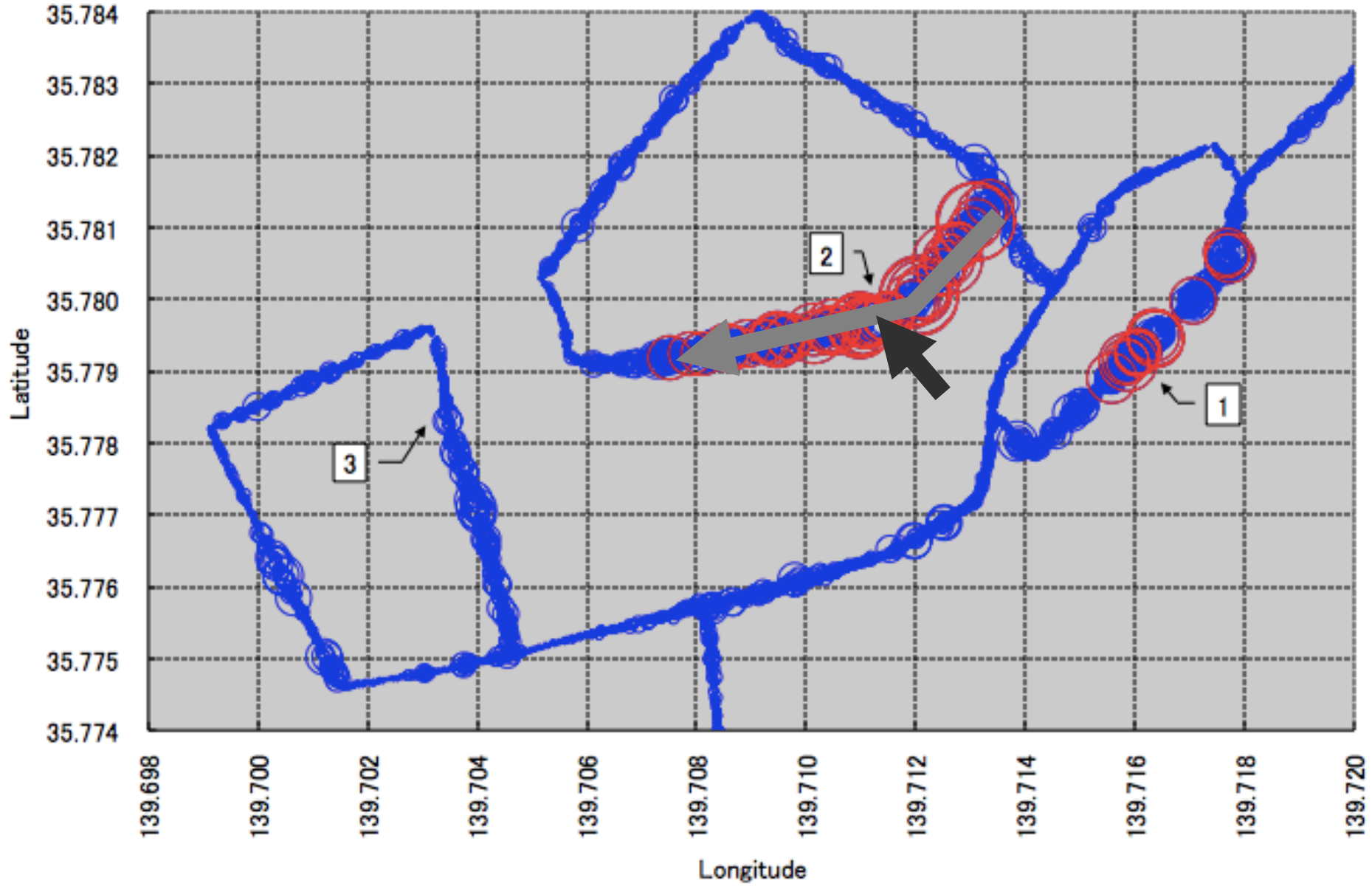
Cracking Index

$$CI = f_{ave} \times a_{ave}$$

a_{ave} : average amplitude

BumpRecorder

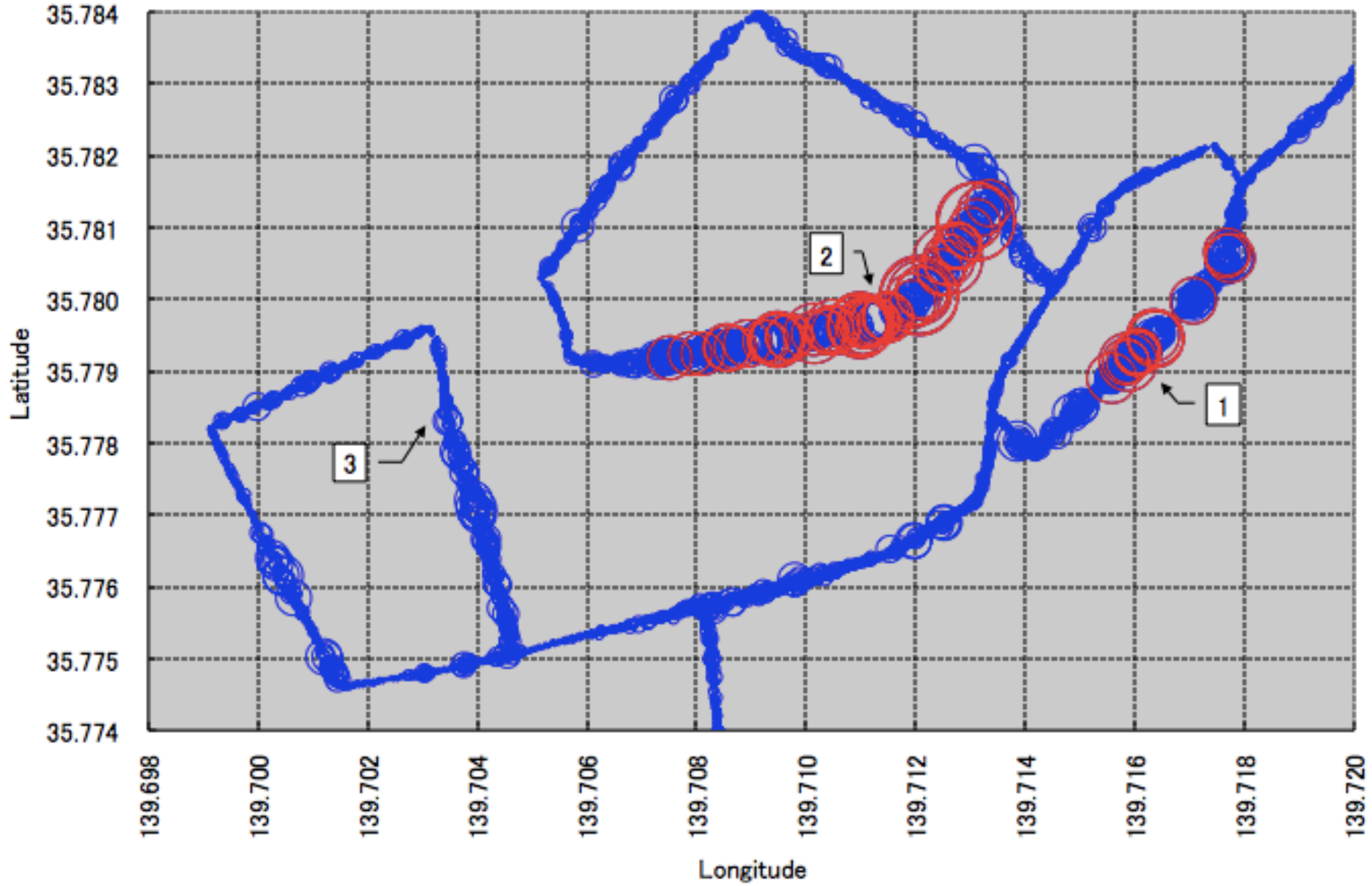
Craking Index : 200Hz



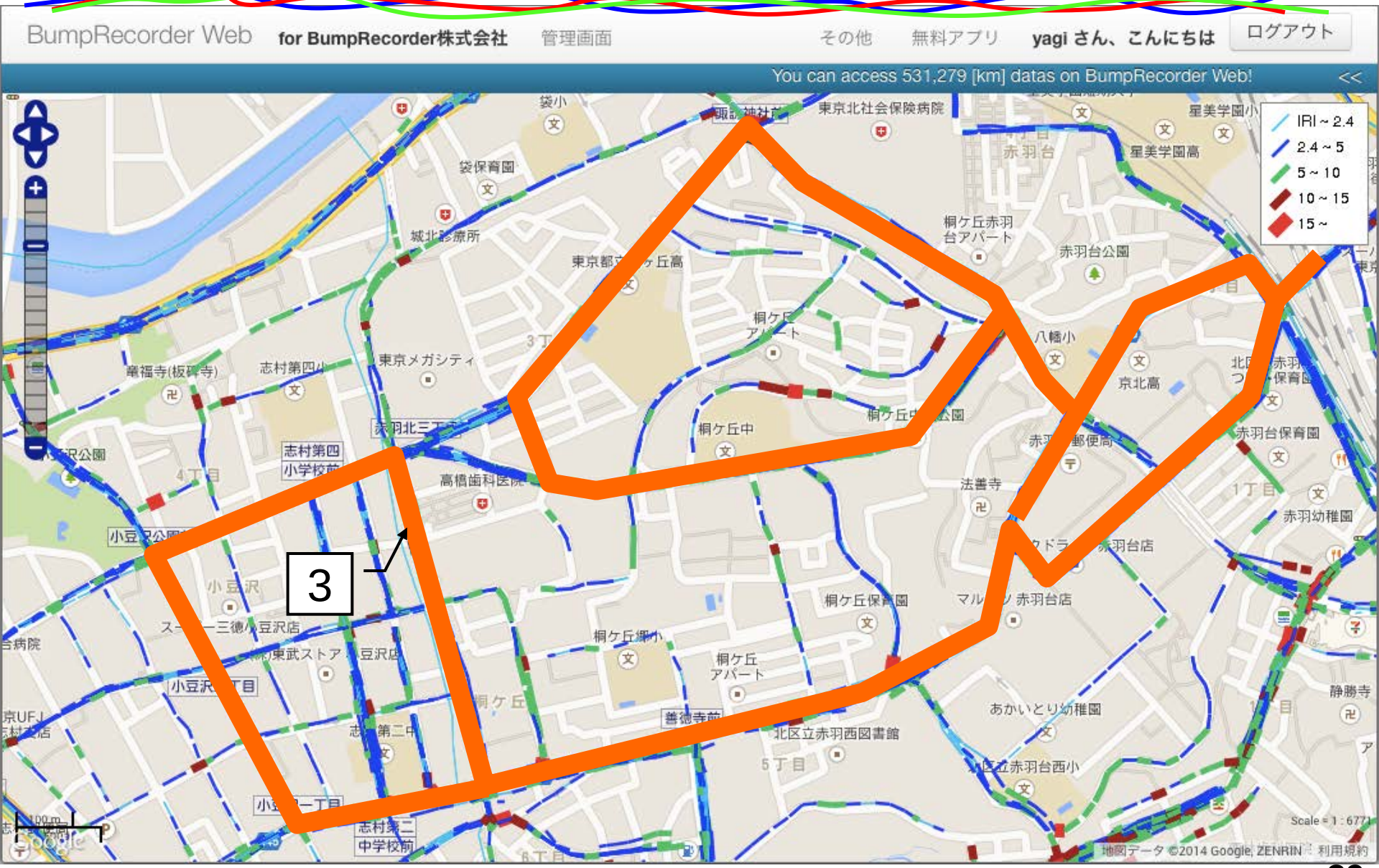
Concrete Road

BumpRecorder

Cracking Index : 200Hz

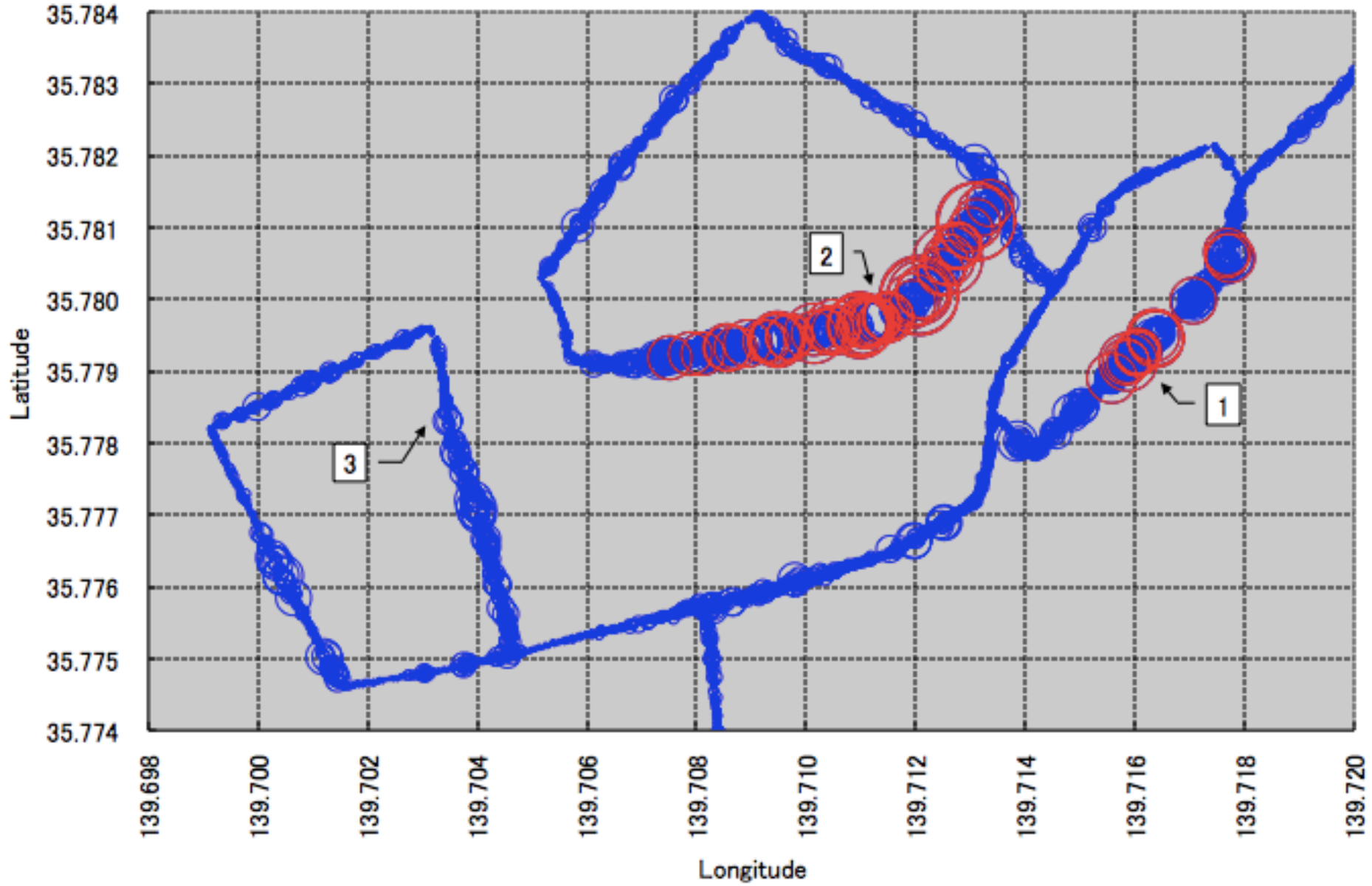


Test Road and IRI

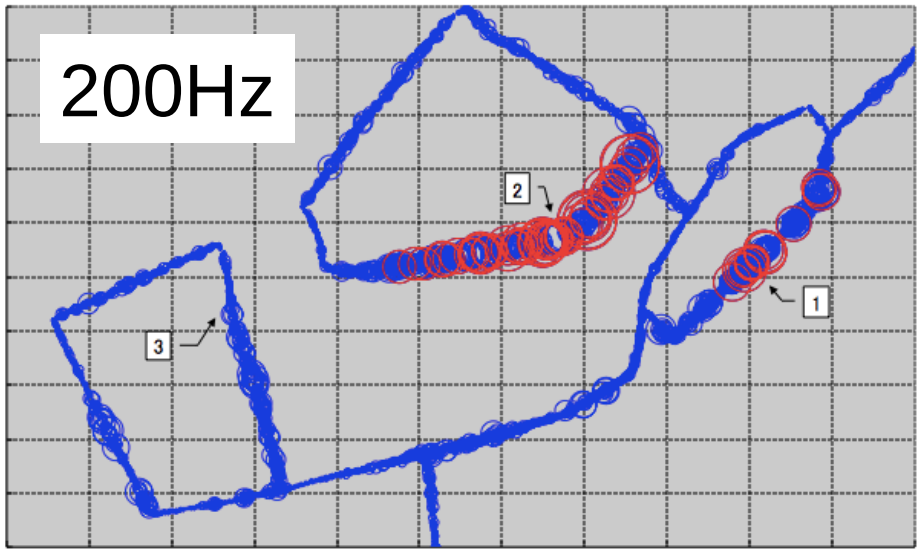


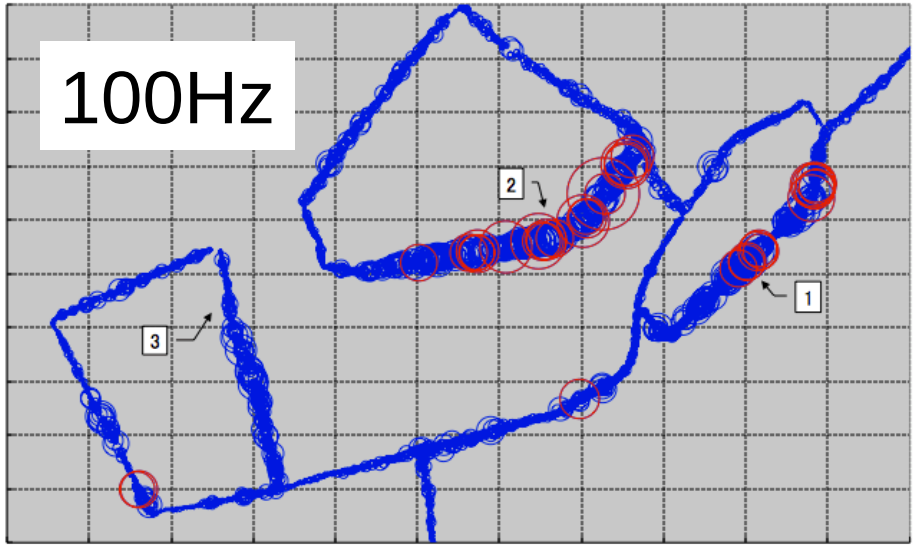
BumpRecorder

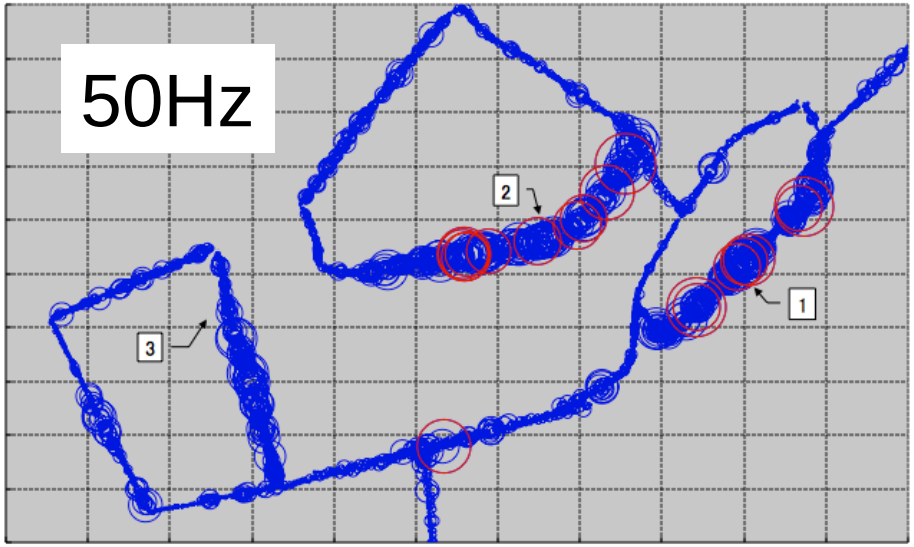
Cracking Index : 200Hz



Influence of sampling rate



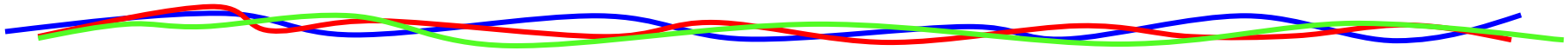




Next step

- ✓ Relationship of Cracking Index and Cracking Rate will be study.
- ✓ Influence of vehicle model, driving speed will be study.

Thank you!



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