Monitoring Snowbanks along Highways Using a Low-Cost Vehicle-Mounted Mobile Laser Scanning System

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Abstract: Monitoring the geometry of Snowbanks that form along highways during winter in a timely and cost-effective manner is therefore essential for winter road management and snow removal planning. While high-end Mobile Laser Scanning (MLS) systems offer precise measurements, their cost is often expensive for regular operation. This study investigates the feasibility of using a low-cost vehicle-mounted MLS system, originally developed for snow surveys on local roads, to monitor snowbanks along major expressways. Field experiments were conducted on the Kanetsu Expressway in Japan, where the point clouds were obtained the both of the custom-built MLS system and a commercial, simplified MLS system (N-Quick). The resulting point clouds were compared in terms of density and cross-sectional snowbank profiles under different surface conditions namely moist and wet pavements. Preliminary results suggest that the low-cost MLS system can capture snowbank geometry with a level of accuracy comparable to that of the commercial system, particularly under dry or moderately moist conditions. However, challenges remain under more adverse conditions, such as wet pavement, where the system fs measurement performance may degrade.

Keywords: snowbank monitoring; mobile laser scanning; point cloud; highway; low-cost sensor

1. Introduction

The collapse of snow banks on expressways can cause property damage and traffic accidents. Therefore, proper management of snow banks is essential. However, conventional surveillance cameras and fixed-point observation alone are insufficient for wide-area snow bank monitoring. Snow banks form on road shoulders and medians, making it effective to utilize a mobile mapping system (MMS) that can record the surrounding environment as a 3D point cloud. In previous research, the authors confirmed the feasibility of using a low-cost, commercial MMS (N-Quick) to monitor snow banks on expressways[1)]. In this study, with the aim of improving the economic viability of snow bank monitoring, we investigate the applicability of a low-cost MMS[2)] developed by the authors for measuring snow accumulation on public roads to expressway snow bank monitoring from the perspective of measurement accuracy through synchronized observation experiments with N-Quick.

2. Methodology

2.1 MMS Overview

N-Quick is a simple MMS based on an in-vehicle LiDAR (Hesai XT32) developed by Nakanihon Air Service Co., Ltd., that outputs a 3D point cloud with location information added in real time. The developed MMS, on the other hand, uses the robotics-oriented LiDAR Mid-360, which outputs a 3D point cloud with location information added through post-processing. Unlike the XT32, the Mid-360 acquires point clouds through non-iterative scanning. The primary measurement area for both MMSs is the rear of the vehicle, and the measurement area is visualized using camera video captured in front of the vehicle. The specifications of the Mid-360 are shown in Table 1.

Table 1: Specification of the Livox Mid-360

Laser scanning range:	360 degrees horizontally, 59 degrees vertically
Detection distance:	40m @ 10% reflectivity
Distance accuracy:	2cm @ 10m
Laser divergence angle:	horizontal 25.2 degrees, vertical 8 degrees
Frame rate:	10Hz
Point rate:	200,000 points/sec (non-repetitive scanning)

2.2 Synchronous observation

A synchronized observation experiment using this device and an N-Quick was conducted on February 27 and March 5, 2025, targeting both inbound and outbound lanes of the Kan'etsu Expressway from Sanya PA to Shiozawa IC. The vehicle speed during measurements was approximately 80 km/h, with the N-Quick vehicle leading the way to acquire point cloud data.

2.3 Target routes and preprocessing

We target three sections of point clouds acquired on February 27th and March 5th, 2025, with different weather conditions. Route A is a portion of the section between Sanya PA and Ojiya IC under cloudy skies, Route B is a portion of the section between Muikamachi IC and Shiozawa IC under light rain, and Route C is the same route as Route B, but in cloudy and wet conditions. For the target routes, we manually delete the moving vehicle point cloud and align the point cloud of this device with the N-Quick point cloud. We then set a baseline along the driving trajectory of the vehicle equipped with this device to sample measurement points for analysis.

2.4 Differences between point density and cross-sectional shape

Centered on the baseline, unit sections measuring 16 m across the road (8 m on each side) and 1 m along the road were set, and point density and cross-sectional shape were calculated within each section. Each unit section was subdivided into 0.1 m-wide subregions in the cross-sectional direction, and the number of measurement points and elevation (median) were calculated for each subregion. To facilitate comparison of shape changes, differences in cross-sectional shape were evaluated using the median absolute error (MedAE) shown in equation (1) after matching the mean elevation of the point clouds from N-Quick and our system for each unit section.

$$\mathrm{MedAE} = \mathrm{median}\left(\left|P_{nq} - \left(P_{ours} + Z_{adj}\right)\right|\right) \quad (1)$$

Here, Pnq and $Pours$ are the elevations of the N-Quick point cloud and the measurement points of this device, and $Zadj$ is the amount of elevation adjustment.

3. Results

The MedAE aggregate results, which represent the difference in point density and cross-sectional shape, are shown in Tables 2 and 3, and example point clouds for Route A and Route B are shown in Fig. 1.

Table 2: Comparison of point cloud densities (points/m^2)

	Unit section			Roadway section		
	Route A	Route B	Route C	Route A	Route B	Route C
Developed device	156	126	107	130	15	18
N-Quick	438	489	484	318	248	313

Table 3: Cross-sectional profile differences (MedAE)

	Average[m]	Standard deviation[m]
Route A	0.010	0.004
Route B	0.056	0.042
Route C	0.079	0.023

The measurement point density of this device varied depending on the route, but ranged from 107 to 156 points per unit section/m², approximately one-third to one-quarter that of N-Quick. On the other hand, focusing on the roadway, the measurement point density decreased for both this device and N-Quick on Route B during light rain.

This trend can also be seen in Figures 1a and 1c, where measurement points are concentrated on the white lines within the roadway in Figure 1c (Route B). Based on the dashcam footage, it is estimated that the road surface on Route A was damp, while the road surface on Route B was wet. Therefore, this device may not be suitable for measuring wet road surfaces. Comparing the cross-sectional shapes, the average MedAE on Route A was 0.010 m, with a standard deviation of 0.004 m. The results obtained by this device and N-Quick were in good agreement. However, on Routes B and C, a clear discrepancy was observed between the measurement results of this device and N-Quick. When examining the cross-sectional shape of unit sections where MAE exceeds 0.1 m, deviations were observed in the road surface position (Fig. 2), suggesting that MAE is high in sections with insufficient alignment.

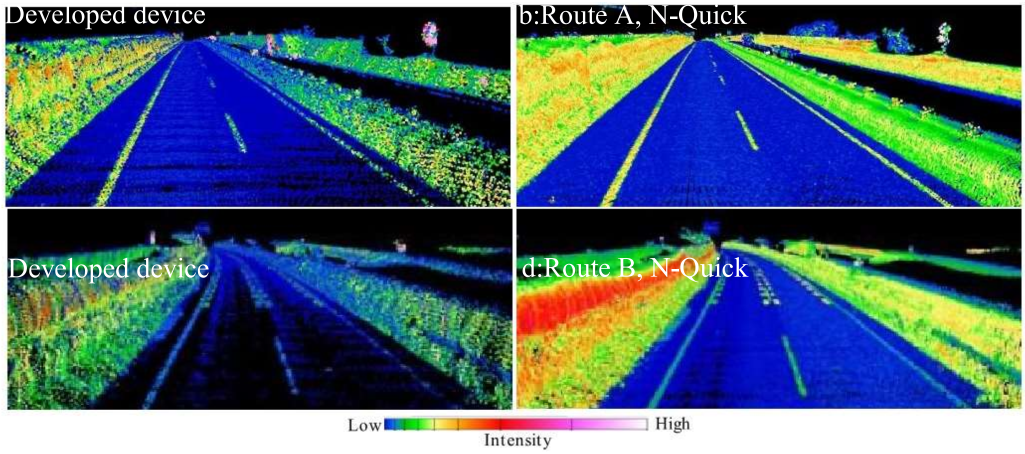

Figure 1:Examples of point cloud in section A and B

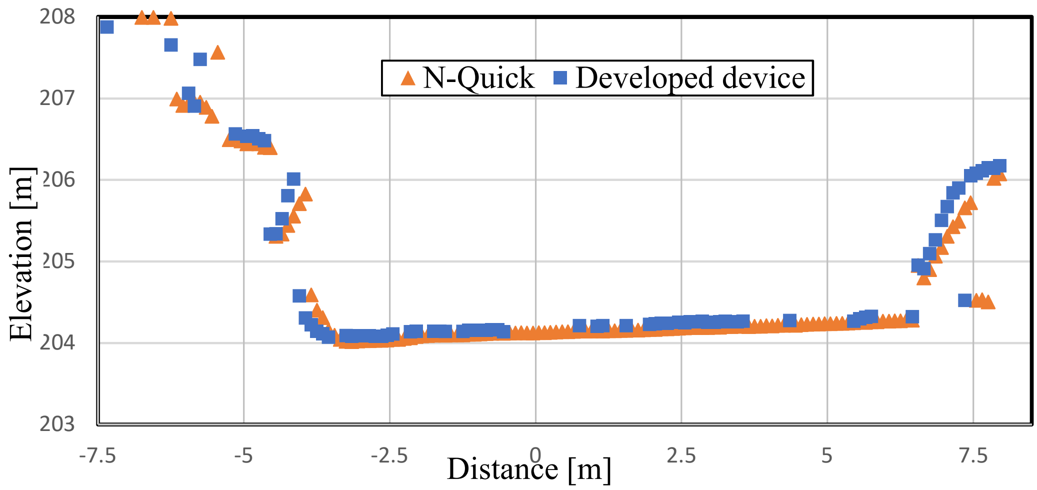

Figure 2:Cross-sectional profile example with large MedAE

4. Conclusion

This study confirmed that the developed device can capture road cross-section shapes comparable to those of N-Quick, demonstrating its applicability to snow bank monitoring. However, it was also revealed that the device's point density significantly decreases on wet road surfaces.

References

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