"Technical Research and Development for Road Policy Quality Improvement" Study Summary

No.	Title	Principal Researcher
No.2022-4	AI-based road management system using ICT and commercial vehicle probe data.	Nagasaki University Prof. Hiroshi MATSUDA

This research aims to improve the efficiency and sophistication of road management using smartphones, drive recorders, and commercial vehicle probe data. We will also analyze road surface degradation mechanisms based on past inspection data, road registers, and traffic volume. Finally, we will develop a next-generation AI-based maintenance and management planning method.

1. Backgrounds, Motivation, Objectives, and Goals

Infrastructure maintenance is the inheritance of years of experience and skilled techniques. This R&D aims to provide automated inspection and diagnostic support by accurately recording the condition of road surfaces using ICT devices such as smartphones and drive recorders and to process the recorded data using AI. We will develop automated technology to support the formulation of road pavement maintenance and management plans that do not involve human eyes or manual labor. Our technology will use accumulated big data, such as AI-derived diagnostic results, multiple statistical information, such as past maintenance and construction history, and significant traffic volume information (commercial vehicle probe data) that causes the most damage to road surfaces. The objective is to develop a centralized visualization method by superimposing spatial, temporal, and critical information to enable road managers to effectively and efficiently perform their tasks and to build a next-generation maintenance and management planning method using AI for the sustainable DX era.

2. Research Contents

As shown in **Table 1**, we will develop a next-generation maintenance management planning method that centrally manages the following by combining spatial, temporal, and critical information.

Table 1 Research Contents

Development Detail 1 (Utilization of digital images)	Development Detail 2 (Development of centralized visualization method)
a. Crack ratio calculation method using image classification AI	d. Pavement degradation data using drive recorders and accelerometer
b. Detection method of road structures using object detection AI	e. Heavy vehicle traffic data
c. Method for detecting objects on the road using SfM and 3D classification method	f. Various road profile data owned by road administrators

3. Improvement of the R&D environment

3.1 AI development environment

An AI server (Dell XE8545) equipped with four GPUs (NVIDIA A100 80GB) capable of high-speed AI processing such as image classification, object detection, and 3D segmentation was installed in the Nagasaki University Data Center to create an environment that enables remote AI processing 24 hours a day, 365 days a year.

3.2 Road deterioration measurement system

An inexpensive road deterioration measurement system was constructed using two drive recorders and one GPS/acceleration logger. This measurement system enables the simultaneous collection of (1) road video (stereo), (2) location information (GPS), (3) 3-axis acceleration, and (4) 3-axis angular velocity (gyro) data.

4. Research results

4.1 AI-based crack ratio calculation method

We focused on calculating the crack ratio of MCI. We developed an inexpensive and accurate method for calculating the crack ratio similar to MCI by combining image processing and deep learning with standard equipment such as drive recorders and action cameras. By using ResNet101, an image classification model, for crack detection and DeepLabV3, a segmentation model, for patching detection, we were able to obtain very high accuracy, with an average correct response rate of about 96% for cracks and an IoU of about 90% for patching detection. Figure 1 shows the crack detection rate for roadway cracks. **Figure 1** shows an example of the crack ratio calculation for a road.

4.2 Detection of road surface damage and objects on the road using AI

We developed a method to detect road surface damage and objects on the road in terms of type, location, and size (rectangular area) from videos captured by a drive recorder or action camera. The method can detect objects for the following classes (**Table 2**) using the object detection model, Faster R-CNN. This study created teacher data using 777 images extracted and scrutinized from road surface videos. The analysis results using the created teacher data show that the object detection index mAP is 54%, which is sufficiently accurate. **Figure 2** shows the results of damage and object detection on the road.

Table 2 Classes of Object Detection

D00	Longitudinal / Wheel mark part	D20	Alligator Crack	D43	Cross walk blur	D50	Manhole
D10	Lateral / Equal interval	D40	Pothole	D44	White line blur	D60	Patching

(a) Calculation by human (Crack ratio: 6.0%)

(b) Calculated by AI (Crack ratio: 7.8%)

Figure 1 Results of crack ratio calculations

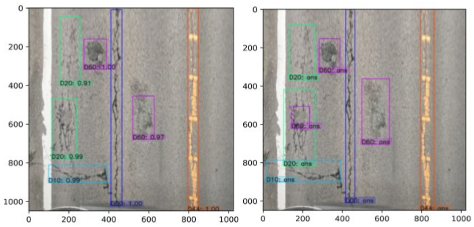

Figure 2 Results of object detection

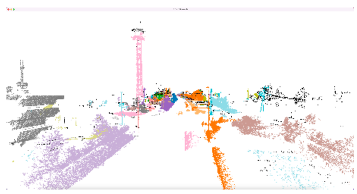

Figure 3 Clustered point cloud

4.3 Analysis method for 3D point cloud data

We analyzed 3D point cloud data measured by MMS (Mobile Mapping System) and 3D point cloud data created by SfM (Structure from Motion) by the Ministry of Land, Infrastructure, Transport and Tourism. First, we presented the MMS and 3D point cloud analysis environment, point cloud separation using planar detection and clustering, and a 3D semantic segmentation method using AI. **Figure 3** shows the results of separating MMS point clouds using planar detection and clustering.

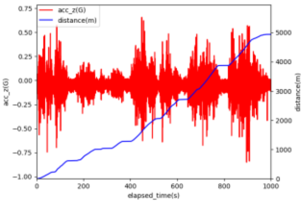

Figure 4 acceleration data and distances

4.4 Evaluation of flatness using GPS and accelerometer data

Figure 4 visualizes acceleration data and distances obtained from loggers. **Figure 5** visualizes the flatness calculated from the acceleration data. The distribution of flatness values between point (a) and point (b) shows that point (b), near the intersection with a relatively large width, has a larger flatness value.

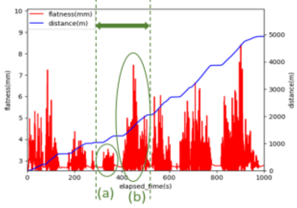

Figure 5 flatness

4.5 Visualization of commercial vehicle probe data

The emergency braking event occurrence data and traffic volume data are visualized in a heat map because there is a huge amount of data.

4.6 AI-based road management system(AIRMS)

AIRMS is developed as a web application and can be used anywhere with browsers such as Chrome, Edge, Firefox, etc. AIRMS is developed using Python, which is used in AI and data science, and has been used in many research projects using AI, including this study. AIRMS is designed to quickly incorporate the research results using AI, including this study. Currently, AIRMS implements the following functions

1) Displaying crack rates on a map from video files and location data.
2) Display of road damage on a map with the addition of speed data
3) Display emergency braking events and traffic volumes from commercial vehicle probe data
4) Display pavement inspection results by registering an xROAD API key.
5) Register and display 3D point cloud data.

Some of the above data can be displayed as superimposed graphs, which can be helpful for road maintenance and management.

4. Prospects

The "Nagasaki Prefecture Infrastructure Maintenance Liaison and Coordination Council," currently under consideration for the establishment, will operate and utilize the road deterioration measurement system and AIRMS, which are the research results. In addition, GPS acceleration loggers will be installed in traveling vehicles to measure deflection response values (invariant feature curves) unaffected by load speed or weight. They will be compared with FWD/MWD deflection amounts. Through hybrid learning of cyber/physical data, we will develop an abnormality detection system for roadbed and roadbed of road pavement underground using invariant structural feature curves, and finally, an AI-based road pavement deterioration diagnosis method using full-field sensing data.

5. Contribution to improving the quality of road policy

This research was conducted by studying the proceedings of the Road Subcommittee of the Social Infrastructure Development Council of the Ministry of Land, Infrastructure, Transport and Tourism. The results are expected to improve road policy quality and are likely to be reflected in practice.