■R&D Topics : **Information and Communications Technologies**
■R&D Theme : **Research, development, and social implementation of screening technologies on pavement and bridges based on large-scale sensor information fusion toward preventive maintenance of infrastructure**
■Principal Investigator : **Masataka Ieiri (Director, JIP Techno Science Co., Inc.)**
■Collaborative Research Groups : **The Graduate School of Engineering, Institute of Industrial Science (IIS), and Research Center for Advanced Science and Technology(RCAST), The University of Tokyo**

R&D Objectives and Subjects

SIP Cross-ministerial Strategic Innovation Promotion Program
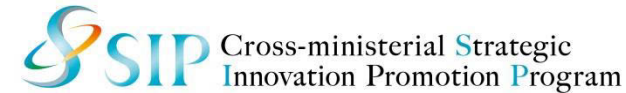
Objectives

To reduce the risk due to earthquakes, typhoons, and accidents, and the cost of maintenance, screening technologies to extract those needing detailed inspection or retrofitting from infrastructure stock are developed and socially implemented.

Subjects

① **Large-scale road condition evaluation using commercial vehicles**：DRIMS, a system for evaluating the International Roughness Index (IRI) based on vehicle responses, is installed in various commercial vehicles; vehicles' response data is collected and analyzed on a large scale. The condition of road networks, including even residential roads, is obtained in pseudo-real-time.

② **Monitoring of bridges and analysis**：Wireless sensing system capable of capturing bridge responses at a cost 10 times lower than conventional sensors has been developed. Wireless sensor systems to monitor multiple bridges on a large-scale have been developed.

③ **Fundamental technologies for low-power wireless sensor networks**：Based on "routing-less multi-hop wireless communication techniques", low-power synchronized sensing with a battery life time of about 20 years has been developed.

④ **Fundamental technologies for big-data analysis and visualization**：Peta-byte class data obtained from about 100 vehicles and 100s of sensors on bridges are stored, processed, and visualized.

Current Accomplishments (1/2)

Sophistication of Measurement app

Ordinary app : sampling timing fluctuates

Acceleration/angular velocity, etc. （on store）
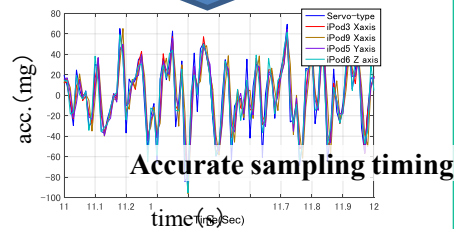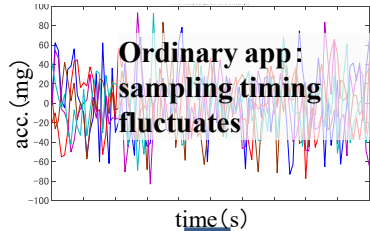
Depending on conditions, higher accuracy than conventional sensors

Accurate sampling timing

Servo-type
iPod3 Xaxis
iPod9 Xaxis
iPod5 Yaxis
iPod6 Z axis

Feedback from social implementation to development

Vehicle parameter identification

Conventional model

Model calibration to reproduce pitching and bouncing

$\ddot{Z}_s$

・vehicle dynamics
・sensor location
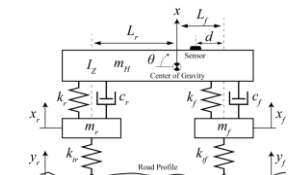
Road profile estimation

Profile estimation （0.02－0.5cycle/m）

Profile comparison

— Kalman filter
— Profiler
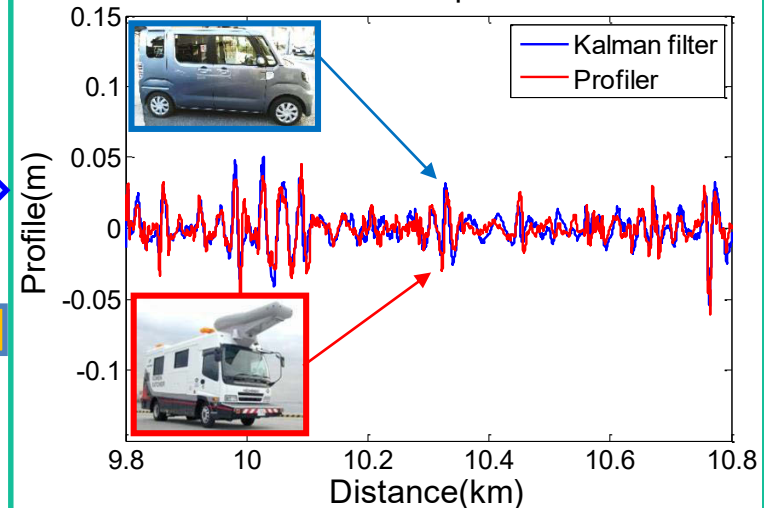
Estimation accuracy is close to the Profiler

Large scale social implementation and visualization

Network-level visualization

Drive records (H27)

	Number	Mileage(km)
Company A	41	23,286
Company B	10	55,062
Company C	6	76,823
Municipality A	10	501
Municipality B	5	6,503

Local visualization

➤ Psuedo-real-time data from 10s of vehicles
➤ Smooth visualization at various scales

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Current Accomplishments (2/2)

Wireless sensor node development

Inexpensive & easy-to-use and accurate & reliable node
1. Seismometer-like accurate acceleration measurement
2. Synchronized sensing network quickly created over multi-hop communications
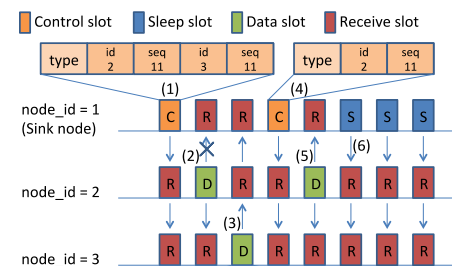3. Long battery life of up to 20 years
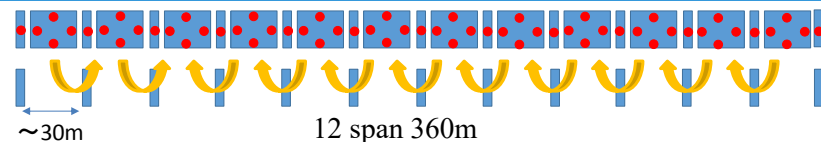
Prototype

Communication module

Routing-less multi-hop communication

➢ Flooding communication completes in 10 ms. By scheduling CTF, dozens of packets are sent via flooding.
➢ MAC and routing are significantly simplified. Fast data collection, reprogramming, high reliability, and other functionalities are realized
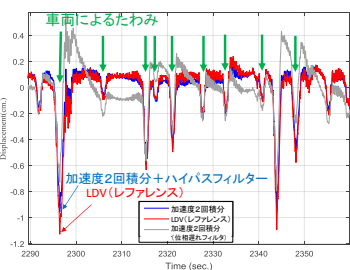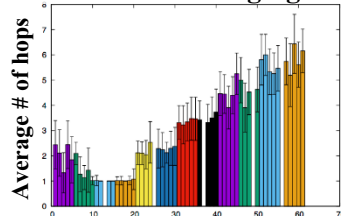
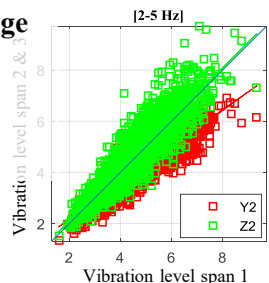Measurement system development is essentially simplified.

Control slot Sleep slot Data slot Receive slot

type | id 2 | seq 11 | id 3 | seq 11 | type | id 2 | seq 11

(1)   (4)

node_id = 1 (Sink node)   C R R C R S S S

(2)   (5)   (6)

node_id = 2   R D R R D R R R

(3)

node_id = 3   R R D R R R R R

Field test 1 : traffic-vibration measurement at viaducts

～30m   12 span 360m

**Robust multi-hop network is established under a challenging environment**

Average # of hops

Spans with large deflection and vibration amplitude are extracted

車両によるたわみ

加速度2回積分＋ハイパスフィルター
LDV(レファレンス)
加速度2回積分
LDV(レファレンス)
加速度2回積分
(位相遅れ＋フィルタ)

Displacement(cm)
Time (sec.)

[2-5 Hz]

Vibration level span 2 & 3
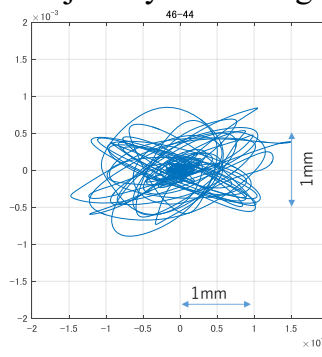Vibration level span 1

Y2
Z2

Field test 2 : earthquake response monitoring

➢ Kumamoto earthquake aftershocks are monitored using more than 10 nodes/bridge. Battery-operated nodes captured more than 50 aftershocks during 2 weeks.
➢ Bearing motion under seismic events were clarified.

Ground motion

acc x(g)
acc y(g)
acc z(g)
time(s)
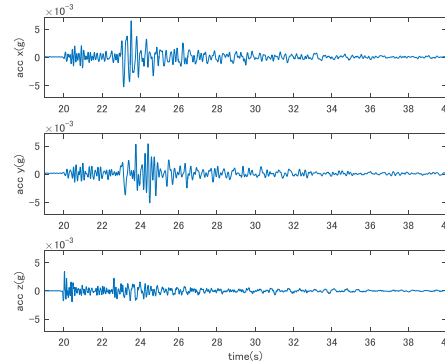
Trajectory of bearing motion

46-44

1mm

1mm

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3

Goals

Road evaluation

Target

IRI estimation accuracy　10-20%

Local damage detection（joints & potholes）

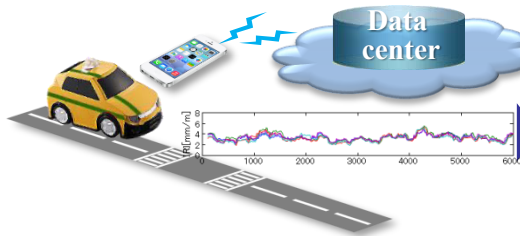Road asset management system using deterioration prediction based on IRI

Data process & visualization platform for 100 vehicles x several years.

Technology transfer to foreign countries
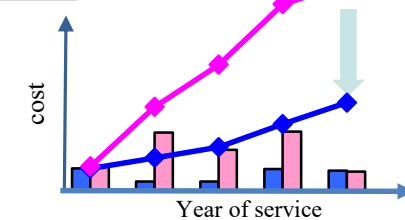
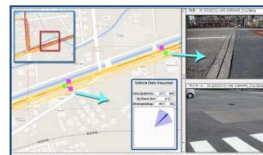**Data collection → Daily management → Asset management**

Data center

Total maintenance costs
- Conventional management
- Strategic management

cost / Year of service

Service based on needs

Uneven joints

Potholes

IRI degradation in past 3 mths.

Deliberate road management based on IRI

Maintenance cost reduction

Bridge evaluation

Target

Sensor node

Seismometer-class accurate measurements

Robust multi-hop network over kilometers

1-month to 20-year battery life

Strain, inclination, temperature

Time synchronization to GPS time. Power-efficient connection to external network

Extraction of bridges of large responses/loads

High-performance node sales

Bridge measurement service

After-quake road closure assessment assistance service

Wireless sensor

Find outlier from similar structure (Screening)

Girder

Abut

Road manager

Alert for high risk locations

Traffic vibrations / Earthquakes → Acceleration → Comparative evaluation of deflection & vibration ex）extraction of vibration-prone spans

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