39 Research, development, and social implementation of screening technologies on pavement and bridges based on large-scale sensor information fusion toward preventive maintenance of infrastructure

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R&D Objectives and Subjects

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.

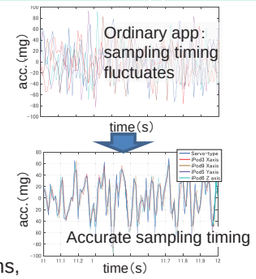
③ **Fundamental technologies for low-power wireless sensor networks :** Based on "routing-less multi-hop wireless communication techniques", low-power synchronized sensing with a battery life time of about 20 years has been developed.

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

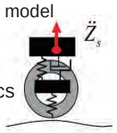
Acceleration/angular velocity, etc.（on store）



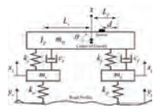
Depending on conditions, higher accuracy than conventional sensors

Vehicle parameter identification

Conventional model



Model calibration to reproduce pitching and bouncing

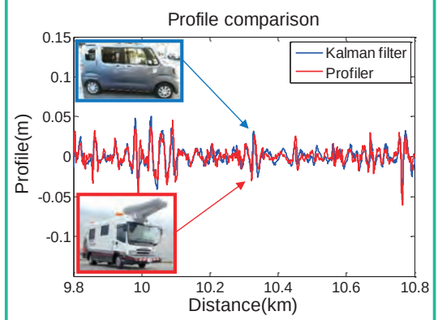


・vehicle dynamics
・sensor location

Feedback from social implementation to development

Road profile estimation

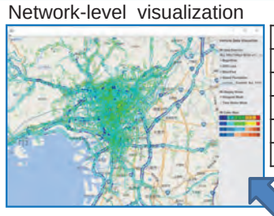
Profile estimation (0.02—0.5cycle/m)



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

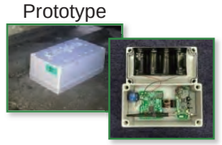
Current Accomplishments (2/2)

Wireless sensor node development

Inexpensive & easy-to-use and accurate & reliable node

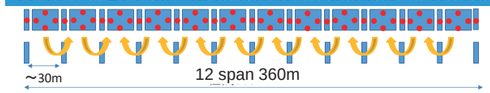
1. Seismometer-like accurate acceleration measurement
2. Synchronized sensing network quickly created over multi-hop communications
3. Long battery life of up to 20 years

Prototype

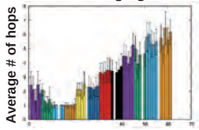


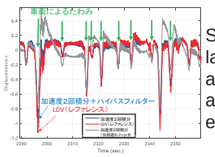
Communication module

Field test 1：traffic-vibration measurement at viaducts

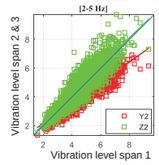


Robust multi-hop network is established under a challenging environment





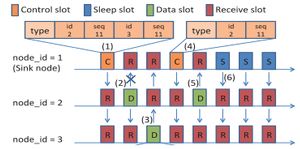
Spans with large deflection and vibration amplitude are extracted



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

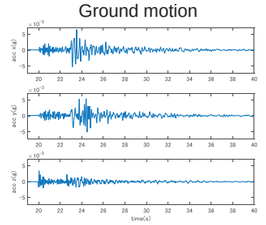
Measurement system development is essentially simplified.



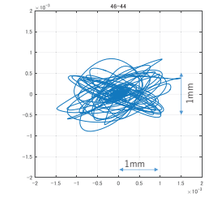
Field test 2：earthquake response monitoring

➢ 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



Trajectory of bearing motion



※We appreciate Kumamoto Office of River and National Highway for their kind advice on the measurement

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

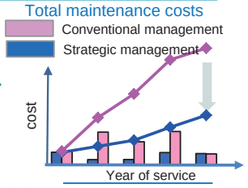
Data collection → Daily management → Asset management

Service based on needs

Uneven joints
Potholes

IRI degradation in past 3 mths.

Total maintenance costs



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

Find outlier from similar structure (Screening)

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

After-quake road closure assessment assistance service