Application of MMS data to road bridge maintenance management

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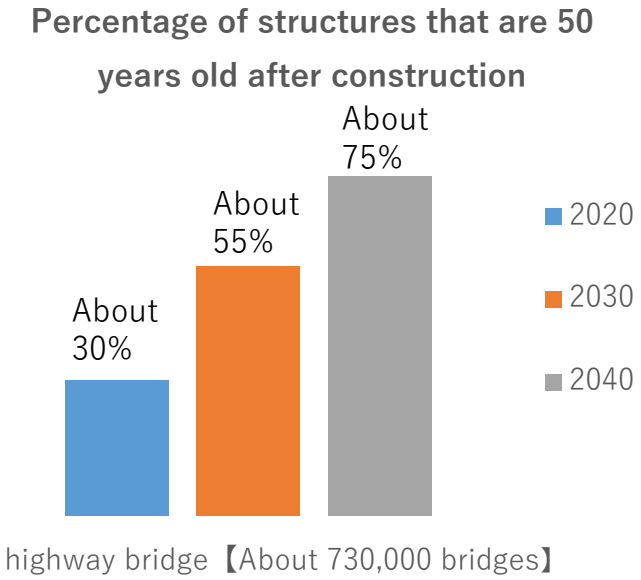
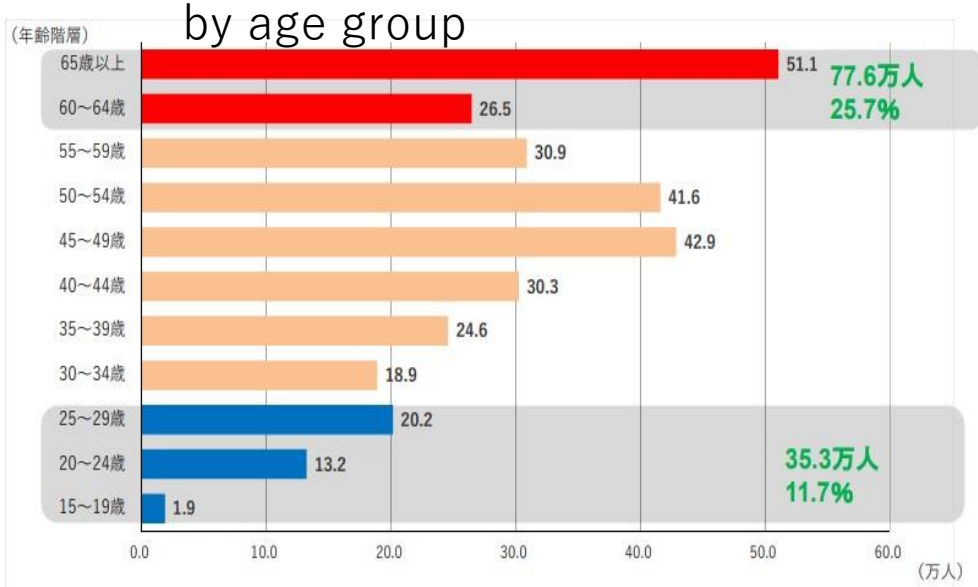
Research Background

Problem

- **Aging infrastructure structures**
- **Increase in severe disasters**
- **decrease in population**



Number of construction technicians by age group



出典：建設業を巡る現状と課題

Maintenance and renewal of structures is becoming more important.

Current road bridge inspection

Regular inspection in Japan

Conducted **once every 5 years** by an engineer with expertise
Inspections are based on **close visual inspection**, and the results are recorded and accumulated as a system for observing long-term changes and evaluating soundness.

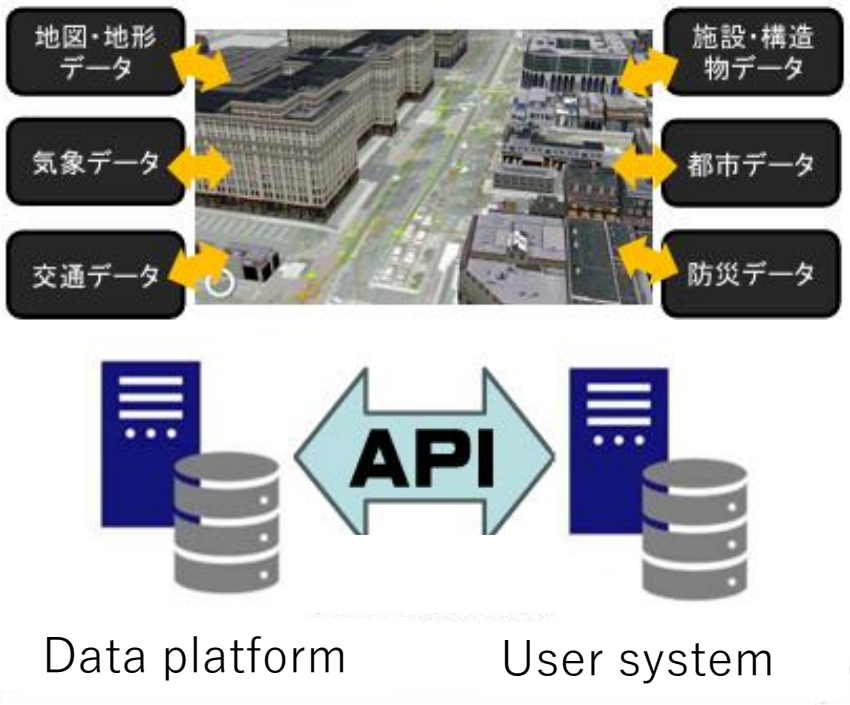
Reference：MLIT

It is a qualitative method with results that vary from inspector to inspector.
A more efficient inspection method is required due to the aging of the system.

Research Background

Utilization of Mobile Mapping system data (MMS data)

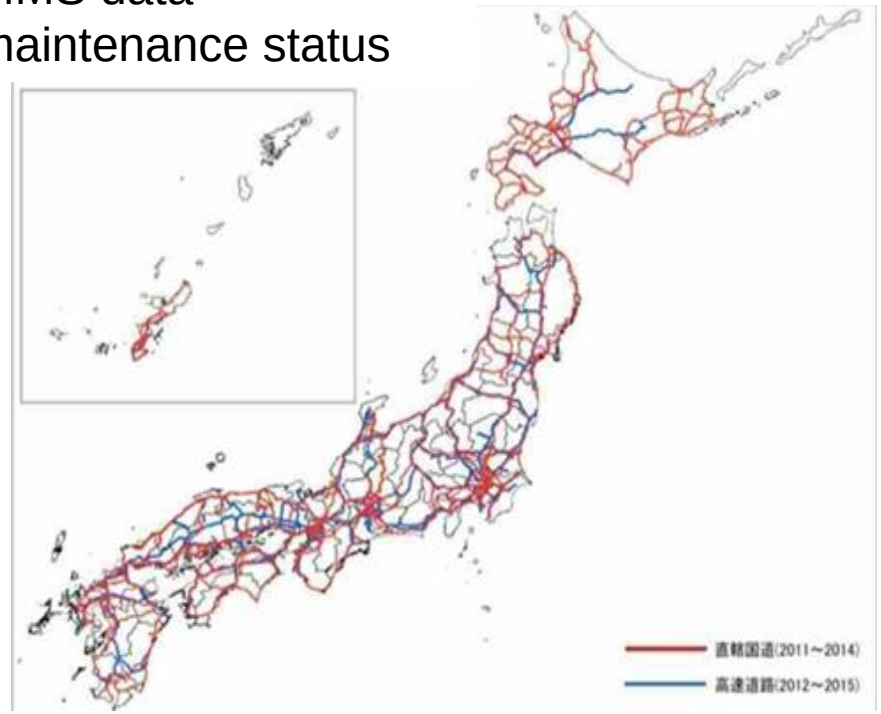
Measurement and provision of 3D data by MMS



出典：「四国技法」第38号

MMS data is measured on many national roads and highways across the country.

MMS data maintenance status



Current: Utilized as data for only creating road ledgers

Future: 3D data should be used in the maintenance and management phase.

Research purpose

Purpose

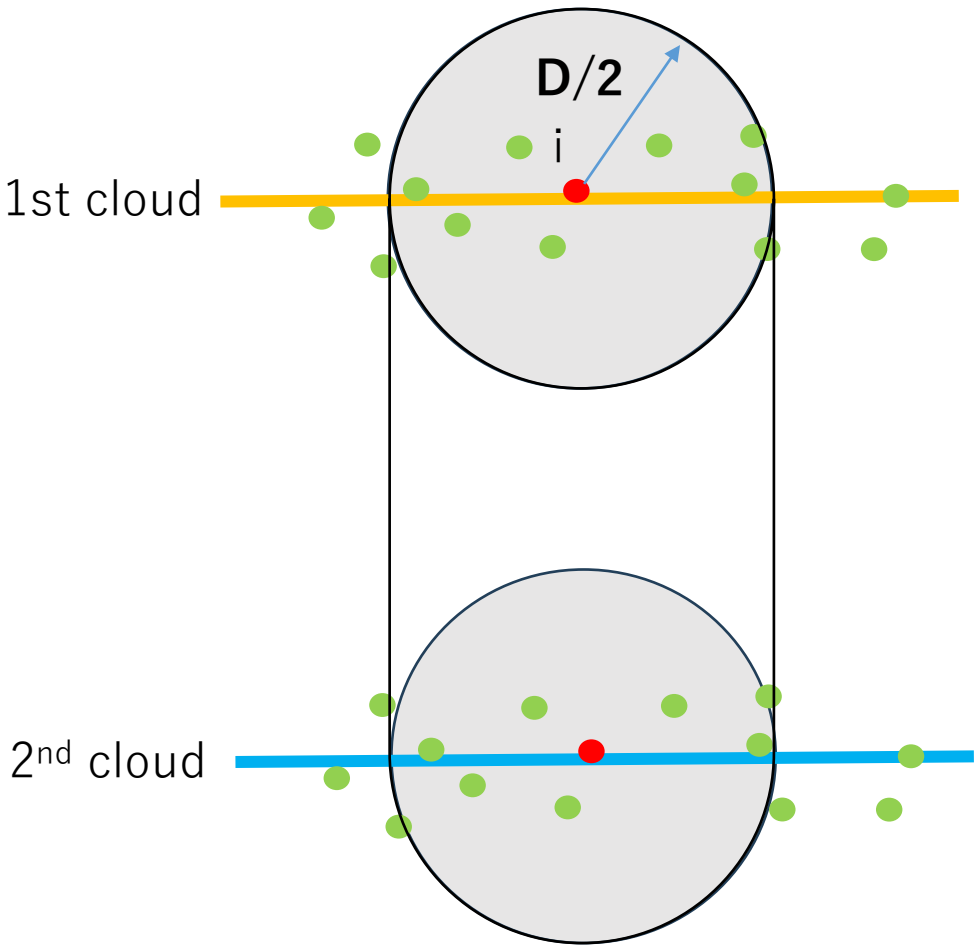
Utilization of 3D data in road bridge maintenance management (Extraction and quantification of deformations using 3D data)
・Maintenance management using MMS data

Verification details

1. Verification with mobile laser scanner(MLS) and terrestrial laser scanner (TLS)
・Density of point clouds
・Accuracy
・Difference analysis

2. Differential analysis using MMS data

Analysis Method



M3C2 algorithm （Multiscale Model to Model Cloud Comparison） (D lague.et al., 2014)

①For the point cloud of the first period, extract the point cloud that is within distance D/2 for any point i.

②Find the optimal plane such that the sum of the root-mean-square errors of the perpendicular distances between the point and the plane is minimized. The eigenvector obtained as the direction perpendicular to that plane is the normal vector.

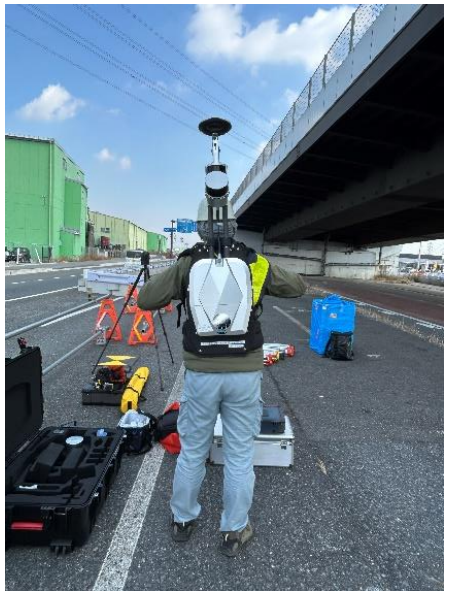
③Project D/2 cylinders centered at point i in the defined direction and extract the point groups inside each. Calculate the average value of each point group and treat the difference of the average values as the distance between the point groups

Research Outline (Measuring Instruments)

Mobile laser system（MLS）

Equipped with GNSS, IMU, and laser scanner
・Self-position estimation by SLAM technology to acquire point clouds in real time
・Measurement while walking with a backpack

Absolute accuracy ≤ 5 cm
⇒ No need to install equipment
Use in locations where equipment is difficult to install



※LiBackpackDCG50H

Terrestrial laser system（TLS）

Measurement by ground-based installation
・Laser beam is irradiated on the target object.

Absolute accuracy ≦ 4mm
⇒ Highly accurate measurements
Lightweight and portable to various sites

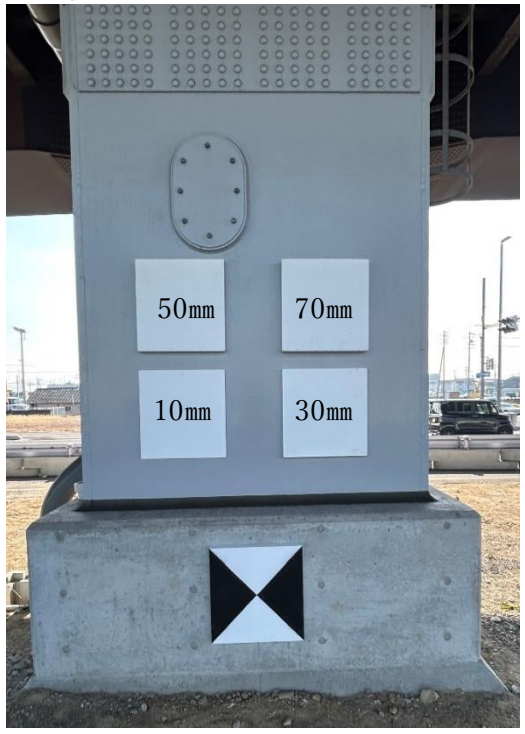
※LeicaBLK360

Research place

Ohi Bridge in Japan

Mesurement method

MLS and TLS measurements before and after specimen installation

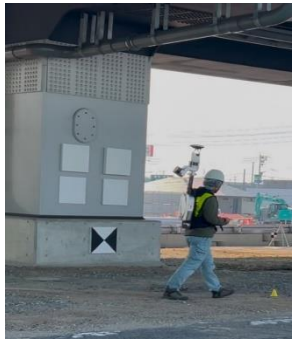


North side specimen

50×50cm

10mm, 30mm

50mm, 70mm



west side specimen

30×30cm

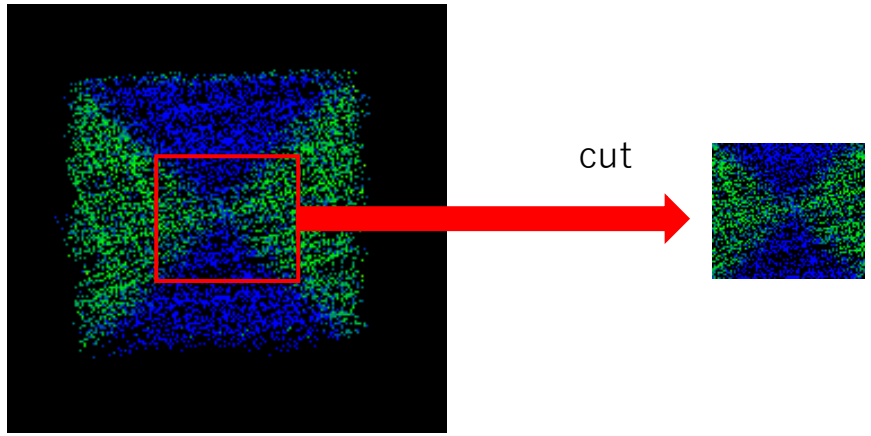
5mm, 10mm

15mm, 20mm

Point cloud density and accuracy verification (MLS/TLS)

Point density

Using a target point and a specimen



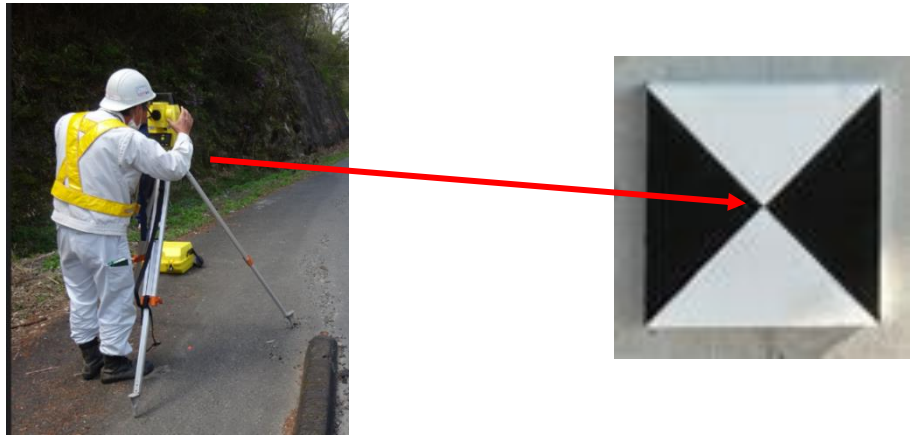
$$DEN = n/S$$

DEN：density（point/㎡），
n：number of points　S：Surface area

MLS density	TLS density
About 24,000point/㎡	About 33,000point/㎡

Accuracy

Measure the center of the specimen
Value from total station is treated as true value



$$DIS = OBS - TV$$

DIS ：accuracy,　OBS：measured value(MLS, TLS)
TV：measured value(TS)

MLS accuracy		TLS accuracy	
North side	west side	North side	west side
ΔXY：15㎜	ΔXY：**67**㎜	ΔXY：9㎜	ΔXY：2㎜
ΔZ ：16㎜	ΔZ ：**22**㎜	ΔZ：20㎜	ΔZ：10㎜

Differential analysis using MLS

North side

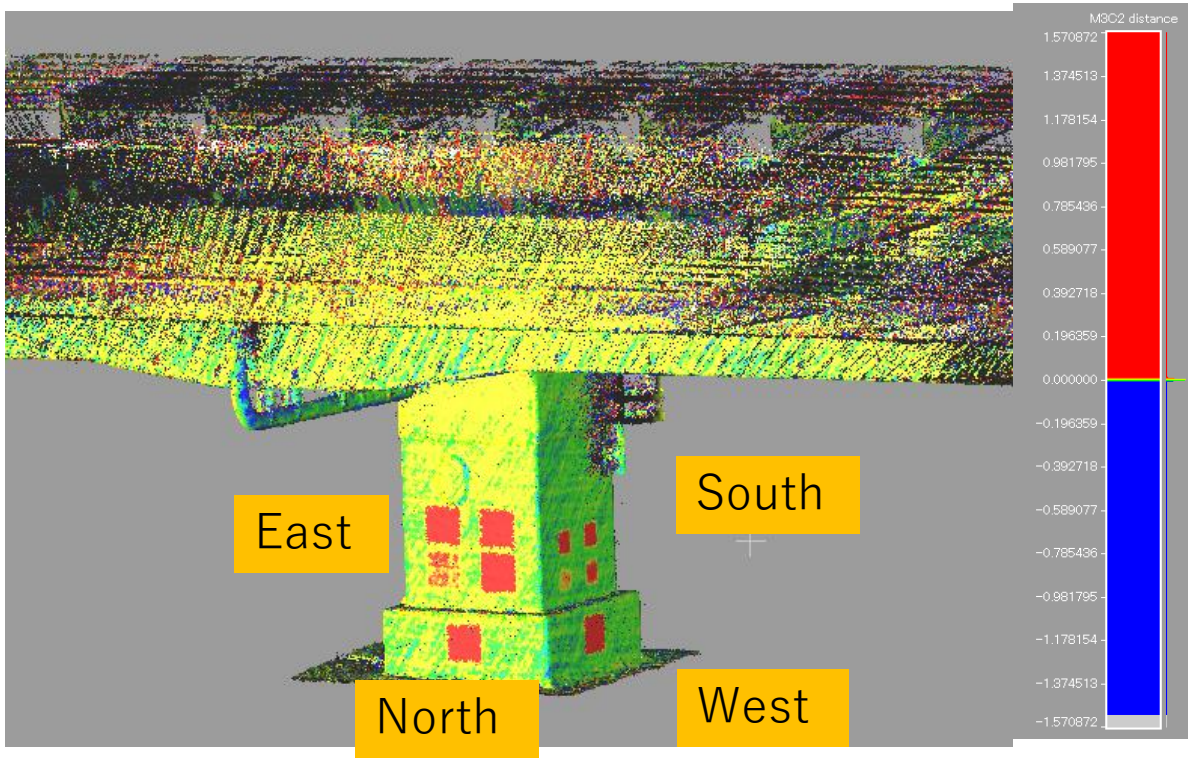
1st data

2nd data

west side

1st data

2nd data



blue＜-0.010m　-0.010m≦green≦0.010m
0.010m＜red

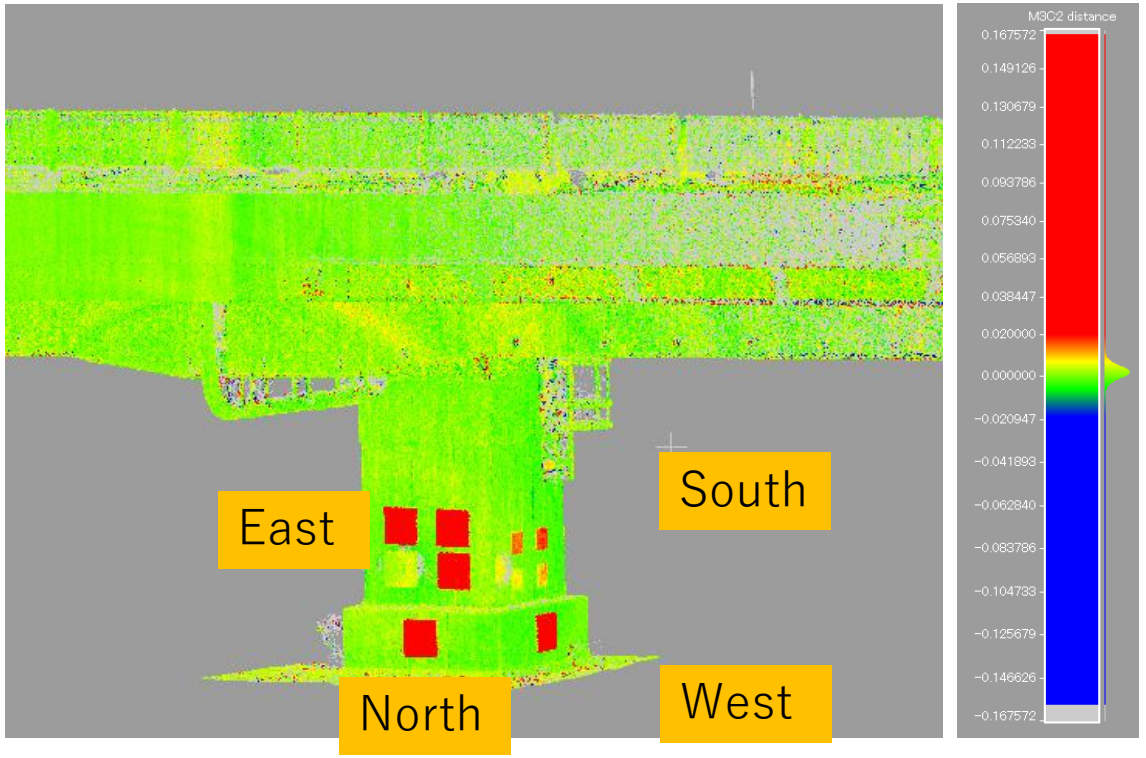
Identifying areas of deformation on a heat map diagram

Identified the presence or absence of specimens larger than 5 mm

Deformation Extraction using TLS

North side

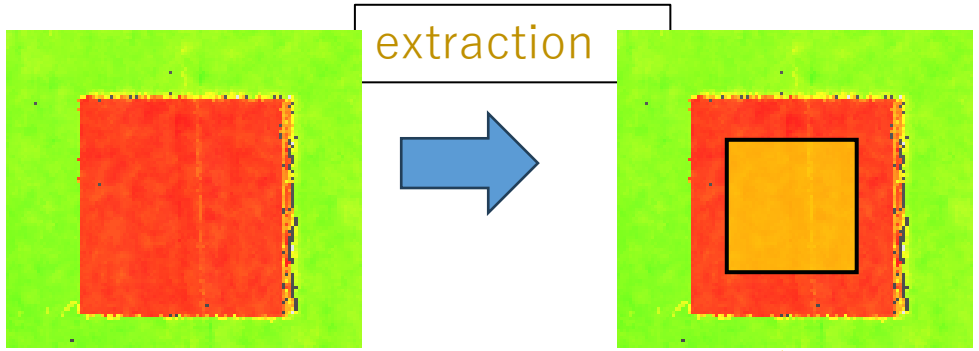
West side



Blue<-0.020　-0.020≦Green≦0.20　0.020<Red

As with the MLS, it is possible to ascertain the presence or absence of specimens larger than 5 mm where the location of the deformation can be seen on the heat map diagram.

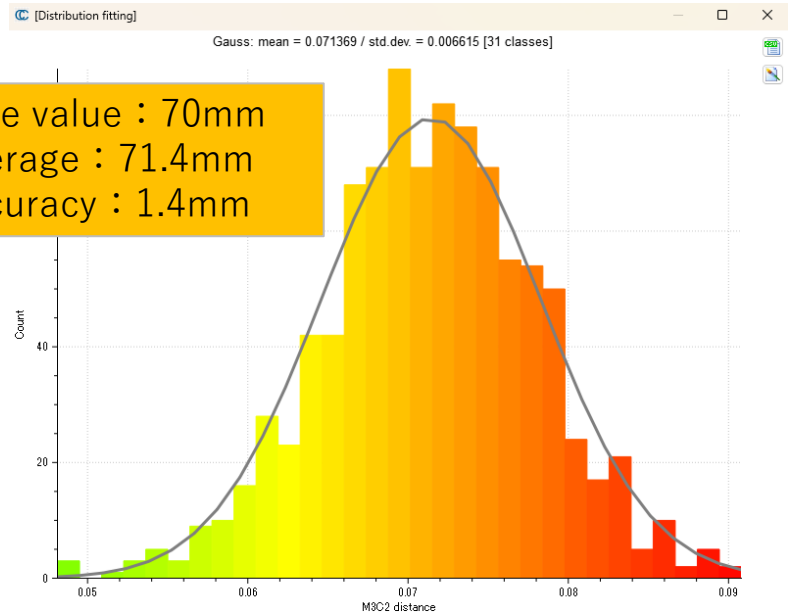
Quantification of deformation



(Extract the area circled in orange)

Extracting
Difference Results

True value：70mm
Average：71.4mm
Accuracy：1.4mm



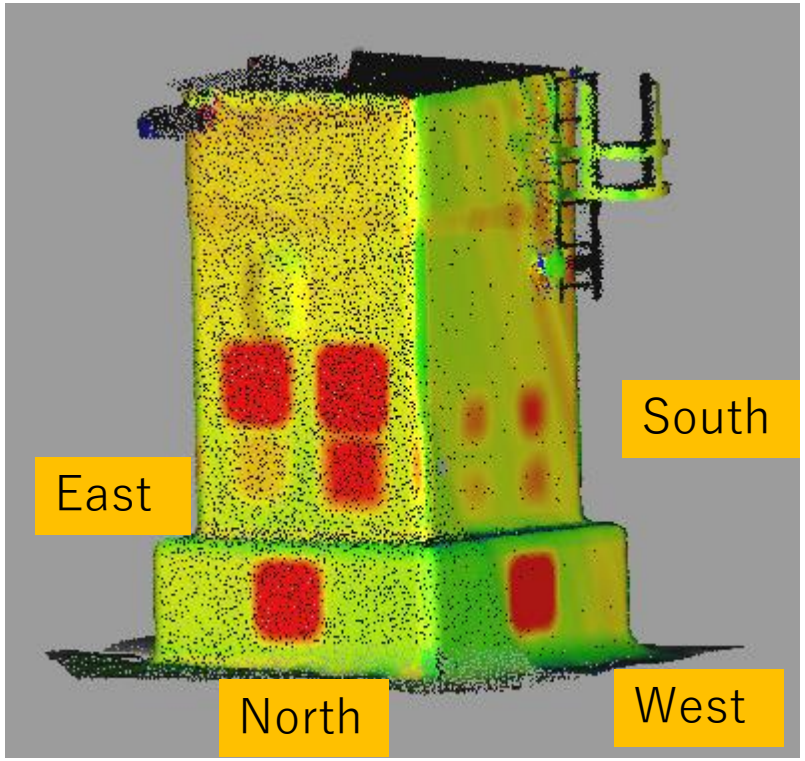
Data Distribution Chart
for Difference Analysis

		True value								RMSE	
		70mm	50mm	30mm	10mm	20mm	15mm	10mm	5mm	5~70mm	5~20mm
TLS0、TLS1	Average	63.4	42.6	22.8		16.8	13.8	9.8	6.6	4.85	1.89
	Accuracy	-6.6	-7.4	-7.2		-3.2	-1.2	-0.2	1.6		
slam0、slam1	Average	71.4	48.9	27.6	8.1	17.6	13.2	10.5	4.7	1.65	1.53
	Accuracy	1.4	-1.1	-2.4	-1.9	-2.4	-1.8	0.5	-0.3		

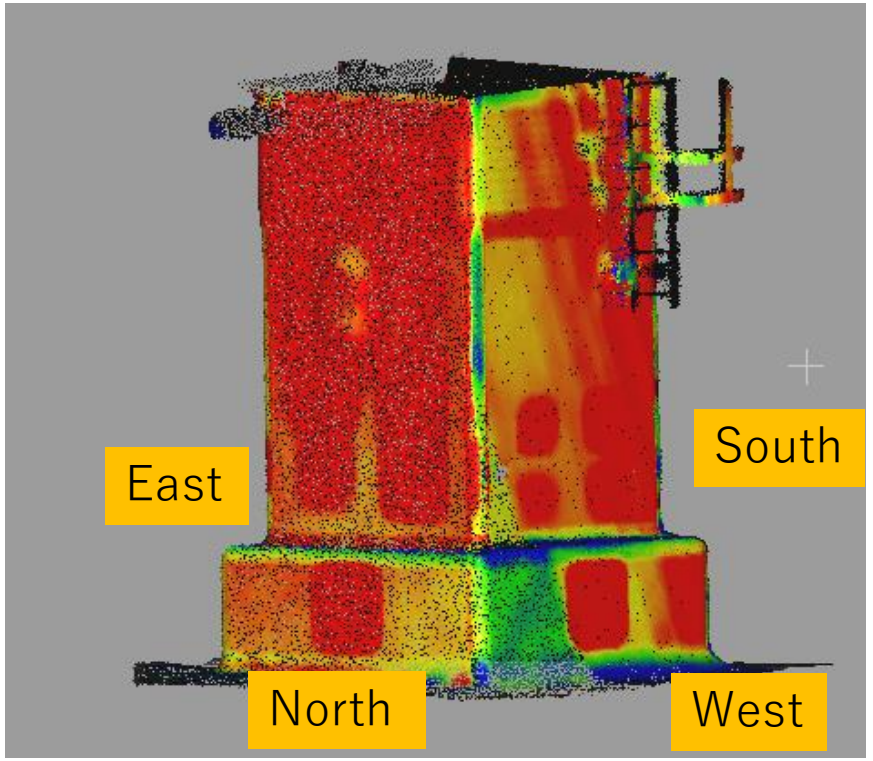
Result of difference analysis

Differential analysis using MMS and TLS data

1st：MMS data (No specimen)　2nd：TLS data　(with specimen)



(Blue＜-30mm　-30mm≦Green≦30mm　30mm＜Red)

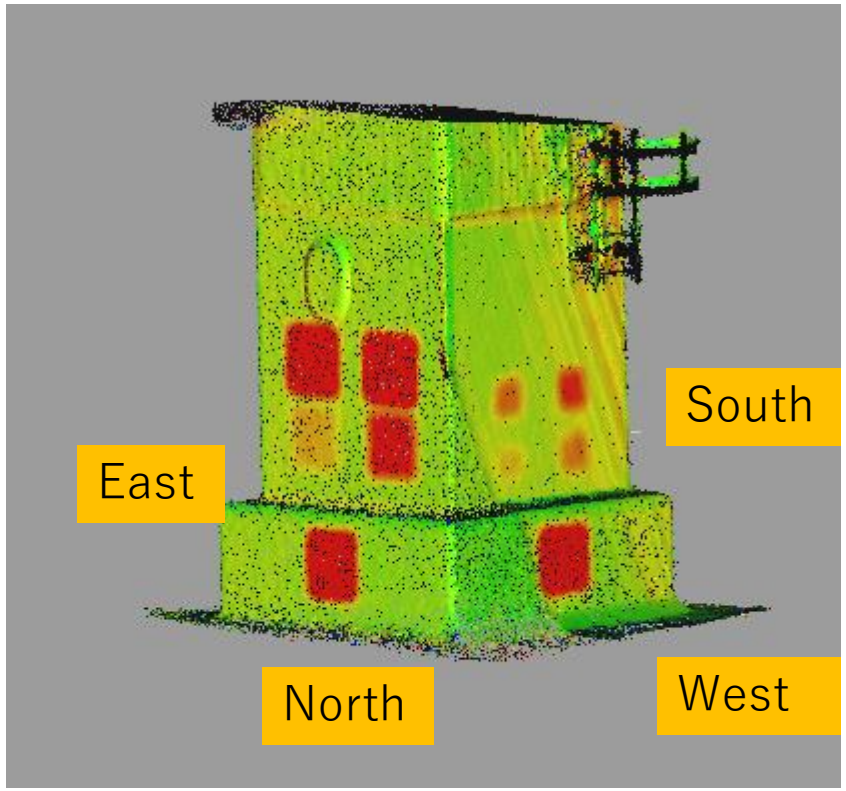


(Blue＜-10mm　-10mm≦Green≦10mm　10mm＜Red)

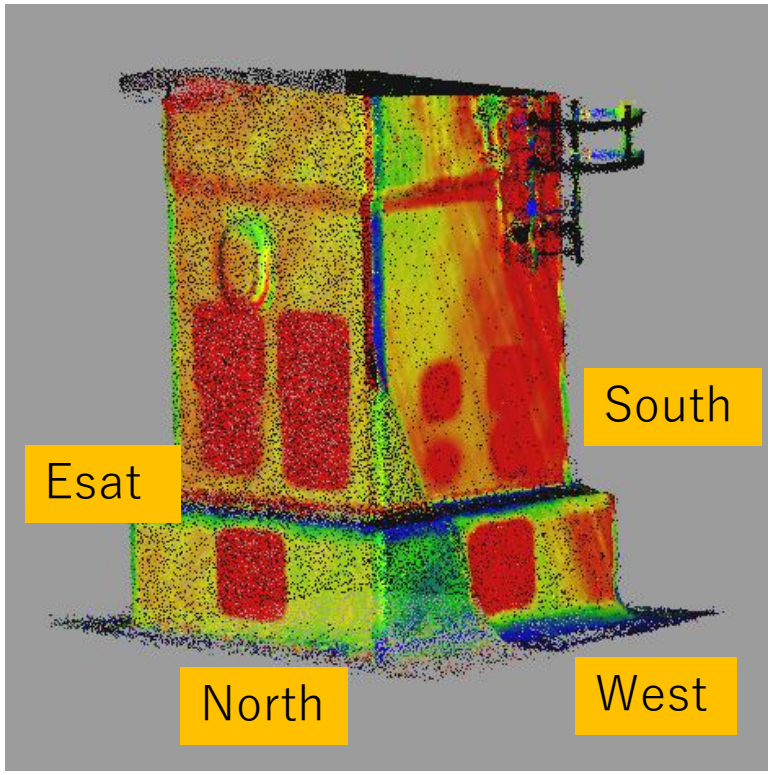
The point clouds are not properly superimposed, and the overall image is out of alignment, but the presence or absence of deformities can be confirmed.

Differential analysis using MMS and MLS data

1st：MMS data (No specimen)　2nd：MLS data　(with specimen)



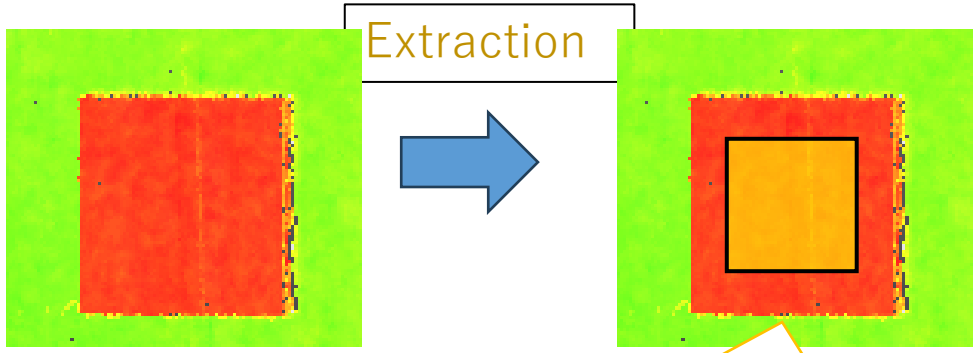
(Blue＜-30mm　-30mm≦Green≦30mm　30mm＜Red)



(Blue＜-10mm　-10mm≦Green≦10mm　10mm＜Red)

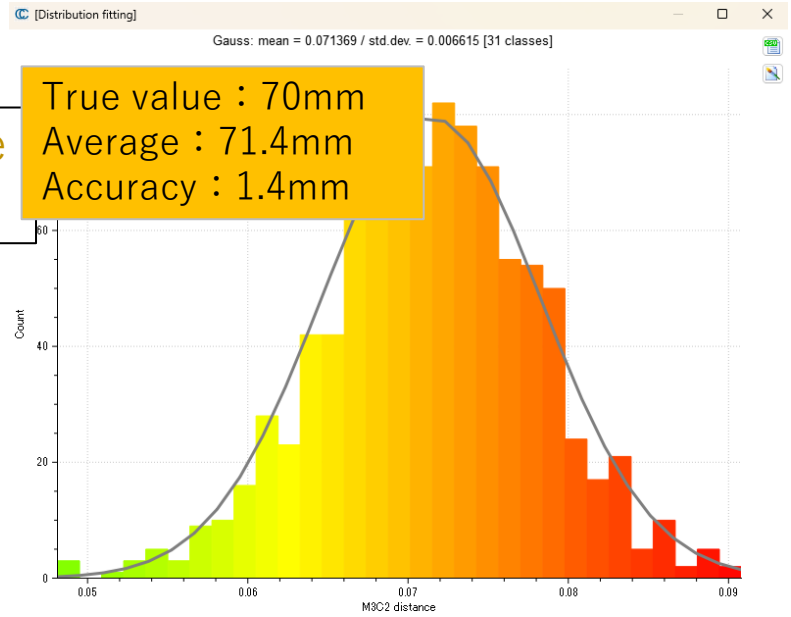
As before, the point cloud data is not properly superimposed, and the overall image is out of alignment, but the presence or absence of deformation can be confirmed.

Quantification of deformity



(Extract the area circled in orange)

Extracting Difference Results



Data Distribution Chart for Difference Analysis

		True value								RMSE	
		70mm	50mm	30mm	10mm	20mm	15mm	10mm	5mm	5~70mm	5~20mm
MMS、TLS	Average	73.1	54.7	32.4	15.7	27.5	19.7	19.7	13.1	6.20	7.71
	Accuracy	3.1	4.7	2.4	5.7	7.5	4.7	9.7	8.1		
MMS、slam	Average	79.4	57.5	35.7	18.1	28.2	20.3	20.2	12.3	7.87	7.95
	Accuracy	9.4	7.5	5.7	8.1	8.2	5.3	10.2	7.3		

Result of defference analysis

Conclusion and future issue

Conclusion

Use 3D data to extract deformations as an adjunct to periodic inspections
→ Visualize damaged areas with heat-map diagrams, making it easier to identify inspection points.

The results are saved and observed over time to identify trends in deformation.

Future issue

Establish appropriate processing methods for 3D point cloud data
- Density of point clouds required for difference analysis
- Clarify how much deformation can be determined