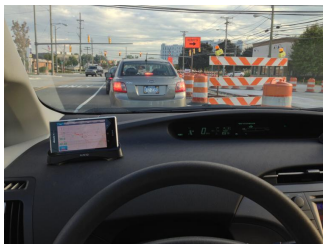
BumpRecorder

Only system in the world

Simple, Friendly, Quality

Pavement Maintenance Management Tool

YAGI, Koichi
BumpRecorder Co., Ltd. CEO
yagi@bumprecorder.com



BumpRecorder Co., Lid.

Outline

Company Outline

BumpRecorder Co., Ltd.
Start up : Oct. 23rd 2013
Funder & CEO : YAGI
Co-funder : Makiuchi, Sato

Main service
- **BumpRecorder** : Roughness measurement system
- Photo report : Human visual inspection supporting tool
- VehicleLocation : Bus location system

- Passable Road : Integrate Probe Infomation

Today has big earthquake

14:07 PM

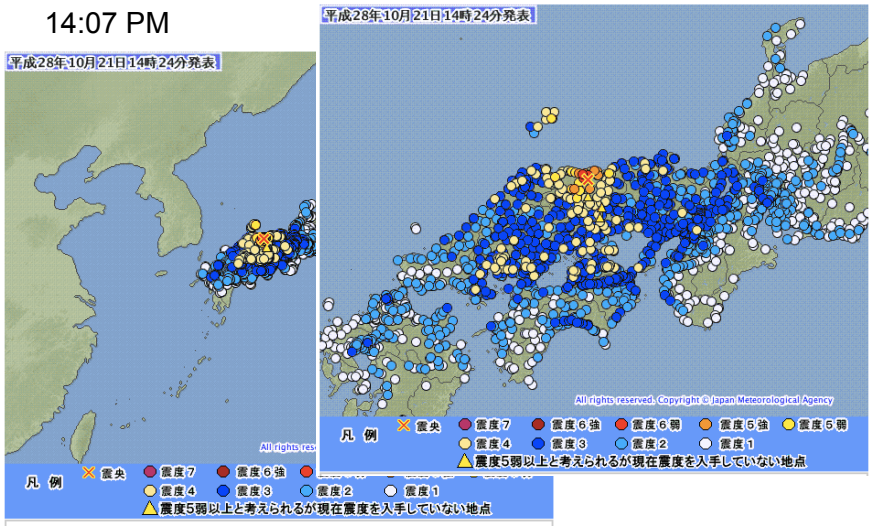


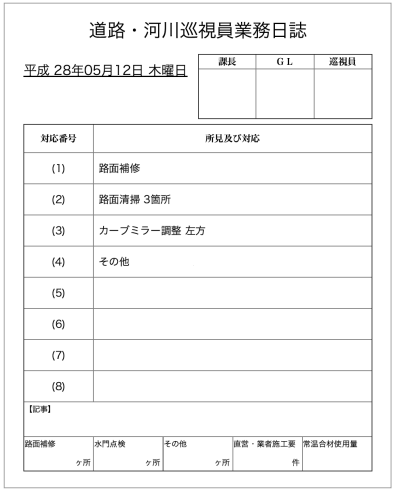
Photo Report

Photo with GPS Info + Comment ⇒ Daily Report

会津若松市にお問い合わせの場合は情報政策課まで

Daily Report

Reduce report writing time & Detail Position Info



道路・河川巡視員業務日誌

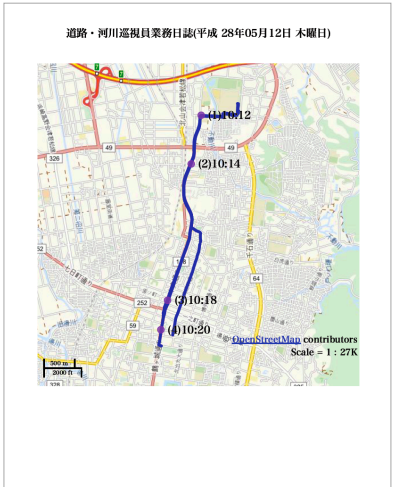
平成 28年05月12日 木曜日

課長	G L	巡視員

対応番号	所見及び対応
(1)	路面補修
(2)	路面清掃 3箇所
(3)	カーブミラー調整 左方
(4)	その他
(5)	
(6)	
(7)	
(8)	

【記事】

路面補修	水門点検	その他	直営・業者施工要	常温合材使用量
ヶ所	ヶ所	ヶ所	件	



VehicleLocation

Company Outline

Main costumers

- National agency
  MLIT (Ministry of Land, Infrastructure, Transport and Tourism)
- Local government
  Aizu-wakamatsu city,
  will be Tokyo Kita ward, Katsushika ward,
  Shizuoka pref & city
- Public authorities
  JICE (Japan Institute of Country-ology and Engineering)
  NILIM (National Institute for Land and Infrastructure Management)
  NIED (National Research Institute for Earth Science and Disaster Resilience)

Company Outline

Main costumers
- Academia
  Tokyo University
  Kyoto University

- Private sectors
  13 companies e.g. TOA Road Corporation.

Today's theme is Roughness measurement for pavement evaluation

Pavement condition at KL

Pavement condition at KL

Pavement condition at KL

Pavement condition at KL

Traditional device

TOA-PMMS で活躍する調査機器 Inertial profiler

● 路面性状測定車（CHASPA）

TOA-PMMS に必要な道路舗装の路面性状データを、迅速に測定するための調査機器です。
「ひび割れ」、「わだち掘れ」、「平たん性」といった路面性状データを同時に計測することができます。計測は一般車両と同程度の速度で走行しながら行うことができ交通規制する必要がありません。

Traditional device

Inertial profiler

Walking profiler

Traditional device

BumpRecorder

Pavemetrics

HOME ABOUT APPLICATIONS RESELLERS NEWS EVENTS CONTACT

Laser Crack Measurement System (LCMS)

Pavemetrics™ Laser Crack Measurement System (LCMS™) is the ultimate single-pass 3D sensor for pavement inspection. The LCMS is able to automatically measure, detect and quantify **all** key functional parameters of pavement in a single pass, including: cracking, rutting, texture, potholes, shoving, raveling and roughness.

The LCMS delivers proven results on more surfaces than any other sensor in the market: from hotmix asphalt to chipseal, porous pavement, and both tined and untined concrete.

Able to perform a complete pavement condition inspection at **full 1mm resolution**, in a single pass, **automatically**, day or night, at 100+ km/h; the LCMS can dramatically reduce your labor costs and time to complete your projects.

Two versions of the LCMS are available depending on your measurement needs, please refer to the specification tabs below for further details.

OUR PRODUCTS

ROAD INSPECTION
- Laser Crack Measurement System (LCMS)
- Laser Road Imaging System (LRIS)
- Laser Rut Measurement System (LRMS)

RAIL INSPECTION
- Laser Rail Inspection System (LRAIL)

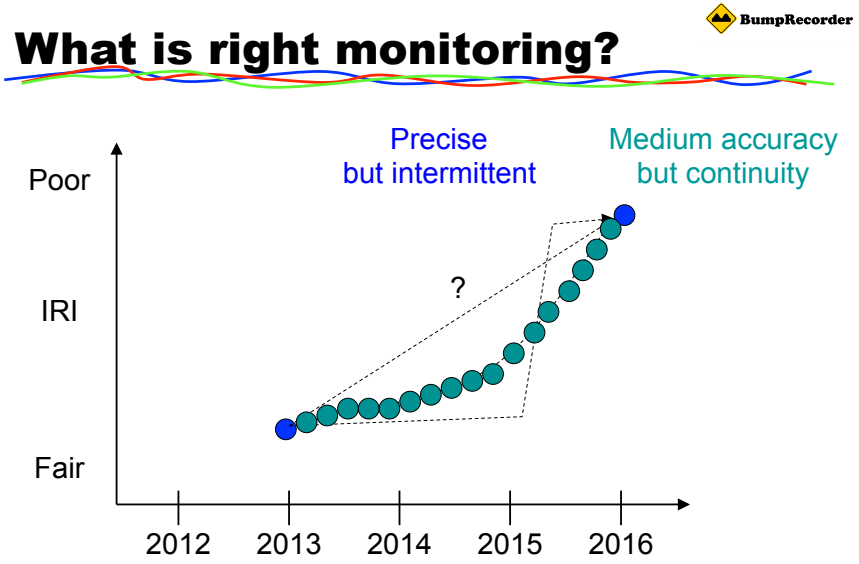
DIGITAL TERRAIN MAPPING
- Laser Digital Terrain Mapping System (LDTM)

TUNNEL INSPECTION
- Laser Tunnel Scanning System (LTSS)

AIRFIELD INSPECTION
- Laser FOD Detection System (LFOD)

What is right monitoring?

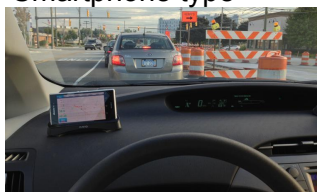
BumpRecorder



What is right monitoring?

BumpRecorder

Pavement health monitoring
Smartphone type



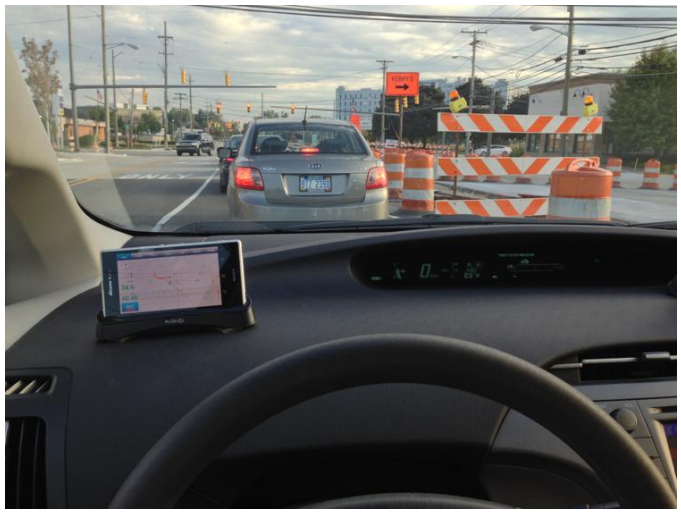
Inertial profiler

Human health monitoring
Blood pressure

CT scanner

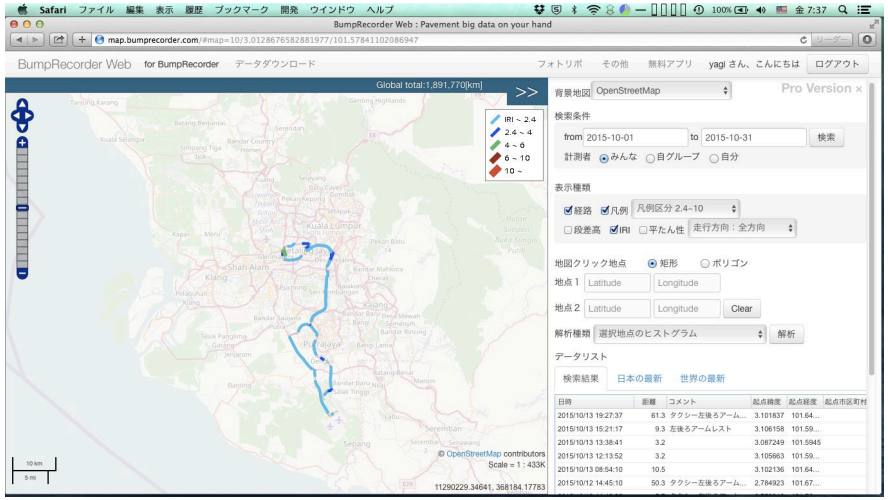
New approach “Smartphone”

BumpRecorder

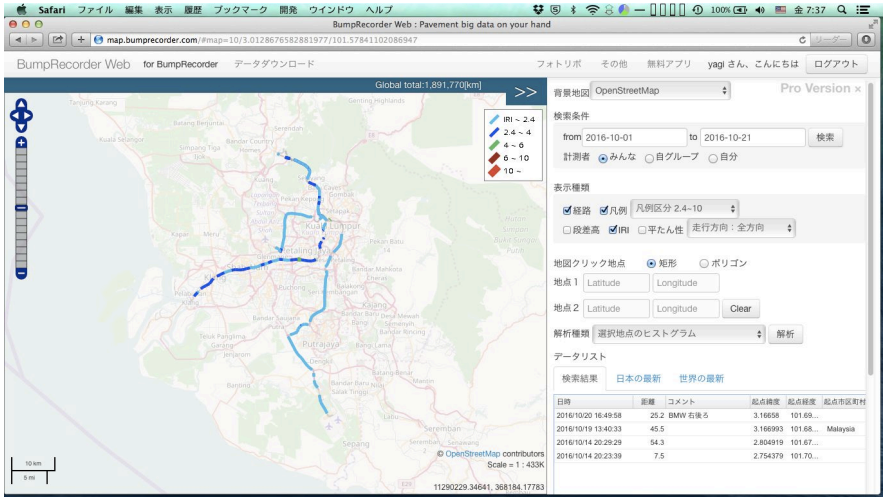


New approach “Smartphone”

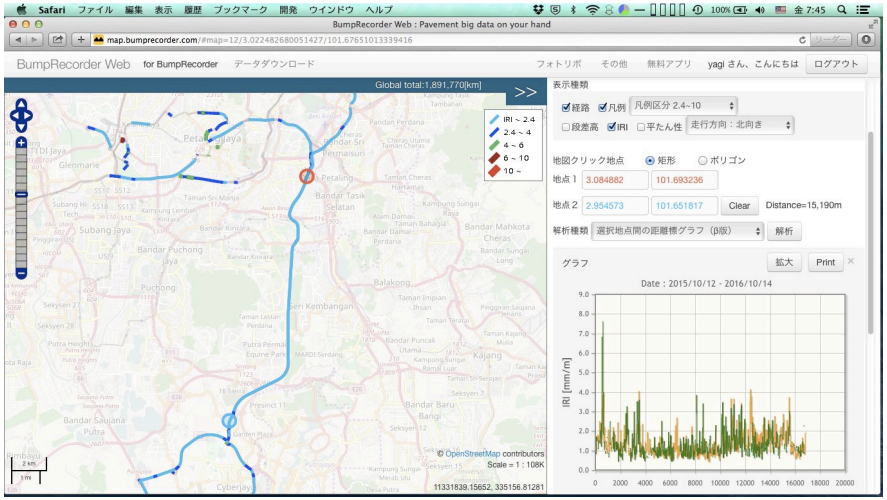
Measurement in KL at 2015



Measurement in KL at 2016



Comparison 2015 and 2016



BumpRecorder

Technology Background

BumpRecorder

Technology Background

1990 YAGI(CEO) was graduate master degree of mechanical engineering at Nagaoka University of Technology in Niigata prefecture.

1990-2000 Developing ITS (Intelligence Transportation Systems) e.g. Singapore ERP, Japanese ETC.

2004 Niigata earthquake was occurred and it was starting development for disaster relief system for transportation.

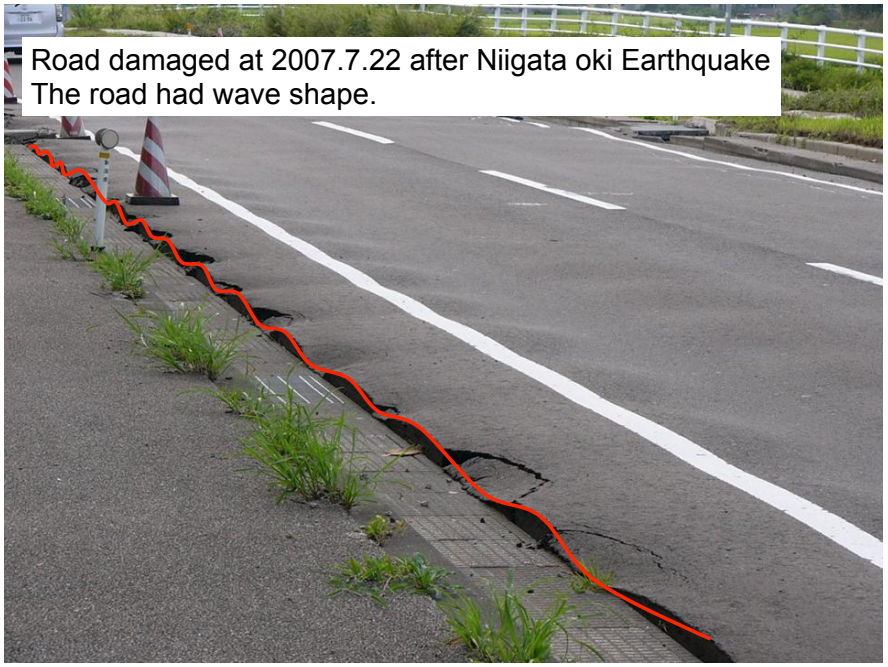
2007 Niigata oki earthquake was occurred and prototype measurement system was developed.

2011 The grate east Japan earthquake was occurred and smartphone application **BumpRecorder** was provided.

2012- MLIT and many private company request to use **BumpRecorder** for Pavement Management.

2013 **BumpRecorder** Co., Ltd. was starting up.

We have 9 years experiments.

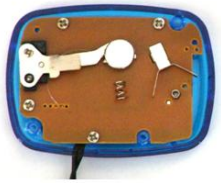


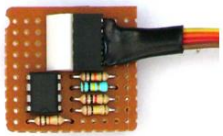
Prototype system

BumpRecorder

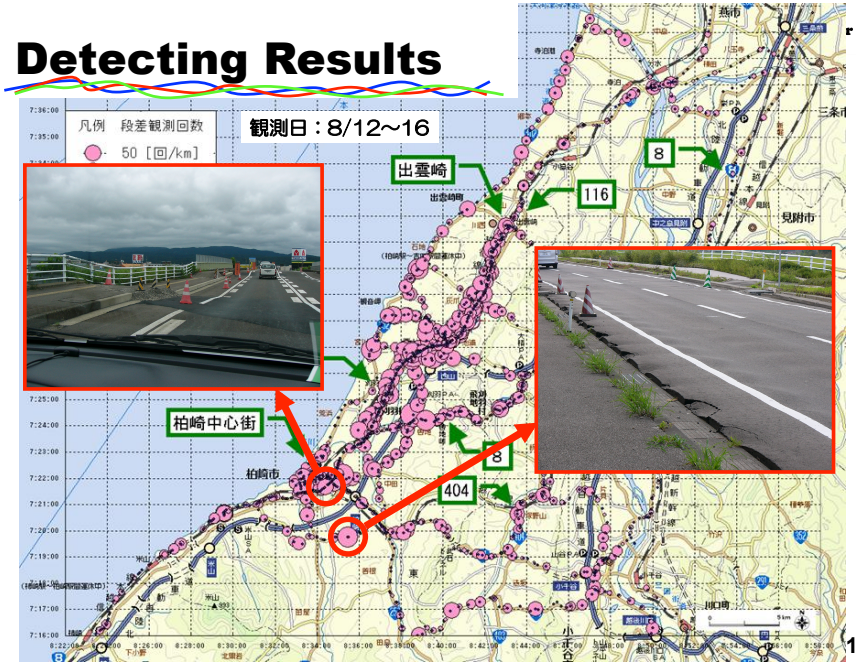
To measure road damaged conditions,
response type device was developed.

Pedometer	Op-amp	Board Computer
Detect vertical movement	Signal convert	Data stored





Detecting Results



Prototype system

BumpRecorder

Pedometer
Detect Vertical Movement

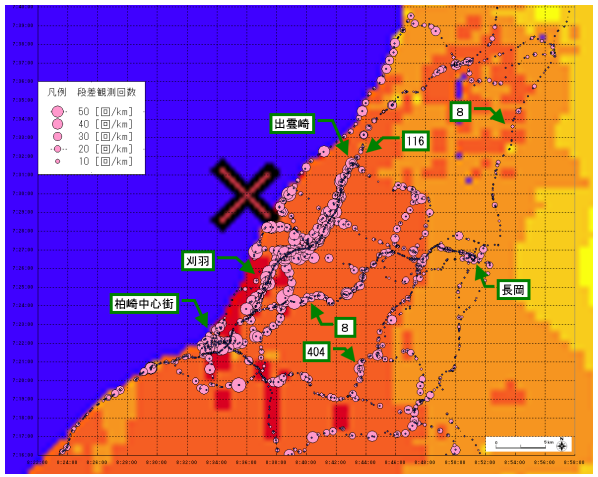
GPS
Recording Position Data

Road damage collection at 2007

Compare with seismic intensity

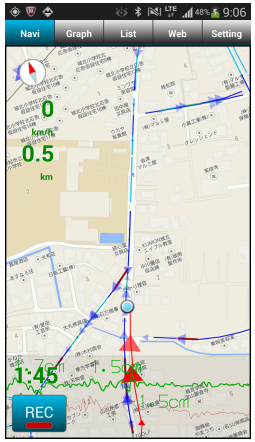
BumpRecorder

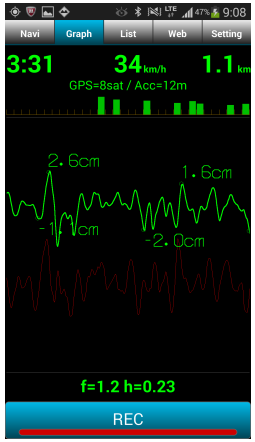
Prototype system was successfully collecting road damage data. Response type is useful for immediate monitoring.



Smartphone app BumpRecorder

Prototype hardware device was converted to smartphone software "**BumpRecorder**" at 2011.





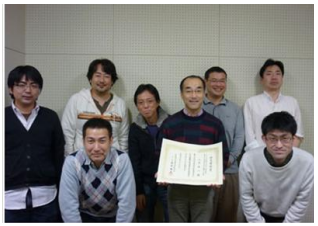
Apply for pavement maintenance

BumpRecorder Won several awards Discuss with stakeholders

Won many awards!

Android Application Award 2011

JSTE Research Award 2011

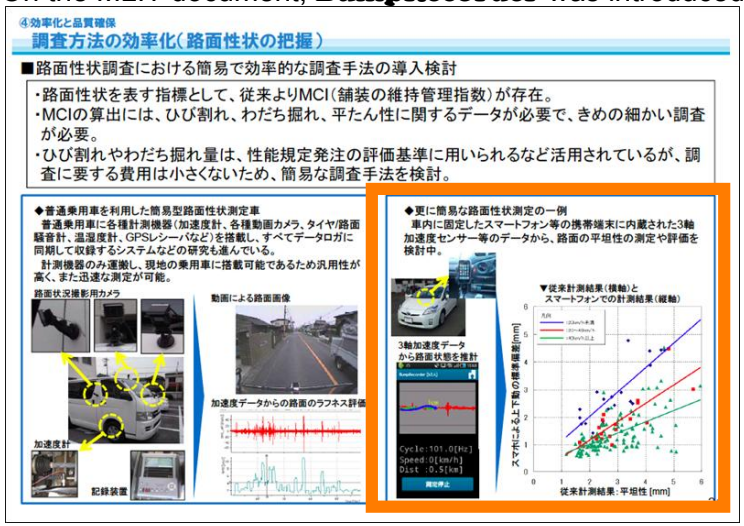


Japan e-Land Map Award 2014

Tokyo Venture Technology Award 2015

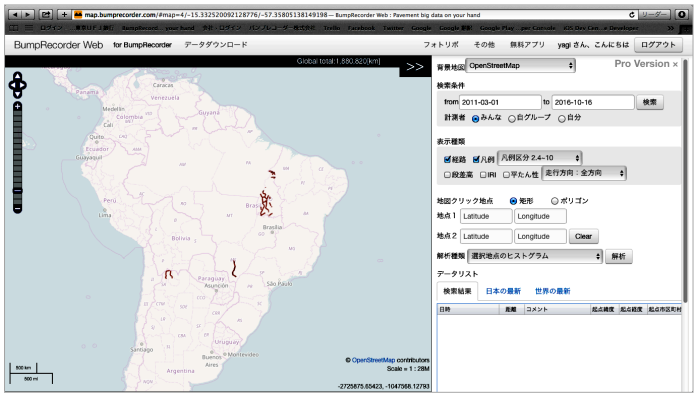
MLIT pushing Smartphone type measurement

On the MLIT document, **BumpRecorder** was introduced.



Every year we discuss with the World Bank

We are discussing with them to apply **BumpRecorder** for the World Bank Brazil project. They were measuring IRI by using **BumpRecorder** in Brazil.

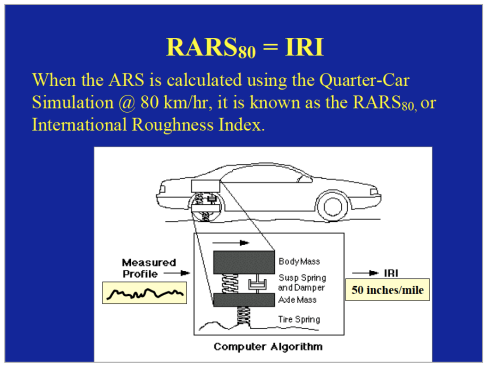


What is IRI?

What is IRI?

IRI is one kind of road roughness evaluating index value.
It is defined average length of suspensions expansion and contraction when it drive 80[km/h] with specific suspension hardness vehicle.

Measuring IRI with actual vehicle is difficult.
Because there are no vehicle like that.



http://www.dot.state.mn.us/materials/smoothnessdocs/IRIIntroduction.pdf

BumpRecorder

What is IRI?

If you want to measure IRI with actual device,
It should be 1 wheel device. Usual car has 4 wheels.
So, it is called Quarter Car.

But it is difficult to drive constant speed 80[km/h] anywhere.

Fifth Wheel Bump Integrator

CSIR

http://www.academia.edu/9039390/ROAD_ROUGHNESS_MEASUREMENT_TECHNIQUES_AND_STATNDARDISATION_OF_RTRRMS_DEVICES

BumpRecorder

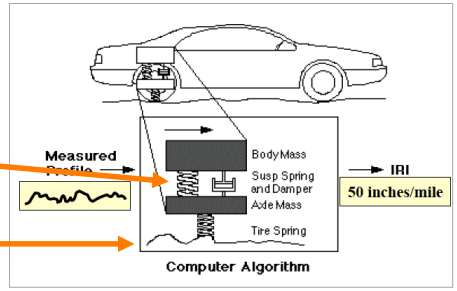
What is IRI?

To improve this problems, QC (Quarter car) simulation is used.

(3) Calculate average length of suspension expansion and contraction, that is IRI.

(2) QC simulation is applied to calculate suspension movement.

(1) Measuring longitudinal profile.



http://www.dot.state.mn.us/materials/smoothnessdocs/IRIIntroduction.pdf

BumpRecorder

IRI is classified 4 class

Some document explained “response type is class 3”.
But I said **BumpRecorder** is class 2.

What is happened?

This is the key point of new technology!

Classification of Roughness Measuring Devices

World Bank sponsored International Road Roughness Experiments (IRRE) conducted in Brazil in 1982, categorised the related equipments into 4 classes, namely Class I, II, III and IV.

Class I: *Gives higher standard of accuracy which enable precision measurement of pavement surface profile.*
- *Rod and Level, TRRL beam, Dipstick, Merlin and Walking Profiler*

Class II: *Profile is measured as the basis of direct computation of international roughness index (IRI), very less accuracy compared to class I measurement.*
- *APJ Trailer etc.*

Class III: *Response Type Road Roughness Measuring System (RTRRMS)*
- *Automatic Road Unevenness Recorder / Bump Integrator / Roughometer, Car Axle Mounted Bump Integrator, Mays Meter etc.*

Class IV: *Methods used in situations where higher accuracy is not essential.*
- *Ride experience, Visual inspection*

CSIR

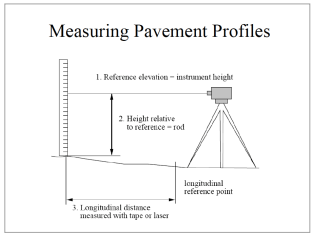
http://www.academia.edu/9039390/ROAD_ROUGHNESS_MEASUREMENT_TECHNIQUES_AND_STATNDARDISATION_OF_RTRRMS_DEVICES

BumpRecorder

IRI classification

Class 1: Precision profiles.
This class is the highest standards of accuracy.
A Class 1 method requires that the longitudinal profile be measured as a basis for calculating the IRI value*. For static profilometric methods, the distance between samples should be no greater than 250 mm and the precision in the elevation measures must be 0.5 mm for very smooth pavements.

* “Calculating the IRI value” means QC simulation.



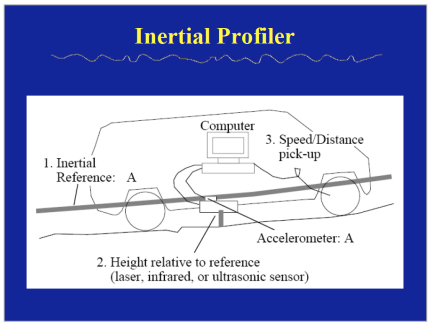
http://www.dot.state.mn.us/materials/smoothnessdocs/IRIIntroduction.pdf

IRI classification

Class 2: Other profilosetric methods.
This class includes all other methods in which profile is measured as the basis for direct computation of the IRI, but which are not capable of the accuracy required for a Class 1 measurement.

Previously, “Other method” is an inertial profiler.

An inertial profiler measure vehicle movement by accelerometer and measure distance from vehicle to road by laser.



http://www.dot.state.mn.us/materials/smoothnessdocs/IRIIntroduction.pdf

IRI classification

Class 3: IRI estimates from correlation equations.
This class includes all roughness measuring instruments capable of generating a roughness numeric reasonably correlated to the IRI. In order to estimate IRI, a calibration is needed which is performed on actual road surfaces. The IRI values of the calibration sites are obtained using a Class 1 or Class 2 method.

Class 3 is NOT defined by response type measurement. Previously just only many class 3 methods were response type method.

BumpRecorder measure profile first, and then calculate IRI. That is class 2.

IRI classification

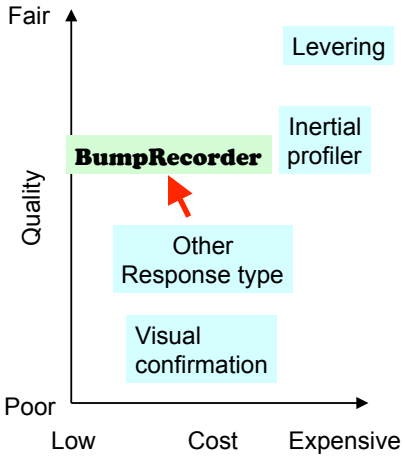
Class 4: Subjective ratings and uncalibrated measures.
This class includes roughness measures that have no verifiable link to the IRI scale.

For example human visual confirmation.

Position of BumpRecorder

BumpRecorder is more precise and lower cost for IRI measurement.

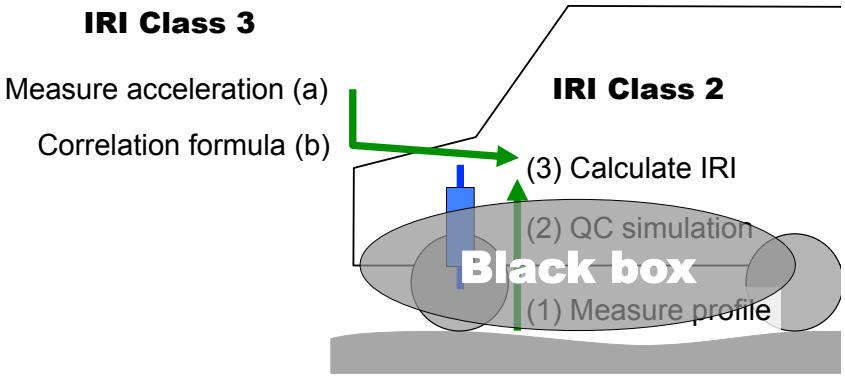
Class 1 Precise Static method	Profilometric QC simulation
Class 2 Other method	
Class 3 Correlation equations	No QC shimulation
Class 4 Subjective ratings	No verifiable



Why not BumpRecorder?

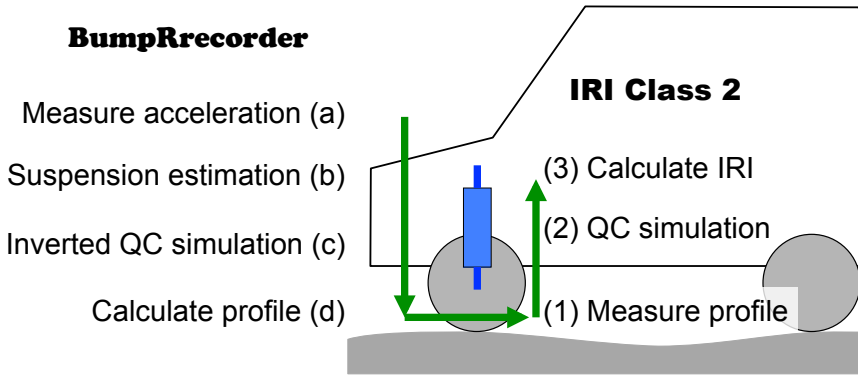
Only system in the world response type IRI class 2

Other response type is IRI Class 3



Calibration driving is needed.
Low repeatability.

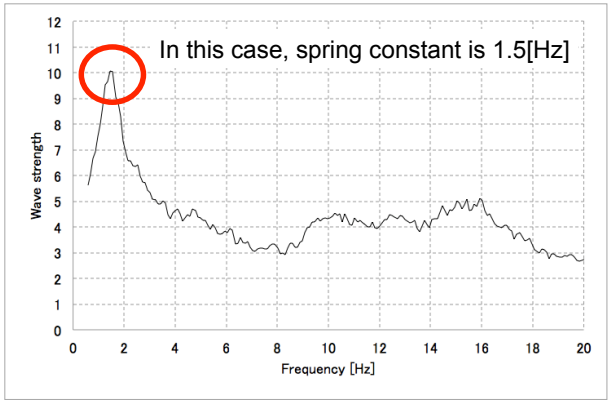
BumpRecorder is IRI Class 2



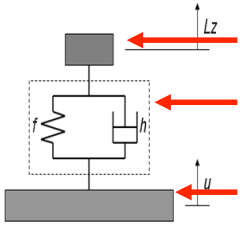
Auto calibration is done during measurement driving.
Good repeatability.

Auto calibration for suspension

BumpRecorder automatically analyze suspensions spring constant by using frequency analysis.
It is only system in the world.



Calculate road profile



(1) Measurer sprung acceleration.

(2) Calculate equation of motion.

(3) Get unsprung movement that is road profile.

To get Unsprung movement “u” which is road profile, calculate equation of motion for 1 mass spring model by using sprung movement “Lz”

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

$$\omega = 2\pi f \quad \text{Angular frequency}$$

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

Compare with competitor

Roadroid users manual

Class 3

You do not need a complex calibration procedure, and the app has a setting for three type vehicles. The correlation of the estimated IRI (eIRI) towards laser beam measured IRI is about 70-80% - depending on road surface type. The accuracy can be increased with some tuning, and the IRI sampling is currently developed with a calculated IRI (cIRI) - to enhance the correlation factor.

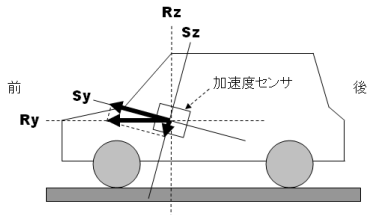
BumpRecorder

You do not need any calibration procedure. All calibration is done automatically. And it is calculating road profile first, and then calculate IRI. It’s variation are +-15%.

Class 2

Another calibration factor : Tilt

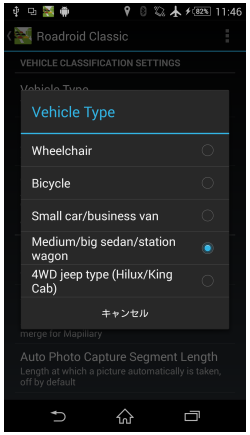
When an accelerometer is tilt, apparent acceleration will be measured on vertical axis at vehicle start, stop, and turn right and left.



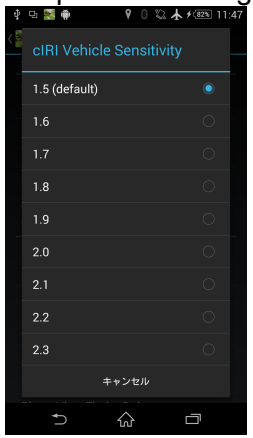
Compare with competitor

Roadroid require manual setting for calibrations.

Vehicle type setting



Suspension setting

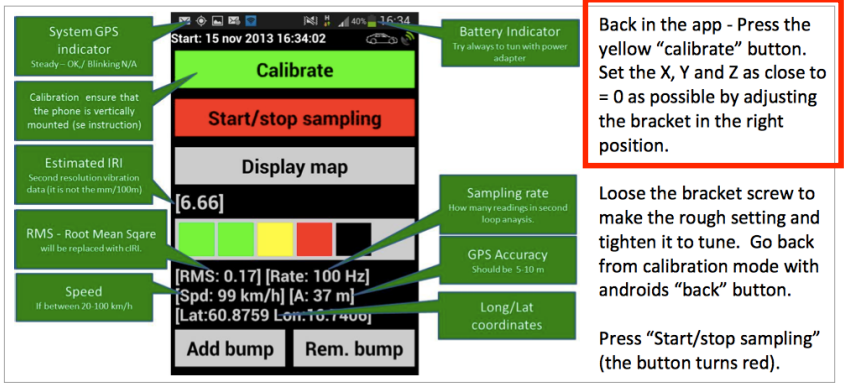


BumpRecorder is NOT requiring any setting for calibrations. All calibration is done automatically.

Competitor system require calibration

Roadroid users manual

An attitude calibration is needed



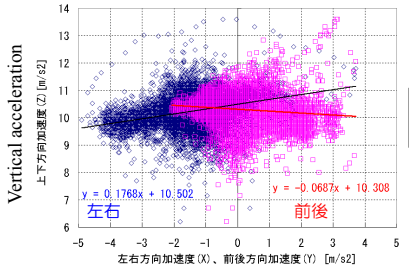
Back in the app - Press the yellow "calibrate" button. Set the X, Y and Z as close to = 0 as possible by adjusting the bracket in the right position.

Loose the bracket screw to make the rough setting and tighten it to tune. Go back from calibration mode with androids "back" button.

Press "Start/stop sampling" (the button turns red).

BumpRecorder is auto calibration

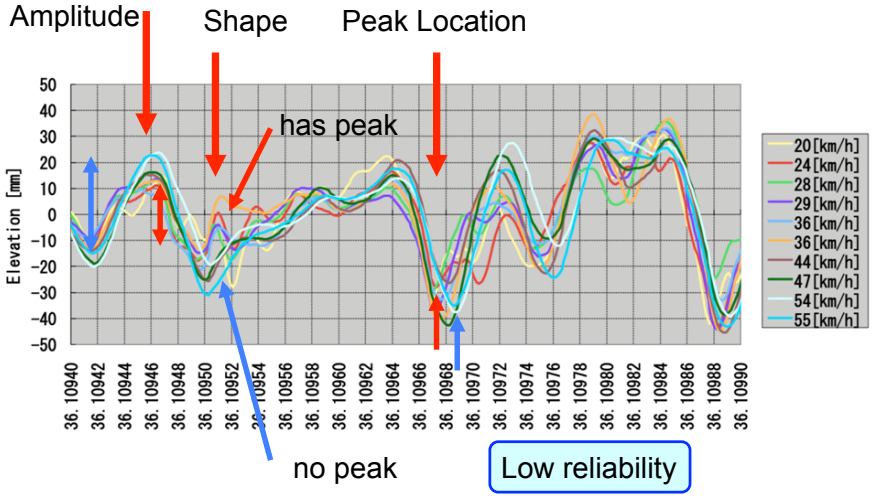
BumpRecorder is an altitude free,
because it correct smartphone tilt automatically.
It is only system in the world.



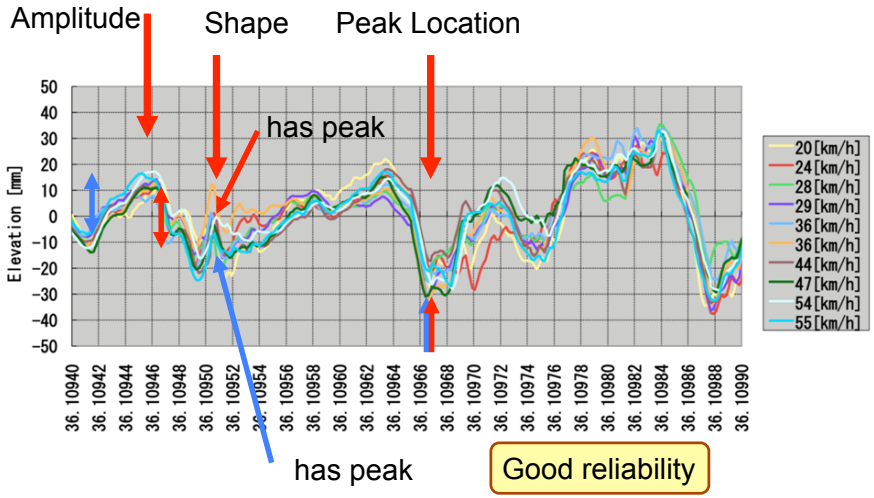
Right-left and front-back acceleration

Verification Result Reliability

Sprung movement



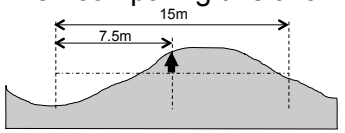
Unsprung elevation



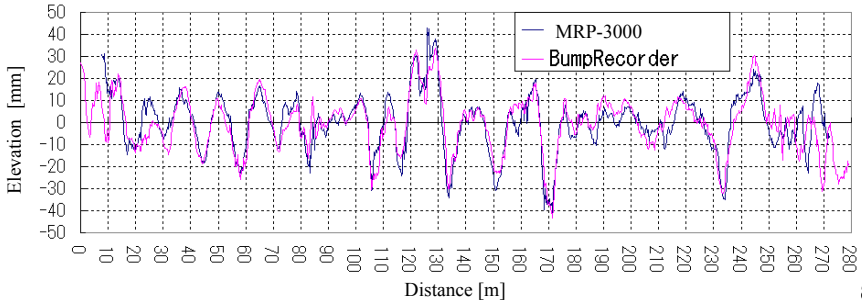
Good reliability

Comparison : Relative height in 15[m] long

Calculating relative height in 15[m] long
for MRP-3000 and BumpRecorder.
Then comparing this two values.



Trend was consistent.
Position gap was not so large.

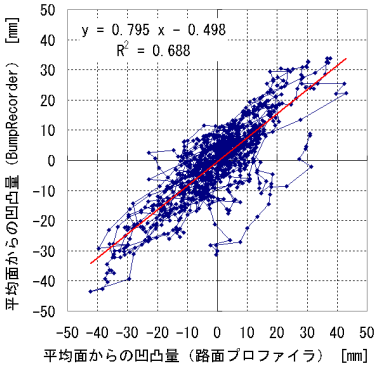


Comparison with KUMATAKA MRP-3000

Comparison : Relative height in 15[m] long

Liner regression was done,
by using result of MRP-3000
and BumpRecorder

- Contribution Ratio : 0.688
= Correlation coefficient : 0.829



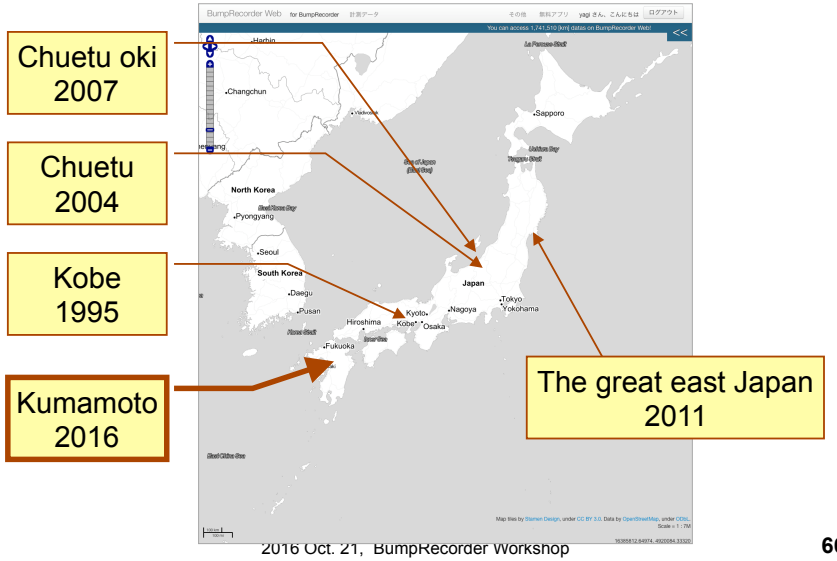
Relative height by MRP-3000 [mm]

BumpRecord

Case study of an actual investigation after earthquake

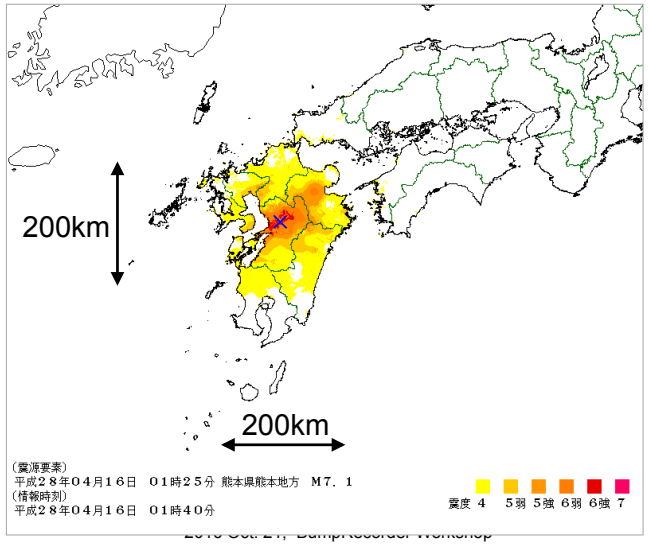
BumpRecorder

Past Earthquake in Japan



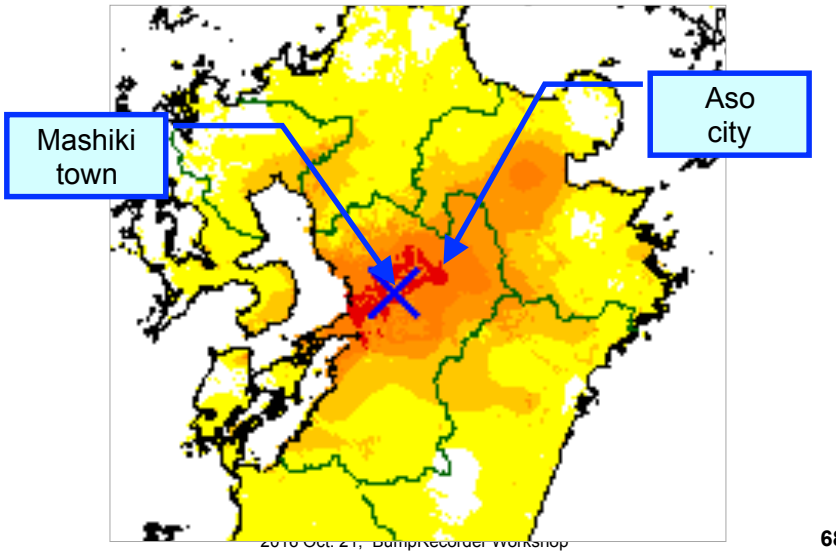
BumpRecorder

Seismic intensity on Kumamoto earthquake



BumpRecorder

Seismic intensity on Kumamoto earthquake



BumpRecorder

Damaged situation in Mashiki town

Mashiki town is located at epicenter of Kumamoto earthquake, where has greatest damages.

Two floor house was collapse down of it's ground floor.

BumpRecorder

Damaged situation in Mashiki town

Left house was damaged and left lane closed for safety.

BumpRecorder

Damaged situation in Mashiki town

Road pavement was peeled.

BumpRecorder

Damaged situation in Mashiki town

Left house was damaged and left lane closed for safty.

Damaged situation in Aso city

Aso city is located at north east plase of epicenter.

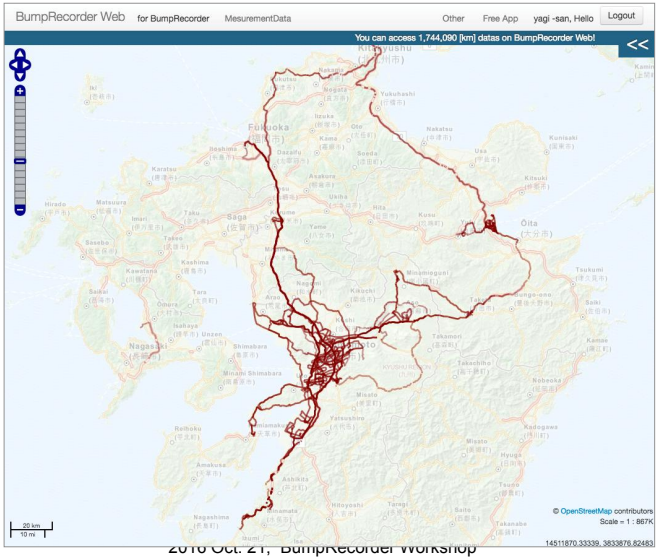
Road was peeled about 7 km long.

Damaged situation in Aso city

Road was peeled and bump step also was generated.

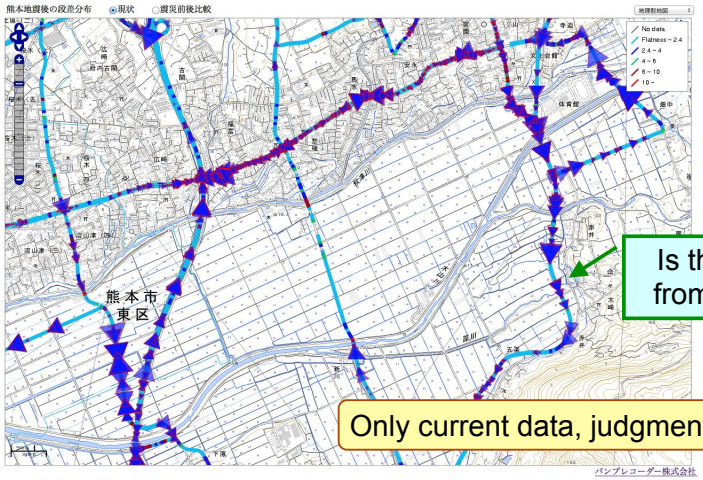
Can we capture these situation by roughness measurement?

Research distance up to 3,400km



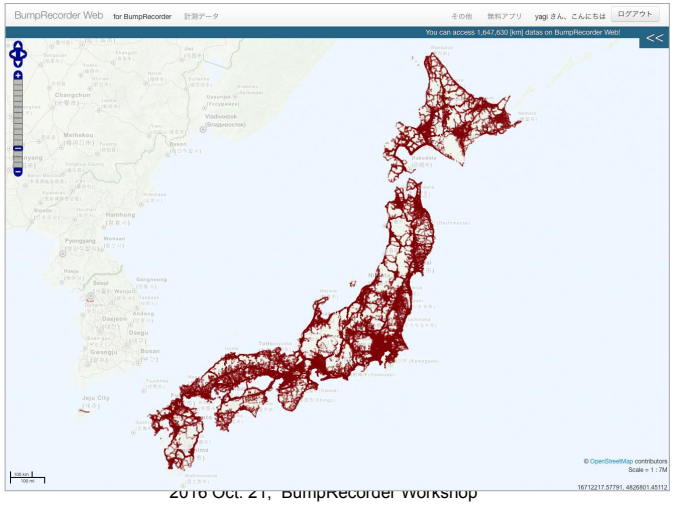
Current roughness status

Line color and triangular shows road roughness and bump step.
All bump step are affects from quake?



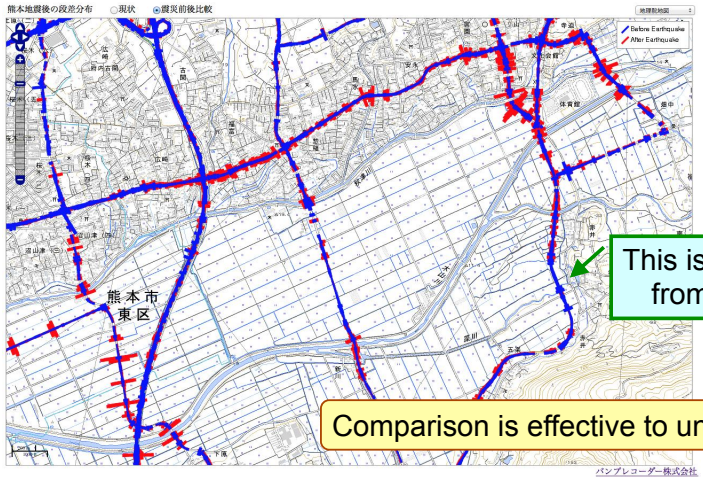
IRI measurement by BumpRecorder

Brown line are already measured which is almost whole Japan.



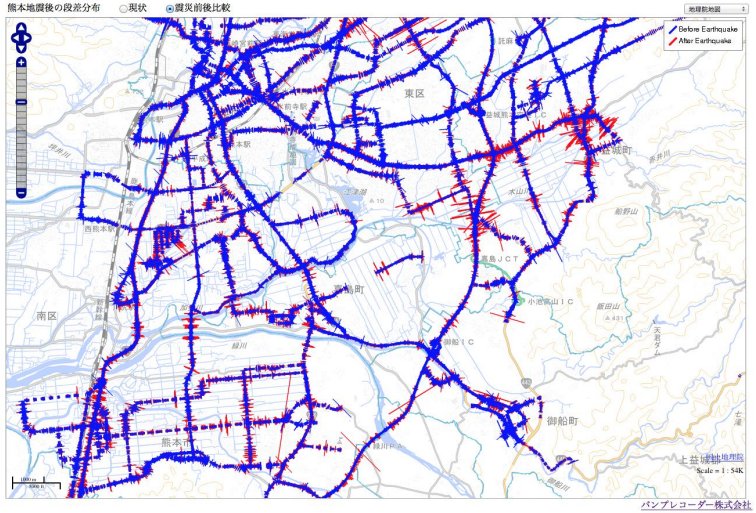
Roughness comparison, before and after

Blue line shows roughness before the earthquake.
Red line shows after quake.



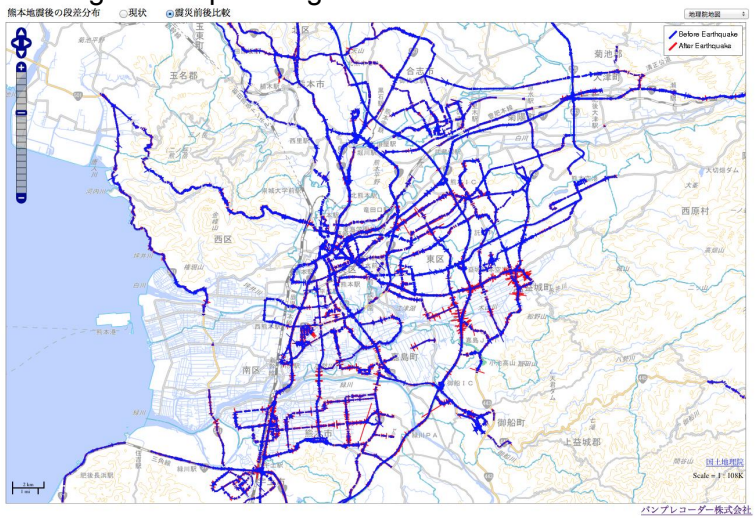
Roughness distribution around Mashiki Town

Mashiki Town has terrible damages.



Wide area roughness distribution

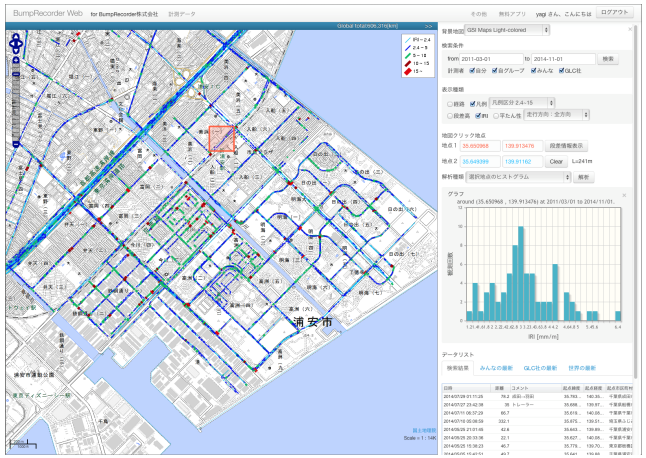
Damages are spreading to south west direction.



BumpRecorder Web
Immediate Reporting Service

BumpRecorder Web

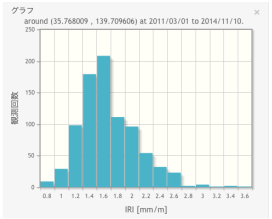
About 10 minutes after upload, result will be shown on **BumpRecorder Web** of map and graph.

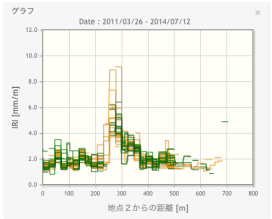


Graphs on BumpRecorder Web

You can draw 3 types of graph easily.

Histogram **Distance base** **Time series**





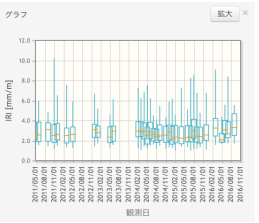


Table on BumpRecorder Web

Reporting table for distance base roughness data.

IRI 距離標テーブル

距離 [m]	緯度	経度	平均 [mm/m]	2016 09/02	2016 07/12	2016 06/16	2016 05/26	2016 03/26	2015 12/30	2015 12/30	2015 12/27	2015 12/24	2015 10/25	2015 09/21	2015 09/21	2015 09/19	2015 08/21	2015 08/13	2015 08/06	2015 08/06	2015 08/01	2015 07/20	2015 07/02
0	35.7	139.7	3.5	1.7	---	3.1	2.6	4.2	3.7	2.8	4.1	4.9	3.2	2.5	3.0	3.0	7.2	3.6	1.9	3.3	3.1	4.7	4.3
33	35.7	139.7	3.9	4.9	---	4.3	---	4.4	3.3	3.5	3.3	3.4	2.9	3.2	2.5	4.2	5.5	4.9	3.5	4.6	5.8	2.7	3.1
62	35.7	139.7	3.1	4.1	2.7	3.7	1.8	2.6	4.3	2.5	3.6	3.1	3.3	3.5	3.7	2.1	---	2.7	2.4	2.6	---	3.7	3.1
89	35.7	139.7	2.1	2.2	---	2.6	2.0	2.5	1.9	2.6	2.2	2.0	1.8	1.8	1.6	2.1	2.8	2.0	---	---	---	1.8	---
113	35.7	139.7	2.8	2.6	4.0	3.0	2.8	3.7	1.6	2.7	3.2	2.6	2.4	2.0	1.5	2.9	---	2.9	3.2	2.9	4.3	2.4	2.6
139	35.7	139.7	2.0	1.8	2.5	2.2	1.7	2.1	2.3	---	1.9	---	1.8	1.6	1.6	---	2.8	2.3	1.6	---	2.5	1.8	2.0
164	35.7	139.7	2.1	2.5	2.2	2.7	1.8	2.1	2.1	1.8	2.1	2.0	1.5	2.1	1.8	2.0	2.8	2.2	1.8	2.0	2.2	1.7	2.2
188	35.7	139.7	2.0	3.3	---	1.8	---	1.6	---	---	---	---	---	---	---	---	2.3	---	1.6	---	---	1.6	1.5
214	35.7	139.7	1.9	2.7	1.8	2.6	1.8	2.2	1.2	1.6	1.6	1.4	1.8	1.7	1.4	1.8	2.7	3.1	1.7	---	2.0	1.5	1.4
240	35.7	139.7	2.4	5.3	2.7	4.3	2.1	3.3	1.4	1.7	1.6	1.7	1.6	1.6	1.4	2.7	---	3.3	2.1	2.5	2.2	2.2	1.9
266	35.7	139.7	3.6	3.6	---	3.8	---	3.1	---	---	---	---	4.1	4.1	3.9	---	2.9	---	---	---	---	3.5	3.4
293	35.7	139.7	3.3	5.3	---	4.3	2.6	4.1	2.5	2.8	2.8	2.5	2.4	2.3	2.0	2.4	8.9	3.1	2.4	3.6	3.3	2.2	2.3
318	35.7	139.7	3.7	---	3.5	5.5	4.2	3.3	3.3	2.9	3.7	3.1	3.5	4.4	4.3	3.1	---	5.2	4.3	2.7	3.2	3.7	3.1
345	35.7	139.7	2.6	3.1	---	3.0	---	2.5	2.5	2.0	---	2.1	2.2	3.0	2.8	---	2.3	3.0	3.1	---	---	2.1	2.1
371	35.7	139.7	2.5	4.6	2.7	3.3	1.8	4.8	1.1	1.5	2.2	1.9	1.4	2.6	3.1	---	3.7	2.5	2.7	---	2.1	1.1	1.0

凡例

0 2.8 <=5.5

Full Auto Measurement IoT device available

Full Auto Device : BL-01

In an actual operation
- Daily patrol is busy, it is difficult operate smartphone for measuring road roughness.

Full auto measurement is available!
- Using "BIGLOBE" made IoT device "BL-01", all measurement operations are automatically done.
- Engine start >> Measurement auto start.
  Engine stop >> Measurement auto stop and data upload.

Conclusion

Conclusion : Why not BumpRecorder?

- **BumpRecorder** Co., Ltd. has experiments of roughness measurement more than 9 years.
- **BumpRecorder** service is not only simple, but also has good quality.
- **BumpRecorder** is a response type measurement system, but it is IRI class 2. That is only system in the world.
- It has auto calibration functions for suspension condition and tilt condition. It is only system in the world.
- **BumpRecorder** has total packages which is include smartphone application, web service, and IoT device.