B-10

Using CalSok to monitor river embankment slopes: Inspection technology improved by regional implementation support

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Situation Surrounding Infrastructure Maintenance

In maintenance methods for dealing with aging infrastructure, it is expected that new technologies will be introduced and used, including robots and sensors. In 2014, MLIT, the Ministry of Land, Infrastructure, Transport and Tourism publicly sought applications on technical R&D to promote the use of infrastructure monitoring technologies, calling for development of monitoring techniques in combined processes from measurement to analysis.

A technology for efficient riverbank monitoring was selected in the area of river embankments, one of the fields covered; and in response, a system for area mole hole detection by a large weeding machine (referred to below as "CalSok") was developed from 2014 to 2016, with funding from the Strategic Innovation Promotion Program (SIP) of the Cabinet Office.

Meanwhile, a regional implementation support team was formed for the sake of regional implementation of the developed technologies, and institutes were selected from eight blocks nationwide to serve as bases.

Aero Asahi, in collaboration with Gifu University, which is one of those bases (Gifu University's SIP project), and the Kisogawa Joryu River Office of MLIT, has evaluated the effectiveness of CalSok in Ibigawa River for the purpose of implementation in Gifu Prefecture. The results are reported below.

About CalSok

CalSok, a measuring system that can be easily attached to the back of a large weeding machine, was developed for the purpose of collecting ground data measurements on sloped surface at the same time as weed cutting and collection. The measurement system consists of a power supply unit, data collection unit, laser scanners (two scanners), digital camera, and GNSS/IMU unit. An important feature is its ability to collect high density point cloud data by laser-scanning embankment slopes at very close range immediately after weed cutting and collection. This system is designed to detect a wide variety of deformations, from micro-level deformations such as holes made by moles (or other small animals) and erosion (gullies), to macro-level deformities such as slope convexities and concavities.* Fig. 1 shows a photo of CalSok mounted on the back of a large weeding machine. Table 1 shows sensor performance, and Table 2 shows overall performance.

* Slope convexity and concavity: This refers to slope deformation due to consolidation settlement of an embankment under its own weight or deformation due to high levels of saturation in the embankment. A concave area forms above a bulging area, or convexity.

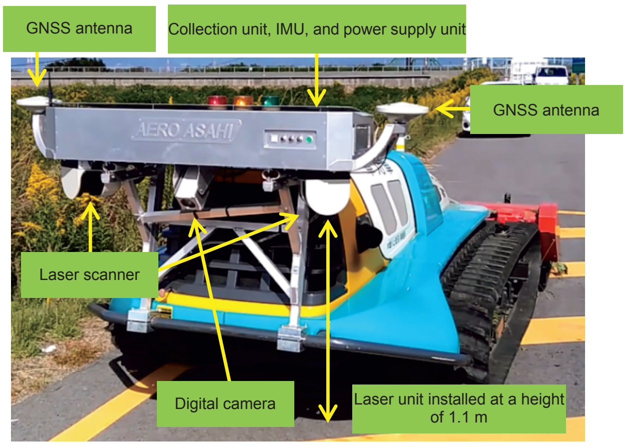

Fig. 1 CalSok

Table 1 Sensor Performance

Sensor	Item	Specifications
Laser scanners	Number of irradiation points * 2 units	57,000 points per second total
	Measurable distance	0.7 to 80 m
	Irradiation angle	190°
	Reflection intensity data	Can be acquired
	Number of units	2 units
Digital camera	Number of pixels	1.9MP x 1 camera
GNSS / IMU	Position accuracy	2 to 5 cm
	Roll and pitch accuracy	0.025°
	Heading accuracy	0.08°

Table 2 Overall Performance

Item	Specifications
Total weight	45 kg (measurement equipment: 35 kg, mount: 10 kg)
Power consumption	120 W
Point density	Approximately 10,000 points per m^2
Ortho resolution	1 mm
Position accuracy	Horizontal: 8 cm, Height: 15 cm
Data capacity	Approximately 15 GB/hour

Past Timeline of CalSok

Table 3 shows the points of the past timeline of CalSok, from R&D to trial utilization and contracting of services.

At Ibigawa River, the area from 43.4 to 43.6 KP (right bank, land side only; referred to below as the "monitored area") was selected for June and November 2017 as an area having a large amount of deformation. Again in October 2018, measurement was performed in the same area as 2017 for the sake of comparison

Table 3 Past timeline

Fiscal year	Event
2014 - 2016	R&D (Agagawa River) with funding from SIP of the Cabinet Office
2017	Trial introduction at two times (June and October) at Ibigawa River in collaboration with SIP regional implementation team
	Trial introduction at two times (June and November) at Maruyamagawa River
	Service contracted by the National Institute for Land and Infrastructure Management, MLIT
2018	NETIS registration (July; NETIS No. KT-180041-A)
	Trial introduction at Ibigawa River for a second year (October) in collaboration with SIP regional implementation team
	Trial introduction at Maruyamagawa River for a second year (June and November)

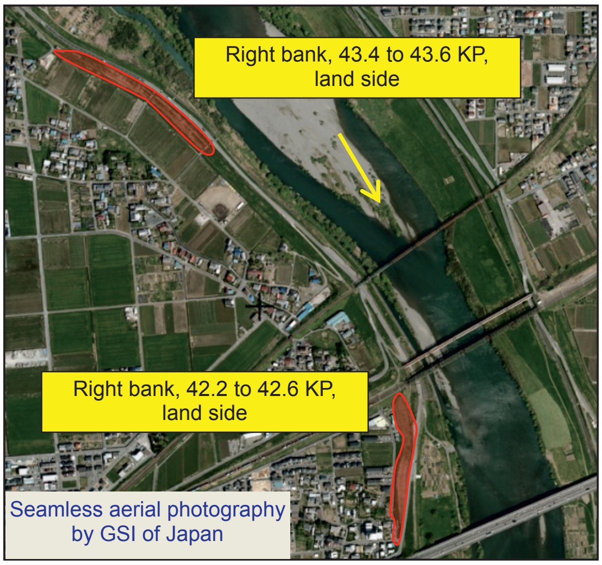

Fig. 2 Areas measured in trial introduction

and evaluation at two times; and measurement was performed in a total of two areas for the purpose of evaluating effectiveness at flood warning area (from 42.2 to 42.6 KP, right bank, land side only). The measurement locations are indicated in Fig. 2.

Measurements at Ibigawa River

The first step toward implementation of CalSok was measurement at Ibigawa River in 2017. However, there was unanticipated failure of measuring instruments. Measurement was performed in conjunction with daily weed cutting and collection, unlike the usage environment in the evaluation field; and this failure was clearly caused by effects on the measuring instruments due to vibration in the weeding machine itself, which could not be determined in advance. To solve this problem, measures were implemented to reduce vibration in the frame and the measurement system.

As a result, stable measurement was achieved at Maruyamagawa River in June 2018 as well as Ibigawa River in October 2018, with practically no malfunctions.

In 2018, when measurement was only performed at a time subsequent to water effluence, measurement was performed during weed cutting and collection for the sake of comparison and evaluation of ground data by

Fig. 3 Measurement during weed cutting

Fig. 4 Measurement during weed collection

measurements at the time of weed cutting and collection, in addition to the above purpose (Figs. 3 and 4).

During weed cutting, measurement is performed while the just-mowed weed clippings remain on the slope surface (Fig. 3); and during weed collection, measurement is performed while clippings are removed on both sides using a front attachment (Fig. 4). This makes it possible to minimize the effects of weed clippings on measurements.

Filtering Process

After measurement, data analysis is performed according to the sequence shown in Fig. 5. Specifically, after creating 3-D data from the measurement data, we eliminate the effects of points having much lower elevation than their surroundings and the effects of surrounding vegetation, etc., and the original data is prepared. Next, automatic filtering of the original data is performed at a fixed mesh interval, the effects of weed clippings are minimized, and the ground data is prepared.

The width of measurement data in a single run (referred to below as “cut width”) and the mesh interval are important parameters in automatic filtering. With regard to the optimal parameter values at present, we have learned from the results of trial measurement data processing thus far that the effects of weed clippings are best minimized when the cut width is 5 m (the weeding machine passing through a range of approximately 1.85 m) and the mesh interval is 5 cm. Therefore, the data collected after weed cutting and after weed collection were respectively filtered with these parameters.

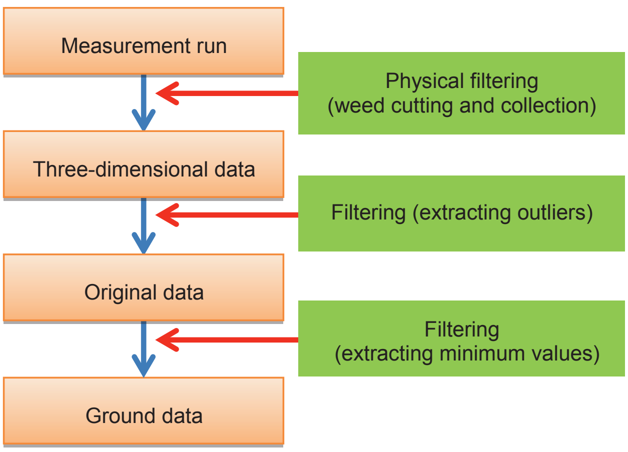

Fig. 5 Sequence of filtering process

Comparison with Shaded Relief Map

To compare the data collected after weed cutting and after weed collection, shaded relief maps were prepared to clearly indicate unevenness in the data. Figs. 6 and 7 are shaded relief maps after weed cutting and after weed collection, respectively.

The effects of weed clippings are still present in the measurement data from the time of weed cutting (Fig. 6), but these effects are minimized in the measurement data from the time of weed collection (Fig. 7).

Fig. 8 is a comparison of the cross sectional data prepared along the transverse lines of Figs. 6 and 7. The data after weed cutting clearly shows unevenness due to the weed clippings, and this also affects the final data quality.

Shaded relief map is widely used, and because shading provides an easily understandable visual representation of the results of measurement by CalSok, Shaded relief map is to be included as a standard type of image data.

As an example of the detailed depiction of deformation provided by Shaded relief map, Fig. 9 shows a

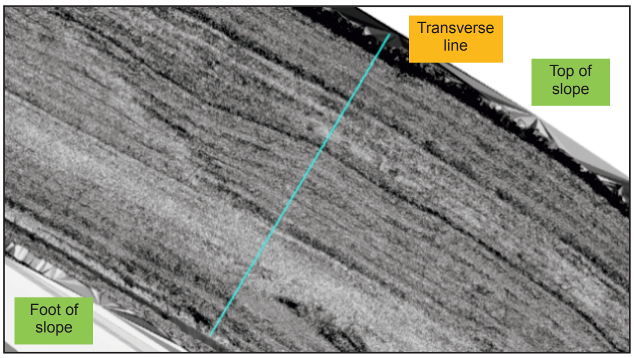

Fig. 6 Shaded relief map based on measurement data after weed cutting

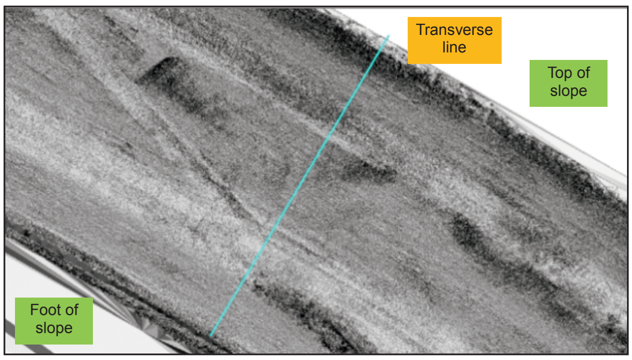

Fig. 7 Shaded relief map based on measurement data after weed collection

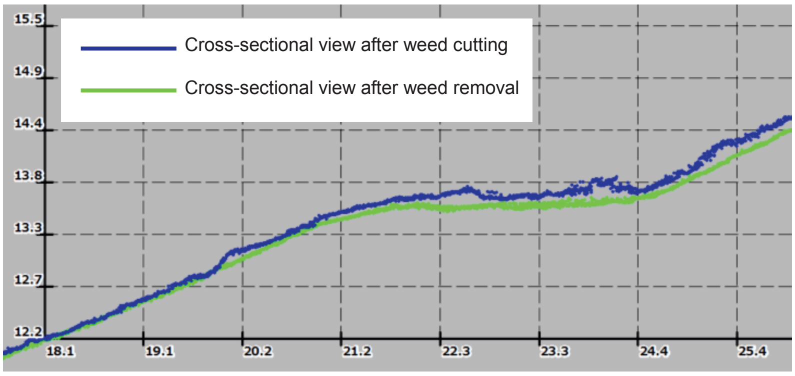

Fig. 8 Comparison of cross-sectional data after weed cutting and after weed collection

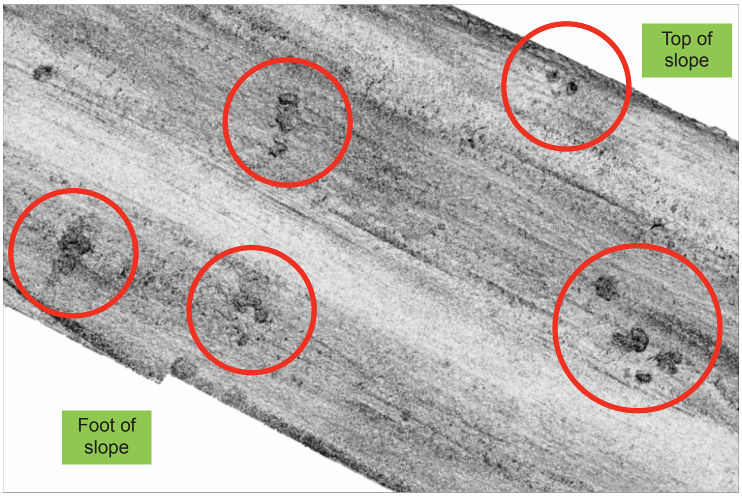

Fig. 9 Mole hills clearly visualized in a Shaded relief map

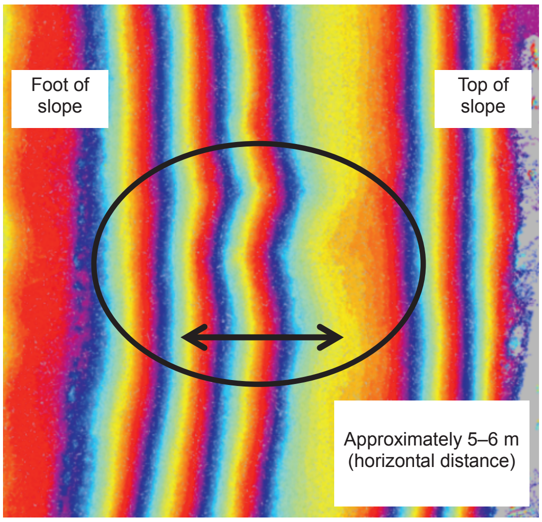

Fig. 10 Iterative color contour map for determining embankment deformation

Shaded relief map based on the June 2017 measurement data. As Fig. 9 illustrates, the mole hills confirmed during measurement can be clearly observed. Shaded relief map is a suitable type of image data to depict micro-level deformations such as slope erosion (gullies) and holes made by small animals.

Use of Iterative Color Contour Map to Determine Deformation Locations

Iterative color contour map is another form of representation that can be effectively used to determine the locations of deformation. Fig. 10 is part of an iterative color contour map prepared from data at flood warning area, from measurements taken after weed collection in October 2018.

Fig. 10 shows a deformation that appears to be an area of convexity. Although this kind of deformity may not necessarily need to be recorded in a river chart, it does seem to be necessary to monitor the progress of deformation through periodic measurements in future.

This makes it easy to use data to determine macro-level changes (such as convexities and concavities) that are not easily confirmed even by on-site visual observation.

Future Outlook

We have heard many comments at times such as the public test field testing of CalSok at Ibigawa River where concerning of future directions, including recommendations to conduct measurements at flood warning area, retain the data as an archive, and conduct analyses as needed, especially in view of data that could contribute to future disaster prevention and mitigation. We will continue to promote wide usage of this technology so that it can be used by many people.

[References]

1) River Engineering Education Council: Textbook for river maintenance technical training course (basic), p. 50, June 2018 [in Japanese]