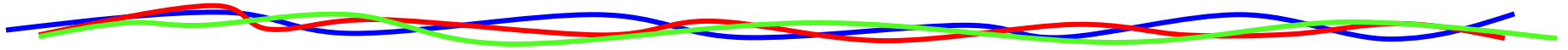


# Road Cracking Detection by Using Smartphone Accelerometer



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# Outline



## Previous Study

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

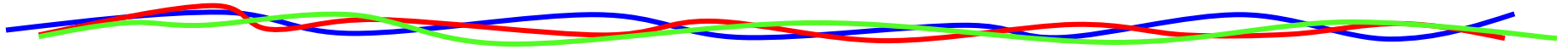
## Challenges

- ✓ 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.

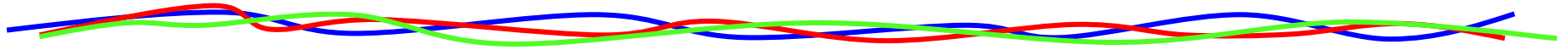
# Detecting Target : Cracking



# Previous Study Roughness Measurement by Smartphone



It is easy to measure.





# Measured at Detroit Road



Smartphone

Cradle

# Measured 440km road in 3 days

BumpRecorder Web

for BumpRecorder株式会社

管理画面

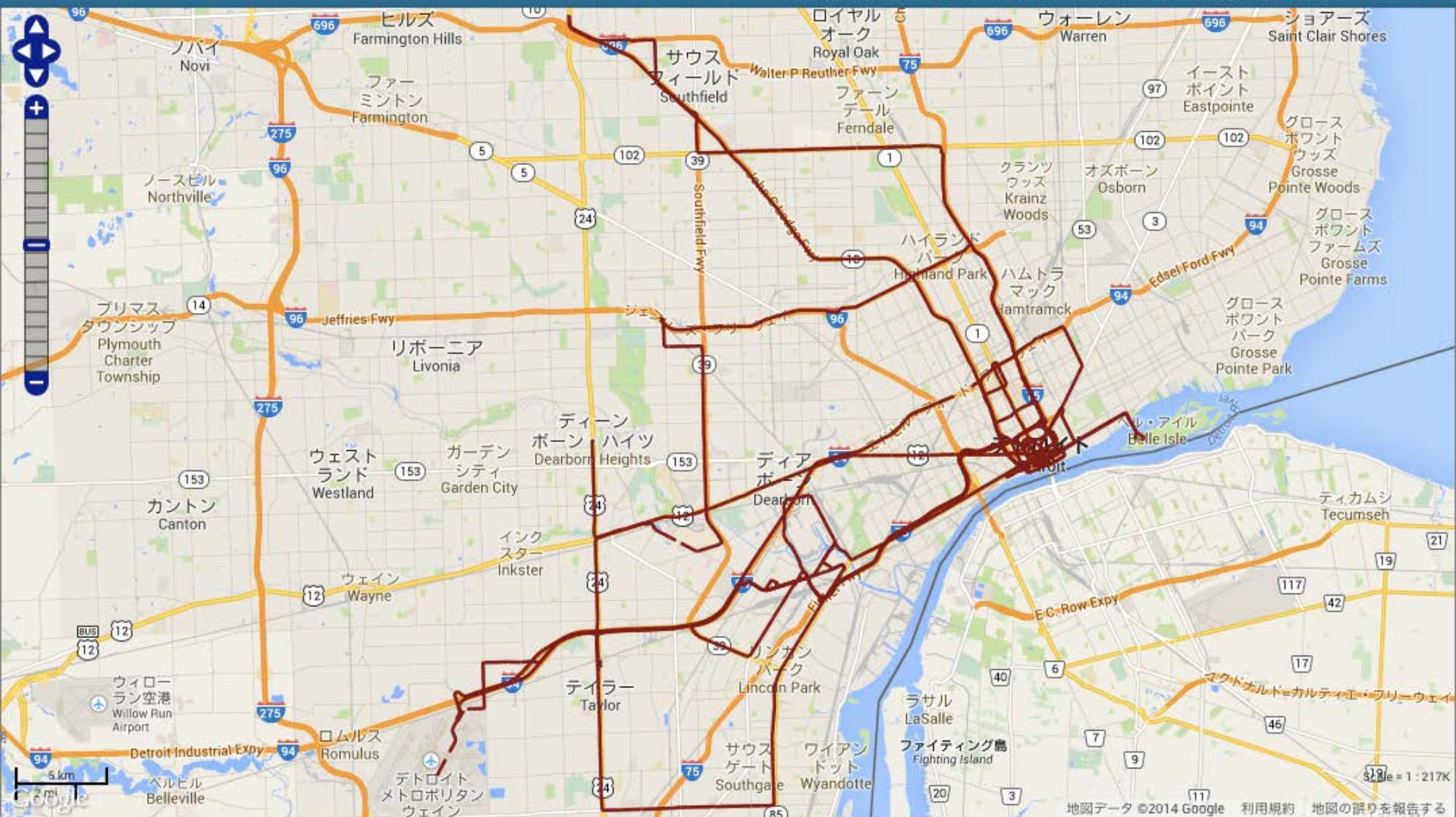
その他

無料アプリ

yagi さん、こんにちは

ログアウト

You can access 524,420 [km] datas on BumpRecorder Web!









# Measurement at Detroit

BumpRecorder Web

for BumpRecorder株式会社

管理画面

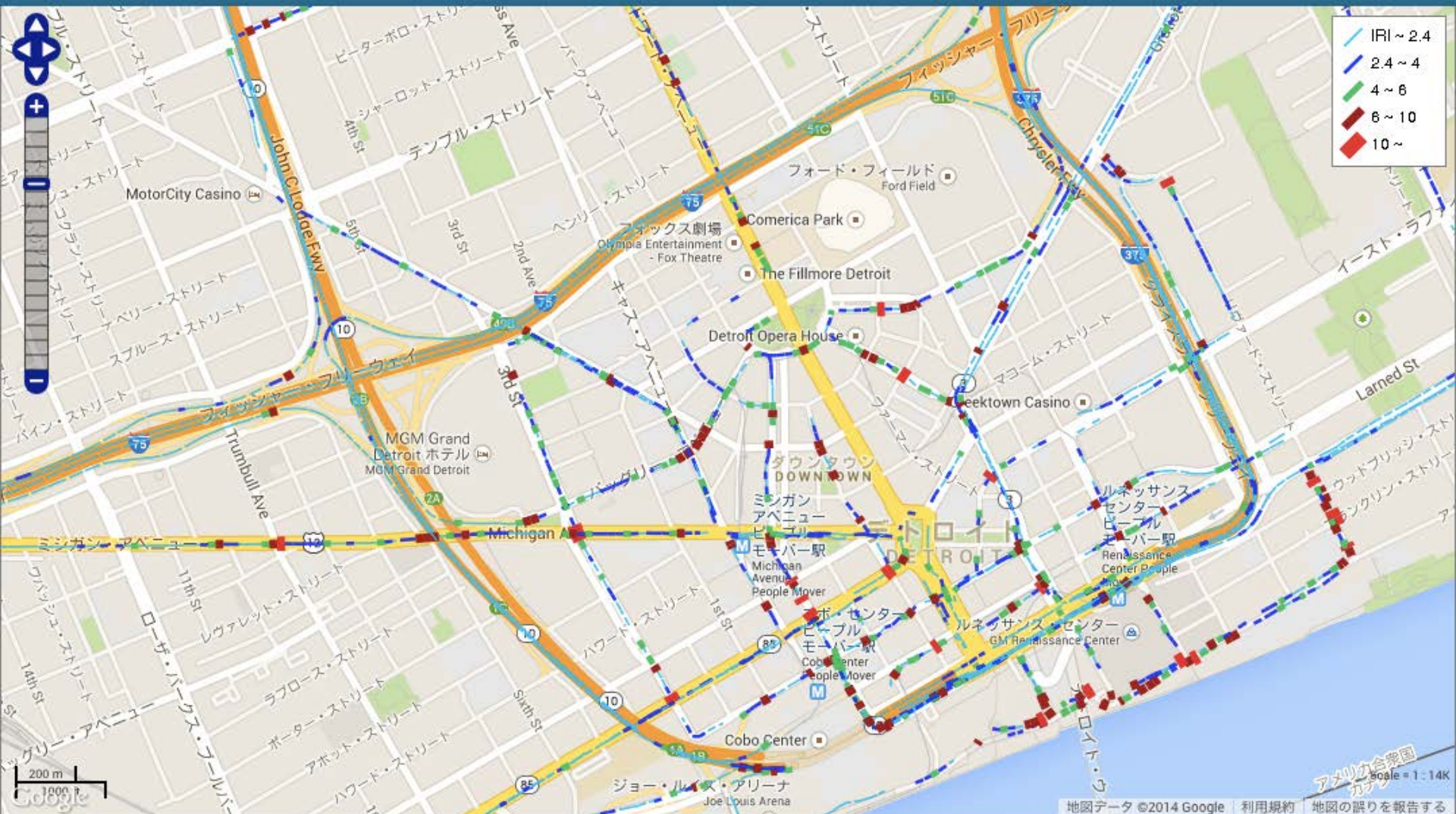
その他

無料アプリ

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ログアウト

You can access 522,238 [km] datas on BumpRecorder Web!





# Measurement at Detroit



# Measured 450km road in 4 days

BumpRecorder Web

for BumpRecorder株式会社

管理画面

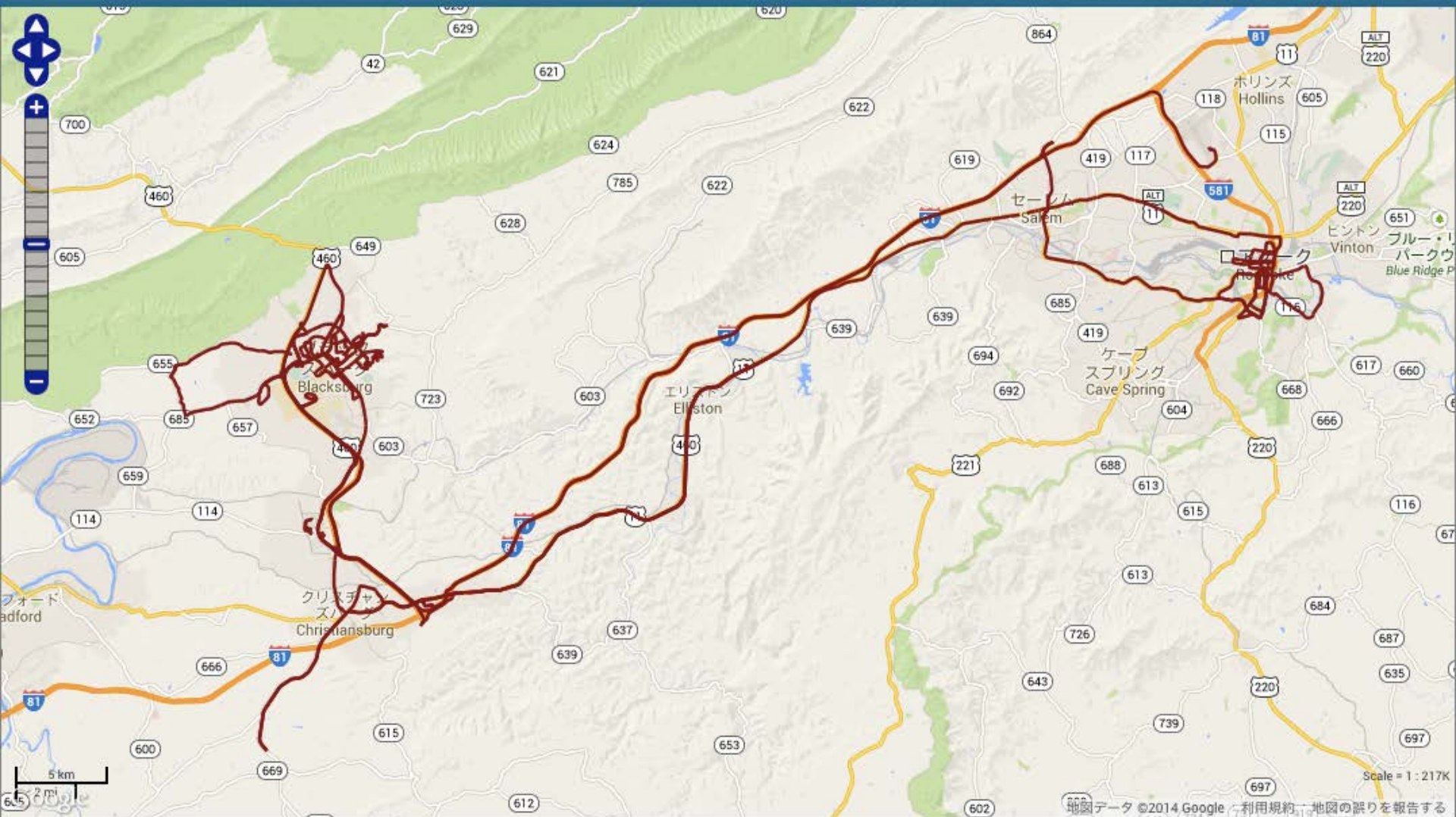
その他

無料アプリ

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ログアウト

You can access 531,934 [km] datas on BumpRecorder Web!





# Measured 390km road in 3 days

BumpRecorder Web

for BumpRecorder株式会社

管理画面

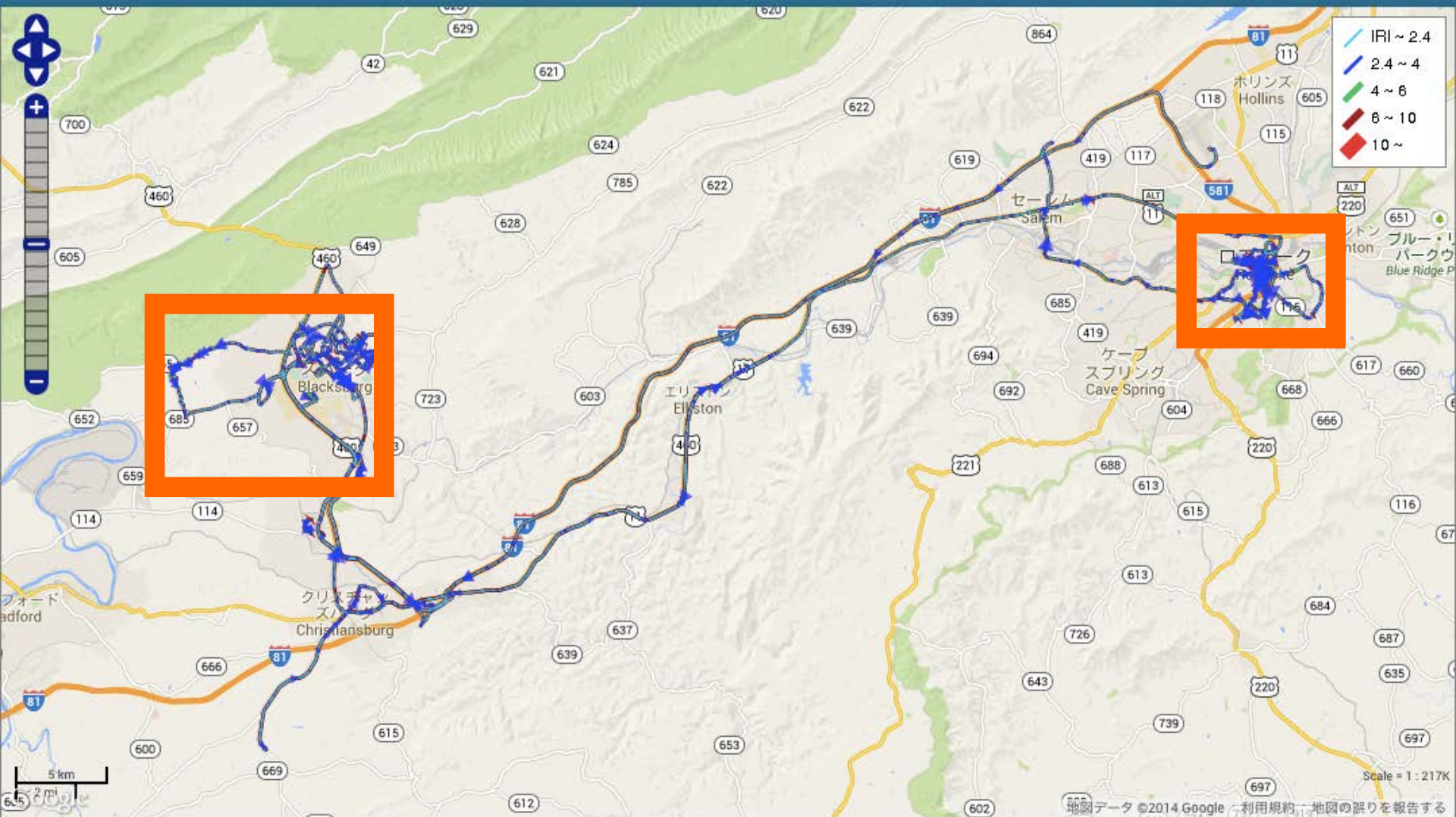
その他

無料アプリ

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ログアウト

You can access 531,934 [km] datas on BumpRecorder Web!



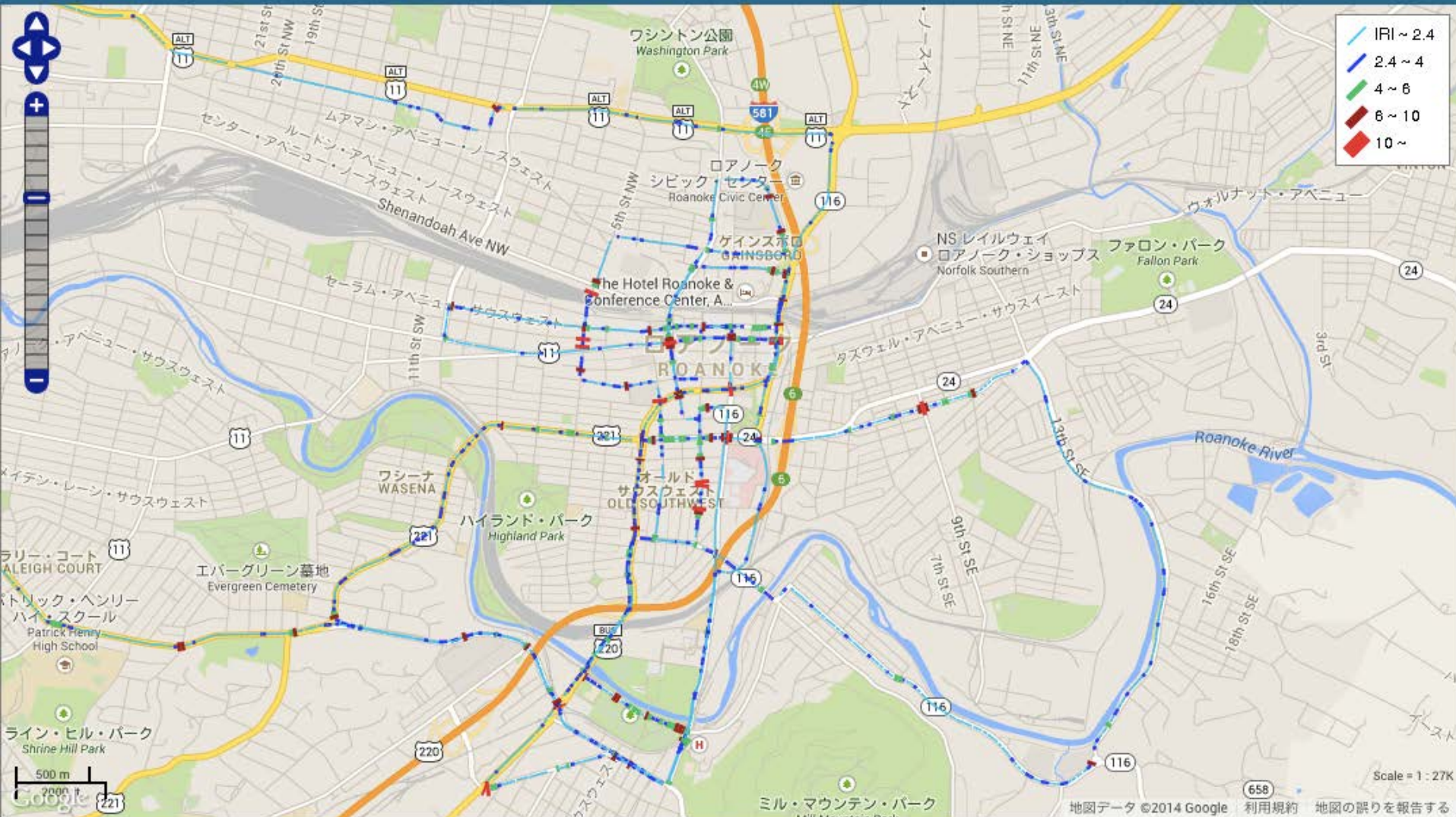




# Measurement at Roanoke

BumpRecorder Web for BumpRecorder株式会社 管理画面

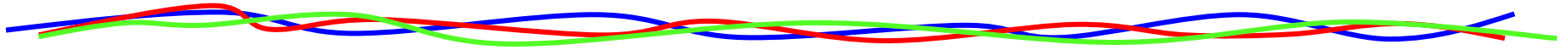
map.bumprecorder.com





# Previous Study

## Technical Side of Roughness Measurement Method



# Roughness Measurement



Using Smartphone

1. Get acceleration data

2. Estimate Spring Constant

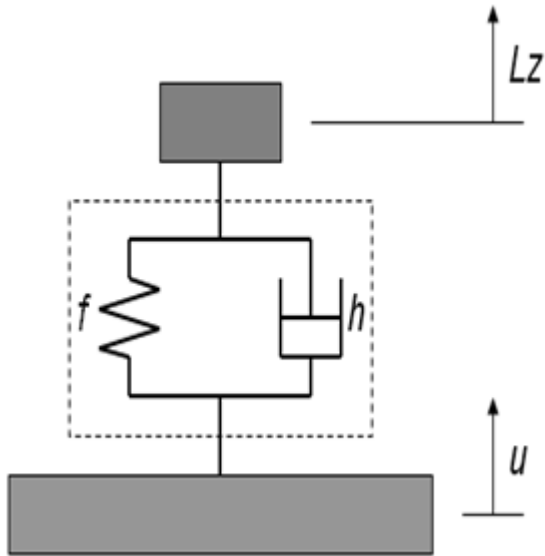
3. Calculate **Un**sprung movement

Road Profile

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

$$\omega = 2\pi f$$

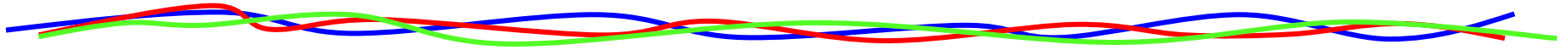
Angular frequency

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

Sum (Integral)



# Efficiency of Unsprung Estimation

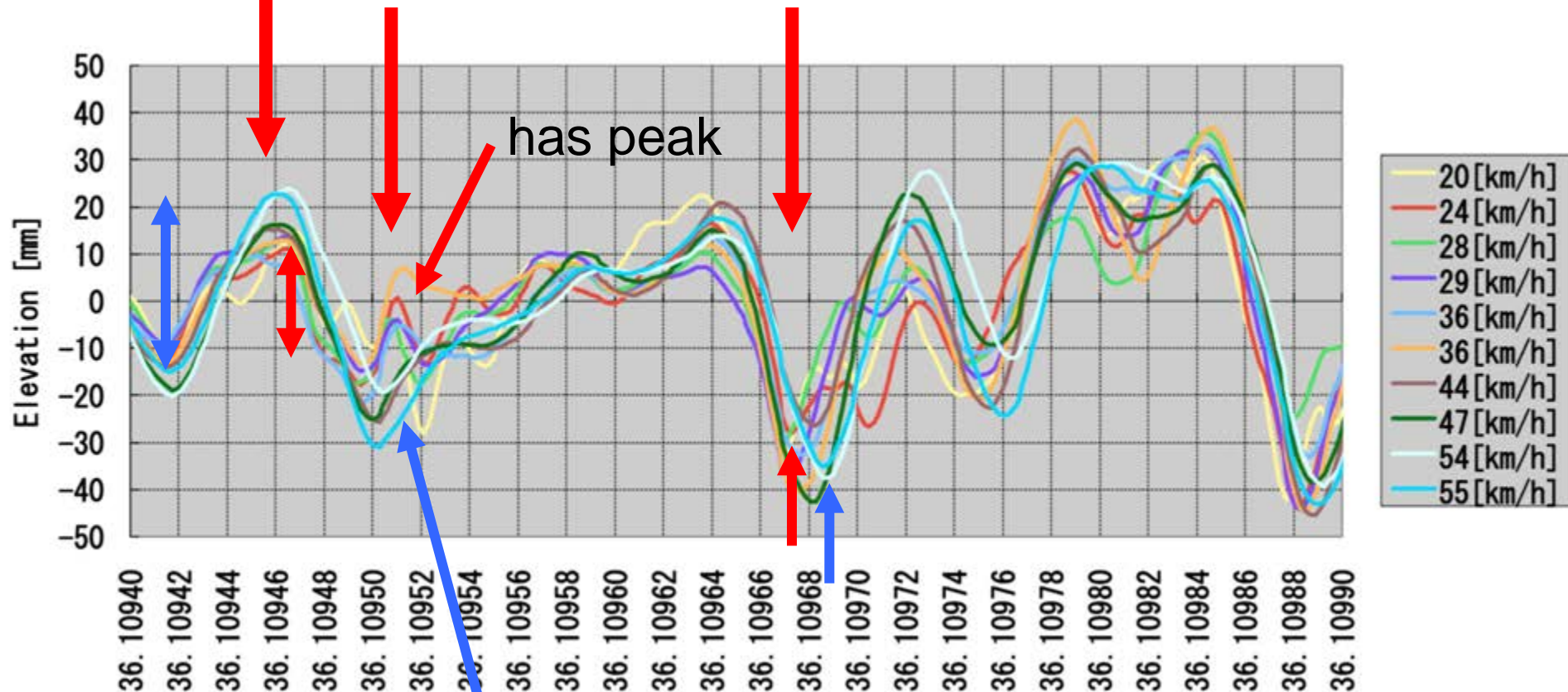


# Sprung movement

Amplitude

Shape

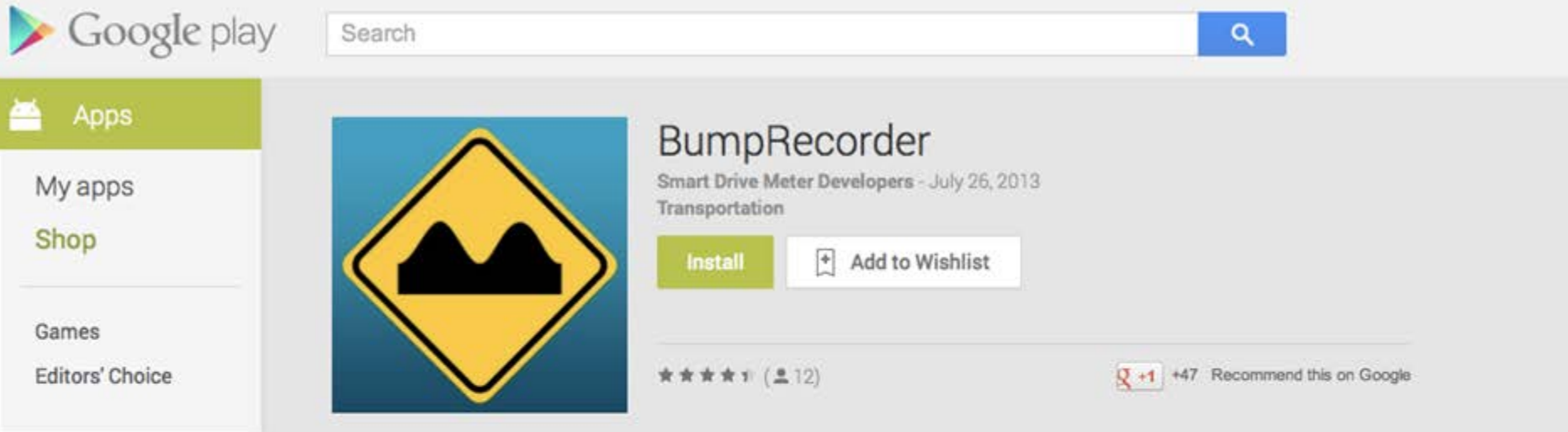
Peak Location



Low reliability



# Smartphone App is Free




Google play Search

Apps

- My apps
- Shop
- Games
- Editors' Choice

**BumpRecorder**  
Smart Drive Meter Developers - July 26, 2013  
Transportation

Install Add to Wishlist

★★★★☆ (12)  +47 Recommend this on Google



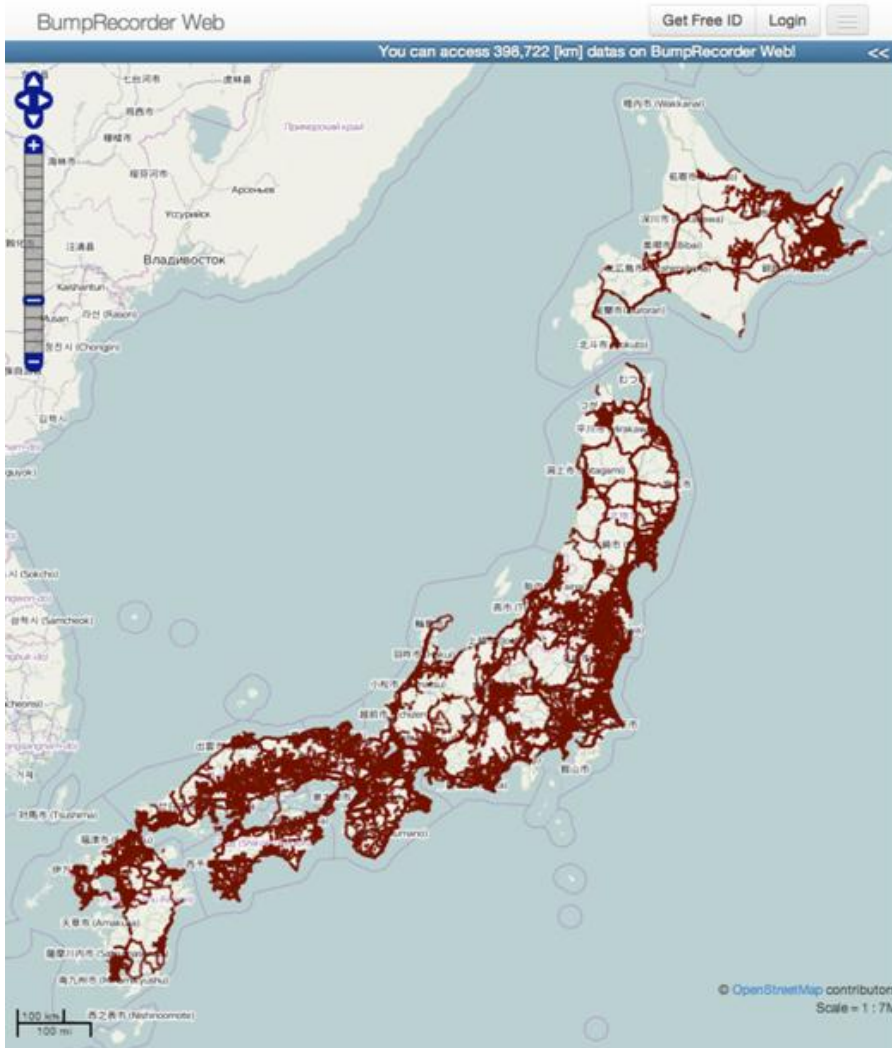
The screenshots show the app's interface in various states:

- Screen 1:** Radar mode showing a map with a red line indicating a bump. GPS speed is 0.0 km/h, time is 0:10. A graph at the bottom shows a bump of 1cm.
- Screen 2:** Similar to screen 1, but with a search bar and a graph showing a bump of 1cm.
- Screen 3:** Graph mode showing a detailed view of a bump. The graph shows a peak of 2cm. Parameters: A=96Hz L=0.42Hz H=2Hz.
- Screen 4:** Settings menu with options: Radar Mode (Head-up), Radar MapType (Full Width), Map Color (High Contrast Color), Set Brightness (slider), and Unit of length (Metric system(Km/N)).
- Screen 5:** Map view showing a blue line representing a recorded bump path on a street map.



# Collecting Data in Japan

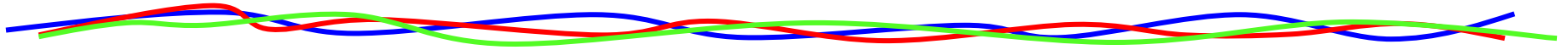
**Already collected over 530,000km Pavement Bump Data.**



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

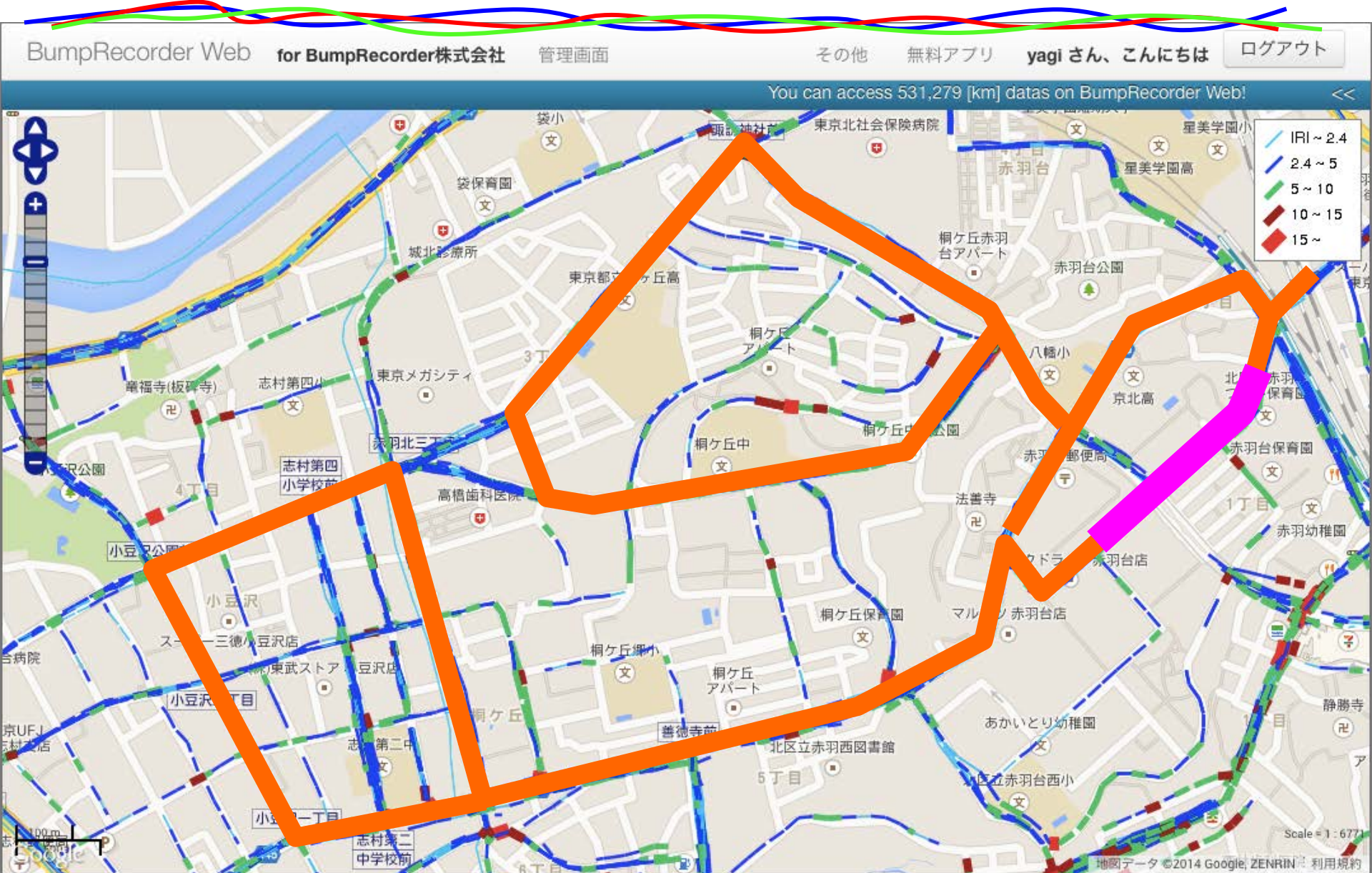


50Hz  
HTC EVO

100Hz  
Aquos Phone

200Hz  
Xperia Z1

# Test Road and IRI

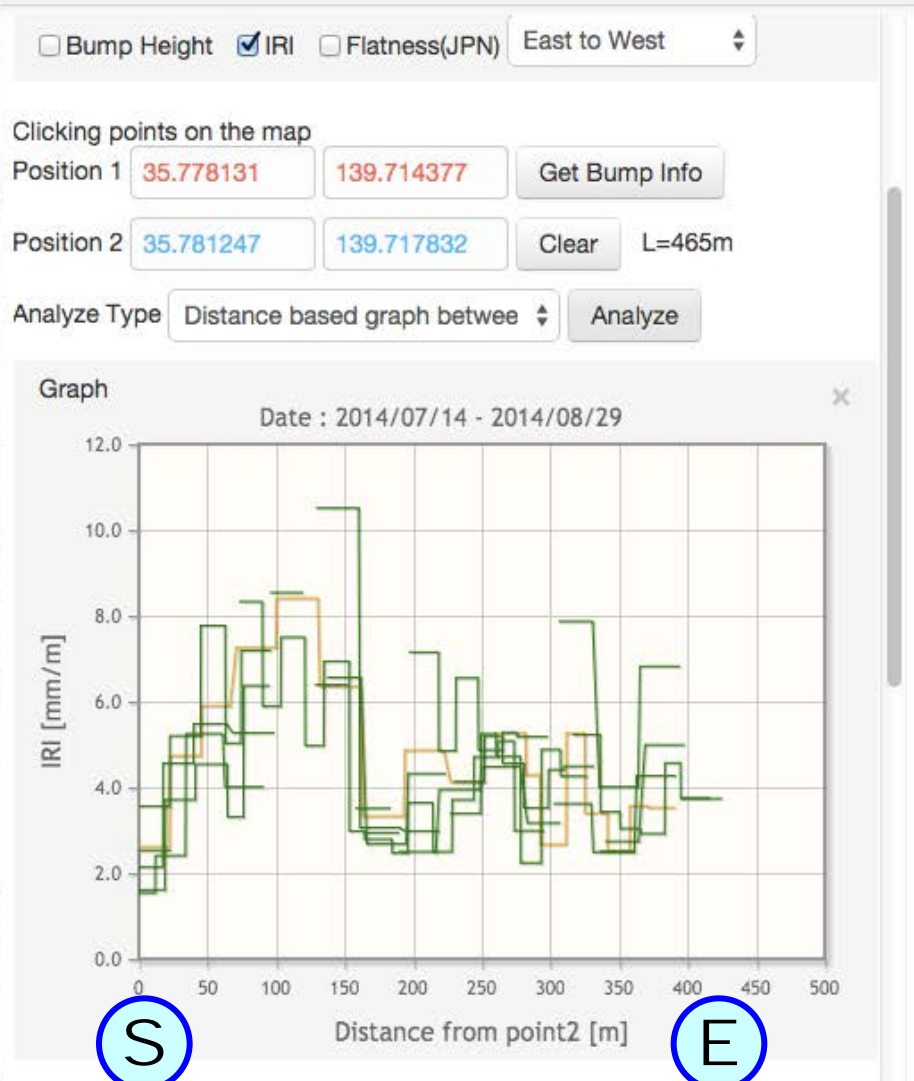




# Test Road and IRI

BumpRecorder Web for BumpRecorder株式会社 Management

Other Free App yagi-san, Hello Logout





# Cracking point 1





# Cracking point 2





# Cracking point 3





# Detection Ideas



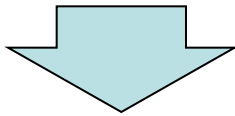
for example

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

BumpRecorder Web

for BumpRecorder株式会社

管理画面

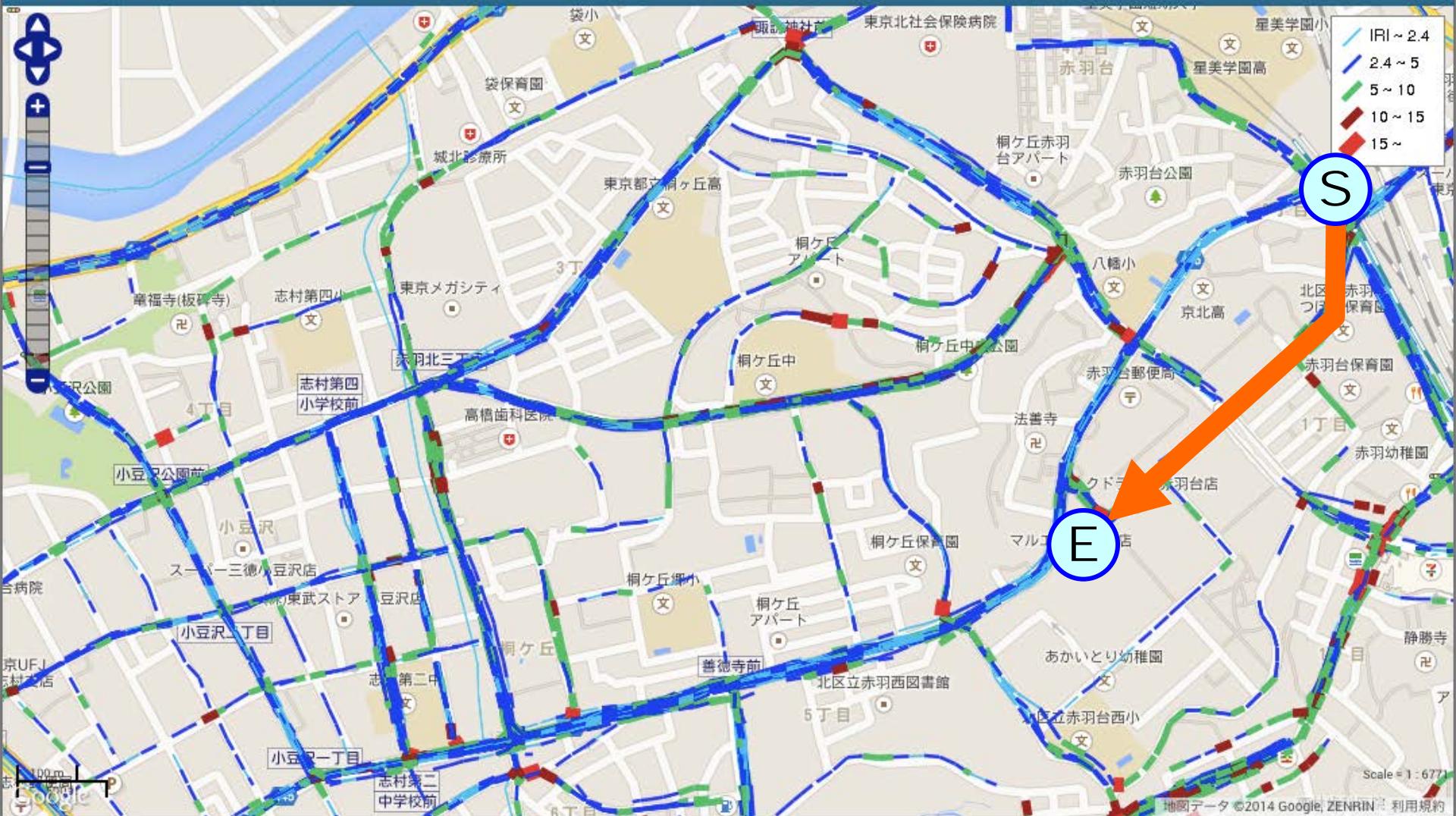
その他

無料アプリ

yagi さん、こんにちは

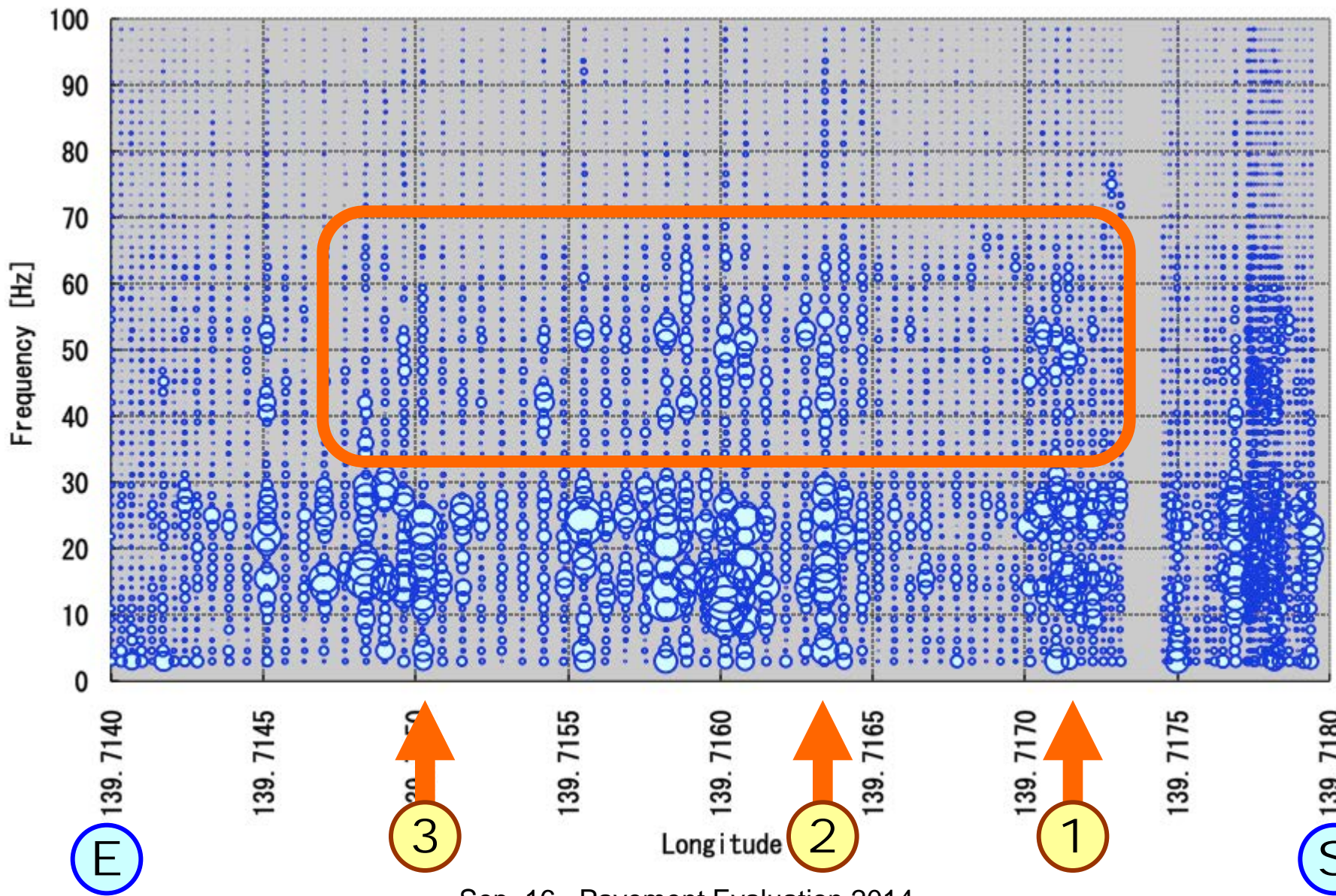
ログアウト

You can access 531,279 [km] datas on BumpRecorder Web!






# FFT Analysis : 200Hz



# Cracking Index



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

# Cracking Index



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

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, it may be cracking.

Weighted Average of Frequency

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

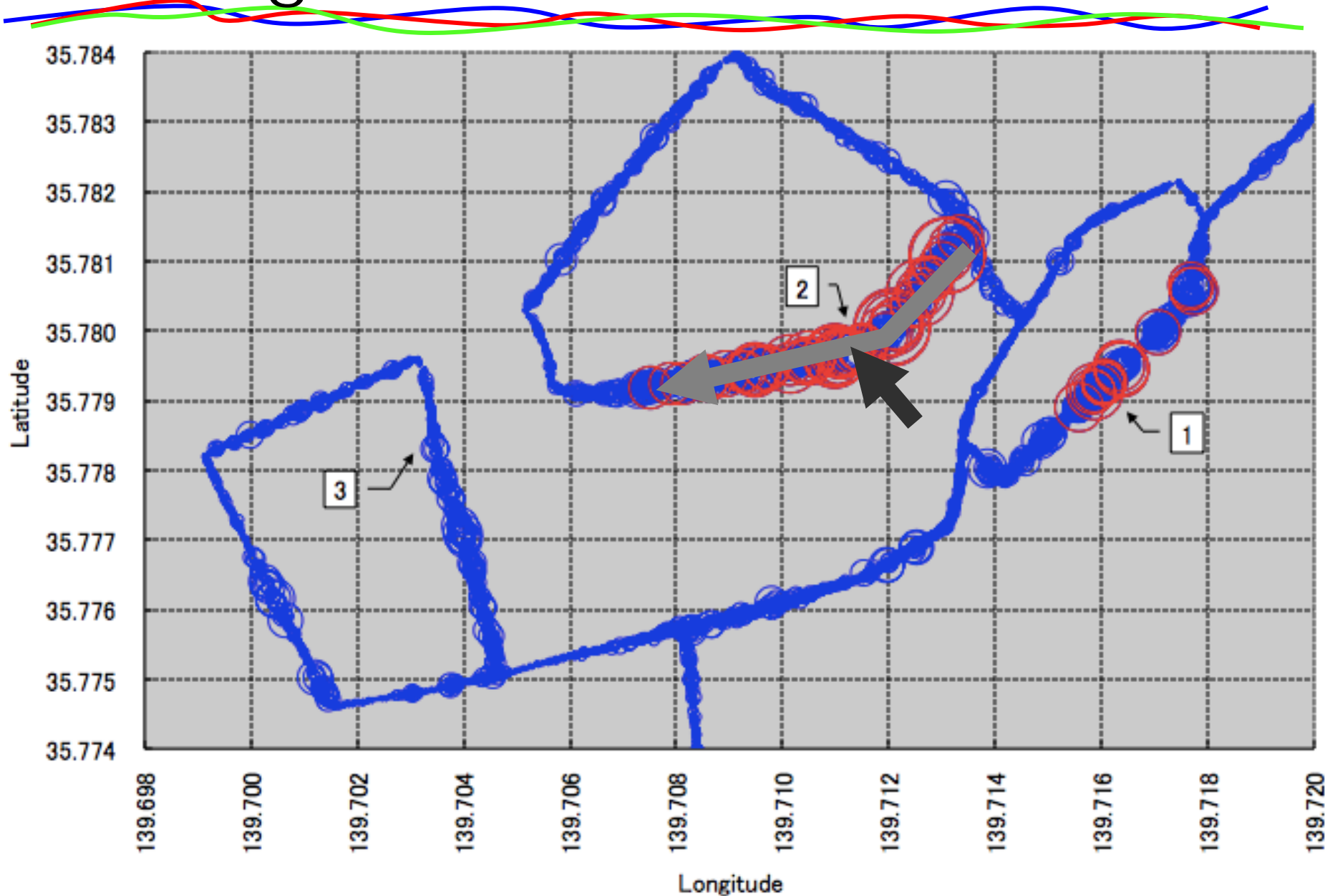
FFT result  
f(i) : frequency  
a(i) : amplitude

Cracking Index

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

a<sub>ave</sub> : average amplitude

# Cracking Index : 200Hz

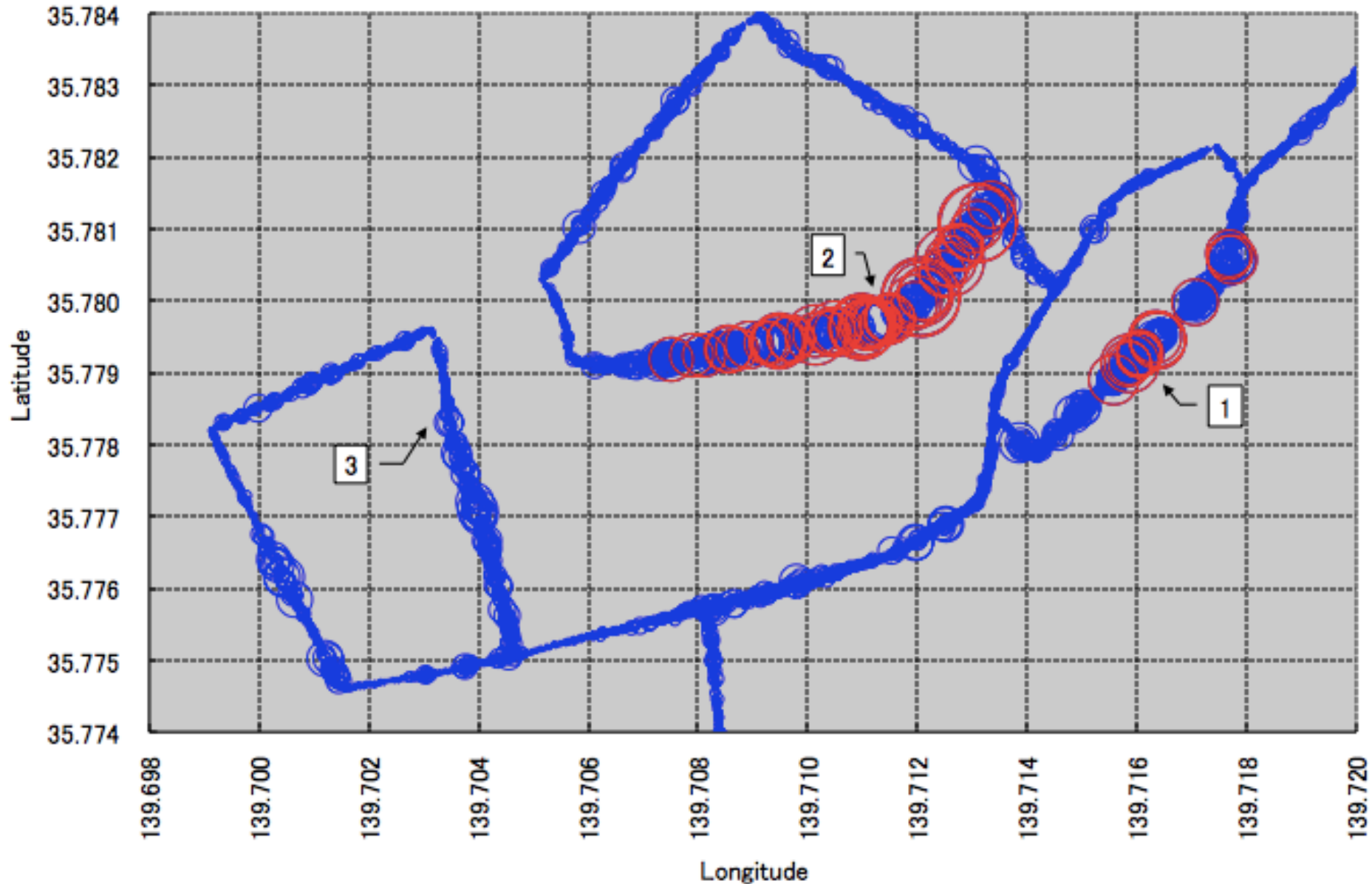




# Concrete Road

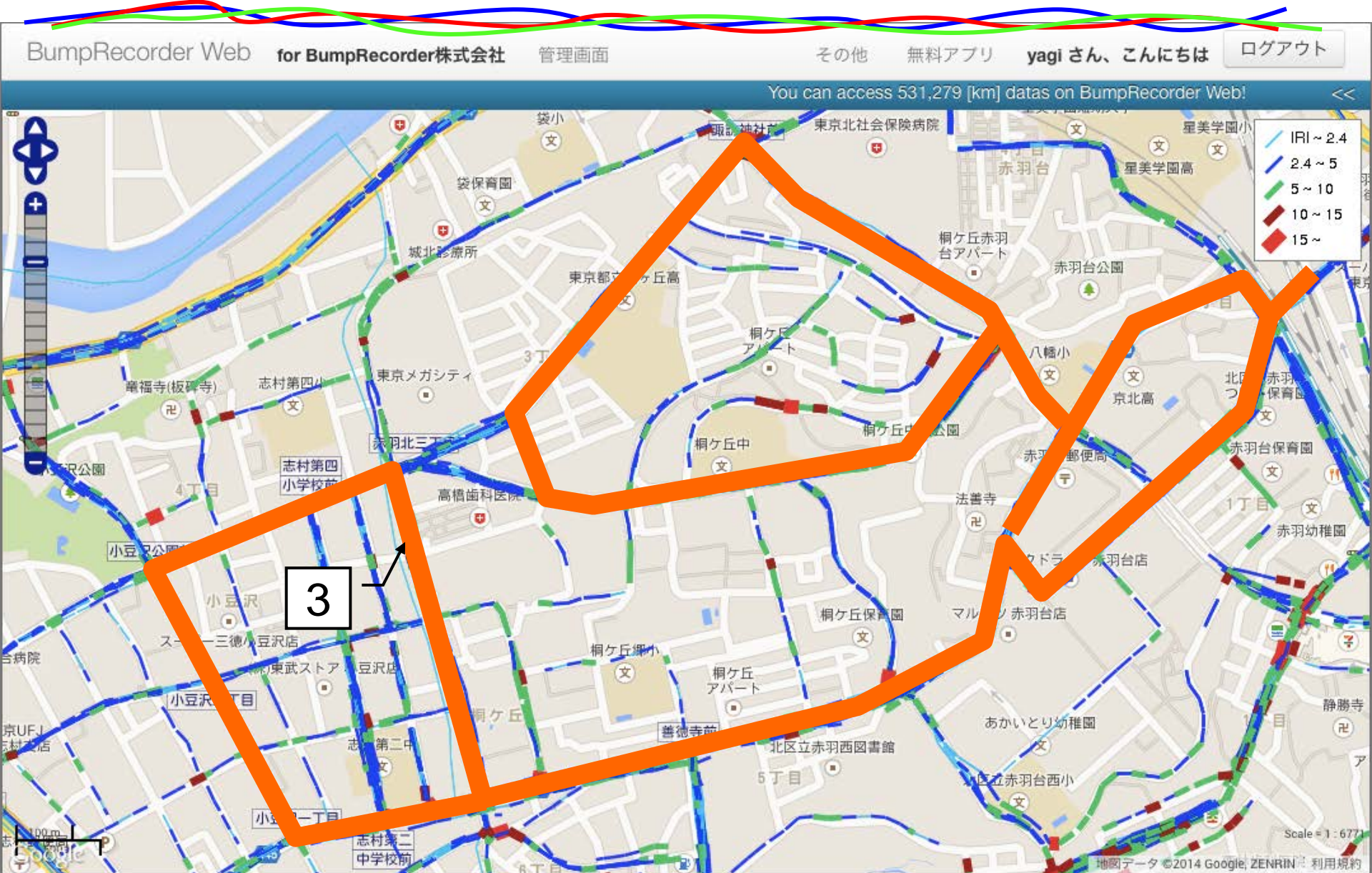


# Cracking Index : 200Hz

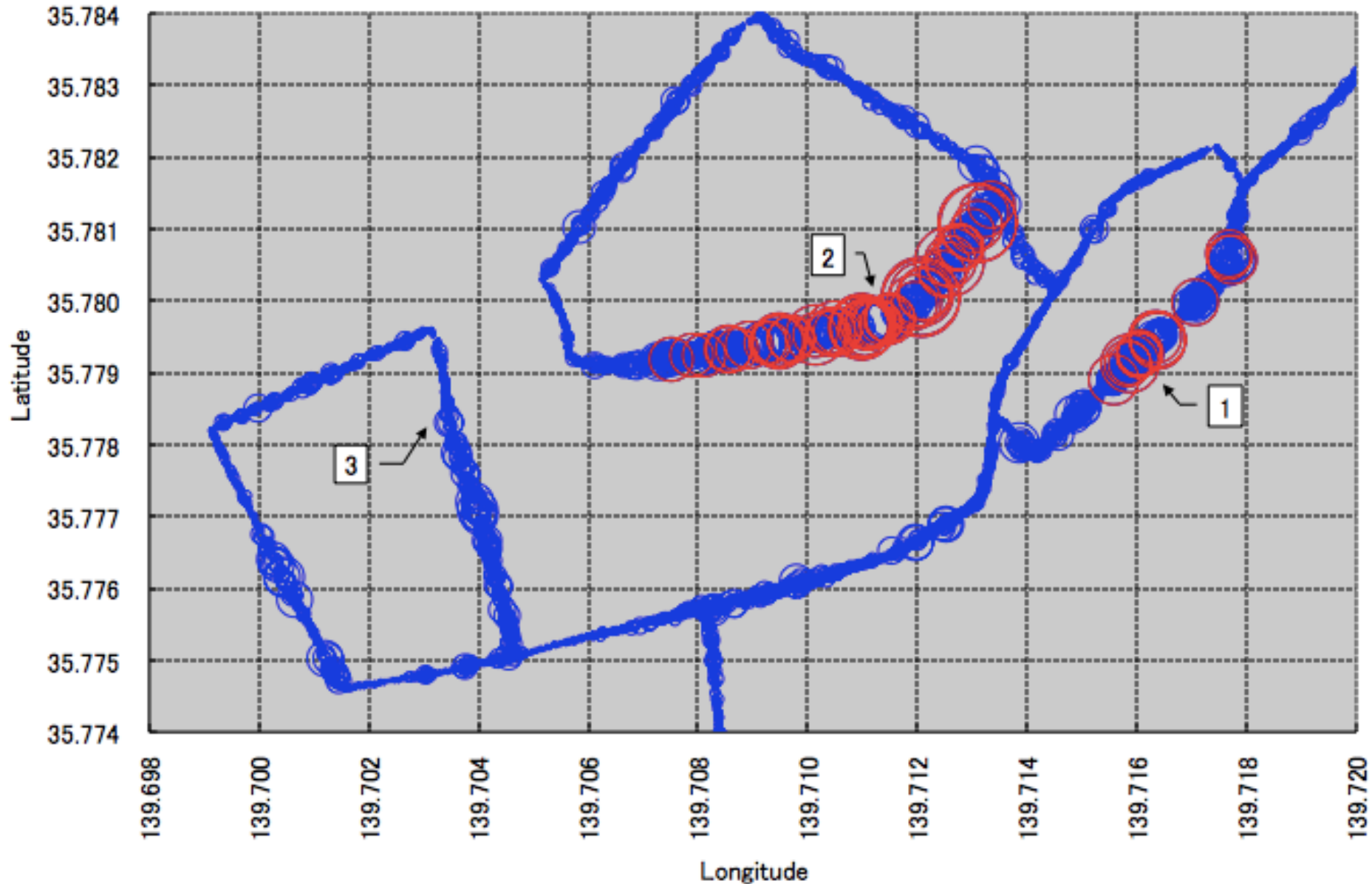




# Test Road and IRI

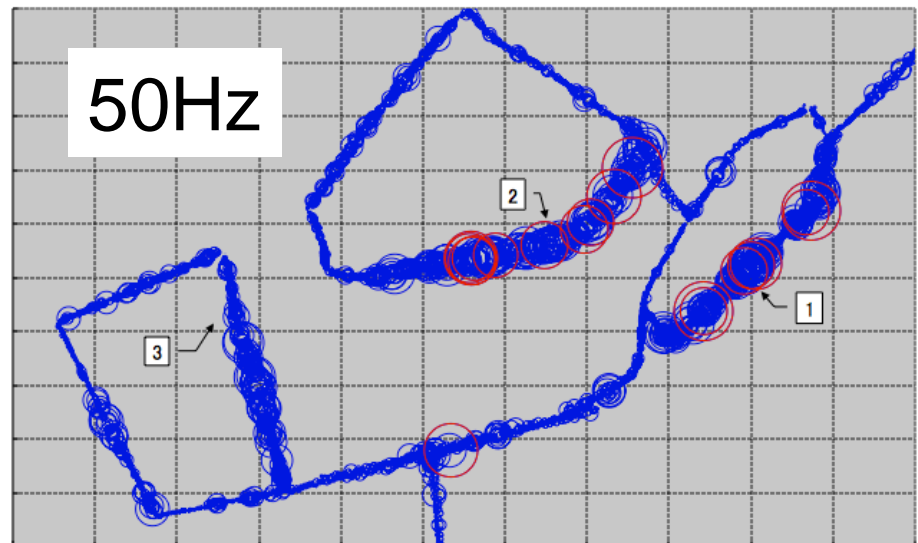
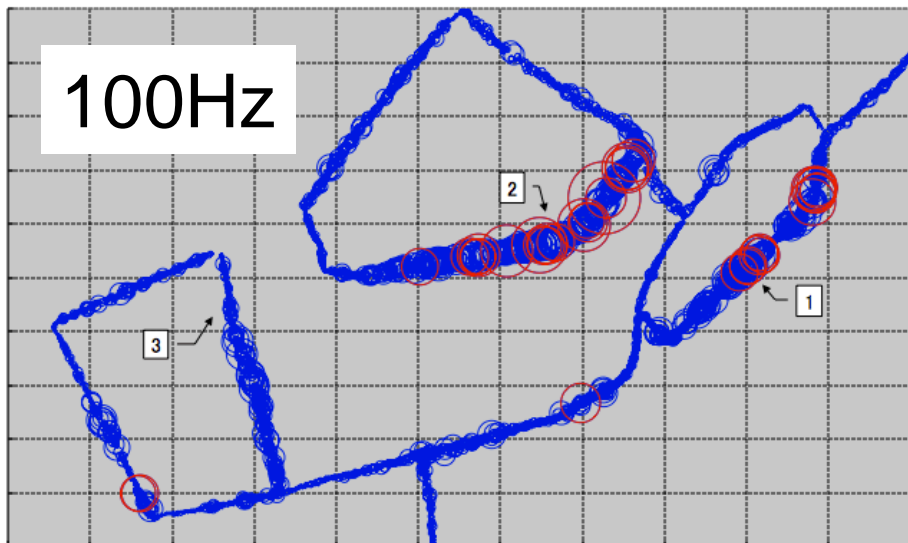
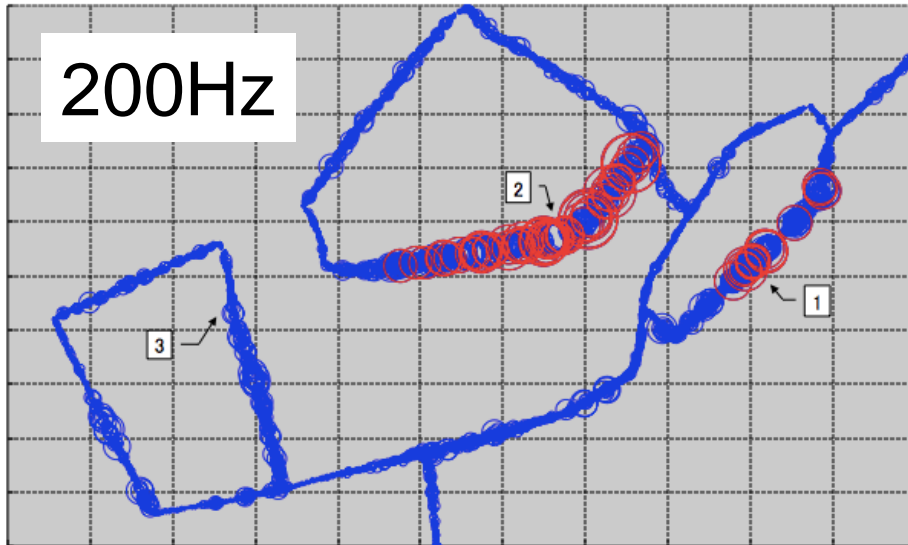


# Cracking Index : 200Hz





# Influence of sampling rate



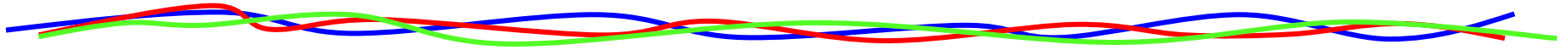
# Next step



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



# Thank you!



e-mail : [info@bumprecorder.com](mailto:info@bumprecorder.com)  
Web site : [map.bumprecorder.com](http://map.bumprecorder.com)