

Cross-ministerial Strategic Innovation Promotion Program (SIP) Website (Cabinet Office) http://www8.cao.go.jp/cstp/panhu/sip\_english/sip\_en.html



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2017.3

# Infrastructure Maintenance, Renovation and Management

# Toward Safer and more Secure Civil Infrastructures driven by Developing Technologies

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The contents are as of March 2017 unless otherwise noted.

# Introduction; The R&D Project of Infrastructure

# **Maintenance, Renovation and Management**

#### Greeting

#### For Safe and Secure Infrastructure Systems

The Cross-Ministerial Strategic Innovation Promotion Program (SIP), in which the Council for Science, Technology and Innovation (CSTI) plays the role of playmaker, has been established to realize scientific technology innovations. As a cross-ministerial and cross-field program, SIP will drive forward with the focus ranging from basic research to commercialization/industrialization "Infrastructure maintenance, renovation and management" (hereinafter referred to as "SIP infrastructure") is one of the issues currently under the focus of the programs.

Civil infrastructures, such as roads, railways, harbors and airports, support our everyday life and social economic activities. Many of them, however, were built during the high economic growth period. As they get older, the increase in maintenance and repair expenditures, along with the possibility of a serious accident occurring during the service, become serious social issues. This program aims at preventing accidents and reducing the burden of maintenance by constructing a systematic infrastructure management that utilizes the most advanced information and robotics technologies.

Unlike mass-produced products, such as vehicles and laptop computers, infrastructures are single products that are designed, constructed, and manufactured individually. Initial conditions of infrastructures vary depending on the time and condition they were built As a result in addition to the difference in usage environment, the speed of infrastructure deterioration also varies. Some infrastructures that have been used for several tens of years may pose a higher risk of accident due to damage. To allow for an effective and efficient preventive maintenance management of infrastructures and to establish a safe and secure

infrastructure system, it is therefore crucial to have technologies that can precisely diagnose and take appropriate measures by closely examining large number of infrastructures individually on-site. It is also essential to minimize the hazards and risks associated with manual handling in the workplace. For infrastructure management run by local governments cost reduction is also a particularly important viewpoint. Currently, infrastructures are being constructed across Asia: however, maintenance has already become a big issue. "SIP infrastructure" aims at introducing new exciting advanced technologies into the range of infrastructure management technologies. Specific examples include the following: support from or replacement with robots for infrastructure inspection: on-site damage detection inside concrete members; inspection of tunnels and bridges by mobile sensors that do not require traffic control; technologies to aerially detect damage/deformation of river levees, dams, and harbors; highly accurate deterioration estimation technology for concrete, developing ultra-high durable repair materials: efficient infrastructure management technology using big data processing; and artificial intelligence.

Japan's infrastructure stock is estimated to be over 800 trillion ven. Infrastructures should function for several decades. Our responsibility to

#### -Biography

the future is to create an infrastructure information platform and to pass on the infrastructures that can be used safely with a minimum maintenance burden to the next generation. The objective of "SIP infrastructure" is to establish the system and we will work hard to achieve it.



PD (Program Director)

Yozo Fujino Distinguished Professor, Institute of Advanced Sciences, Yokohama National University

Yozo Fujino graduated from Department of Civil Engineering, at the University of Tokyo in 1972. After completing his Master's degree (Civil Engineering) at the University of Tokyo, he received the Doctor of Philosophy from the University of Waterloo in 1976. He joined the Earthquake Research Institute at the University of Tokyo; the Institute of Structural Engineering at the University of Tsukuba: and Department of Civil Engineering at the University of Tokyo. In 1990, he was appointed as a professor of Department of Civil Engineering at the University of Tokyo. In 2014, he joined the Yokohama National University, and has served in his current position from October 2014. He is a Professor Emeritus of the University of Tokyo. His expertise includes structures, vibration control and monitoring of civil infrastructures with emphasis on bridges. He was awarded the Medal with Purple Ribbon of Honor from the Emperor of Japan in 2007, and the 2015 Hattori Hoko Award (The Hattori Hokokai Foundation) . among others

#### Outline

In Japan, amid the aging of infrastructures, emerging risk of a serious accident such as the Sasago tunnel accident in 2012, and the increase in maintenance and repair expenditures are topics of concern. Systematic infrastructure management utilizing new technologies is essential both for preventing accidents based on preventive maintenance system and minimizing life cycle cost of infrastructures under the conditions of the tight financial grounds and the decreasing number of skilled engineers. Particularly, technologies that utilize the world's most advanced ICRT\* are expected to create new business opportunities in the existing infrastructure maintenance market and to offer business expansion opportunities into Asian countries that face similar problems

To achieve this, we will improve the standard of maintenance by using low-cost preventive maintenance while stressing the necessity to match the needs of infrastructure maintenance with the seeds of technical development. and developing new technologies into more attractive technologies that can be used on-site.

By achieving this, we aim at contributing to regional revitalization, as well as maintaining the important internal infrastructures to high standard while backing up a variety of regional

economic activities. Furthermore, we will create an attractive and ongoing maintenance market and build a base for overseas expansion based on successful regional examples.



#### **Overall Plan**

To minimize the opportunity loss of regional revitalization resources such as logistics, service, and tourism, it is vital to implement efficient and highly economical maintenance, renovation, and management. This is important considering that infrastructures such as roads, railways, harbors, and airports are public assets and domain whose functions should always be maintained.

The following points are important in achieving the efficient maintenance and management of infrastructures, which are estimated to be worth a total of 800 trillion yen.

- · Cooperation with a wide range of advanced technology fields including civil engineering and ICT/robotics technologies
- · Coordinating technologies based on adaptations on-site
- · Technical specification menu based on the various different situations of end users
- · Technical managerial viewpoint including organization management to utilize the technology appropriately
- · Sustainable support system for technical development

Without relying only on the results of technical development at each ministry, national research institute, university, and private company, an

#### Exit Strategies

Since there is a diverse range of situations, targets, and technologies of infrastructure maintenance, we intend to implement infrastructure maintenance by optimally putting individual technical development together in the asset management phase. In the meantime, the development of IoT and other related technologies is remarkable, and construction of a platform that includes networked heterogeneous technologies, such as monitoring and sensing by robots and traveling vehicles, is rapidly becoming more of a real possibility. As a result, this has become a major strength that will allow us to drastically reform infrastructure maintenance. Therefore, we will advocate the promotion and cooperation with newly developed individual technologies by constructing an IoT platform to develop a scheme which will advance the integration of technologies through both asset management and the IoT platform.

As the base of this exit strategy, we will actively cooperate with key universities regional universities, national research institutes, the Ministry of Agriculture, Forestry and Fisheries, the Ministry of Land, Infrastructure, Transport and Tourism, and local governments to create a unique framework for infrastructure related research. Specifically, we are considering the following business deployment patterns: "unique technological developments that have an individual theme," "deploying business to local governments through regional universities," "deploying business to the state administrative system through national research institutes," "establishing a permanent

residents.



\*IoT: Internet of Things

organization system to support industries," and "exporting and globally deploying technology." Of these patterns, we place greatest importance on "custom-made technical implementation support that suits regional characteristics." and investigate a technical support system from the base institutes, a fund support system,







Roll Out Infrastructure Maintenance and Renovation Management in the Regions

and the establishment of various technologies and sustainable support in local governments. In addition, we plan to implement a business model that will both help regional revitalization, and prepare an environment for business, by establishing a technical strategy plan based on reputation management



# **Inspection, Monitoring** and **Diagnostics Technologies**



Ultrasensitive magnetic nondestructive testing for deterioration evaluation and creating a preservation plan of infrastructures



Inner defects inspection for tunnel lining using rapidly scannable non-contact radar and synthetic soundness diagnosis system



Illustrative images for inspection and diagnosis using non-contacting radar

Remote sensing of concrete structure with the high-sensitive near-infrared spectroscopy



Near infra-red imaging technology that can analyze the deteriorated components of concrete remotely in a short period of time and at a low cost

Wide area displacement monitoring for early detection of deformation or damage of civil engineering structures using satellite SAR'<sup>1</sup>



Efforts for site verification using Satellite SAR technology



Inspection, monitoring and diagnostic technologies have been developed to fully estimate damages of civil infrastructures. R&D subjects such as an internal defect inspection technology using supersensitive magnetic nondestructive testing, an integrated diagnostic system using high-speed traveling noncontact radar, remote diagnostic technology using supersensitive near infra-red spectroscopy, a pavement inspection system, floor slab deterioration detection using onboard underground probe radar, and the displacement monitoring technique for infrastructures using Satellite SAR (Synthetic Aperture Radar) are in progress.





\*1 SAR: Synthetic Aperture Radar



• Simple pavement inspection system utilizing an airport ground vehicle



A monitoring site demonstration on the runway of an airport

#### Detection of floor slab deterioration using the onboard underground probe radar



Detection of deteriorated portions inside a floor slab using an onboard high speed scan radar

# Structural Materials, Deterioration Mechanisms, Repairs, and **Reinforcement Technologies**

efficient maintenar	nce systems	Exposure test of a PC test beam
Comparison of two-year ex normal carbon steel and an	kposure test results between nticorrosion steel (at Irabu Ohashi Bridge)	deteriorated by ASR <sup>2</sup>
Carbon steel	Anticorrosion steel	Contraction of the second
Test surface Cracks Bottom surface Concrete test block	Test surface No cracks Bottom surface Concrete test block	Fly ash concrete
Reinforcing bar	Reinforcing bar	Concrete with no fly ash mixed
		2

<sup>12</sup> ASR<sup>1</sup> Alkali Silica Reaction

Extensive R&D activities have been in progress amidt urgent social demands in this category of the SIP project in oreder to develop simulation models for the deterioration mechanisms of structural materials and innovative estimation system for deterioration progress of infrastructures, to organize a core base for R&D of structural materials to develop effective maintenance technologies, and to promote the commercialization and wider application of precast members using highly-durable concrete for society

#### Precast products using high-durability concrete

•••



# **Robotics Technologies** (For Inspection, **Disaster Measures**, etc.)



Various robots have been developed to inspect civil infrastructures, such as bridges and tunnels, safely and economically. At the same time, a wide range of R&D tasks are ongoing for a study of applicable structures for the introduction of robotics technologies, and establishing an integrated database to centrally manage the information for the effective utilization of robotics technologies. With these efforts, the implementation in society of robots for infrastructure maintenance is highly expectd.

Hammer test flying robot system for bridge/tunnel inspection



Hammer inspection multicopte





Multicopter with passive rotating spherical shell



Semi-submerged work robot using remote control

Transport robot for unmanned construction in the semi-submerged environment



### i Information and **Communications** Ŀ **Technologies**



i

<sup>3</sup> iDRIMS (Measurement) is an iOS application that measures the condition and quality of the road surface

using acceleration/angular velocity sensors installed in the iPhone/iPod touch Integrated data management platform for civil Infrastructure sensing



# **Asset Management Technologies**

limited budget.



The main subject of R&D is to develop data management systems fully utilizing information and communication technologies (ICT) to take advantage of the enormous amount of information on maintenance, repair and renewal of civil infrastructures for contributing to the real application of advanced ICT for society. Specific R&D fields are data screening based on integrated large-scale sensor information for pavements and bridges and so on, data management enabling comprehensive control of a variety of information and data analysis and visualization technologies for making the stored data effectively applicable for real operation on-sites.

Damaged position viewer (example)



Display of the whole map

The IRI\*4 viewer and the abnormal de viewer show the information independently \*4 IRI:International Roughness Index Ride comfort index

Along with real applications of R&D outcomes for society, SIP contributes to secured and safe infrastructures by cooperating with infrastructure administrators. The advanced technologies including non-destructive test methods and innovative numerical analysis have been developed for maintenance of road structures. In addition, SIP also proposes a highly sustainable asset management system from the viewpoints of contract scheme, human resource training, private sector utilization, and collaboration with the local residents to maintain enormous number of infrastructures which local governments should manage with a



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Cross-ministerial Strategic

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	Kenji Ikushima(Tokyo University of A&T)
	Hiroyuki Toyokawa(AIST)
	Hitoshi Nohmi(Alouette Technology Inc.)
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Spectroscopy	Kazuhiro Tsuno(Shutoko Engineering Co., Ltd.)
	Masahiro Murakawa(AIST)
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Cracks Automatically from High-resolution Images	Toru Hara(Alpha Product INC.)
Direction-moving Robot	Yasuo Kimura(NTT Advanced Technology Corp.)
sing Maintenance Vehicles	Yusho Ishikawa(The University of Tokyo)
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c. for Bridge Inspection	Yasuhisa Fujiwara(Sumitomo Mitsui Construction Co., Ltd.)
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inge and Volumetric Water Content	Lin Wang(Chuo Kaihatsu Corp.)
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### Interdisciplinary R&D of NDE techniques for innovative maintenance

Principal Investigator Masahiro Ishida (Chief Researcher, Public Works Research Institute)

Collaborative Research Groups The University of Tokyo, Riken

#### **R&D** Objectives and Subjects







Degradation of concrete slabs

#### Objectives

Develop a diagnostic method for concrete structures by visualization techniques using X-ray and Neutron sources

#### Subjects

- Develop a portable visualization system using high-power X-rays and use it on actual bridges
- Downsize the water visualization system using small scale Neutron sources and examine its feasibility for water detection in concrete slabs
- Develop a diagnostic method based on visualization to evaluate deteriorated structures

#### **Current Accomplishments (1/2)**



### **Current Accomplishments (2/2)**



#### Goals

### Implementation of developed techniques for domestic bridges

#### Final goals

- Establishing the fundamental technologies of X-ray transmission imaging and limited angle CT reconstruction through inspections of actual infrastructures using the portable high power X-ray sources. →Detection of fractures or corrosion of steel in millimeter resolution. →Securing radiation safety by controlling air dose under 250 mSv/3month at the boundaries of controlled areas.
- →Clarifying applicable conditions of the X-ray back scattering imaging.
- Investigate the on-site applicability of compact neutron sources through in-lab experiments on deteriorated existing structures
- → inspect the defects in concrete slabs with the imaging technique using backscattered (reflected) neutrons  $\rightarrow$  develop a prototype of the transportable accelerator neutron source
- · Develop an analytical method to simulate deteriorated PC girders with corrosion and fractures in PC wires - Re-anchorage of PC wires is properly considered
- Develop a diagnostic evaluation of deteriorated concrete bridges using visualized inner structures - propose guidelines for diagnostic analysis using visualization techniques

### Exit strategy for practical application

- · Downsize the system for more prompt activity to extend its application
- · Endorse the proposed guidelines by organizing a public committee
- Promote the proposed techniques through the consulting activities with CAESAR, PWRI.
- · Demonstrate its safety by conducting actual inspections lead by CAESAR as often as possible

### Dissemination to the world

Find and collaborate with counterparts in countries where the system would be officially applicable in bridge inspection

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## **Development of Laser Ultrasonic Visualization Technology for** the Degradation Diagnosis of Steel Bridges

Principal Investigator Junji Takatsubo (Director, Tsukuba Technology Co., Ltd.)

Collaborative Research Groups AIST, Fukken Gijyutsu Consultants Co., Ltd.

#### **R&D** Objectives and Subjects

#### Objectives

2

- · Current crack inspection of steel bridges is carried out using MT(Magnetic Particle Test), but has the following problems:
- ① It takes time to tear off the coating
- ② Recoating is necessary after inspection
- ③ Internal cracks cannot be detected
- · In order to solve the above problems, we will develop a remote measurement system using laser ultrasonic technology, which can efficiently detect cracks under coating

#### Subjects

- · Development of a high-speed laser-scanning system to measure the video image of ultrasounds propagating in a bridge
- · Construction of a laser optic system which enables remote measurement
- · Manufacture of a small and light-weight laser ultrasonic visualization system
- · Development of an image analysis method to detect the location and size of cracks



### **Current Accomplishments (1/2)**

#### Prototype system can be carried in a small crane bucket with two persons

The only instrument in the world that can inspect a steel bridge on-site by a video image of the propagation of ultrasonic waves.



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#### Slit flaws under coating can be detected from 2 m away



Portable system for

field operations



Measured images of ultrasonic propagation on a steel bridge

#### Inspection of coating

Inspection of internal cracks that are under coating



### **Current Accomplishments (2/2)**



#### Efficient for steel bridge inspections

Inspection part



Steel bridge on National Road No.50

Inspection area (inside the green frame )

Goals



International Plan

· Fatigue cracks that were coated could be detected Detected crack lengths agreed well with the MT results



Visualized crack echo

Fifty-percent reduction in inspection duration and cost

# **NON-CONTACT INSPECTION**

Using reflection sheets **Remote Inspection System** Inspection object: Stiffening plate, Welding member

# CONTACT INSPECTION

Using contact sensors Portable Quick Inspection System Inspection object: Steel floor

- Cracks of 5 mm in length under coating can be detected from a position 5 m away (by non-contact inspection).
- Cracks of 1 mm in length under coating can be detected (by contact inspection)
- Road bridges, Highways, Railways, Industrial facilities



Ultrasensitive Magnetic Nondestructive Testing for Deterioration **Evaluation and Creating a Preservation Plan of Infrastructures** 

Principal Investigator Keiji Tsukada (Professor, Okayama University)

Collaborative Research Groups SUSTERA, JAPEIC, Kyushu University

#### **R&D** Objectives and Subjects

#### Objectives

3

The purpose of this research is to develop a non-destructive testing (NDT) method using highly-sensitive magnetic measurements. Many infrastructural elements, such as bridges, are composed of steel, and the corrosion and cracking of steel can lead to serious problems. Conventional magnetic NDT methods are limited to only surface evaluation of steel structures. Therefore, in this study, we fabricate an inspection instrument that uses a magnetoresistive (MR) sensor and a SQUID sensor, which has the highest sensitivity among magnetic sensors, to realize a new NDT method using magnetic measurement to evaluate corrosion and cracking within and behind steel structures. Comprehensive development of the measurement and analysis method is carried out for detecting changes in magnetic signals due to corrosion and cracking of various steel structures, and a guideline for infrastructure management is established based on the developed NDT method.

#### Subjects

- Basic magnetic inspection system: To realize quantitative evaluation and visualization of flaws in a way that can be understood by anyone without expertise, a magnetic inspection system was developed that can detect flaws inside steel structures of various shapes, and the method of extraction and display of flaws was examined.
- · Instrument for field inspections and field tests: Two types of inspection instruments were developed; a portable instrument using an MR sensor and a highly sensitive instrument using SQUID, and the structure of the inspection part and system size, including power supply, were optimized to install the actual device easily. Using these instruments, a field test was performed and the usefulness of these two instruments was clarified.
- Social implementation: We spread information about the usefulness of the developed new magnetic inspection method both inside and outside Japan, and promoted standardization for JIS and ISO.

#### **Current Accomplishments (1/2)**

#### Portable inspection equipment using magnetic sensors

The magnetic resistive sensor-based nondestructive inspection method can detect not only surface defects but also inner defects because it can analyze magnetic response over a wide range of frequencies from extremely low to high. Furthermore, power consumption of the developed portable inspection equipment is low.

The developed magnetic inspection methods are as follows:

- Extremely low frequency eddy current testing (ELECT)
- Unsaturated AC magnetic flux leakage testing (USAC-MFL)
- ELECT can detect thickness changes in corroded iron steel plates. At present, the detection limit is 16 mm in thickness.
- USAC-MFL can detect surface and internal cracks in iron steel. Cracks with depths lower than 10 mm can be detected.

These developed magnetic non-destructive testing methods. ELECT and USAC-MFL. can be applied easily to painted and rusted surfaces



#### **Current Accomplishments (2/2)**

#### **Development of NDE system with** ultra-high sensitivity

Superconducting guantum interference device (SQUID) magnetic sensors using oxide superconductors have ultra-high sensitivity and can be used by easy cooling with low-cost liquid nitrogen. Recently, fatigue cracks in steel deck plates which originate at the backside welding points have been recognized as a large problem in maintenance of bridges and metropolitan highways. Magnetic particle inspection or ultrasonic testing from the backside of the deck plates are currently used for maintenance. By utilizing a SQUID magnetic sensor which has ultra-high sensitivity even at low frequencies, development of a nondestructive evaluation (NDE) system which enables inspection of small fatigue cracks and further nonthrough cracks in steel deck plates through an asphalt pavement is expected. So far SQUID magnetic sensors with high tolerance against magnetization in steel plates have been developed, and detection of non-through slit-like defects in test steel plates from the distance comparable to the thickness of asphalt pavement has been demonstrated. Recently, an inspection system which can be applied to inspection on roads has been developed and trial testing on steel deck plates has started.

#### Goals









Example of detection of a non-through slit in a test steel plate



SQUID magnetic sensor

Inspection system for trial use on a road







Ultra-high sensitive inspection equipment



## R&D of laser directive noncontact diagnosis system for maintaining degraded infrastructures

Katsumi Midorikawa (Director, RIKEN Center for Advanced Photonics) Principal Investigator

Collaborative Research Groups QST, JAEA, ILT

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#### **R&D** Objectives and Subjects

### Objectives

In Japan, large infrastructures such as tunnels and bridges constructed during the period of rapid economic growth in the 1960's will reach the end of their working lifetimes within 10 to 20 years. In order to solve this societal issue, we develop novel nondestructive inspection methods using laser technology.

#### Subjects

- · Detection of 0.2 mm cracks by 3D remote measurement system by LIDAR and water detection by spectroscopy
- · High speed inspection system by laser hammering
- · Defect removal by remote drilling and cutting by QCW fiber laser
- Tunnel maintenance total system with existing technologies (a. mapping D/B b. MMS) and the above new methods



#### **Current Accomplishments (1/2)**

3D and spectroscopic measurement of inner wall of tunnel using frequency-shifted feedback (FSF) laser Measurement objectives: (1) Crack of 0.2 mm width (2) 0.1 mm difference level (3) Spectroscopic detection Measurement principle: LIDAR (Light detection and ranging)

Measurement of 0.1 mm

difference level

LIDAR + interferometric analysis













Spectroscopic measurement



- 1. Remote and non-contact operation of drilling and cutting of degraded parts are feasible.
- 2. Control of a quasi-continuous wave laser enables suppression of heat affected zones and high processing efficiency.
- 3. Fast drilling speed is realized with optimization of laser irradiation conditions.



#### **Current Accomplishments (2/2)**

# GOAL : Development of a high-speed ar remote inspection method for lining concrete.





# Replacement of "Hammer" and "Ear" with Lasers

#### [Accomplishments]

- · Development of compact, high repetition rate high power YAG laser by the improved system and unique optical layout
- 50 points/second measurement by using a lightweight, rigid, and large size scanning mirror
- · Development of prototype high-speed inspection system for outdoor operation

#### Goals

- ① Technical final numerical target of research and development
- Outline of products and services
- ③ Social Implementation





Principal Investigator Atsushi Yashima (Professor, Gifu University)

Collaborative Research Groups Celery Co. Ltd., Const. Res. Ctr. Gifu Pref.

#### **R&D Objectives and Subjects**

Objectives



5

The maintenance work of pavement is often planned based on rutting, cracking, IRI and FWD data. However, repeated damage to pavement are observed at many places. This surface damage to pavement partly originates from the weakness of the subgrade, damage to the embankment and infiltration of ground water. In order to avoid repeated maintenance work on pavement, the condition of embankment structures should be evaluated by an easy logging technique from the pavement surface. In this research, an automatic technology for surveys and evaluations of pavement, as well as embankment structures, is proposed by using surface wave logging and electric resistivity logging. Collapses of road embankments due to large earthquakes and heavy rainfalls have also been reported. These

collapses were also caused by inappropriate groundwater treatment and slaking/weathering of embankment materials. The proposed automatic technology for surveys and evaluations of embankments by using surface wave logging and electric resistivity will evaluate the stability of embankments during large earthquakes and heavy rainfalls.

#### Subjects

- ① Development of a fully-automatic survey & evaluation system for surface wave logging
- 2 Development of a fully-automatic survey & evaluation system of electric resistivity logging and an increase in investigation depth
- ③ Speed-up and generalization of preliminary analysis of field investigation data
- ④ Standardization of pavement & embankment stability by using S-wave velocity and electric resistivity
- (5) Development of a data base of survey & evaluation results
- 6 Development of a road management system with survey planning and maintenance planning (Web-GIS)



#### **Current Accomplishments (1/2)**

- 1 The automation surface wave & electric resistivity logging system was designed and manufactured.
- 2 The desired target inspection speed, 500 m per hour (mean speed) was achieved.
- (3) The stiffness (Vs) & electric resistivity ( $\Omega$ ) of the embankment was continuously obtained for many sections.
- ④ Hybrid survey by the automatic survey technique developed in this study and FWD was successfully carried out. Detailed information about the pavement, subgrade and embankment was simultaneously obtained.









④ Hybrid survey system with FWD

#### **Current Accomplishments (2/2)**

- ① There have been many reports on collapses of road embankments due to heavy rainfalls and large earthquakes. These collapses were caused by inappropriate groundwater treatment and slaking/ weathering of embankment materials. In order to evaluate the stability of an embankment, we have to know the stiffness, soil profile and groundwater conditions in the embankment.
- 2 The stiffness, soil profile with fine content information and groundwater conditions were continuously obtained along the road embankment by Shear-wave velocity (Vs) & electric resistivity ( $\Omega$ ).
- ③ The stability of the embankment was evaluated by Vs and  $\Omega$ . We were able to understand the stability levels continuously along the road embankment. This continuous information along the road will be utilized to narrow down further detailed investigation sections.
- ④ The liquefaction potential value (FL) of embankments were calculated based on the stiffness, soil profile with fine content and groundwater tables in the embankment/natural ground. That information was obtained by Vs and Ω.

Guais	
Development of a fully-automatic survey & evaluation system of surface wave logging & electric resistivity	② Eva of t
logging	• E
survey speed ≧ 500 m/hour	• E
survey depth $\geq$ 20 m for Vs logging	• E
survey depth $\geq 10$ m for $\Omega$ logging	re
resolution for Vs logging;	Dev
0.2 m for pavement, 1.0 m for embankment	plar





# S-wave velocity electric resistivity . stable or unstable Vs fast





#### aluation of pavement performance and the stability he embankment

- valuation of the stiffness of the pavement & the embankment valuation of the stability of the embankment
- valuation of the liquefaction potential of the embankment esolution along the road; 2.0 m
- elopment of a road management system with survey ning and maintenance planning (Web-GIS)





# Non-destructive Inspection of Rebar Corrosion in Concrete

Principal Investigator Kenji Ikushima (Associate Prof., Tokyo University of A & T)

Collaborative Research Groups IHI Inspection & Instrumentation Co., Honda Electronics Co.

### **R&D** Objectives and Subjects

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to be 40 - 60 % in corrosion products.



Acrylic or Teflon type Water type Specified electromagnet B = 0.47 T in steel bar. Weight < 2 kg.









### Goals

Target and reaching objective in SIP		
Main Target	Reaching objective	
Bridge Floor Covering depth: 30 mm - 50 mm	<ul> <li>✓ Completion of the prototype instrument</li> <li>✓ Index parameters for the corros stage</li> <li>✓ Accumulation of on-site investig</li> </ul>	

Toward social implementation of this technology

① Induction of routine checks

- Application of routine checks for bridges (once every five years).
- --- Promoting a paradigm shift from visual checks
  - to non-destructive evaluations with scientific evidence ---

#### ② Device rental & sales

- The enhancement of its visibility and reputation to consultants and inspection companies through rental services.
- => The establishment of the position as the representative tool that can detect rebar corrosion.

#### ③ Technical training

- Penetration in the association. (The Japanese Society for Non-Destructive Inspection etc.)
- (4) Technological assistance and sales overseas

Cooperation and spread of activities with American bridge maintenance companies.







### R&D of Backscatter X-ray Imaging System for Concrete Inspection

Principal Investigator Hiroyuki Toyokawa (group leader, AIST)

Collaborative Research Groups BEAMX Corp., Nagoya University

#### **R&D** Objectives and Subjects

#### Objectives

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Social infrastructures in Japan are aging rapidly. Sixteen percent of the 700,000 road bridges of 2 m or longer are 50 years or older, at present. This percentage increases to 40% in the next 10 years, and will be 65% in 20 years. We try to find damage and defects in concrete structures at an early stage so that we can make the lifetime of the concrete structure longer. There are expectations for the development of a novel method to evaluate defects in concrete structures non-destructively.



#### Subjects

The development of x-ray backscatter imaging system is our technical goal. The system must be portable, robust, and reliable. A high-energy x-ray generator, which emits Bremsstrahlung x-rays of up to 1 MeV in electron energy will be developed. A novel x-ray imaging detector for backscattered x-rays with high efficiency and high spatial resolution has to be developed.



Good: Flexibility in sample shape and location
 Bad: Scan depth is limited to 3 cm

#### **Current Accomplishments (1/2)**

C-band X-ray, a portable x-ray generator based on an electron accelerator





Machining of cavity





③ C-band X-ray

④ Radiography

#### One-dimensional multi-slit x-ray imaging detector •





(2) Scintillator



③ X-ray camera

#### **Current Accomplishments (2/2)**





We have succeeded in developing a one-dimensional multi-slit x-ray imaging detector, which is like a line sensor for backscatter x-rays. A fan-beam x-ray is irradiated onto a concrete slab in area of 20 cm x 5 mm, and the backscattered x-rays from the concrete slab are distinguished by the novel detector.

Goals			
Milestone / achievement level			
	Item	Milestone	Achievement
	Imaging inside concrete	Recognize rebar of 1 cm diameter in concrete with cover depth of 10 cm	Cleared
Inspection of defects of a	Recognize 20% density degradation of concrete under asphalt of 8 cm thickness	Cleared	
	roadbed	Recognize pot-hole under asphalt of 8 cm thickness	Cleared

#### Roadmap being on the market



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#### C-band x-ray: 700 – 900 keV, 2 Gy/h

We have succeeded in developing a table-top electron accelerator-based high-energy x-ray generator "C-band X-ray", which generates x-rays of 900 keV or higher with 2 Gy/h.

#### One-dimensional multi-slit x-ray imaging detector



Backscatter x-ray image of a rebar in concrete T. Tooyama, 76th JSAP Autumn meeting, September 2015





# **R&D of Vibration Imaging Radar**

Principal Investigator Hitoshi Nohmi (CEO, Alouette Technology Inc.)

Collaborative Research Groups Waseda University, Saitama University, Tokyo University

### **R&D** Objectives and Subjects

#### Objectives

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By development of vibration visualization radar (VirA), we aim for improvement of safety and efficiency of inspection/monitoring of infrastructure, such as bridges and elevated roads.

- Monitoring Capability Safety and Efficiency
- Extract vibrations in infrastructures from observed radar phase images · Measure vibrations without blocking traffic.
- · Easy to transport and install.
- Non-contact vibration measurement system.

#### Subjects

- 븆 Develop vibration imaging radar system (VirA) using Digital Forming Technology. VirA observes infrastructures, such as bridges, as radar phase images up to 1000 times per second, and extracts vibrations at specific points. VirA measures (displacement) and variation as images with a vibration amplitude  $\leq 0.1$  mm, max. vibration frequency 500 Hz and an operational range of 100 m to 10 km.
- Develop a vibration analyzing algorithm and visualization program.
- 4 Investigation of required measurement accuracy for infrastructure monitoring.
- Comparative verification with conventional infrastructure monitoring equipment.
- Application to infrastructure monitoring.

#### **Current Accomplishments (1/2)**

Contrast table of VirA Target specification and verification confirmation results

-				
No		Target Spec	Result	
1	Observation Angle	EL : 30 degrees AZ : 45 degrees	EL : 30 degrees AZ : 45 degrees	
2	Observation Range	100 m~10 km	Confirmed range 30 m~4,500 m	There is no place to confirm for more than 4,500 m.
3	Azimuth Resolution	0.5 degrees	0.5 degrees	
4	Imaging Reputation Speed	500 times/Sec	500 times/Sec	
5	Vibration Frequency	250 Hz MAX	250 Hz MAX	
6	Vibration Amplitude	≦0.1 mm	≦0.1 mm	
7	Consumed Power	4 RX Module ≦300 W 6 RX Module ≦400 W	4 RX Module 250 Wtyp 6 RX Module 350 Wtyp	
8	Size	2,000 (W) x 1,50 ≦70 Kg (without (6 Rx Module)	00 (D) x 1,600 (H) mm mounting base)	





(Displacement comparison with LDV)



(TX Module)

If) 2m 16ch×4Modu

(RX Module)

100

16ch × 2Module

(Frequency histogram comparison with LDV)

#### **Current Accomplishments (2/2)**

### (Analyzed example of a bridge girder)

- · Display acquired radar data as 1ms frame rate movie







(Comparison measurement with LDV)



## Inner Defects Inspection for Tunnel Lining using Rapidly Scannable Non-contact Radar and Synthetic Soundness Diagnosis System

Principal Investigator Toru Yasuda (Technical Director, Pacific Consultants Co., Ltd.)

Collaborative Research Groups Walnut, iSystem Research, Sanei, Forum8

#### R&D Objectives and Subjects

### Objectives

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- ① The 1<sup>st</sup> Objective of this study is to develop an inspection technology detecting the inner defects for concrete lining using a rapidly scannable non-contact radar as a complement of hammering test.
- ② The 2<sup>nd</sup> Objective is to develop a synthetic diagnosis system to comprehensively assess soundness, as well as a database compilation of various conditions of unsoundness, including inner defects, by 3D visualization technology.



### **Current Accomplishments (1/2)**





#### Goals

Ac	chieved goal and level	
Items	Achieved goal	Achievement level
Radar system	System configuration • Detection accuracy : 80% • Longitudinal direction 5 cm Sectional direction 1 m • Detection depth : 20 cm	<ul> <li>Radar system completed</li> <li>Successful reception of target inner defect signal</li> <li>Detecting depth : 20 cm over</li> </ul>
3D visualiza- tion system	<ul> <li>Position &amp; lining joint synchronization,</li> <li>Damage progressive evaluation S/W</li> <li>3D visualization VR S/W</li> </ul>	<ul> <li>Position &amp; lining joint synchronization completed</li> <li>Progressive S/W completed</li> <li>3D visualization completed</li> <li>DB iTAMS completed</li> </ul>

#### Social Implementation Image

	Exit strategy	Target	Schedule, remarks
1	Application for inspection works of radar & S/W	Own works, lending to others	Expand quickly after SIP termination We aim to increase our share to about 20% in 5 years.
2	Support and supplement for close inspection and hammering test	Ministry of Land, Infra & Transport, etc.	Linking with trial of next generation social infrastructure robot promotion, standardization by reviewing the inspection revision procedure
3	Technical guidance, consultation in the field	Municipalities	Linking with SIP program of Gifu University, etc. Promotion of diagnosis system
4	Radar & S/W sales to domestic and overseas	Consultant, inspection companies	Radar system: Sales of about 5 units per year S/W : Sales of about 10 units per year
5	Overseas expansion of measurement works & technical assistance	ASEAN	Overseas business model using mobile measuring vehicle Radar measurement service Application using diagnostic software







#### Remote sensing of concrete structure with the high-sensitive 10 near-infrared spectroscopy



New technology implemented in our equipment

#### Principal Investigator Kazuhiro Tsuno (Shutoko Engineering Co., Ltd.)

Shutoko Engineering Co., Ltd., AIST, Tohoku University, Fuji Electric Co., Ltd., Collaborative Research Groups Sumitomo Electric Industries, Ltd.

#### **R&D** Objectives and Subjects



### **Current Accomplishments (1/2)**



#### **Current Accomplishments (2/2)**

oQuantification of salt damage by Multi-component analysis



oVisualization of the amount of water distribution (bridge pier)





Visible camera image

#### Goals

#### **Final Numerical Targets**

- 1. Remote diagnosis of water and chloride content at the surface of concrete at 3 m intervals.
- 2. Measurement time: 10 sec per 1 m × 1 m area.
- 3. Equipment weight: under 5 kg

#### Concept Illustration of New Maintenance



Contour diagram of concrete deterioration distribution by remote diagnosis via primary screening. Labor-saving by extracting maintenance positions with high priority.

Analysis of concrete data

### New Business Concept

- 1) Application in the primary screening of reinforced concrete structures
- 2) Evidence of a long-term maintenance plan against fatal deterioration

#### Inspection Service with Consulting Support







# R&D of learning-type hammering echo analysis technology



Conventional

approach

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judgment

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Proposed approach

In addition to the amplitude informatio

of each frequency component, focus o

(Extract features that can be used

between judgment examples of experts

Multivariate analysis

Ex.) With or without hollow

Objective judgment 🔶

Automatically learn the relationship

and feature values

characteristics in time domain

#### Principal Investigator Masahiro Murakawa (Team Leader, AIST Artificial Intelligence RC)

Shutoko Engineering Co., Ltd., East Nippon Expressway Co., Ltd. Tohoku branch, Collaborative Research Groups Nexco-Engineering Tohoku Co., Techny Co., Ltd.

### **R&D Objectives and Subjects**

### Objectives

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Hammering echo signal analysis based on machine learning Improvement of hammering echo device as the first stage of inspection

#### -Easy and Reliable

- -High precision (detection of damage in difficult areas even by experts)
- -Reduction of total man-hours, including report preparation
- Realization of quantification and accumulation of hammering inspection results, and their visualization

#### Subjects

- · Digitalization of hammering echo, and anomaly detection by its collection and analysis
- · Using acoustic signal analysis based on machine learning, automatically distinguish hammering echo differences and detect damaged parts of structures
- · Develop a device which is usable in combination with an ordinary inspection hammer, validate the proposed approach in an actual structure

#### **Current Accomplishments (1/2)**

- Learning in two stages
- Even at the phase where data with supervised labels is not sufficiently gathered, the presence or absence of anomalies can be judged at the first stage
- Corresponds to the differences of the hammering echoes triggered within various structure types
- Applicable toward any hammering equipment by virtue of its versatility

First stage: unsupervised learning method

Feature value

Statistica

analysis

Judgment

Normal or abnorm

Types of anomalies

- · Learn what is "normal" on site for each structure under examination
- · Define the degree of anomaly as deviation from the learned "normal"
- Calculate the degree of anomaly for each hammering point
- Second stage: supervised learning method
- · Accumulate the judgment results in the first stage with supervised labels
- · Decision learning based on accumulated results
- · Improve decision accuracy of presence / absence of anomaly

#### Validity verification experiment on a tile-hitting echo test in a tunnel





Even in a noisy tunnel it was possible to reliably find an area where some tiles are floating

Confirm that it is an extremely noise-resistant method of analysis

#### **Current Accomplishments (2/2)**

#### Development of a hammering device for difficult-to-inspect points

#### · For hammering of unreachable areas in abutments, piers, etc. · Detection of internal defects in concrete, not only the exfoliated areas Reduction of man-hours for scaffold installation

- Uses a solenoid for hammering actuator •
- Introduces a mechanism that allows the part hitting the surface lines up well with the target Used in conjunction with automatic trace acquisition system of
- hammering (under development)

investigation

# Development of handcart-type

hammering device

#### Current manual hammering echo inspection





Developed device (prototype ver. 2)



- ① Set up a development system that continually improves the technology
- 2 Deploy the developed equipment with technical consulting / support from SIP regional bases
- ③ Provide an analysis engine as SaaS (Software as a Service)
  - Intensive system administration and operation
  - · Stable supply of services and permanent upgrade



Evaluating experiments for test pieces and actual bridges of local governments

Grasping damage conditions of the floorboards before pavement excavation (non-destructive investigation)

Detection of slab deterioration or cracks in the asphalt pavement surface Reduction of man-hours and excavation costs of hammering echo



vance by hand pushing, approx. 1.5 km/h speed



floorboard Interface fracture between thickening part and floorboards



### Inspection and diagnosis system of port structure using radio controlled boat



Capturing images by the

radio-controlled boat

Create 3D models

Extraction of

orthochromatic images

Register orthochromatic

images in the software

Extract damaged parts

Determination of the

degree of deterioration

Deterioration diagnosis flow of

this technology

### Principal Investigator Tetsuya Ogasawara (Penta-Ocean Construction Co., Ltd.)

Collaborative Research Groups Penta-Ocean Construction Co., Ltd.

#### **R&D** Objectives and Subjects

#### Objectives

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- (1) To install a camera on a radio-controlled boat via a high-performance oscillation suppressing device in order to develop a system that should capture the images of the lower sides of piers efficiently while suppressing the effects of wave shaking.
- (2) To diagnose and monitor deterioration by image analysis and to conduct experiments for the efficient maintenance and objective management of port facilities.



#### Current Accomplishments (1/2)

Establishment of a comprehensive inspection and diagnosis system using a radio-controlled boat and designated software

- Using a radio-controlled boat and designated software developed in 2014 and 2015, we investigated the bottom of the pier and verified the importance of this system in 2016.
- $\circ~$  After the creation of 3D models by SFM / MVS from the captured images, we extracted the orthochromatic images. Upon the comparison of the diagnosis results of the software with the results from humans, both were found to be in agreement. Thus we have confirmed the benefits of this technology.



Investigation conditions of the actual pier using a radio-controlled boat

#### Advantages of this technology

- A person without specialized knowledge can inspect and diagnose without going 1 directly to the lower pier.
- 2 Investigation speed is doubled → Increases efficiency of inspection.
- 3 Accumulation of objective data by images  $\rightarrow$  Understanding the state of deterioration quantitatively, even upon the change of the person in charge.
- **(4**) From the 3D models, the state of deterioration can be understood with ease.
- (5) Reduces the burden on inspectors while surveying in narrow places and prolonged surveys.
- 6 Post-processing can be done efficiently using this software. It is possible to understand the state of deterioration quantitatively and compare the temporal changes in deterioration.



#### **Current Accomplishments (2/2)**



	O Inc
	O Th wi inv pe

- them in magazines



34

35



# Development of the special GPR including a chirp radar in the survey of a cavity and a settlement of the back-fill material

Principal Investigator Shigeji Yamada (KAWASAKI Geological Engineering Co., Ltd. Business Division, Metropolitan Area Maintenance Director)

### **R&D** Objectives and Subjects

#### Objectives

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As a new technology, "Vehicle traction type GPR for deep cavities", where we develop a searching depth, and "Multichannel GPR for cavities under reinforced concrete", where we apply cavity detection under reinforced concrete that is hard to detect, are introduced. We provide better discovery precision of cavities and loosening areas around quay walls than conventional techniques and improve survey costs reduction and monitoring systems.

### Subjects

<Vehicle traction type GPR for deep cavities>



We apply asphalt pavement to quay walls

Ability to detect deeper than using conventional technology Ability to detect cavities and settlements of back-fill material.

Improvement of operational efficiency by vehicle traction.

<Multichannel GPR for cavities under reinforced concrete>



We apply apron pavement to the guay wall Ability to detect cavities under reinforced concrete that it is hard to detect with conventional technology. Improvement of operational efficiency by investigating 3 survey lines at the same time.



### **Current Accomplishments (1/2)**

#### <Vehicle traction type GPR for deep cavities>

- <Results>
- · Resolution of cavity detection is less than 10 cm when monitoring
- · Ability to detect back-fill material through the improvement of search depth.
- · Improved operational efficiency by setting survey lines with GPS





· 2015/9/29

Detect a cavity

of the cavity

GL-0.90 m

ately 1 m



Operation flow

#### Monitoring of the cavity









Cavity width

Vertical extension velocity of the cavity Before earthquake : 15 cm/155 days 0.1 cm/day After earthquake: 35 cm/190 days 0.18 cm/day

### **Current Accomplishments (2/2)**



### Goals

#### Final targets

thi	Targets	Degree of achievement	Further consideration
Vehicle traction type GPR for deep cavity	<ul> <li>Ability to detect cavities and back-fill material</li> <li>Resolution:10 cm</li> <li>Improvements of operational efficiency</li> <li>Ability to detect deeper than conventional technology (from 1.5 m to 3 m)</li> </ul>	<ul> <li>Resolution: less than 10 cm</li> <li>Improved operation efficiency by the setting of a survey line by GPS</li> <li>Ability to detect back-filling material under 3 m</li> <li>Cost reduction by system improvement</li> </ul>	<ul> <li>Examination of technology with objectivity</li> <li>Examination of determination method by a third person</li> </ul>
Multichannel GPR for cavities under reinforced concrete	<ul> <li>Ability to detect cavities</li> <li>Resolution 10 cm</li> <li>Ability to detect under reinforced concrete</li> <li>Improve operational efficiency</li> </ul>	<ul> <li>Ability to detect cavities of less than 5 cm in thickness</li> <li>Ability to detect cavity under reinforced concrete with a thickness of 38 cm</li> <li>Improved operation efficiency by multiple surveys</li> </ul>	<ul><li>Monitoring (cavity range expansion)</li><li>Examination of determination method by a third person</li></ul>

#### Advantage of new technology

実施項目	Rate of cost reduction	Labor-saving efforts
Vehicle traction type GPR for deep cavities	15% decrease	• Field - work Days: 1/5
Multichannel GPR for cavities under reinforced concrete	19% decrease	<ul> <li>Field - work Days: 3/5</li> <li>Analysis Days: 2/3</li> </ul>







# 14 Development of the Monitoring System for Port Facilities using Satellite and SONAR

Principal Investigator Takeshi Nishihata (Penta-Ocean Construction Co., Ltd.)

Collaborative Research Groups Japan Aerospace Exploration Agency (JAXA)



#### **Current Accomplishments (2/2)**



Evaluated accuracy of ALOS-2 observation with experiment model. Marked 1.0cm std. for avarage of every observation and 0.4 cm std. for every observation





Goals

Time flow for practical use



Validation and improvement for these application is planned to be continued.

ALOS/AVNIR-2 ©JAXA

11.2.10

Detected damages on roads

(red plots)



Measurement method, feature and Goal			
	Satellite	Sonar	
Application scene	<ol> <li>Port facility deformation monitoring at disaster</li> <li>Periodic inspection of port facility</li> </ol>	<ol> <li>Grasp obstacles under sea on disaster</li> <li>Periodic inspection of port facility under sea</li> </ol>	
Applicable condition	<ol> <li>Emergency satellite observation at disaster within 12 hours in Japan</li> <li>Differencial InSAR : cm order accuracy by using 2 scenes</li> <li>Timeseries InSAR : mm order accuracy by using 15 or more scenes (data acquisition pace : 4scenes per year)</li> <li>Range : 50 * 50 km square</li> <li>Horizontal resolution : 3m</li> </ol>	<ol> <li>Rigging and initiallization requires 3 days for real time monitoring.</li> <li>Detection of deformation by cm order of coastal facilities         <ul> <li>inspection area 50°×50°(beam resolution with 0.4 deg)</li> <li>maximum scope depth 150m</li> <li>significant wave height under 2m</li> </ul> </li> </ol>	
Cost	<ul> <li>Satellite data's cost</li> <li>Personnel expenses</li> </ul>	<ul> <li>Leasing cost for sonar system</li> <li>Ship and labor expenses</li> <li>Personnel expenses for analysis</li> </ul>	
<ul> <li>Manualization about deformation monitoring at disaster and periodic monitoring by FY30.</li> </ul>			

#### Obtain patent, article submission

Domestic/Overseas practical use



## Monitoring by using Ground-Base Synthetic Aperture Radar and Array-type Ground Penetrating Radar

Motoyuki Sato (Professor, Tohoku University) Principal Investigator

#### Collaborative Research Groups Tohoku University, NICT

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#### **R&D** Objectives and Subjects

#### Objectives

- · Quick and wide area monitoring of taxiways and runways
- Innovative technology combining Ground–Based Synthetic Aperture Radar (GB-SAR) and Ground Penetrating Radar (GPR)

#### Subjects

- Quick detection of surface anomalies by **GB-SAR** in large areas
- · Repeat monitoring every 5 minutes.
- A 400 m x 400 m area can be observed within 10 seconds.
- · Understanding of the surface conditions of pavement



Introduction of new methodologies using electromagnetic waves that replaced conventional sounding tests

#### Precise inspection by GPR

- Up to 1 m depth in pavement
- 2 cm resolution
- · Understanding the condition of the 2 cm thickness layer



GB-SAR

### **Current Accomplishments (1/2)**

#### • GB-SAR Validation at Haneda airport

- Set a GB-SAR on the roof of a building for continuous monitoring of the ground surface of Runways and Taxiways
- Interval measurement (Minimum 1 min.) and displacement detection by Interferometry (Minimum 0.2 mm)
- 17 GHz(Ku band) frequency
- · All weather, day and night, 24-hour monitoring
- Automatic early warning

#### Phenomena observed by GB-SAR

- · Deformation of the pavement surface caused by blistering
- · Deformation caused by the weight of airplanes
- Debris

#### Advantages of the use of GB-SAR

- Full automatic measurements
- · Automatic detection of anomalous displacement
- · Detection of the fast rate change of displacement
- · Continuous monitoring
- Five year continuous monitoring was conducted by our group at Miyagi prefecture for land slide monitoring
- · Acoustic sounding inspection cannot be used for continuous measurement



GB-SAR system installed at Haneda airport



Interferometric SAR image of the pavement surface obtained at Haneda airport

#### **Current Accomplishments (2/2)**

#### GPR Validation at Taxiway at Haneda airport

- in real time
- good agreements
- sounding test detected the anomaly.





Goals

#### Final Goals

- ★ Cooperative operation of GB-SAR and GPR
- Wide area monitoring by GB-SAR (Continuous) 400 m x 400 m in 3 minutes, detection resolution 1 mm
- · Precise measurement by GPR (Anomaly points detected by GB-SAR) Measurement resolution 0.5 cm, Up to depth of 50 cm
- ★ Life Time
- GB-SAR 20 years
- · GPR 20 years

#### **Expected Deployment**

- Daily Monitoring
- · Continuous monitoring by GB-SAR
- · Automatic warning, if a surface anomaly is detected
- · Automatic announcements for the operator
- · GPR measurement of the spots where GB-SAR has detected an anomaly
- · Alternatively, regular inspection by a vehicle mounted GPR is also possible

#### Regular Inspection

· Regular inspection of planned areas by a vehicle mounted GPR

Cross-ministerial Strategic Innovation Promotion Program

GPR



Measurement area by GB-SAR



GB-SAR arrangements to cover all the area of Haneda airport



## Monitoring system for a round of airport paved road inspection, utilizing a technique for detecting cracks automatically from high-resolution images.



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Collaborative Research Groups Alpha Product INC., Osaka Institute of Technology

#### **R&D** Objectives and Subjects

#### Objectives

 The objective of this research was to develop a system that could record the length and width of cracks on the surfaces of the runway of an airport and transcribe the obtained crack data on existing CAD plane views of the roads, to supplement the rounds of visual road inspections performed by an airport worker.

#### Subjects

#### <Automatic Extraction of Cracks>

 Images taken with two digital video cameras are processed automatically with dedicated software. Cracks extracted automatically from the images are displayed in different colors by width (in 0.5 mm increments). The length of the cracks is aggregated by width.

#### < Conversion and Transcription to CAD Data>

 The obtained data is converted into DXF format and transcribed correctly onto the existing plane views (CAD) drawings) of the airport based on GPS coordinates and azimuth orientations measured at the start of shooting the video.

#### <Shooting System>

- The video is recorded by two persons using a handcart. Combined use of a laser pointer allows the operators to maintain linearity. The shooting system is capable of taking images of an area approximately 12 m × 3,000 min 5 hours. The system can also be moved with a tug vehicle.
- The shooting system can be disassembled to load on the work vehicle. The system is assembled by two persons. Assembly and disassembly time for the system is approximately 30 min and 15 min, respectively.
- · All devices of the system use a rechargeable battery as power source. The estimated operating time of the system is approximately about 4 hours at a temperature of 0 °C.
- · Use of a Doppler laser range finder allows correct measurements of moved distances.

#### **Current Accomplishments (1/2)**



#### < Automatically Extracted Crack (No. 10) >

The figures below show Crack No. 10 and the aggregated lengths of the crack by width. The crack is indicated in different colors by width.



\* Examples of an actual image and the extracted crack

A series of images are pieced together and stored separately. The stored images are available for viewing anytime.



#### **Current Accomplishments (2/2)**





< Real-time Image Display >

Images can be displayed on large monitors (2 pcs) in real time.

#### Goals

Intellectual property rights acquisition and trademark registration The automatic crack extraction technique has been register the New Technology Information System (NETIS) of the Minis Land, Infrastructure, Transport and Tourism (registration No.: NETIS KT-130046-V).

The shooting system, FOCUS-α, has been registered trademark.

- The following three business models are under consideration
- 1. Sales of the entire system, including the analysis soft Estimated price: Approximately JPY 20 million to JPY 25 m
- 2. Sales of the shooting system alone. Data analyses with performed by our company.

Estimated analysis charge (at this time): Approximately JPY 5,600/100 m<sup>2\*</sup>

- 3. Sales or rental of the automatic extraction software with a extraction accuracy, and the image connection and CAD conversion software Estimated price : Approximately JPY 2 million to JPY 3 million
- \* Image connection (per 100 m) and crack data extraction.

CAD data conversion will be charged separately.

As of January 2017

Data of a tunnel segment pressure breaking test by elapsed time (in one-minute increments) Photos (i)-(iii) show development of the crack over time.

ation	Specifications of Shooting System		
ed in	Item		Video camera cautious shooting
try of	Shooting Method		Continuous shooting while moving
,	S	hooting Area-hours	10,220 m²/h
	E	xtraction Accuracy	0.35 mm
		Shot Image	8,800,000 pixels
as a	S	hooting Equipment	4K digital video camera
		Focal Distance	37 mm
	Num	ber of Video Cameras	2 pcs
		Lighting	LED lights (used always)
n	Power Source		Rechargeable battery (internal/external
	Ancillary Devices 1		Aluminum handcart
ware	Ancillary Devices 2		Laser range finder/Red Laser
illion	Shooting Operation		Continuous shooting speed: 5 km/h
	Preparation for Shooting		Installation of the laser
ill be	Shooting	System Transport Vehicle	1 (carrier)
		Automatic Crack Extraction	Automatic continuous extraction
fixed data	Image	Color Classification of Crack by Width	With
	Processing	Image Connection (per Shooting Direction)	Automatic connection
		Image Connection (Another Camera)	Automatic connection
on	Crack Date	e Conversion into DAD Data	Dedicated software is used

#### Data Processing Specification

Item	Automatic crack extraction from images	
Extraction Accuracy	For runway: 0.35 mm (0.1 mm max.)	
Processing Speed/Image	Approx. 4 seconds	
Number of Processing Steps	5 steps	
Adjustment of Processing Steps	Automatic adjustment (after making settings)	
Applicable PC	Core-i7 3 GHz or more, RAM 32 GB or more	



### R&D of the crack detection system for runways with a 3D camera and all direction-moving robot



Principal Investigator Yasuo Kimura (NTT Advanced Technology Corporation, Network Service Innovation Business Unit)

#### **R&D** Objectives and Subjects

#### Objectives

Subjects

Cracks appearing on the surface of runways bring degradation of asphalt and causes surface peeling. The large-scale surface peeling affects the operation of aircraft. The large parts of the actual crack detection are manual operation so that the detection performance depends on the human skill of inspectors.

We must improve this situation in the ordinal routine work of crack detection. Our object is to develop a high-performance crack detection system by using 3D cameras mounted on an all direction-moving robot.



Source: MLIT "Variation of asphalt pavement and curren status of airport paving inspection technology'

The crack detection system for runways with a 3D camera and all direction-moving robot is able to quickly detect the many types of cracks on runways by analyzing 3D data automatically captured by 3D cameras mounted on an all direction-moving robot.



### **Current Accomplishments (1/2)**

#### All direction-moving robot

We have developed the all direction-moving robot with a low-positioned center of gravity, three-wheel moving configuration, and spring dumper for suspension in order to suppress the affection for the 3D data due to unevenness of the road surface and due to wandering when moving and stopping. We have realized the automated crack detection system for runways by the fact that our system can capture 3D data automatically without moving conditions and send to the data server.



#### **Current Accomplishments (2/2)**

#### Reduction of wasted time in analyzing data

Typical 3D data requires much processing time due to the shooting process, data transfer, and data analysis. We can obtain a total processing time of 30 seconds for 3D data corresponding to a 70 MB data file (70 cm x 50 cm square area) compared with our prototype processing system. With one 3D camera system, it takes one thousand hours to execute crack detection for the whole runway of a typical airport. To reduce the processing time, we can show the demonstration of our system in cases of operating four 3D cameras simultaneously, as below.



#### Data mapping

- We can manage the measuring 3D data and show the resulting cracks on the map. The main features of our system are as follows:
- (1) Tree view display and data storing
- (2) Balloon display of data
- (3) Measuring data display in detail
- (4) Graphically display the measured data

It is easy to identify the cracks with collaboration in the mapping system, which can improve the performance of crack inspection in the field.

#### Goals

Achievement	t of Goals	Su	
Items	Achievement of items		
3D data capturing	<ul> <li>250 hours sweeping time for runway area (Width 60 m × Distance 3,000m) with a four camera configuration.</li> <li>750 hours aata analyzing time with 8 server multi-operation system</li> </ul>	PHASE I	
Detection of cracks	<ul> <li>linear cracks with more than 1 mm width can be detected automatically</li> <li>alligator cracks can be detected with a manual assistance.</li> </ul>		
Visualization of monitoring data	<ul> <li>monitoring data can be projected onto the map</li> <li>3D graphical representation</li> </ul>		
Concrete p	roduct concepts	Ne	
<ol> <li>Alternative insortion</li> <li>support and runways</li> </ol>	spection method for ordinal inspection assistance of ordinal inspection work for	①Ar	
<ul> <li>② Crack detection system business for promotion</li> <li>automated crack detection system</li> <li>3D surface analyzing system</li> </ul>			
<ul> <li>③ Technical cor</li> <li>• system supp</li> </ul>	nsulting ort and consulting for different fields		
④ New Busines	S		

· New Monitoring services for building and other structures



### upport for ordinal inspection



High precision and effective inspection can be performed by using 3D data analyzing with our programed robots.

#### ew concept of crack monitoring system rea assigned inspection ②Full inspection with many robots We capture assigned areas divided by a 3D camera's pixels and . send their Robot 2 data to the server system Many robots cover the inspection area Full inspection Area restricted simultaneously inspection





## 18 R&D of a Simplified System for Monitoring the Airport Pavement Surfaces Using Maintenance Vehicles



### Principal Investigator Yusho Ishikawa (Professor, The University of Tokyo)

Collaborative Research Groups The University of Tokyo, Pacific Consultants Co., LTD., Social Capital Design, Inc.



### **Current Accomplishments (1/2)**

#### A. Simplified system for monitoring airport pavement surfaces

- ♦Technical challenges
- Develop easily operable system that can be operated by airport administrators
   Monitoring system that can acquire large amounts of detailed data over a short duration of maintenance
- ♦Current system conditions
- Develop a measuring dolly that is equipped with an optical camera, infrared sensor, and GPS device and then mount this on a vehicle owned by the airport administrators so that it can be used during pavement inspections
- Must be able to acquire and accumulate data and take pictures at vehicle speeds of 30 km/h
- Ultimate goal
- Accurately determine surface cracks that are 1 mm or wider and deformations at vertical and horizontal resolutions of 5mm and 3cm, respectively



B. System for discriminating airport pavement surface irregularities

- Technical challenges
- $\succ\,$  Generate wide-area images that cover the entire airstrip surface
- > Discriminate road surface deformation to a high degree of accuracy
- Current system conditions
- Be able to integrate images from video camera to generate wide-area images that cover the entire airstrip surface
- Detect alligator cracks and linear cracks that are 1mm or greater from these integrated images and then record them in a database (DB) with the position they were detected in
- Detect and record deformations with a depth of 1cm based on the irregularity information obtained by an infrared sensor









Discriminate deformations while excluding grooves

#### **Current Accomplishments (2/2)**

#### C. UI for a system to identify distress on airport pavement

- Technical challenges
- Accumulate deformation data through several on-site verification tests and determine if there have been changes over time
- > Find connections with previous data
- Current system conditions
- Visualize deformations and past conditions using functions such as deformation lists, evaluation level distribution, wide-area overhead pictures, and deformation stacked viewing
- Administrator can refer to the same information using an office PC or an on-site tablet terminal

D. Verification of the advancement of maintenance control work

- Improving work efficiency using data analysis
- Use data obtained from the system to not only understand daily pavement deformation but also apply data analysis to extract deformation trends and regularity
- Improve maintenance control work using verification data
- > Understand on-site needs to verify efficacy of various systems
- Verify results from verification tests to achieve higher efficiency for procedures based on system implementation and current pavement inspections
- Advance on-site work by developing a guide application function that can improve the driving accuracy during monitoring

#### Goals

Objectives		
Application Items		Objectives
A : Simple monitoring system	Detect 1mm wide su resolutions of 5mm a	Inface cracks and view deformations at ho and 1cm, respectively
B : Deformation discrimination system	Create linking image positions, discrimina	es of airstrips, display high-speed images te linear/alligator cracks, and record dam
C: UI development	Create user informa airstrip, showing fluc units	tion that can distribute deformation trends stuation in damage rank, and understand
D : Advance maintenance control	Analyze trends such deformation databas pavement inspectior	as temporal changes and spatial distributes. Example: Establish work procedures with improving
<ul> <li>Service Provider</li> <li>System lease/maint inspection]</li> <li>Sales, maintenance for a simple pave system</li> <li>Perform repairs w malfunctions</li> <li>Improve and modify</li> <li>(Provide services that advanced maintenan</li> <li>Confirm and anal trends by analyzicollected during in status, and usage st</li> <li>Provide proposal t improved efficiency control work</li> </ul>	tenance and a, and inspection ement inspection when a system the system at relate to ce control work] yze degradation spections, repair iatus that will lead to for maintenance	<ul> <li>Airport Manager</li> <li>Used by administrators</li> <li>Dolly used for airport</li> <li>Control</li> <li>Used by administrators</li> <li>Used by adminited by adminited by administrators</li> <li>Used by admin</li></ul>
Providi	ing services for da	ily pavement inspections







nance contr work

1



Development of wide area displacement monitoring for early detection of deformation or damage of civil engineering structures using satellite SAR



Principal Investigator Masafumi Kondo (National Institute for Land and Infrastructure Management)

#### **R&D** Objectives and Subjects

#### Objectives

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Monitoring displacement of many civil engineering structures both in normal times and after natural disasters by utilizing satellite SAR data covering a wide area without sensors on the ground surface



We are conducting the following studies to develop a new displacement monitoring method using satellite SAR as a core technology

- ①Development of a monitoring method for practical application for rockfill dams
- 2)Research on applicability for concrete dams or other structures
- ③Development of a reliable monitoring method combining SAR, conventional survey, GPS, etc.

#### **Current Accomplishments (1/2)**

(1) Trial of displacement monitoring for five rockfill dams in one scene using ALOS/PALSAR data Target dams : Five rockfill dams

Data used : ALOS/PALSAR (2006-2011) (Spatial resolution:10m, wavelength: 23.6cm (L-band))



Difference between SAR and conventional survey / GPS

	Current surveying method	Average error (RMSE) (unit: mm)	
Taiho subdam	GPS	6.0	
Haneji dam	conventional survey, partially GPS	4.4	
Fukuji dam	conventional survey, partially GPS	4.3	
Kanna subdam	conventional survey	5.5	
Benoki dam	conventional survey	6.7	



Example of displacements of Taiho subdam after several years from completion using ALOS/PALSAR



Displacement obtained by satellite SAR was in good agreement with GPS (average error: 5 mm).

We have confirmed that displacement monitoring by satellite SAR is practical for rockfill dams, wing good accuracy

Comparison of displacement between SAR and GPS

Sato et al. : Interferometric SAR time series analysis for external deformation monitoring of five rockfill dams using ALOS/PALSAR data, Journal of JSCE, F3, Vol.73, Jan 2017.

#### **Current Accomplishments (2/2)**

(2) Trial of displacement monitoring for various rockfill dams across Japan using ALOS-2 data Target dams : Nineteen rockfill dams Data used : ALOS-2 (2014-) (Spatial resolution 10m, wavelength 23.6 cm (L-band))







Example of displacements of Taiho subdam dam after about ten years from completion using ALOS-2

Locations of dams

Target dams were selected across Japan

for future practical use in many dams Applicability for concrete dams is under study



Comparison of displacement between SAR and GPS

#### Goals

[Current progress for final goals]

- (1)For practical use of satellite SAR for deformation monitoring of rockfill dams
  - Accurate displacement measurement in normal times
  - Wide and early displacement measurement after earthquakes
- 2 Research on applicability for deformation monitoring of concrete dams or other structures Trial measurement for concrete dams (under study)
- ③Development of a reliable monitoring method combining SAR, survey, GPS, etc. · Accurate displacement monitoring by satellite SAR at places without displacement data (under study) · Reliable monitoring technology combining satellite SAR and other methods (conventional survey, GPS, etc.) (under study)

#### [Final Goals]

- Realization of efficient and effective displacement monitoring by combining satellite SAR and other methods
- · Contributing to improvement of monitoring technology for life expansion of civil engineering structures, including dams, by complementary use with conventional methods





Displacement obtained by satellite SAR was in good agreement with GPS (average error: 2 mm).

We are continuing further studies toward practical use for rockfill dams.

Preparation of technical manual for satellite SAR

based displacement monitoring of rockfill dams





Understanding the scouring situation by ALB (Airborne Laser **Bathymetry**)



Principal Investigator Hiroaki Sakashita (PASCO CORPORATION)

### **R&D** Objectives and Subjects

#### Objectives

 To establish a monitoring methodology to quantitatively evaluate the scour of pier foundations under the water surface by utilizing ALB (Airborne Laser Bathymetry) measurement



#### R&D Contents (2014 – 2015)

Comparison and analysis with conventional method (shallow survey), evaluation of ability to understand the scouring situation  $\rightarrow$  Ensuring the same accuracy as in the past and implementing safe and efficient measurement of wide riverbed topography.



1. ALB survey, bathymetry

Development of efficient and effective scouring monitoring methodology using ALB Effective scouring monitoring by efficiently understanding the amount of surface river bed variation in 3D shape of scouring, which was difficult previously.



me accuracy



3D display of scouring s

Contribution towards efficient and effective facility management

### Current Accomplishments (2/2)





#### Services to Offer

Acquiring 3D topography data for monitoring scour situation around the piers.





Acquisition of high-definition 3D topography data Creation of cross-section at arbitrary position

Efficient comprehension of wide riverbed topography by aircraft → Utilization of scouring monitoring for the improvement of river management and bridge management

bridge.

(2014 - 2015)

of measurement results, and profit creation.



Monitoring scouring situation



## R&D of monitoring system for bridge performance assessment based on vibration mode analysis

Principal Investigator Tadao Kawai (Professor, Osaka City University)

Collaborative Research Groups IMV Coporation

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**R&D** Objectives and Subjects

Objectives

· Development of monitoring system for aged deterioration or damage of bridge based on vibration mode analysis.



#### Subjects (2014-2017)

- · Implementation of vibration monitoring system for bridge.
- $\rightarrow$  Remote system to monitor amplitude ratio of pole.
- · Development of estimation method for support performance of pole.  $\rightarrow$  Detection of a scoured or deteriorated pole.



(2014-2016)

### **Current Accomplishments (1/2)**



4. Scanning of river bed	5. Char
Detection of progress of scour by scanning around a pole with ultrasonic sonar before and after typhoon.	Close co amplitude scanning d
Bridge axis	Water lev
C C C C C C C C C C C C C C C C C C C	Average (Smol) 30° August 3 20° Septender 3 31° Septender 3
<ul> <li>Verification of correlation between scour and amplitude ratio for better estimation.</li> </ul>	<ul> <li>Detection progress amplitude</li> </ul>

**Current Accomplishments (2/2)** 

# Goals Numerical target Management cost cut of 50% by remote monitoring and efficient inspection Users Railway companies, highway companies, local governments, etc. How to use/Places of use Sales method Sale or rental of monitoring unit. Services to Offer

Attach sensors and radio gateway on pole of bridge to monitor amplitude ratio of pole through Internet connection.

> Rent WEB base cloud service for inspection and management of bridge.

ure:

ratio.

Offer useful services for quick correspondance in emergency and efficient management of bridge inspection.

Cost of typical system (20 poles)

Initial: 800,000x20=16,000,000 yen Management (year) 20,000x20+600,000=1,000,000 yen

Detection of scoured pole and efficient inspection

→ Quick correspondance in emergency and efficient management

52

(2014-2016)



Ш

TILL

1011



#### Creation of Monitoring System using Equipment with Robotic 22 Camera and etc. for Bridge Inspection

Principal Investigator Yasuhisa Fujiwara (Sumitomo Mitsui Construction Co., Ltd.)

Collaborative Research Groups Hiatchi Industry & Control Solutions, Ltd.

**R&D** Objectives and Subjects

#### Objectives

This research aims to develop a regular monitoring system to determine the information of a bridge deteriorated due to aging at locations that cannot be inspected at close range, such as girder ends and bearings.



The position of the camera can be

determined, enabling inspection the same

location.

Can exclude the environmental influences Can correct the color tone image of a location that cannot be inspected at a close range.



#### 4. Capture reference distance using stereo photography

3D configuration of the structures can be recognized by using stereo photography of 2 digital cameras. However, a reference distance on the structure's surface is required.

Therefore, an L-shaped scale of the robotic camera Which responds to inclined surfaces was developed to improve the accuracy of this noncontact measurement system



The accuracy of stereo photography in the case where the camera is not in front of the structure's surface was improved.





bridaes

Robotic camera for bridge inspection has been sold by Hiatchi Industry & Control Solutions, Ltd. and SMC Civil Technology, Ltd., and distributed for bridge inspection. Moreover, it is not only for sale but also for rental

Sales method

GPS, digital camera, and laser scanner should be prepared by the user by purchasing or renting from the market

### Services to Offer

- . The instrument for monitoring, consisting of robotic camera, digital camera, and laser scanner, is provided.
- A proper inspection technique to monitor girder end and bearing can be selected
- · An Internet database system is set up which can store the deterioration data due to aging
- ➡ The data can be referenced and edited by login to the system from the inspection site.

Monitoring which is useful for detecting the indication and change of damage becomes possible. Realize a monitoring system with high data access accuracy and ease of usability



Improves the damage detection performance. Improves the clarity of cracka





How to use/Places of use



Monitoring of girder end using robotic camera (Elevating Type)



Cloud service for storage system is provided by Hiatchi Indústry & Control Solutions, Ltd. and other service companies.

Inspection sheet (database)



### R&D of quantitative evaluation system of cracks on distant slabs by digital image analysis technology

Principal Investigator Kenichi Horiguchi (Taisei Corporation)



#### **R&D** Objectives and Subjects

#### Objectives

· Development of a system that can quantitatively evaluate the deterioration stage of road bridge slabs by image analysis



#### Subjects (2014-2018)

- Development of digital imaging technology by UAV and pole
- -> Realization of high-definition image shooting eliminating the influence of vibration
- · Development of image analysis technology capable of extracting and quantitatively evaluating planar damage
- → Estimation of area of free lime and hidden crack width
- · Image technology that can obtain analysis results quickly on site → Realization of faster processing using tablet PC



(2014-2016)

# **Current Accomplishments (1/2)**

#### 1. Shooting technique of distant and narrow spaces

Conventional inspection of bridge slabs is implemented by visual inspection and freehand drawing by inspectors. In this developed technology, it is possible to quantitatively calculate the width and length of cracks by creating a crack drawing from images taken with a digital camera mounted on a UAV or a pole.

# Result of crack image analysis Photographing by UAV

Crack length per width

- · Possible to shoot distant and narrow spaces of slabs
- Accurate drawing of cracks from digital images
- · Accurate calculation of crack width, length, and density Eliminate errors by inspector

#### Investigation of places using areas under the high bridges as stores Investigation of places where

installation of scaffolds is extremely difficult with remote island bridges

#### 2. Quantitative evaluation technique of planar damage

When free lime is generated in bridge slabs and covers cracks, cracks inside the free lime cannot be quantitatively evaluated. In this developed technology, the area of free lime can be quantitatively calculated from image analysis and the width of hidden cracks can be estimated.



- Free lime areas can be calculated by image analysis
- The width of cracks hidden by free lime can be estimated · From the image analysis results of cracks, accurately
- evaluate the degradation stage of slabs
  - Possible to free up investigation site in a short time
  - · Enables efficient shooting at sea

### **Current Accomplishments (2/2)**

#### 3. Rapid technology for image analysis processing

In the conventional inspection conducted by an inspector, it takes time to collect inspection data and draw freehand, and it was difficult to immediately obtain inspection results at the site. This developed technology can simplify image processing and can also be processed on a tablet PC, so that results can be obtained quickly on site.

#### Conventiona



### Goals

# Numerical target Among inspections of 500,000 small and mediumsized bridges, realize more than 1% share Users Inspection company of structure, local government, especially municipalities How to use/Places of use 1) Selling system packages to inspection companies 2) Analysis agency businesses utilizing cloud function Sales method Technical support to inspectors, System change to an easy-to-use analysis agency businesses utilizing interface cloud function Services to Offer Provide data that quantitatively evaluate damage stage of road bridge slabs



Choose the appropriate shooting method

Crack wid Quantitatively grasp the cracked quantity

Possible to quantitatively evaluate the degree of damage of bridge slabs which was difficult in the past → Provide information for checking and prioritizing countermeasures and maintenance



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Utilization

examples



#### [Efforts toward practical application]

inspection company



A trial example of detection of cracks in video provided by University of the Ryukyus

Image analysis

result

Management of inspection data agency business

ridth average 175 mm	Damage Level	Criteria o crack wid	
20.011	а	0.05mm	
	b	0.10mm	
民族國際	с	0.20mm	
(mm)			

а	0.05mm	Crack width, length,
b	0.10mm	Calculation of crack width
с	0.20mm	from free lime area

Accurately grasp the damage level of the bridge slab







**Current Accomplishments (2/2)** 



Site

Abutmen

Remote monitoring Utilization example of the bridge

>ACM※

of damage and deterioration

· Realize a remote monitoring system with Easy installation and Long-term usage without power distribution work. · Realize sensor data indexing enabling understanding of the state of the bridge without professional knowledge.

Foundation

Base station

corrosion monito

Shoe

Pier

Enable proactive maintenance of the bridge by monitoring slight changes in evaluation indexes.

~

Offer Information

ALC: No.

(Web Application

44444

58

(2014-2016)



# R&D of the technology which monitors the displacement rate of a manmade structure with high accuracy and efficiency

Principal Investigator Minoru Murata (NEC Corporation)

#### **R&D** Objectives and Subjects

### Objectives

· Development of technology which monitors the displacement rate of infrastructures in a wide area (manmade structures such as bridges) with high accuracy and efficiency



- Analyze satellite image data of target bridge.
- → Check the displacement rate (mm/year) at multiple points on a bridge.
- → Check the ground displacement (subsidence/uplift) around a bridge.
- Confirm measurement accuracy by verification experiments.  $\rightarrow$  Measure and verify the displacement by placing a reflector at a test site (error: Approx. 0.5 - 1 mm).



Vertically moved Reflector C only

Approx. 8.0m

(2014-2015)

Conducted accuracy verification of this method at NEC test site.

Reflector A

-Reflector B -Reflector C

-Reflector D

Reflector E

Line

-Reflector C Approx

High Accuracy Monitoring

Measure artificial structures such as a bridge to an accuracy of millimeters.

mm), the accuracy of this method is 0.5 to 1.0 mm.

According to the calculation result of Reflector C movement (approx. 8.0

#### **Current Accomplishments (1/2)**



Reflectors (A - E) placed

at NEC test site

Analyze SAR image of a wide area to measure the displacement rate of a bridge within the area at once.



#### Wide Area/High Density Monitoring Extract an abnormal part of manmade

- structures such as bridges.
- Extract a point of focus for close visual inspection

Earthquake-resistant land promotion project (Large-scale filled development land screening)

Provide a quantitative criteria for specifying a dangerous location (secondary screening). (Substantially reduce the burden at a site.)

Date [yyyy/mm/dd]

#### **Current Accomplishments (2/2)**



Goals



→ Achieve advanced preventive maintenance of infrastructure.

25

60

(2014-2015)

Scene	Application
dge Inspection	Screening (priority of close visual inspection)
	Displacement with age monitoring (fixed point monitoring, forecast)
rge-scale filled veloped land monitoring	Screening of filled developed land (Specify dangerous area)
po monitoring	Security for highway, etc.
bsidence monitoring	Effect of tunnel construction (shield work)
	Uneven settling of buildings
	Uneven settling of airport/port
	Subsidence of commercial facilities (filled ground)
	Uneven settling of plant/outdoor tank
nitoring of facilities, klings, houses	Select facilities, etc. which are in danger of collapsing at the time of disaster, -> Preventive maintenance
temence to anoroper natruction	Monitor the health of construction (pilling, etc.).
initoring of effect of engthening work	Monitor the health after construction.

Provide a report or GIS data to the user.

(High displacement rate)

Subsidence due to shield work

Subsidence monitoring service



### R&D of Monitoring System for Detecting Surface Failure by pore pressure sensor with inclinometer

Principal Investigator Yasunori Shoji (OYO Corporation)

#### **R&D** Objectives and Subjects

#### Objectives

·Development of a monitoring system for detecting surface failure in-situ and transferring the data and alert to governments and residents.



2. Packaged system

Composed of

1)Rain gauge.

③Tilt sensor,

October, 2015.

verification

We

failure

2 Pore pressure sensor,

wireless communication

system, and power unit.

Verification test on a

slope near a national

road is ongoing from

confirmed

At the moment, there is

no evidence of slope

at

operating normally

of December, 2016.

test

- 3 Tilt of the slope simultaneously and transferring the data and alerts automatically to any place.
- $\rightarrow$  Providing one-stop service of determining suitable monitoring locations, designing the system, installation, and achieving data transfer

#### **Current Accomplishments (1/2)**

#### 1. Determining monitoring locations

• The thickness and geology of the surface layer is investigated by using the Soil Layer Strength Rod developed by PWRI. Then suitable measurement locations are selected.



· Suitable monitoring location can be selected according to geological condition.

Utilization

example

#### Early warning data of slope failure will be transferred to public administrators and residents.



observation point.



the

is

as

the

Early evacuation can be carried out and slope failure hazards can be mitigated.

(2014-2016)

sensor

use with

Pore pressure sensor

with tilt sensor

Obsenation

(Road etc.)

target

08

Rain gauge with

telecommunication system

Current Accomplishments (2/2) (2014-2016) 3. Easy data acquisition, transfer, and display Flow of utilization The process of acquiring data, transferring the data, and issuing alert to public administrators and residents is automated. 1. Determining the monitoring location 2. Packaged system winter b (2) day Data center (image) ·Alert message is transferred by e-mail 3. Easy data acquisition, according to data. transfer, and display ·Message can be sent to cellular phone No.00 and PC by internet. ·Threshold level can be set at three levels at maximum. Message can be sent to 20 users at The system, which can detect maximum simultaneously. the status of the slope at an early stage of the failure, is \* The message is subject to change. established. The system can contribute to conduct early evacuation and -Easy to investigate the status of the slope at the monitoring point mitigate the slope failure ·Can be customized to combine the data with a digital map to hazards. visualize the data for easy understanding. Goals Rain gauge with Numerical targets unication system Pore pressure sensor with Reduce cost by 20% compared to the current system tilt sensor · One-stop service that reduces time by 30% from Rain gauge with Geological experts installation to data acquisition. tel nicatio **Data interpretation** Users sure sensor Automatic data transmission 8 Public administrators of  $\sim$ Data transmi administrators, residents, etc. Observation 0 E-mail transfer target Base station of cell-phone How to use/Places of use (Road etc.) Data server communication system computers 08 Places of use are slopes along roads and resident areas. Image of the operation of monitoring system after implemented. Sales method Providing one-stop service of Prime consultant, who conducts determining suitable monitoring locations, designing the system, Geological investigation experiments, installation, acquiring the data, enables one-stop service planning. transferring Services to Offer in a second Providing one-stop service of determining suitable monitoring locations, designing the system,



	Pore pres with tilt s
of local governments, road	

Subcontract to consultants.

installation, acquisition and transfer of data.



Location of the alerted slopes

The system can give status information of the slopes in real time in an easily understandable way.  $\rightarrow$  Early evacuation reduces slope failure hazards.

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Status of the slopes



# 27 R&D of Early Warning Monitoring System of Slope Failure using Multi-point Tilt Change and Volumetric Water Content



#### R&D Objectives and Subjects

#### Objectives

Research and develop a highly accurate, multi-point early-warning system for slope failure using low-cost tilt sensors.







### **Technical Service** International Support Early warning of slope failure Prevention of secondary disaster Assess pre-failure phenomena of slopes Dynamic monitoring of landalides n mountainous areas Application to Internet of Things and trends in Big data Numerical targets Installation time reduction of Cooperation with Regional Bureau of MLIT about 60%. to develop research results Economic improvement of about 40% by reducing equipment and installation costs. Users Local autonomies, Regional Bureaus of MLIT, Private businesses, International supporting organizations, etc.

# e Failure Early-Warning Monitoring System Based on Multi-point Tilt Measurement and Water Content







Mole (Small Animals) Hole Detection System Attached to Large Weeding Machine



Principal Investigator Kiyoshi Suzuki (Aero Asahi Corporation)

#### **R&D** Objectives and Subjects

### Objectives

Development of a monitoring system for the advancement on inspection of embankment utilizing the measuring system attached to a large weeding machine .



• Able to detect from small- to Developed measuring equipment large-scale deficiencies ,such as that can be easily attached to the rear of a large weeding machine. mole hole to depression of slope. Detection accuracy is superior CASS THE to conventional visual inspection. Measured at a normal driving so later spots June wenty eig Difference between the two datasets October

**Test site** 

 Acquire high-resolution terrain data simultaneously with weeding. Accurate and detailed measurement of embankment unaffected by vegetation

The system detected Utilization deficiencies in Example a test field site.

Small- to large-scale deficiencies are detectable

ground

ground

Mole hole

10.0 June October



a newly developed algorithm.

Eliminating noise from large amount of point data



Results of analysis can be provided quickly.

field

The detection system

is effective in actual



# Current Accomplishments (2/2)



Developed field inspection support system which provide information on deficiencies. Mobile tablet with AR function.

Cloud-based computerized inspection system









• Upgrading future monitoring system of river embankment by a database of detailed terrain data and inspection results

· Easier and more efficient field inspection

More objective inspection not relying on

inspector's experience.







Sale or rental of the equipment Upgrading the maintenance system of embankment (2014-2016)

Field inspection support service



R&D of "Electric resistivity monitoring system for the state of water 29•32 contents in river levee" and "Monitoring system for internal state of river levee utilizing geophysical exploration and ground water observation"

Principal Investigator Hideki Saito and Akira Shinsei (Oyo Corporation)

#### **R&D** Objectives and Subjects

#### Objectives

 Development of a screening method to determine priority observation location in case of flooding and a monitoring method for status changes in river levee.



### Subjects (2014-2016)

• Development of an interpretation technique for time-lapse geophysical data...  $\rightarrow$  Concentration on priority areas for observation in case of flooding.

1km Resistivity changes between before/after rainfall > showing changes in water

(2014-2016)

• Development of an observation method for internal state changes by flooding.  $\rightarrow$  Monitoring changes of water content in the levee in case of flooding.



ble portion -> need for mon

### **Current Accomplishments (1/2)**



#### Current Accomplishments (2/2)

### 4. Clarify the internal state of levee

Resistivity changes show water contents inside the levee body





Goals
Numerical target
Efficiency in monitoring locations determined by the method. Goal to reduce costs for patrol by 10%.
Users
River administrators
How to use/Places for use
Conducting geophysical surveys in the same line of river levee before and after rainfall or small flooding.
Sales method
Electric and seismic surface wave surveys conducted by geophysicists.
Services to offer



Determining the monitoring location in case of flooding and providing changes in the states of levee after flooding

 $\rightarrow$  It can be applicable to other fields, including slopes, reclaimed land, etc.

(2014-2016)



Land streamer type surface wave survey

nd consultation ers

Flood prevention and maintenance by river administrators



Trailing type electric survey





#### R&D of monitoring system including a detection of river levee 30 deformation



0 0

 $\bigcirc$ 0

nfiltration sensor

0 0

0 0

Current land features

0 

10

(2014-2016)

Principal Investigator Shunsuke Sako (Japan Institute of Country-ology and Engineering, General Incorporated Foundation) Consisted of three Japanese bodies; PHOTONIC SENSING CONSORTIUM for Collaborative Research Groups

Safety and Security, SAKATA DENKI Co., Ltd., KITAC CORPORATION

### **R&D Objectives and Subjects**

# Objectives



 $\rightarrow$  While not requiring visual inspection, realize a monitoring system that allows measurement of levee deformation due to infiltration or erosion.

### **Current Accomplishments (1/2)**



within Levee Body
Conducted the measurement of water level within the levee body. Focused on the phenomenon that levee deformation grows according to the water level within the levee body.
<ul> <li>O ally rainfall</li> <li>O a</li></ul>
Practical Process Flow of Outcomes
1. Developing Monitoring System for Levee deformation with Sensor Devices

Current Accomplishments (2/2)

4. Measuring Water Leve

#### erosion nat levee 10 to the 12.0 11.0 10.0 9.0 8.0 7.0 2/2016 04/2016 06/2016 08/2016 2016 In Sep 2016, the velocity was around 3.6 to a m/s and the erosion caused at that time was as the approx, 50 cm. While the erosion sensor was running properly, nothing was detected. . Measuring Levee Deformation with Optical Fiber Sensor )W . Measuring Levee Deformation with Erosion Sensor Measuring Water Level within Levee Body

# Goals

### Numerical targets

Realize a cost reduction by 60% compared to that of the conventional visual inspection for the following flood fighting

- Critical flood fighting point A (38.6 km) against infiltration - Critical flood fighting point A (84.0 km) against erosion (For the case of LCC 10 years later)

#### users

- Administrators of rivers under Ministry of Land, Infrastructure, Transport and Tourism
- •Administrators of Class B rivers under prefectures
- Embankment administrators of railways or roads
- Observers of slope deformation, etc.

#### how to use/Places of use

 In order to monitor the deformation due to infiltration/erosion at rivers under direct control and Class B rivers under prefectures, install sensors at estimated critical flood fighting points. points

#### Services to Offer

socio-economy.'

Instead of the conventional qualitative levee management by visual inspection, obtain quantitative real-time information at site office



By utilizing the real-time information and promptly providing information to protect people's lives and property, contribute to "No failure to escape" and "Minimization of damage on



70





Posi

Insta Nainter

Av me

Citizens

9.0

8.0

70

6.0

**Analysis Model** 

•By developing the correlation diagram between the volume of strain measured with the optical fiber sensor as well as the water level within the levee body, we can identify the moisture condition inside of the levee body, which affects the levee deformation.

Comparative Verification of Measurement Results Derived from Analysis Model

Realize real-time and quantitative monitoring of levee deformation with an optical fiber sensor and an erosion sensor.

#### Cost comparison list

	Visual inspection	Optical fiber sensor		Erosion sensor
ion installed		Three units	Single unit	Sensor: 10 m inerval Receiver: 100 m interval
illment cost		¥112 mill	¥38 mill	¥60 mill
ance cost(yr)	¥16 mill	¥3 mill	¥3 mill	¥1.12 mill
of 5 yrs later	¥82 mill/5yrs	¥126 mill/5yrs	¥53 mill/5yrs	¥66 mill/5yrs
f 10 yrs later	¥164 mill/10yrs	¥141 mill /10 yrs	¥68 mill /10 yrs	¥72 mill /10 yrs
ost items	Labor cost	Materials + Construction + Labor cost		Materials + Construction + Labor cost
ailabilty of asurement	Impossible: At night or when covered with flourish vegitation	24 hrs, 365 days avaiable		24 hrs, 365 days avaiable



On the basis of the new technology developed, the administrator provides the information to citizens. By providing high quality information, the administrator earns the citizens' trust, and furthermore, the system is manufactured/procured. This enables generation of profits





### Effective Use of Satellite SAR Observation for River Embankment

Principal Investigator Takeshi Katayama (Infrastructure Development Institute)

Collaborative Research Groups Japan Aerospace Exploration Agency, Pacific Consultants CO., LTD.

#### **R&D Objectives and Subjects**

### Objectives

31

Utilize satellite observation to collectively monitor a wide range of embankments at a frequency of several times a year, and improve embankment monitoring efficiently.



· Developing methods to calculate long-term displacement of river embankment

- Accuracy verification of calculated displacement
- Considering how to display the result of calculation
- $\rightarrow$  Conventionally, it was necessary to visually inspect all managed sections. However, it becomes possible to extract points for which detailed check is to be conducted.



#### **Current Accomplishments (1/2)**

(2014-2015)

#### 1. Establishment of displacement analysis model about ground level by using ALOS observation data

- · Comparing analysis results by ALOS satellite observation with actual survey results
- · We confirmed that we could obtain the displacement of average ground level in the certain section (displacement calculating section) inside the embankment.
- Based on this comparison verification, we examined a method of analyzing satellite images.
- This method can be applied to analysis using observation data by ALOS-2 (Operation period: from May 2014 to the present)



Orange points indicate the relative displacement of the mean ground level in the section including the crest of embankment (approximately 10 pixels. The pixel size is about 10m x 10m.) The straight line links the 3 survey results



This diagram indicates subsidence amount of the embankment. The white rectangular frame indicates the section (displacement calculation section) in which the relative displacement of the average ground level was calculated.

- Accomplishment of grasping displacement of average ground level such as height of embankment crest by satellite image analysis
- It is possible to grasp long-term tendency of deformation of the height of embankment crest

#### **Current Accomplishments (2/2)**

conducted on-site verification as follows;

area with those in un-weeded areas

significant difference was shown (in the graph right below).



any significant difference in the distribution of errors.

#### Numerical target

Accuracy of several hundred square meters as a minimum area unit to grasp displacement amount of average ground height.

River Offices (Ministry of Land, Infrastructure, Transport and Tourism, Prefectures)

#### How to use/Places of use

Obtaining displacement of crest height of embankments by using SIPT in River Offices.

#### Sales method

- Work on manualization of our technology and tools.

#### Services to Offer

observed images and display image processing results. Monitoring long-term displacement of crest height of embankments through displayed images.

It is possible to grasp long-term displacement of crest height of embankment continuously along rivers several times a vear.

 $\rightarrow$ Improve efficiency of river embankment monitoring by extracting priority inspection sections

(2014 - 2015)





Principal Investigator Atsushi Homma (Research Association for Infrastructure Monitoring System)

#### R&D Objectives and Subjects



# Current Accomplishments (2/2)

### 3. Monitoring system for concrete structures under chloride attack

#### Accelerating tests on RC beam specimens (2015)

Performed accelerating tests by salt water immersion And electrolytic corrosion using RC beam specimens, in which 6 sensors were installed for monitoring re-bal corrosion and chloride penetration. Performance of the sensors was evaluated focusing on applicability for existing bridges.

### Verification tests on existing bridges(2016)

nstalled sensors to monitor the progress of Deterioration due to chloride attack to existing bridges and verify their applicability in on-site environment (Measurements will continue until 2017)



Develop guidelines for practicable and effective

monitoring methods based on the state of

An image of fixed point collection type monitoring system

(2) Patrol collection type monitoring Focused on a technology that wirelessly collects sensor data using vehicles running at 80 km/h, we confirmed that a routine inspection patrol vehicle doing other work is able to collect the data.

Develop guidelines for specific methods to collect monitoring data using wireless communication.

#### Goals

#### Final target value

deterioration due to chloride attack.

Aim to achieve a service life of 100 years by maintaining bridges appropriately and effectively through the facilitation of the use of monitoring in accordance with the guidelines.

Target users

All road administrators (the state, local public bodies, expressway companies, etc.)

### Usage method, locations to use, etc.

Introduce monitoring systems in accordance with the objectives, target bridges, management systems, etc. to the inspection guides etc. for each road administrator based on the guidelines.

#### Flow of spreading the guidelines

Share the results at lectures, technology exhibitions, etc. Cooperation with local public bodies

#### Outline the service provided

Propose utilization methods of monitoring systems for bridge maintenance using guidelines

[Examples of expected use]

- · Improve the efficiency of inspection works by making more effective inspection plans based on regular monitoring data.
- · Improve the accuracy of inspections and reduce the number of failures to notice damage by carrying out monitoring to help to inspect spots that are difficult to access.
- · Improve safety by introducing monitoring to damaged structures.
- · Devise reasonable repair and reinforcement methods by confirming the effects after any repairs and reinforcement through monitoring

It's possible to introduce a monitoring system that matches the objectives of road administrators

→ Achieve more advanced and more efficient bridge maintenance works

- phenomenon that should be noticed and

effective monitoring methods based on the soundness of the floor slab and girder.

- Performed mapping of deterioration
- monitoring technologies that can catch the phenomenon in accordance with the soundness of the bridge. Develop quidelines for practicable and

- - Conceptual diagram of technology mapping (floor slab) deflection / scillation Slope Acc Cracks Optical fibe (surface) Video deflection Accelerometer Interna damage AE metho





- administrators Deal with the growing burden caused by mandatory
- close visual inspections Support the inspection of areas which are difficult to approach, such as an overpass
- Monitor bridges that need measures but they cannot be taken for a while
- Monitor important regional bridges at low cost
- Matching the applicable situation with the applicable monitoring technology required by road administrators

data

(2014-2016)



Promote the use of monitoring for national roads, expressways Send information/give advice to local public bodies



### Clarification of Deterioration Mechanism of Infrastructures and **Development of Technology for Efficient Maintenance and** Management through COE for Infrastructure Materials Research



#### Current Accomplishments (2/4)

## Clarification mechanisms & Application of NIMS seeds for Infrastructure Maintenance

and advanced technology for establishment of maintenance flow



#### Current Accomplishments (3/4)

### Establishment of new maintenance management flow (Kyoto University) & Development of repair materials and highly durable cement (Tokyo Institute of Technology)



Principal Investigator Koichi Tsuchiya (Director of RCSM, NIMS)

Collaborative Research Groups Kyoto University, Tokyo Institute of Technology

### **R&D** Objectives and Subjects

### Objectives

[Social Backgrounds]

- · It is necessary to develop an efficient maintenance and management flow to deal with a large stock of social infrastructures with a limited budgets and human resources in Japan.
- · It is necessary to establish a feasible and highly accurate degradation diagnosis method as well as innovative repair technology
- [Purpose of Research & Development]
- · Development of diagnostic technology with reduced labor, reduced cost and well-planned maintenance suitable for maintenance in local authorities.
- · Fostering multi-disciplinary researchers/engineers who have a birds-eye view over materials and structures for the future.

#### Subjects

- Establishment of COE for infrastructural materials R&D to promote collaboration. industrial - academic - government interdisciplinary cooperation and human resource development.
- Clarification of deteriorating mechanisms in RC infrastructures.
- · Improvement of remaining life assessment for infrastructures by clarification of the correlation between 1) environment in service, corrosion products and cracking or 2) concrete cracking and load capacity, using advanced inspection technologies, such as non-destructive evaluation and corrosion environment sensors, which have been cultivated in NIMS.



• Development of efficient repair materials and long-life materials as well as evaluation methods

#### Current Accomplishments (1/4)

### Consolidation to COE for infrastructural Materials R&D with industrial - academic - government cooperation

 About 30 researchers and engineers who belong to the "SIP-Social Infrastructure Materials Lab" and various analytical apparatus for infrastructural materials R&D are located in the Advanced Structural Materials Research Bldg.



- New industrial academic government cooperative group named "TOPAS" has been established to promote Infrastructural Materials R&D.
- "Infrastructural Material Cluster" (31 industries, 8 academic institutes or public labs, and 120 persons) plays an important role in the project, such as 1) information exchange, 2) several educational programs (young scientist forum, summer school, cluster seminars] and 3) discussion and investigation of cooperative R&D for social infrastructural implementation.

Current Accomplishments (4/4)



Goals

— Actual Reflection of R&D Results to the Society ————

Strong promotion at "Intrastructural Materials Cluster" to establish the high-efficient Maintenance Flow





### Developing hybrid mechanoluminescence materials for visualization of structural health

Principal Investigator Chao-Nan Xu (Principal Research Manager, AIST)

#### **R&D** Objectives and Subjects

#### Objectives

- We develop novel mechanoluminescence (ML) materials for nondestructive inspection of structural degradation and damage by visualization of the stress/strain distribution. The novel ML materials have a unique property that the ML intensity increased quantitatively with the stress/strain change, and such a property can be employed to quantitatively evaluate degradation distribution and status at the same time for efficient inspection and repair.
- · We develop ultrasensitive ML materials for a direct view of the micro-cracks and degradation in the structures, such as welded areas, etc., in steel bridges, even without removal of the surface paints/films. The preventive detection of fatigue cracks and preventive repair can ensure effective maintenance.

#### Subjects

- · Development of ultrasensitive ML materials for effective visualization of structural degradation, stress/strain concentration and cracks
- Development of hybrid materials for quantitative analysis of degradation/damage degrees
- Implementation of the field verification test of developed technology aiming to use during the periodic inspections of infrastructures (highways, etc.)



#### **Current Accomplishments (1/2)**

Ultrasensitive ML materials for visualization of the invisible fatigue micro-cracks

- We developed a new ultra-bright and sensitive ML material, which can emit higher than 100 mcd/m<sup>2</sup> to a small strain of 0.1%
- Using the newly-developed ultrasensitive ML materials, effective visualization of fatigue micro-cracks could be achieved with 0.003% strain variation.
- Under the same experimental condition, the newly-developed ML material enhanced the ML to 5 times compared to the previous materials.





- (A) Metal specimens coated with current (top) and SIP newlydeveloped ultrasensitive ML sensors (bottom).
- (B) Strain curves of the test with maximum strain of 0.003% are used to simulate vehicles passing by on a highway.
- (C) ML image of micro-cracks during the vibration cracks can be clearly seen by the new sensor, whereas they cannot be seen by the previous sensor.

#### **Current Accomplishments (2/2)**

Newly-developed ML materials toward efficient, low-cost and labor-saving maintenance

- Field test of newly developed ML method was carried out on the steel welding joints with paint cracks occurring at highway bridges, without the removal of the anticorrosion paint to search if fatigue cracks had occurred or not.
- After the ML test, conventional magnetic testing (MT) was carried out to confirm the reliability of inspection results of the ML method. The result strongly confirmed the reliability and effectiveness of the ML method. Compared to ML, MT is timeand cost-consuming, the pretreatment of paint removal damages the inspected target also.
- SIP newly-developed ultrasensitive ML method was confirmed to be effective to search for cracks and visualize stress/strain concentration even without paint removal.
- The maintenance specialists highly appreciated the ML method to be of great merits in both labor and cost saving and to be a practically useful technology to detect fatigue cracks in steel without paint removal, to evaluate repair status, and to visualize stress concentration.

Goals

Optimization

High durability

#### Quantitative targets ML performance Quantitative analysis of stress/strain concentration, visualization of strain distribution level of 0.01% Crack detection sensitivity Detection of micro-cracks with depth shallower than 1 mm Social implementation • We are developing a business environment on the fatigue crack visualization of steel bridges, effective confirmation of crack repair status, and stress concentration evaluation for repair necessity determination. The world's first ML technology Contribution to effective infrastructural maintenance and management To improve ML materials Field Standardization Sensitivity verification test guidelines and Quantitative for robustness user manual

and reliability

Generalization and dissemination of technology

Established the Mechanoluminescence Technology Consortium for technology innovation, standardization, generalization. https://unit.aist.go.jp/kyushu/MLTC/index.html Contact: mltc-s-ml@aist.go.jp

preparation



Effective detection and visualization of invisible cracks underneath the anti-corrosion paints

Field demonstration: Fukuoka Urban Expressway



Paint removal is not necessary.

ML enables visualizing the crack in the structure underneath the

MT method ath is 12 mn

Paint removal is necessary. Crack visualization by particles dues to magnetic flux leakage.

A crack was successfully found by the ML method (before paint removal), and was also confirmed by MT method (after paint removal)





Kenji Higashi (Professor, Osaka Prefecture University) Principal Investigator

Osaka Prefecture University, Technology Research Institute of Osaka Prefecture, Coaken Techno Collaborative Research Groups Co., Ltd., Kanmeta Engineering Co., Ltd., Osaka Prefecture University College of Technology

#### **R&D Objectives and Subjects**

#### Objectives

- Objective: To realize safe and secure infrastructure by developing a repair technology that enables easy maintenance and control with the utilization of a newly developed thermal spraying alloy of excellent corrosion durability; the developing repair technology is suitable for solving problems determined through field study on the corrosion damage to steel structures, especially to steel bridges.
- Development of a thermal spraying alloy: Developing a thermal spraying alloy with an excellent corrosion prevention performance, especially for dents, the edge portions and the small end faces of steel bridges, as well as with the high durability in severe salt-attack environments.
- Development of a thermal spray method in narrow spaces: Accelerating the progress speed of the technology we are developing by utilizing a compact and lightweight plasma arc spraying technique, which was developed by the West Nippon Expressway group and establishing its application to narrow spaces.

#### Subjects

- Field study: To clarify the problem as a repair technology through the investigation of the actual corrosion damage.
- Development of a thermal spraying alloy: Developing a thermal spraying alloy excellent in corrosion resistance and self-repairing ability; the alloy composition was designed based on the first - principle calculation and the evaluation of corrosion resistance using electrochemical techniques.
- Adaption to the plasma arc spraying method: Carrying out the tests for confirming the adaptability of the plasma arc spraying method, which is considered as an adequate technique for a thermal spraying on a narrow space.
- Evaluation of corrosion prevention performance: Performing the verification testing of the developed thermal spray coating by a combined cyclic testing of up to 6,000 hours with a cross-cut sample. Carrying out atmospheric corrosion tests in heavily corrosive salt-attack environments, such as along the coast of the Sea of Japan.
- Partial repair as field trial: Preforming a partial repair as a field trial, to the girder end structure of a bridge to verify the workability, the cost and the performance of thermal spray coating with the developed alloy.

#### Current Accomplishments (1/2)

To develop a new thermal spraying alloy with high durability for salt-attack environments, as well as high resistance to the corrosion of dents, edge portions and small end faces.



of Al-Mg-Ca alloy

of Al-Mg-Ca alloy

#### Current Accomplishments (2/2)

To demonstrate durability of the newly developed thermal spray coating and establish a repair technology using it, based on the results obtained by combined cycle testing and the partial repair as a field trial at an actual steel bridge.

Determination of alloy composition with excellence in corrosion resistance using electrochemical techniques Target Problem Corrosion resistance performance Rapid dissolution Salt-attack of the coat due to environment high corrosion rate Cathodic protection to th coated defective part Poor durability Edge portion, resulting from a Anti-self corrosion small thickness of small end face of the coat the coat Self repairing ability of the Rusting from the coated defective part Dent defect in the coat stance to self ·Corrosion potential Combined cycle Polarization Testing method measurement measurement testing ·Polarization measurement Intensity of · Level of corrosion potential Evaluation criteria Appearances ·Passivation or de-passivation corrosion current 0 Al 0 × Conventional material Al-Mg 0 0 0 0 New alloy Al-Mg-Ca 0 0 Improved

(Samples for evaluation were prepared by flame spraying ◎ very good, O good, × poor \* A time for a start rusting from cross-cut area

#### Goals

- Development of new thermal spraying alloy with high durability by utilizing state-of-the-art computational materials science and the latest knowledge about corrosion and corrosion protection mechanisms.
- developed thermal spraying alloy



by 25 %\*

on Al-Mg surface

polarization curves

Combined cycle testing

Carrying out an accelerated test using the combined cycle testing, which is assumed showing a satisfactory correlation with outdoor exposure.

A time for a start rusting from cross-cut area was improved by 25%.





Al-Mg-Ca Al-Ma The appearances of the coats (100 µm thickness) after being subjected to combined cycle testing for 6,000 hours.

Partial repair as field trial at an actual steel bridge

A partial repair as a field trial was carried out on an actual steel bridge of West Nippon Expressway Company Limited by the plasma arc spraying using a newly developed thermal spraying alloy

The workability of thermal spraying and the quality of the spraved coat satisfied the in-house quality control provisions of West Nippon Expressway Company Limited.



Steel bridge under repair



Finish state: after repai

Demonstration of the workability of the repair method and the durability of sprayed coating that uses the



#### Principal Investigator Toshiki Ayano (Professor, Okayama University)

Collaborative Research Groups Oriental Shiraishi Corp., Landes Co., Ltd., JFE Steel Corp.

#### **R&D** Objectives and Subjects

#### Objectives

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In order to extend the lifespan of damaged bridges and to shorten the period of traffic regulation during renewal construction, a precast concrete member with high durability has been developed with blast furnace slag sand.

- PC (Pre-stressed Concrete) PCa member
- $\Rightarrow$  Durable to traffic load under water supply conditions
- RC (Reinforced Concrete) PCa member  $\Rightarrow$  High resistance to freezing and thawing without AE agent

# Subjects

Publication of the guidelines for the manufacturing of highly durable PCa members with blast furnace slag sand, and construction with it on a site.

- Clarification of the mechanism of blast furnace slag sand to improve the durability of concrete
- Establishment of a supplying system for the blast furnace slag sand in the domestic precast factories
- Establishment of the inspection and quality control system to manufacture the reliable products

#### **Current Accomplishments (1/2)**



Performance to protect against the rusting of steel













Difference of quality of blast furnace slag sand in manufacturing plants [P2015-242333]



# Goals







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



#### Masataka leiri (Director, JIP Techno Science Co., Inc.) Principal Investigator

The Graduate School of Engineering, Institute of Industrial Science (IIS), and Research Collaborative Research Groups Center for Advanced Science and Technology(RCAST), The University of Tokyo

### **R&D Objectives and Subjects**

#### Objectives

39

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.





# 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 ield test 1: traffic-vibration measurement at viaducts \*\*`\*\*\*`\*\*\*`\*\*\*`\*\*\*`\*\*\*`\*\*\*`\*\*\*`\*\*\*`\*\*\*`\*\*\*`\*\* ΨΨΨ $\mathbf{V}$ 12 span 360m ~30m Robust multi-hop network is established under a challenging environment Spans with large deflection

and vibration

amplitude are extracted

**Current Accomplishments (2/2)** 

### Goals

		Data and	I		
Road evaluation			lection		
Targe	et		A Long		
IRI e	IRI estimation accuracy 10-20%				
Local potho	I damage detection (joints & bles)				
Road deter	l asset management system using ioration prediction based on IRI	Ser	vice based		
Data 100 v	×				
Techi	nology transfer to foreign countries				
			High-perfo		
Brid	r light porto				
Targe	et		Bridge me		
	Seismometer-class accurate measurements		Find outlier 1 (S		
Se	Robust multi-hop network over kilometers				
nsor	1-month to 20-year battery life		T		
node	Strain, inclination, temperature		_11_		
Û	Time synchronization to GPS time. P				

High-perfo
Bridge me
Find outlier
(
4
- 16

#### Extraction of bridges of large responses/loads

efficient connection to external network



#### 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.



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





### R&D on Technologies for Collecting, Transmitting, and Processing Sensing Data of Civil Infrastructures (Underground Structures)



#### Shuichi Yoshino (Senior Manager, NTT Network Innovation Laboratories) Principal Investigator

Collaborative Research Groups NTT Advanced Technology Corporation, Tokyo Metropolitan University, and FUJI TECOM INC.

#### **R&D Objectives and Subjects**

Underground structures with severe communication environments can be monitored by collecting and using sensing data using wireless communication suitable for the environment.

_		Conventional	Improvements achieved through our R&D	
Objectives	Inspection	Periodic inspection every several years     Reports from residents and others	Installing and utilizing long-term maintenance-free sensors	
	Monitoring	<ul> <li>Traffic blocking at manhole openings and closing and installing/removing work</li> </ul>	<ul> <li>No need for manhole opening/closing</li> <li>Automatic data collection by mobile and stationary APs</li> </ul>	
	Diagnosis	<ul> <li>Judgment only with the data at inspection</li> <li>Diagnostic variation due to workers</li> <li>Degradation diagnosis and prediction are impossible</li> </ul>	<ul> <li>Improved leakage detection accuracy by utilizing past data</li> <li>Workers' skill independent diagnosis</li> <li>Soundness evaluation of water pipes by constant monitoring</li> <li>Speed up response in case of disaster</li> </ul>	

	Technology	Contents of R&D	
Subjects	A) Sensing data collection and transmission technology	<ul> <li>Drive-by data collection: activation of terminals from running vehicles</li> <li>Static data collection: long distance data communications to APs</li> </ul>	
	B) Sensing data handling technology	<ul><li>Infrastructure facilities monitored data handling technology</li><li>Techniques to lower power consumption of sensors</li></ul>	
	C) Optimal planning of water leakage monitoring systems	<ul><li>Evaluating and determining leakage and accident risks in the area</li><li>Optimizing the installation points of water leakage monitoring sensors</li></ul>	
	D) High sensitivity sensor terminal technology	<ul><li>Economical data collection and operation methods</li><li>High sensitivity sensor terminal technology over wide frequency bandwidth</li></ul>	
	<ul><li>C) Optimal planning of water leakage monitoring systems</li><li>D) High sensitivity sensor terminal technology</li></ul>	<ul> <li>Evaluating and determining leakage and accident risks in the area</li> <li>Optimizing the installation points of water leakage monitoring sensors</li> <li>Economical data collection and operation methods</li> <li>High sensitivity sensor terminal technology over wide frequency bandwidth</li> </ul>	

### **Current Accomplishments (1/2)**

#### A) Sensing data collection and transmission technology

#### Established basic data transmission technology

- (i) Link budget analysis
- ·Radio wave propagation characteristics clarified in multiple frequency bands by electromagnetic field analysis and water supply pipeline test bed verification
- Data transmission frequency band (920 MHz band) and terminal activation frequency band (125 kHz band) selected
- · Link budget analysis completed by selecting modulation method, error correction method, antenna, etc.
- (ii) Basic performance of data transmission technology evaluated
- · Transmitter/receiver circuit for terminal activation/data transmission prototyped
- Static data collection method goal (30 m transmission) confirmed in test bed field between underground and ground. Drive-by data collection goal (running terminal activation and transmission) also confirmed
- · Terminal activation and data transmission performance in actual field movements confirmed

#### B) Sensing data handling technology: saving monitoring sensor power

#### Target (continuous operation for over 5 years) achieved

· Continuous operation for about 10 years with one battery (capacity 10 Ah) confirmed from power consumption evaluation performed through device circuit design and simulation



#### **Current Accomplishments (2/2)**

#### B) Sensing data handling technology: infrastructure equipment monitoring data processing technology

#### Usage of small/medium diameter metal pipes confirmed (iii) Measured data used to confirmed recognition rates of effectiveness of basic technology for water leakage

- (i) Usage of actual data guantified water leakage determination task
- · Micro/fine water leakage sound characteristics propagating through pipes
- Water leakage sound characteristics due to pipe material, tube diameter, leakage volume, etc.
- Particular irregular noise for each place/time slot
- (ii) Analytical methods designed to address problems · Machine learning using multidimensional feature extraction
- focusing on sound pressure/frequency distribution Irregular noise removal method focusing on statistical stationarity of sound
- Individual learning model for each place focusing on temporal change of sound and location-independent common learning models

#### C) Optimal planning of water leakage monitoring systems

#### Modeling and formulation established as mathematical optimization problem

- ·Facility location problem "k-median problem" focused on to formulate basic networks to examine optimal planning of leakage sensors
- ·Fundamental method evaluation completed by designing optimum installation points through weighting taking important risks
- in formulated networks into account Formulated network exar

# Goals

#### Final goals

Complete technical verification in actual water supply syste Complete the function expansion of data collection and analysis technology in conjunction with other themes to expand applicability domain.

A)	Sensing data collection and transmission technology	Development of trans data without opening underground
B)	Sensing data handling technology	Determination of leaks level by utilizing mach extraction
C)	Optimal planning of water leakage monitoring systems	Development of priori monitoring plan for wa
D)	High sensitivity sensor terminal technology	Development of a pra detect micro leakage

#### Deployment image

Domestic	Monitoring of water pipes to enable early
Overseas	Reduction in water leakage, developmen improvement in water supply infrastructu





invented technology

Learning models confirmed recognition rate of 98% plus for long water supply pipes of small/medium diameter. Models covered all verification data places including the actual environment. A common learning model independent of place is now being evaluated.

Effectiveness of invented technology in various fields is now being evaluated



#### Design of high sensitivity sensor and integrated sensor terminal completed

Pipes efficiently and effectively monitored through high sensitivity sensor terminal design completed over wide frequency bandwidth with doubled conventional sensitivity



Designed integrated high sensitivity sensor terminal

ems of local	governments	for socia	l implementation.	

mission technology that can acquire long-term and closing manholes from sensors installed

age levels without dependence on worker's skill ine learning using multidimensional feature

ty evaluation system for optimum water leakage ater supply pipeline network

ctical level high sensitivity sensor terminal that can sound on a long term basis.

detection and prevention of leakage

t of water supply management projects, ires



### R&D of Integrated Data Management Platform for Civil Infrastructure Sensing



Jun Adachi (Professor, National Institute of Informatics) Principal Investigator

<sup>Collaborative Research Groups</sup> Hokkaido University, Tsukuba University of Technology, Nagaoka University of Technology

### **R&D** Objectives and Subjects

#### Objectives

41

- Data Management Technologies : to develop efficient multimodal monitoring data management technology for analyzing, storing and utilizing massive data.
- ✤ Analysis Technologies : to extract features that may reflect structural deformation for defining new structural-deformation indices through the collaboration between structural analysts and data scientists.
- Time Synchronization Sensing Technology : to develop multimodal sensing technology for integration of various sensors with autonomous time synchronization.

#### Subjects

- \* R&D on an exploratory visual analytics environment that integrates varieties of analysis and isualization tools with database systems.
- ✤ Accurate vehicle detection and feature extraction related to structural deformation of bridges by combination of frequency analysis, signal processing and data integration technologies.
- R&D on a multimodal sensing module with an autonomous time synchronization using Chip-Scale Atomic Clock (CSAC) that integrates various sensors.

**Current Accomplishments (1/2)** 

Data Management Platform -



# monitoring Tracking peak Visual analyses of long-term vibration data Tfrequency THE LEADER MANAGEMENT acceleration(RMS)





- Metrics and use guidelines for sensing data analysis



# Development of Technologies on Wide Variety of Data Processing, Storage, Analysis and Application to Achieve Advanced Infrastructure Management

Principal Investigator Isao Ueda (East Nippon Expressway Company Limited)

Collaborative Research Groups Social Capital Design (Inc.), Yokosuka Telecom Research Park, Inc.

#### **R&D** Objectives and Subjects

#### Objectives

42

- 1) Matching needs related to maintenance and technology development requirements: With the NEXCO East Group maintenance operations as the field of evidence, set matching development conditions (seeds) after clarifying the work issues/needs.
- 2) Development of formats for using new technology in the field: In addition to effectively using existing assets, such as current systems and stored data, we will deploy the actual operation in stages while verifying and evaluating new technology in the field.
- 3) Improve the standard of maintenance through preventive maintenance: In order to use a wide variety of data effectively, owners, management, and the field should share information functionally, and develop a "user" environment for supporting accurate judgments and smooth enforcement.
- 4) Achieve at a low cost; Concentrate on the use of current systems and open data, as well as the adoption of standard technology, and utilize this for government bodies.

#### Subjects

- <u>Visualize</u> various information in an <u>integrated</u> way in accordance with the work of the administrator.
- · Realize a circulation of information with external bodies, through open data, etc.
- · Valid data for operations, analysis methods and expressions, etc., should be reflected in the DB
- Grasp issues practically during DB use and set realistic policies
- Apply standardization from to infrastructure from all directions. reorganize and document
- Design data model/API, etc., while envisaging an actual method
- Based on site verification, process and correct data in stages
- Fully automate data cleansing and multimedia processing

#### **Current Accomplishments (1/2)**

Achievements ①: Data model, System Architecture, and DB Design for Infrastructure Maintenance, with IoT in Mind

#### Overview of Achievements

- (1) Develop a data model for managing infrastructure, from acquisition to the use of a wide variety of data. This includes data stored in the past and data envisaged in the future, such as sensor data, and organize this into "Road Information Specification (1stedition)". This model can be applied to administrators of different infrastructures, such as expressways, national highways, and local roads, and it can be described in both the specifications of buildings and maintenance information.
- (2) Develop web-based "Road Information Database API Specification (1st edition)" that is not dependent on database software and can search across multiple databases.
- Needs/issues and Effectiveness of Main Achievements

The infrastructure administrator has a wide variety of data and there are many issues, such as data format compatibility and data definitions. Therefore, circulating and using data has been difficult.

Through this achievement, through the linking and searching of geographical information located in multiple databases, effective utilization has become possible through data integration and linking.

Technical Novelty and Superiority

A data model is essential for circulating and using a variety of data across organizations and operations, but there is no data model in the road management field that can comprehensively express data for both expressways and ordinary roads.

Furthermore, it has become possible to integrate multiple databases, while maintaining existing systems in a short period at low cost.





#### **Current Accomplishments (2/2)**

Achievement (2): Develop dialog-based UI according to usage formats in the field

- Achievement Overview
- Our goal is to develop a dialog-type user interface, reflecting the format used in the field, to utilize the DB developed under " Current Achievements ①". This can be achieved through API and messaging. Also, while verifying the DB functions, develop test applications that can be verified in the field.
- Needs/Issues and Effectiveness of Main Achievements In the field of infrastructure management, by sharing the same information at the same time between the head office, regional head offices, business offices, and the field, and by grasping facility and position-related information from complex perspectives, it is possible to make accurate judgments. This achievement has made it possible due to links and display real-time data between different devices in multiple fields.
- Technical Novelty and Superiority

Achieve multi-scale UI to meet the needs of a variety of maintenance fields. By linking and displaying managed objects in a variety of ways from multiple views, this has achieved comprehensive management and decision-making. Furthermore, to meet cases where maintenance is being operated in multiple bases, they have developed mechanisms to automatically collect and synchronize multimedia data managed in a distributed way.



#### Goals

- (1) Overview of Products and Services Using Achievements in SIP We will construct a framework for supporting infrastructure management in government bodies, in which data (text/images etc.) that is inspected and diagnosed by the infrastructure administrators of local public bodies, etc., is stored in the DB, and undergoes integrated analysis and evaluation. In order to respond flexibly to the scale and financial authority of the infrastructure administrator of the municipalities, ordinance-designated cites and prefectures. Social Capital Design, Inc., have provided this as a cloud system. Based on a cloud system, they are providing technical support and data cleansing for inspection and diagnosis, in collaboration with regional universities, etc.
- 2 Form of Implementation When Implemented in Society Regional universities and technical centers, etc., provide services such as operational improvement and technical advice, and nurtures human resources using infrastructure maintenance data based on this cloud system to localize public bodies, etc. (this is planned for implementation at Tohoku University and in Yamagata Prefecture in 2017) It is envisaged that construction consultants and IT companies, etc., shall use this system in various regions, and its services will be provided in regional units.



Data model that can be described as both building "specifications" and "maintenance information"

Data models

(example of data hierarchy)

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Development of infrastructure inspection system using semi-autonomous multi-copter equipped with flexible electrostatic adhesive device.



#### Tadahiro Hasegawa (Professor, SIT Tokyo) Principal Investigator

#### **R&D** Objectives and Subjects

#### Objectives

Inspection efficiency might be low and a dangerous operation

Low cost, high efficiency, safety inspection is required





Image of our R&D theme

#### Subjects

1) Technological development to adhere to a concrete wall by using electrostatic adhesive principle A flexible electrostatic adhesive device with adhesive force of 1 kgf or more, when applying 10 kV

### 2) Validity verification of infrastructure inspection, by constructing a demonstration system

- ① Transport inspection equipment and approach infrastructure wall by small UAV. Development of semi-autonomous multi-copter with wired power supply cable
- 2 Wall inspection using close-range photographic camera. Development of crack detecting algorithm for close range visual inspections using camera





#### **Current Accomplishments (2/2)**



it can be used not only for close-range visual

inspection but also for repair work.

### Goals

# 1) Flexible electrostatics adhesive device · Can adhere to a concrete wall, on uneven surfaces Adhesive force of 1 kg or more - Adhere a multi-copter with three adhesive devices 2) Semi-autonomous multi-copter Can switch between manual operation and Collision avoidance function Self-localization accuracy of about 10 cm at bridge 3) Realize the flow of our inspection system Social Implementation Image of • User : Inspection agency Place : bridge · Application : Close-range visual inspection, crack repairs, fixing an inspection device to a bridge wall





Our multi-copter is enabled to inspect concrete





The camera unit enables to acquire the shift of the copter and senses crack by image processing. Quantitative analysis makes crack detection more precise.





The hammering unit hammers object surfaces and is driven by a motor and a spring. The echo is captured using a microphone and is analyzed to see if there are defects. Quantitative analysis makes defect detection more precise.

#### **Current Accomplishments (2/2)**



The motion simulator of the multi-copter accelerates R&D of the multi-copter system.

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Value enter

Inboard

B clatance senace

Stack detection

# Achievements

International conference

- Overview : Device enabling easy inspection; the device flying • Takahiro Ikeda, Kenichi Ohara, Akihiko Ichikawa, Toshio with propeller that is equipped with a simple Fukuda, "Pilot Study on Control of One DoF Manipulator on manipulator implemented inspection device. Quadcopter for Hammering Check," Proc. of 2015 Intl. Symposium on Micro-NanoMechatronics and Human Japanese Patent Application No. 2015-091386 Science, pp. 199, November 23 - 25, 2015.
- Junpei Kishikawa, Kenichi Ohara, Takahiro Ikeda, Akihiko Overview : Main moving device controlling own position hanged Ichikawa and Toshio Fukuda, "Vision-based Localization for Atomated UAV Automated Multicopter Control," Proc. of 2016 Intl. Symposium on Micro-NanoMechatronics and Human Science, TP-14, November 28 - 30, 2016.
- Domestic conference: 6 presentation

#### Goals





MU Farcs pecting point primiting. 3057 ING29JFERTER retury inspecting path energiant unit

The control system is being developed; the multi-copter uld be controlled by tablet/PC inputting path.

Patent (Japanese Domestic)

Title of invention : Device for flight

Self-position est

Title of invention : Device for moving

by plural wire-reel suspension mechanism modulating the length of the wire. The device can move with equipped propulsion mechanism in a direction that it is not bound by the suspension mechanism. Japanese Patent Application No. 2015-091387





Shigeki Sugano (Professor, Waseda University) Principal Investigator

#### Collaborative Research Groups Chiba University

#### **R&D** Objectives and Subjects

Objectives

- Development of an intuitive interface between operator and robot - To be used in complex and strange working environments, such
- as pipelines, under bridges.
- Extraction of the standard and common human characteristic model for operation
  - The human measurement when operating the robot or drones.
- In this study, the pipeline inspection robot control is the test case



#### Subjects

Construction of the virtual pipeline inspection simulation

2 curve + 2 curve

- · Clarification of the professional human model by measuring the human brain and muscles and a working score, such as the curvature of operations and time of accomplishment
- · Design of robot configuration and a control method based on the extracted human model Construction of the intuitive robot design methodology
- · Compared with the conventional method, this study focuses on human centered design



Current Accomplishments (2/2)





- - - ✓ Inspector of bridges, pipes, etc.
    - Operator of crawler robot
  - Location
    - ✓ Bridge, pipe, debris workspace
  - Business
    - ✓ Sale from Future Robotics Co. and Kikuchiseisakusvo
    - Purchase of infrastructure company and order company



#### Development of Bridge Inspection Robot System Supported by 47 the Provisional and Flexible Scaffolding Structure

Dr. Shigeo Hirose (Representative Director/Chairman, HiBot Corp.) Principal Investigator

Collaborative Research Groups CTI Engineering Co., Ltd. / Tokyo Institute of Technology

#### **R&D** Objectives and Subjects

#### Objective

- Proposing a bridge inspection device capable of operating in complicated structures with an extendable arm mechanism. Inspection is carried out with a movable camera and illumination solution.
- Easy inspection is obtained by stitching the acquired images in the bridge virtual 3D model
- > Evaluation of the inspected surface is improved by acquiring additional data with a tapping device

#### Contents

- > The inspection device is controlled under the bridge surface by controlling simultaneously the length of 4 wires
- > Possibility to carry out visual and tapping inspection close to the surface
- $\succ$  By extending the arm equipped with attitude sensor, operator can further inspect the surface
- > Winches are fixed utilizing clamping devices and the arm is control from a movable compact control cart
- > UAV and sling shot devices are used for the guiding of the initial wire
- Database for the acquired data to facilitate the inspection

#### **Current Accomplishments (1/2)**

#### Main Items of Development

- New robotic system to allow new detailed inspections
- The following images show the operation of the new system



- 1. Setting of the four clamps for the winches' installations
- 2. UAV or slingshot is used to take the wire from one side to the other of the bridge. Four wires are set under the bridge(A)(B)
- 3. By controlling the 4 wires the camera system is moved under the bridge surface (C)(D)
- 4. The whole system is recovered by following the inverse procedures



Crack Scale for comparison (0.7 mm)



0.1 mm cracks on the bridge surface

# **Current Accomplishments (2/2)**

# Experiments and demonstrations were carried out on November 1st 2016 at Sakiku Bridge (Ibaraki Pref.) and on January 26<sup>th</sup> 2017 at Tozawa Bridge (Kanagawa Pref.)

#### Supporting winches (prototype)



 Each winch can be firmly set on the bridge using clamps and auxiliary wires

- By controlling the four winch wires length, the arm can be arbitrarily set in an area of 5 m by 10 m
- Arm can be moved at a speed of 8 cm/s

Winch

## Extendable Camera Arm (prototype) Mass: 15 kg



 Inspection device as end -effector of the arm Arm extension mechanism max. extension:3 m

extension speed: 10 cm/s Arm tilting mechanism inclination angle control:  $\pm 11$ 

# degrees

#### Goals

Final Specifications of the Robotic System (March 2019)				
1	Extendable Arm speed	0.3 m/sec		
2	Extendable Arm maximum length	2.5 m		(
3	Arm roll control range	More than 20 degrees		
4	Continuous operation time	More than 3 hours		
5	Dust and water protection	IP55		(
6	Mass of the extendable arm	Less than 15 kg		-
7	Largest area covered by four winches	30 m × 30 m		I
8	X, Y arm position resolution	within 100 mm		

Finale Specification for the visual inspection Unit (March 2019)			
1	Pitch range	±90 degrees	
2	Yaw range	360 degrees	
3	Minimum crack width	0.05 mm	
4	Dust and water protection	IP56	
5	Mass	Within 2.0 kg	
6	Continuous operation time	More than 3 hours	



UAV for wire guiding

# UAV for wire guiding (prototype)



UAV flying test

- Confirmed the hovering function based on several sensors' data, such as from cameras, gyro, etc.
- Confirmed stable flight while taking a wire of 10m under the bridge to connect the lateral sides

### Camera Unit (Prototype)



- Attached as end effector of the arm
- Mass: 0.7 kg
- Pitch range: -90 ~ +35 degrees
- •Yaw range: 360 degrees
- Crack resolution inspection.
- in low luminosity, up to 0.15 mm

Camera Unit

#### Inspection system targets Inspection operator x 1 Number of Assistants x 2 operators Total: 3 operators Robotic system 1 h Setting time Inspection 3.5 h Database generation with 3D image rendering and location Inspection output information (possibility to track the bridge crack changes) Traffic No regulation required regulation Inspection Inspection of the lower sides of ocation piers

• The system could be an alternative for the actual inspection vehicles currently utilized.

• Targeting a nationwide cooperation with inspection companies and an increase in the number of bridges that can be inspected



- differentiate between clear and non-clear hammering sounds
- · Conducted wind tunnel testing at a JAXA facility to verify its flight stability under normal winds of 8 m/s.
- · Developed easily deployable safety net system

\*LRF : Laser Range Finder









Wind tunnel testing at JAXA facility



Prototype of safety net system



wind (avg.) environment

<Handy inspection unit>

· Easy inspection under 6 m high area





- its performance
- · Apply its technology to different types of inspection



#### 49 **R&D** of The Variable Guide Frame Vehicle for Tunnel Inspection



Satoru Nakamura (Chief researcher, Tokyu Construction Co., Ltd.) Principal Investigator

The University of Tokyo, Shonan Institute of Technology, Tokyo University of Science, Collaborative Research Groups Ogawayuki Seisakusyo Inc., Kikuchi Seisakusyo Co., Ltd.

#### **R&D** Objectives and Subjects

### Objectives

•Tunnel maintenance engineers have conducted human-eye based close inspection using mobile elevating work platforms up to this point in time. The conventional inspection method requires traffic regulation for road users. One of objectives of this R&D is to reduce the traffic regulations during inspection works that are convenient to both road users and administrators.

•It takes much time for conventional inspection and hammering tests of wide areas. Be sides, conventional depending on inspectors. We have proposed a "Variable guide frame vehicle" that is new maintenance technology.



#### **Main Theme**

#### (1) Variable Guide Frame(VGF)

- Can be changing shape according to the various tunnel geometries and obstacles
- (2) Protective Frame Vehicle Can protect road users from falling concrete pieces.
- (3) Crack Measurement Unit

Can integrate visible images and 3-dimensional shape depth data (range image) by the light-section method and distinguish between cracks and dirt automatically.

(4) Hammering Test Unit

Can detect possibility of concrete spall from hammering sounds through machine learning.

#### **Current Accomplishments (1/2)**

### Inspection vehicle for regulation less traffic



## **Protective Frame Vehicle**



Topics] Performed traveling test on an experimental tunnel Performed frame assembling test on a test field

 Traveling along a road and inspecting tunnels. Dividing traffic areas and inspection areas for

· Can be assembled and disassembled on-site

### Benefits of the inspection vehicle

Can take necessary reaction force for hammering test from the Variable Guide Frame.

[Overview]

safety work.

within a short time.

- Can realize a precise inspection with a little traffic regulation.
- Variable Guide Frame allows us to inspect kinds of tunnels.



#### **Current Accomplishments (2/2)**



# Benefits of the inspection device

Can reduce processing time for removing noise such as dirt in images.

Can be finding signs quickly such as diagonal cracks that may cause concrete spall.

Goals		
R&D Final Goal Detection accuracy rate of deformation with Variable Guide Frame Vehicle • Cracks: over 80% (width over 0.5 mm) • Concrete deformations: over 70%	Road Variab	
C Supporting inspection of road tunnels mana	ged by n	
<ul> <li>O We lend out the inspection vehicle and provide technical gu The cost of the inspection vehicle will be lower than a mobil engineers.</li> <li>O We will establish an association about inspection vehicle, w dispatch, support for planning and report preparation.</li> </ul>		
R&D for practical application		
Tunnel management support system (under develor Tunnel management support system draws up insport records and photo ledgers from inspection data acc by inspection vehicle, and it also presents optimal re- methods, materials, and repair engineers. This system calculates the Life Cycle Cost (LCC) tunnel, and will support municipalities to settle seven of engineers.	pment) ection quired epair of the er lack	

R&D Point 3. Crack Me

Tunnel inspection

VGF vehicle

We considering calibration method on-site.

et of this inspection system

tunnels managed by municipalities severe lack of engineers

le Guide Frame Vehicle is applicable to about 55% of tunnels in Japan

nunicipalities

idance for local consultants and inspectors. le elevating work platform and inspection

hich will promote diffusion, lending, operator



We will make a system to support municipalities to settle sever lack of engineers, and give a basic information of infrastructure.

#### **Development of Unmanned Aerial Vehicles for Observing and** 50 Hammering Aged Bridges at Short Range

Kazunori Ohno (Assistant Professor, Tohoku University) Principal Investigator

RICOH Co., Ltd., Chivoda Engineering Consultants Co., Ltd., Collaborative Research Groups Japan AeroSpace Technology Foundation, Tokyu Construction Co., Ltd.

#### **R&D** Objectives and Subjects

#### Objectives

R&D of UAV (Unmanned aerial vehicle) for observing and hammering aged bridges

- Inspect bridges which may not be accessible by a bridge inspection vehicle in a similar time as the conventional system takes
- Minimize cost and time for scaffolding
- Minimize traffic regulation
- Software facilitating formatting inspection reports

#### Subjects

- 1. Inspection UAV with a spherical shell that can safely collide with a bridge and reach inner structures of the bridge
- 2. Communication relaying UAV that can attach to a bridge and connect the inspection UAV and the operator
- 3. AI (artificial intelligence) that supports detecting the position and level of damage in inspection images
- 4. Performance demonstrations conducted by specialists of inspection, aerospace, and construction



Final R&D outcomes

#### **Current Accomplishments (1/2)**

#### Inspection UAV with spherical shell (Tohoku University)

UAV protected by a spherical shell which does not crush in a collision

#### Evaluation by MLIT (2016)\*

- "Does not require scaffolding dislike conventional methods"
- "Can take photos of 0.2 mm width damages (e.g. cracks) with onboard full HD cameras"



Structure of shelled UAV



#### UAV capable of attaching to a bridge and relaying communication

- Magnetically attaches itself and relays communication to the inspection UAV with minimum power consumption
- · Keeps the operator and the inspection UAV connected to avoid accidents that may be caused by communication loss



Operation of comm. relay



UAV inspecting inner bridge structure

(Diameter: 0.95 m, weight: 2.5 kg)

Exp. of magnetic adhesion to a real bridge

#### **Current Accomplishments (2/2)**

#### Detection of damage in inspection images (Tohoku University, RICOH)

#### Reconstruct a panorama of bridge and detect damages from a close-up video

- Automatic reconstruction of a panoramic image by image processing
- Support making an inspection report by locating damage in respect to the panoramic image
- Support measuring cracks in software

#### Performance demonstrations (Chiyoda E.C., JAST, Tokyu Construction)

Toward robot technology that works in the real fields. performance demos have been periodically conducted by specialists





Inspection demo at a real bridge (Chiyoda E. C.)

Aerodynamic evaluation in a wind tunnel (JAST)

Goals

#### [Final goals]

Dev. item	Final goal
Close visual and hammering inspection of bridges by UAVs	<ul> <li>Target: concrete and metal bridges</li> <li>All devices carried by a car</li> <li>Preparation less than 15 mins</li> <li>Multiple lightweight cameras (&lt; 300 g) wide angle</li> <li>Continuous flights (10 mins/flight)</li> <li>30-40 mins flight in total for each span</li> <li>Hammering device to detect damage</li> </ul>
Detection of damages using panoramic images and report generation	<ul> <li>Panoramic image reconstruction from inspection video (few to tens of hours/</li> <li>Semi-automatic position/level detection of cracks and corrosion</li> <li>Report generation by pipeline of above to</li> </ul>

#### [Social implementation plans]

By member or licensed companies

- 1. Manufacturing/sales/rental/maintenance of UAVs and/or image analysis and reporting software
- 2. Education and qualification of operators and instructors



Semi-automatic detection of a crack on a concrete slab

Repeatable evaluation using artificial weather (Tokyu Construction)

# [Bridge inspection solution]

Reduce traffic regulation by using UAVs, and simplify the making of reports by image processing and autonomous functions Conventional Proposed for Planning Planning Outdoor Outdoor Image collection Using inspection UAV vehicles by p Teleop. Video Vis. and hmr Hammering inspection /span Marking Image processing ו ח ח Close-up video to nic image (auto Photos Damage detection ools Analysis by Al of Describing images and hmr. sounds ndoor Report generation Report writing Organizing damage mapping Damage map Tool-assister report formatting and report



SIP Cross-ministerial Strategic Innovation Promotion Program





Alternative inspection methods using robotics Contact danger areas easily

 Consecutive inspection as getting into touch with infrastructures









(\*2:internal abnormality by steel corrosion)



Naoyuki Sawasaki (Fujitsu Limited) Principal Investigator

Fujitsu Limited, Nagoya Institute of Technology, Tokyo University, Hokkaido University, Collaborative Research Groups Docon Co. Limited

### **R&D** Objectives and Subjects

We propose a bridge inspection robot system that captures proximity images and a 3D-model-based maintenance database to link inspection data with 3D models. Our system can make on-site bridge inspections more efficient and support bridge maintenance operations.



#### **Current Accomplishments (1/2)**

Fea

We prototyped two-wheeled multi-copters for bridge inspection.

turoo	• It can take proximity-images with constant distance to bridge surface.
luies	<ul> <li>It is robust against windy conditions because of skin friction of the wheels.</li> </ul>



#### **Current Accomplishments (2/2)**

We prototyped a 3D model-based bridge maintenance system for long-term use. ① Geotagging technology based on SFM (Structure from Motion) using 360 degree spherical camera (2) A 3D model-based bridge maintenance data model which is as extension of the ISO standard of the 3D-CAD model 3 Semi-automatic 3D-CAD model generation technology (4) Application software for viewing past inspection data on 3D-CAD models using tablet PCs



### Goals

- Development of multi-copters for taking proximity images of high pier bridges Wind-resistant stability available for practical use, mechanism and a control system for safe remote control
- Utilization of inspection data to make bridge maintenance tasks more efficient • Establishment of basic technology for high level utilization of inspection data





#### **New Development of Unmanned Construction** ~Realization of Remote Operated Working System in Shallow Water Area∼



Screen

Display

Remote Contro

Room

Shin'ichi Yuta (President, New Unmanned Construction Technology Research Association) Principal Investigator

Collaborative Research Groups New Unmanned Construction Technology Research Association

#### **R&D** Objectives and Subjects

#### Background

- Remote/Unmanned Construction is an unique technology which is developed in Japan for emergency construction in an eruption or earthquake disaster.
- Recently, water disasters (landslides, debris flows, floods) have occurred frequently because of torrential rain.



2 Engine Mechanism

Operation Support

System Technology

Resistance

1 Water

- Construct an unmanned construction system which realizes the series of post-disaster restoration work at river edges or semi-underwater places at a depth of about 2 m.
- Develop remotely operated heavy carrier robot which runs efficiently and stably under various conditions in several hundred meters from shallow water to land areas.

\_\_\_\_\_ [Concrete R&D Subject]

3 Acquire Traveling Performance

Body Stability

(5) Cargo Stability

6 Traveling Robustness

(8) Traveling Support

Sensing Technology





An amphibian heavy carrier robot is requited for post-disaster restoration work at river edges or semi-underwater places.

#### R&D Objectives

Expand applicable scope of unmanned construction to dangerous river edges and shallow water areas for the quick post-disaster restoration of frequently occurring water disasters

#### **Current Accomplishments (1/2)**



#### II. Development of Remote Operation Support and Guidance System for Semi-underwater Traveling R&D Achievement (H26~28) [Development of Remote Operation Guidance System Using GNSS-IMU] The following improvements and experiments are executed in H28 for the better operationality in the operation screen of the operation quidance system .... (1)Transmitted carrier body (for better visibility of planned trajectory) 2 Rectangle display of traveled trajectory (for easy recognition of traveling direction 3 Addition of circumferential scene (for improvement of operationality on land) Rectangle display of traveled trajector (Revised from line display) Revised display screen of remote Operation support guidance system Test road for the experiments Results of on land traveling comparison test using revised remote operation support guidance system Planned travel course (goal point) Position and orientation of remote operated heavy carrier robot (moving point) 動計(復務① 動跡(往路③) Absolute position data is measured by RTK-GPS positioning method of GNSS 軌跡(往路①) system 軌跡(往路② Traveling direction and body tilt angle are measured by IMU.

Current Accomplishments (2/2)

The error of real trajectory from planned trajectory was a maximum 50 cm using a revised remote operation support guidance display system.

### Goals





(At the end of SIP Project) Increase the toughness of the country -----

Overseas deployment (Export carriers and their operation techniques)

#### Research and Development of Infrastructure Structures and 54 Inspection Devices for Advanced Inspection of Civil Infrastructure



Kenichi Fujino (Principal Team Leader, Construction Technology Research Principal Investigator Department, Public Works Research Institute)

Public Works Research Institute, Japan Bridge Engineering Center, Japan Collaborative Research Groups Construction Machinery and Construction Association

#### **R&D** Objectives and Subjects

#### R&D Objectives

 Aging social infrastructures (bridges, tunnels) require reliable maintenance for people to be able to use them safely and securely. However, concerns are being expressed about a labor shortage in the construction industry and a technician shortage in public organizations, etc., due to the declining birthrate and aging population.

• This research looks at inspecting social infrastructures (bridges, tunnels) safely, efficiently, and economically. In addition to examining the structuralization of infrastructures that better suit inspection work, this research also proposes an optimal inspection system where infrastructures, robots, and people work together to clarify concerns about the design of structures in order to introduce equipment, such as robots, more efficiently.

• As a target to be reached by the end of FY2018, taking the development and dissemination of robotic technologies into consideration, we will work toward the early realization of "support and efficiency improvement of our existing close visual inspection" using robotic technologies on the precondition that existing control standards and techniques are used as a base.

#### R&D Subjects

·We will work on the following support (research and development) to achieve the early introduction of robotic technologies on-site in order to realize "support and efficiency improvement of our existing close visual inspection" using robotic technologies. Target sites for introduction include locations where we expect the introduction of robotic technologies to produce effects, such as "hard-to-inspect spots" (according to the needs of infrastructure administrators, etc.).

- (1) Examine the structures of infrastructures (new and existing) that take inspection into consideration.
- (2) Prepare procedures for installing additional equipment.
- (3) Establish performance requirements for robotic technologies to solve "hard-to-inspect spots," etc.
- (4) Develop operation guidelines for location sensing technology (markers), examine methods to deliver damage diagrams
- \* The main objective of (1) and (2) is to take measures against "hard-to-inspect spots".

#### Current Accomplishments (1/2)

Bridaes

#### Main hard-to-inspect spots and proposed countermeasures (proposal to improve work efficiency and improving hard-to-inspect spots)

<Classification of hard-to-inspect spots (classified in the previous years)>

Cases of about 120 typical hard-to-inspect spots were extracted and analyzed in order to classify hard-to-inspect spots based on data from about 23,000 bridges across national roads under direct control of Ministry of Land, Infrastructure, Transport and Tourism by conducting field surveys on Honshu-Shikoku Bridges and the Tokyo Bay Aqua-Line, etc. Measures which contributed to improving the inspection efficiency, etc. were examined and proposed based on the relevant classification.





demonstrations experiments etc.

**Current Accomplishments (2/2)** 

#### Goals

The following table summarizes the results in order to introduce robotic technologies for infrastructure maintenance to realize "support and efficiency improvement of our existing close visual inspection" as an exit strategy at the end of FY2018.

	Issue	
	(1) Narrow inspection space (measures against hard-to-inspect spots)	<ul> <li>Proposal of structures (r</li> <li>Design of an inspection</li> </ul>
	(2) Hard to inspect visually due to obstacles (measures against hard-to-inspect spots)	Preparation of Guideline
	(3) Infrastructure inspection using robotic technologies	<ul> <li>Clarification of a utilizati technologies on-site</li> <li>Design of an inspection</li> </ul>
	(4) Improve inspection efficiency and accuracy	Development of operation

#### [R&D Objectives and Subjects]

OSupport measures for introducing robotic technologies on-site

- (Structures of infrastructures, inspection support facilities, etc.) (1) Examine the standard of infrastructure structures
- (new and existing) that takes inspection into consideration
- (2) Prepare procedures to install additional equipment (system)
- (4) Develop operation guidelines on location sensing technology
- (markers), examine standards to deliver damage diagrams,

+

- O Clarify the utilization method and performance requirements of robotic technologies on-site
- (3) Establish performance requirements for robotic
- technologies that are utilized for infrastructure inspection

Tunnels

shortening the inspection time by about 10 to 20% (according to test calculations based on the field survey)

· Shorten the work time by conducting shoulder

A marker that can be recognized using camera, radar, etc

#### Final result

new and existing) that take inspection into consideration support equipment (system)

es for installation of additional equipment (new and existing)

tion method and performance requirements for robotic

support equipment (system)

on guidelines on location sensing technology (markers)

### [Outcome]

maintenance etc.

Improved efficiency in infrastructure by introducing robotic technologies,

+





### Establish an unification system of robotics information for civil infrastructure

#### Principal Investigator Hirokuni Morikawa (National Institute for Land and Infrastructure Management)

(Supported by Advanced Construction Technology Center, Nomura Research Institute)

### **R&D** Objectives and Subjects

Objectives

- · It is important to assume a robotic technology at the maintenance of civil infrastructure and a disaster effectively.
- This research contributes to developing robotic technology through the matching between needs and seeds.
- · And more, this research supports the social implementation, Development of new business and the evolution of the global market.



#### Subjects

- · Unification about robotic technologies for the maintenance of infrastructure and the disaster.
- Establishment of an unification system of robotics information related to civil infrastructure for robotic developers and users.
- · Administration of the community for an implementation and an industrialization of robotic technologies.
- · Provision of information and procurement will support Ministry of Land, Infrastructure, Transport and Tourism and local governments in time of the disaster.

#### **Current Accomplishments (1/2)**

#### Running on Simple Data-Base for Infrastructure Maintenance and Disaster

· We have pigeonholed robotic technology and added search function to the system based on the evaluation results of the field demonstration which is for maintenance of bridge, tunnel, underwater structure and for disaster response including disaster investigation, disaster recovery.

The field demonstration is held by the Ministry of Land, Infrastructure and Transport project "Development and Implementation of the future generation civil engineering robotic technology"

Section Needs		The number of Seeds
1100000-00	Support/alternative of crossed-eyes	28
Bridges	Support/alternative of HAMMERING TEST	5
	Move/Approach of inspector	0
warmen P	Support/alternative of crossed-eyes	6
Tunnels	Support/alternative of HAMMERING TEST	6
	Support/alternative of crossed-eyes of Dam	11
Underwater	Evaluating bottom sediment and water of Dam	2
000000000000000	Support/alternative of crossed-eyes of river	2
	Picture/topographic data of mass failure /volcanic hazard	12
Disaster Investigation	Physical property investigation/measurement of mass failure/volcanic hazard	4
1640/2003/1	Information acquisition of tunnel collapse gas	0
	Image capture of tunnel collapse	6
	Emergency rehabilitation of excavation, dozing, and banking	4
Disaster Recovery	Emergency rehabilitation of drainage	1
	Circulation of information of mechanical excavation	4

DB

Providing



The Map Search dialog box

- - (DiMAPS)
    - > Positioning as the part of the infrastructure maintenance national meeting
    - > Positioning as the part of WG of the i-Construction promotion consortium

#### **Current Accomplishments (2/2)**

- · Start the community for development of robotic & social implementation to construction site
- · The interchange of robotic developers and users is started on this year.
- Now, 71 attendees communicate about howto/know-how for robotic technologies on this community.
- · There are especially themes for the summary of bridge inspection;
- -an application of UAV for inspection
- -a development of 3D modeling technology

### Goals

#### Preparation for the sustainable administration of this system

- > Need more consideration of improvement, convenience, effectiveness and sustainability by using this system .
- Study for the systems management after SIP.
- Start an unification system of robotics information for civil infrastructure by the autonomous system from 2019.
- > This system will become as "an intellectual information hub" for all robotics users in Japan.

#### Valued creation and cooperation with measure of MLIT

> After full-scale operation in 2019 will cooperate with the integration disaster information system



And Anna ist false





The integration disaster information system (DiMAPS) Source: http://www.mlit.go.ip/river/bousai/bousai-gensai/bousai-gensai-4kai.htm



#### **Current Accomplishments (2/2)**

#### R&D of Maintenance systems for road administrator and municipalities

- Vietnam





#### Koichi Maekawa (Professor, The University of Tokyo) Principal Investigator

Nihon Univ., C.E.Management Integrated Laboratory Co., Ltd., NIPPO Corp., East Nippon Expressway Co., Ltd., Metropolitan Collaborative Research Groups Expressway Co., Ltd., Yokohama National Univ., Tohoku Univ., Kyoto Univ., Osaka Univ., Kochi Univ. Tec., National Inst. Tec. Kochi Col., Tokyo Inst. Tec., Tsukuba Univ., JSCE, Hokkaido Univ., Shutoko Eng. Co. Ltd., Highway Tec. RC, Kyushu Univ.

#### **R&D Objectives and Subjects**

#### Objectives

#### R&D of Innovative hardware and software :

We are developing various technologies to reduce the life cycle cost of road infrastructures. Our research covers whole maintenance processes such as Inspection, Performance verification, repair & strengthening and renewal.

#### **R&D** of management system :

We are also developing a maintenance system for infrastructures in municipalities.

Implementation at home and abroad is our final goal. Developed technologies are implemented for domestic road infrastructures and municipalities. The scheme will be prepared to export the developed system.

#### Subjects

#### Key technologies for road maintenance

3-D radar, Multi-scale simulation, Data assimilation, Survival analysis, Durable bridge decks, Water jets, Surface finishers, Water proofing material, Pre-cast bridge decks, Quality control system

#### Maintenance system for administrator

Asset management system, Management database, Education system, PDCA cycle of maintenance, Bidding model & Contract model, Business model

#### Exportation

Preparation of ISO on the maintenance of concrete structures, Formulation of international hubs in other Asian countries, Information transmission

#### **Current Accomplishments (1/2)**

#### R&D of various technologies for bridge decks







Kazuyuki Torii (Kanazawa University) Principal Investigator

Kanazawa Institute of Technology, Ishikawa National College of Technology, Collaborative Research Groups Nagaoka University of Technology, University of Fukui

#### **R&D** Objectives and Subjects

#### Objectives

Bridges in Hokuriku region are exposed to the following severe environments :

> In the coastal areas, salt damage deterioration due to airborne salt brought by monsoon

- > In snowy regions, salt damage deterioration due to the spraying of anti-freezing agents
- > ASR degradation in bridges using reactive aggregates, e.g., and esitic stone
- In mountainous areas, frost damage spreads easily at high altitudes

Main purposes : unlike aging deterioration, this degradation occurs early and complexly. This R&D proposes a sequential flow, i.e., inspection-diagnosis-monitoring, evaluation-judgment, countermeasures (reinforce, repair, renovation) as the basis maintenance management system

Implementation : the Hokuriku region and other areas with the same kind of early deterioration



OElucidating the early-aged degradation mechanisms of salt damage and ASR damage, and developing methods for using roads safely for long periods of time

Investigating actual conditions of salt damage & ASR deterioration in road bridges of the Hokuriku region

·Making the girders and slabs simulated degradations with actual sizes, then evaluating safety and serviceability • Standardizing fly-ash concrete, slowing down the process of salt damage and ASR degradation

- · Developing sensible inspection techniques, including simple monitoring technology

ODeveloping a maintenance management system which can be operated by local governments

• Establishing evaluation methods for structural health, a method of ranking for repair work, budget methods, and proposing an evaluation-judgment method corresponding to early deterioration

·Holding open seminars regularly, developing human resources

#### **Current Accomplishments (1/2)**

Elucidate the relationship between rock types/mineralogical features and ASR degradation Elucidate the degradation mechanisms by investigating PC girders undergoing ASR degradations





Developing a database for the As a result of the load tests, characteristics of ASR degradations is important in the inspection and diagnosis of ASR of fly ash concrete

ultimate strength and toughness were improved due to the use

o with fly ash

0 10 20 30 40 50 60 70 80 90 100 110 120 130 14 displac

× without fly ash



#### **Current Accomplishments (2/2)**

Diagnose the health of early-aged deteriorated slabs by using a large, mobile impact vibration exciter



FWD Light

Self-propelled Impact Vibration Equipment





From an age-healthy relationship, a tendency of monotonous deterioration until the 40th year can be observed and some recovery work is done after 40 years.

#### Goals

Grasping the actual conditions of structures accurately, improving the accuracy of diagnostic technology, repeating effective maintenance and establishing maintenance management which can be turned into preventive maintenance carried out by local governments in the next 50 years Features : This project does not propose a nation-wide standard maintenance system; it develops a standard one for the Hokuriku region based on regional characteristics, to improve the safety of infrastructure and to reduce wasteful spending



slabs using fly ash concrete

deterioration

#### Monitoring for early-aged degradation bridges



**Development of Life-Cycle Management System for Port and Harbour** Facilities - Integrated Framework from Inspection to Assessment



Ema Kato (Port and Airport Research Institute, MPAT) Principal Investigator

Collaborative Research Groups) Tokyo Institute of Technology, Tokyo University of Science, Toa Corporation, Nakabohtech

### **R&D** Objectives and Subjects

#### Objectives

Implementation of maintenance and management support tools for port facilities based on a life-cycle management system

- · Development of inspection and monitoring technologies for port concrete/steel structures
- Proposal of appropriate maintenance and management techniques for individual port facility management bodies
- · Improvement of formulation methods of maintenance and management plans for the optimization of life cycle costs

The proposed tools contribute to simplifying maintenance work and reducing maintenance cost, aiming to enhance the international competitiveness of Japanese ports and improve disaster prevention functions of port facilities.

#### Subjects

Development of inspection and monitoring technologies for piled piers

- ✓ Development of 4 types of inspection devices; 1. ROV equipped with a camera system for visual inspection of concrete superstructures, 2. Non-contact ultrasonic thickness gauging system, 3. Sensor for anti-corrosive coatings, and 4. Sensor-aided maintenance system with IT
- Proposal of an inspection scheme according to requirements of maintenance and management

Improvement of evaluation and prediction of performance for piled piers

- ✓ Development of performance evaluation methods for anti-corrosive coatings of steel piles
- ✓ Development of performance evaluation methods for concrete superstructures

Improvement of the Life-Cycle Management system for open-type wharves

✓ Methodology establishment of maintenance and management plans for optimization of life cycle costs

#### **Current Accomplishments (1/2)**



**Current Accomplishments (2/2)** ROV equipped with a camera system for visual inspection Improvement of location identification and operation-supporting system ✓ Promotion of demonstration tests Non-contact ultrasonic thickness gauging system ✓ Enhancement of precision by improving detection of multiple reflection waves Sensor for performance evaluation of anti-corrosive coating ✓ Examination of the threshold value of sensors for corrosion ✓ Promotion of demonstration tests Sensor aided maintenance system with information technology Inspection data Accuracy of data for performance evaluation Improver For enhancement of performance evaluation techniques with accuracy evaluation of inspection data nent of Evaluation of deterioration variation in concrete structures





Reflection in Technical Standards for maintenance and management of Port and Harbour facilities Technical Standards and Commentaries for Port and Harbour Facilities in Japan Manual on Maintenance and Rehabilitation of Port and Harbour Facilities Guidelines on Strategic Maintenance for Port Structures



### R&D of development of strategic asset management technologies for trunk agricultural water facilities

Principal Investigator Isamu Nakajima (Head of Facilities Maintenance Unit, Institute for Rural Engineering, NARO)

Walnut Ltd., TRIBOTEX Co. Ltd., Kubota Corp., Reitaku University, Ishikawa Collaborative Research Groups Prefectural University, Fukushima Agricultural Technology Centre, Okayama University

### **R&D** Objectives and Subjects

### Purpose of R&D

- ① To develop new inspection and diagnosis technologies to maintain the functions of agricultural water facilities, including a total of 400,000 km of agricultural water canals and about 12,000 km of pipelines.
- 2 To develop a maintenance information database and a personnel development system in order to support organizations and technologists who maintain facilities.



#### **Current Accomplishments (1/2)**

- Development of technology to detect locations of 1 leaks in water pipes
- Detection of water leakage position by small submarine type leakage exploration robot





Measurement precision of prototype leak investigation robot now being tested in an outdoor pipeline leak test field. Proving test underway on Miyakojima Island.

Inspection and diagnosis countermeasure technologies -

#### ② Development of technology to monitor the state of and to maintain pumping equipment

#### Conventional method

Disassembly inspection of pump equipment (once every 10 to 20 years)

#### Development technology

Lubricating Oil Diagnosis method (oil extraction - analyze and quantitatively diagnose equipment deterioration)



Proving test equipped with measuring devices attached to drainage pumping stations at 2 places (Niigata, Aichi)



- ③ Systems to support preparation of trunk water facility renewal and improvement scenarios
- (4) Method of providing information to pass on agricultural water facility Building a personnel training and R&D network model centered on regional management technologies
- A web-based application to enable an iPad or cell phone to be used easily to build a GIS database of maintenance/disaster information accumulated in land improvement districts where day-to-day management of facilities is conducted.





G	bals		
.s		]	Equipment development
agnos	leak investigation		Improvement based on development and in-situ
, di			Reflection in technical
ction	(2) Remote monitoring of pump		documents
spe	system		Development of diagnos
<u> </u>			Studying the method by in-situ testing
		1	
ies	③ Preparing a web-based system for function diagnosis renewal	5	System development
olog	scenario		mprovement based on
techno	④ Information recording software to pass on management technologies	t	esting of system prototype
out		F	Personnel training
Supp	(5) Building a personnel training and R&D network centered on local universities	Ti or In	rial operation of local n-the-job training noroving manuals

Overseas development as maintenance technology for agricultural water facilities in Monsoon Asia

Development of methods of inspecting and diagnosing facilities that used to be difficult to inspect visually

#### Maintenance organization support systems

#### 5 Building a personnel training and research network centered on local universities

universities and contributing to regional asset management while creating organizations and preparing a technical manual containing expertise on operation methods



