Development of Rotary Snow Blower Vehicle Driving Support System using Quasi-Zenith Satellite on the Expressway in Japan

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Abstract

The rotary snow blower vehicle operated for removing accumulated snow on road shoulders must be performed even in the conditions of a poor visibility due to a snowstorm or road markings completely covered by snow. The operators of the vehicle have to pay full attention to avoid contacting road structures and ordinary cars passing just beside the snow removal vehicle. Therefore, we have developed a high-precision snow removal vehicle positioning device using a quasi-zenith satellite and a high-precision expressway map for the first time in Japan. The device can indicate precisely the exact position of the snow blower vehicle on expressways in real time and the operator can drive the vehicle by watching a monitor showing the assistant information provided by the device. The error of the indicated location would be relatively small such as less than a few ten centimeters and several tests have been carried out in a special test field and on the expressway in Hokkaido

Keywords –

Quasi-zenith satellite based driving support system; Snow and ice countermeasure

1. Introduction and background

Since most of the expressways operated by East Nippon Expressway Company (NEXCO East) pass through snowy areas, one of the biggest challenging operational tasks is to ensure smooth and safe traffic even in cold winter.

However, as Japanese future population is in decline, it is anticipated that skilled workers will be aging and it will be difficult to secure the required workers. Since it is expected that snow and ice countermeasures will need to be performed by workers with lesser skills in the future, it is necessary to create an environment that enables such work to be performed more safely and reliably than at present.

In addition, snow and ice countermeasures on expressways involves various types of work and requires skilled operators. The visibility in the environment is particularly bad during snowfall and in snowstorms, and it is difficult for snow and ice work vehicle operators to determine the position of their vehicles on the road at such times, and this labor-intensive work requires the operators to pay close attention to avoid colliding with general vehicles and road structures.

The scarcity of skilled workers in the future is expected to inevitably require this work to be performed by unskilled workers. As such, it is necessary to create an environment where even unskilled operators can perform the work safely and reliably, and this required aiming to provide support for operators by means of driving support technology.

Therefore, we have developed a high-precision snow removal vehicle positioning device using a quasi-zenith satellite and a high-precision expressway map for the first time in Japan. As Wang & Noguchi (2019) reported, the satellite is going to be used in the Japanese agriculture. The device can indicate precisely the exact position of the rotary snow removal vehicle on expressways in real time and the operator can drive the vehicle by watching a monitor showing the assistant information provided by the device. The error of the indicated location would be relatively small such as less than a few ten centimeters and several tests have been carried out in a special test field. In addition one of the tests was conducted on the expressway in Hokkaido.

In this report, we would like to outline this novel approach to provide a real time exact location on the expressway by comparing a quasi-zenith satellite information with a high-precision map data and some representative test results are going to be explained.

Figure-1. Snow and ice countermeasure work on the expressway (snow blowing work)

Figure-2. Expressway during snowstorm

2. Outline of the developed system

Snow blowing work is performed while running at low speed between the white line of the shoulder and the curb of the shoulder, and the operator of the rotary snow blower vehicle must take care that the vehicle does not run outside the white line on the shoulder into the vehicle lane or collide with guardrails on the shoulder of the road. Using a quasi-zenith satellite positioning device and a high-precision map of the curb, it is possible to continually identify the positional relationship between the rotary snow blower vehicle and the shoulder white line and curb when the vehicle is running out of bounds into the lane or colliding with the guardrails. In this study, we developed a system to warn the operator of a rotary snow blower vehicle when the vehicle was running out of the shoulder area. (Figure-3)

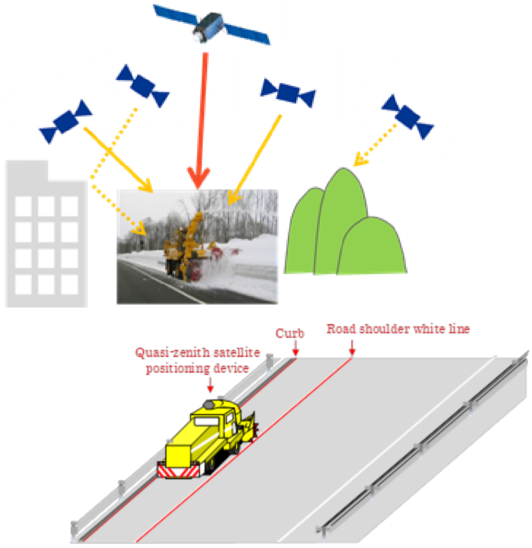


Figure-3. Narrow working range of rotary snow blower vehicle

3. Creation of high-precision maps

3.1 Map creation range

The road features required for snow blower work were created as map information from high-precision three-dimensional point group data by a mobile mapping system (MMS) to create the three-dimensional maps. The target section is 3.0 km (32.4 KP to 35.4 KP) of the outbound lane between the Iwamizawa Interchange and Iwamizawa Service Area on the Hokkaido Expressway. (Figure-4)

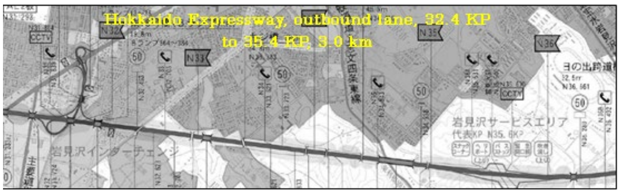


Figure-4. High-precision map creation range

3.2 Mapped road features

The features required for monitoring when the rotary snowblower vehicle runs out of bounds into the vehicle lane and the road features required to avoid colliding with vehicles and blown snow when removing snow are mapped from the high-precision three-dimensional point group data.(Figure-5)

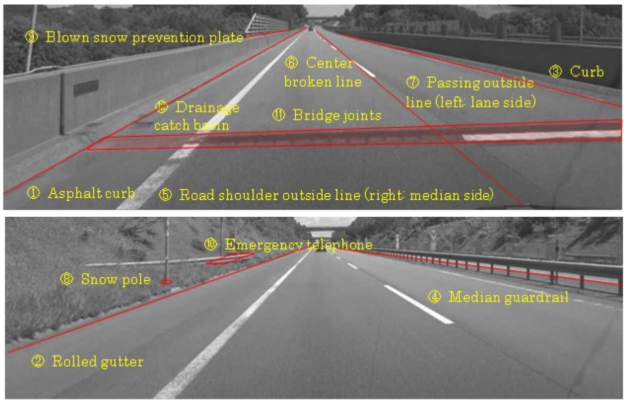


Figure-5 Mapped features

4. Guidance system

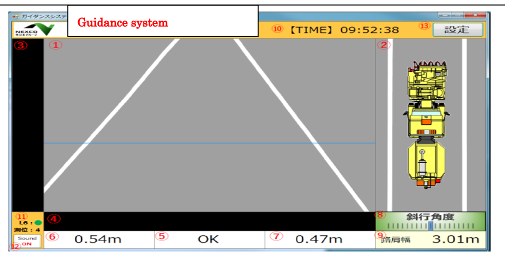
4.1 System screen

The system recognizes the running position of the rotary snow blower vehicle from the satellite information and uses the result of collation with the map data to provide guidance for the snow removal work by judging when the vehicle is running out of bounds. The system screen is composed of two screens, a 2D display and a 3D display, and the 3D display screen also displays various types of information about objects requiring caution to make it easier to understand the vehicle's current position and the situation ahead of the vehicle. (Figure-6)

4.2 System operation when a warning is issued

As shown in Figure-7, in both the 2D and 3D screens, when the vehicle goes out of bounds, the white line on the side the vehicle went out on changes to a red line, “OUT” is displayed in the “Running status” display field, an arrow (⇒) is displayed indicating the side the vehicle went out on, and the amount the vehicle went out of bounds is displayed in meters in red in the "Clearance width (out-of-bounds width)" display field.

Screen display



Display description

① 3D display area	Displays an image of the vehicle viewed from behind. Displays the curb ahead and objects requiring caution, and the white lines turn red when the vehicle runs outside the lines on the left or right. The blue line indicates the front position of the vehicle.
② 2D display area	Displays an image of the vehicle looking down on it from directly above. The white lines turn red when the vehicle runs outside the lines on the left or right. There is no display of objects requiring caution.
③ Outside the road shoulder warning information	A warning is displayed when there is an object requiring caution outside the road shoulder 30 m ahead of the vehicle.
④ Road warning information	A warning is displayed when there is an object requiring caution in the road 30 m ahead of the vehicle.
⑤ Running status	When the vehicle is running in the shoulder lane (within the white lines), "OK" is displayed, and when the vehicle runs outside the lane, "OUT" is displayed in red letters. An arrow is displayed indicating the side on which the vehicle ran outside the lane.
⑥ Left clearance (out-of-bounds width)	Displays the clearance to where the left side of the vehicle runs outside its lane. When vehicle is outside its lane, the background turns red and the distance outside the lane is displayed.
⑦ Right clearance (out-of-bounds width)	Displays the clearance to where the right side of the vehicle runs outside its lane. When vehicle is outside its lane, the background turns red and the distance outside the lane is displayed.
⑧ Skew running angle	Displays the skew running angle of the vehicle.
⑨ Road shoulder width	Displays the width of the road shoulder at the point where the running vehicle is located.
⑩ Current time	Displays the current time received from the satellite.
⑪ Reception status display	Displays the reception status and type of position information output from the receiver.
⑫ Sound switching	Switches the warning sound ON and OFF.
⑬ Settings	Switches to the setting screen for vehicle information.

Figure-6. System screen

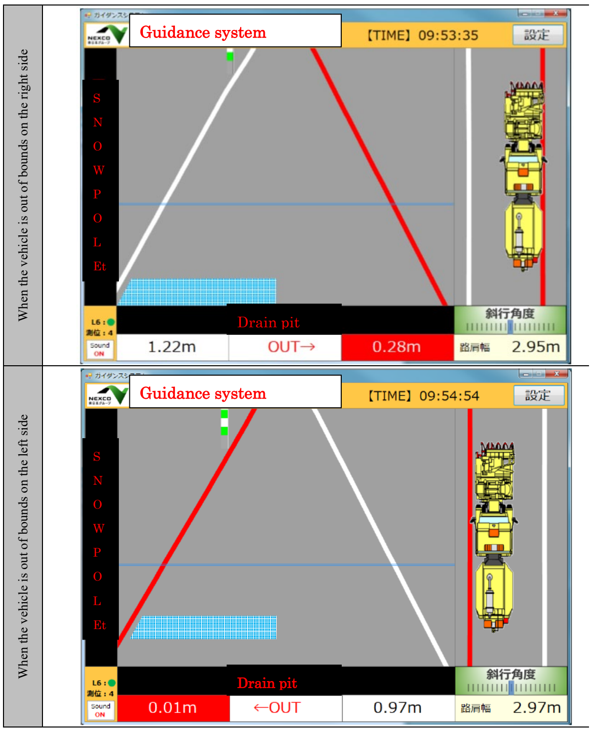


Figure-7. System operation when a warning is issued

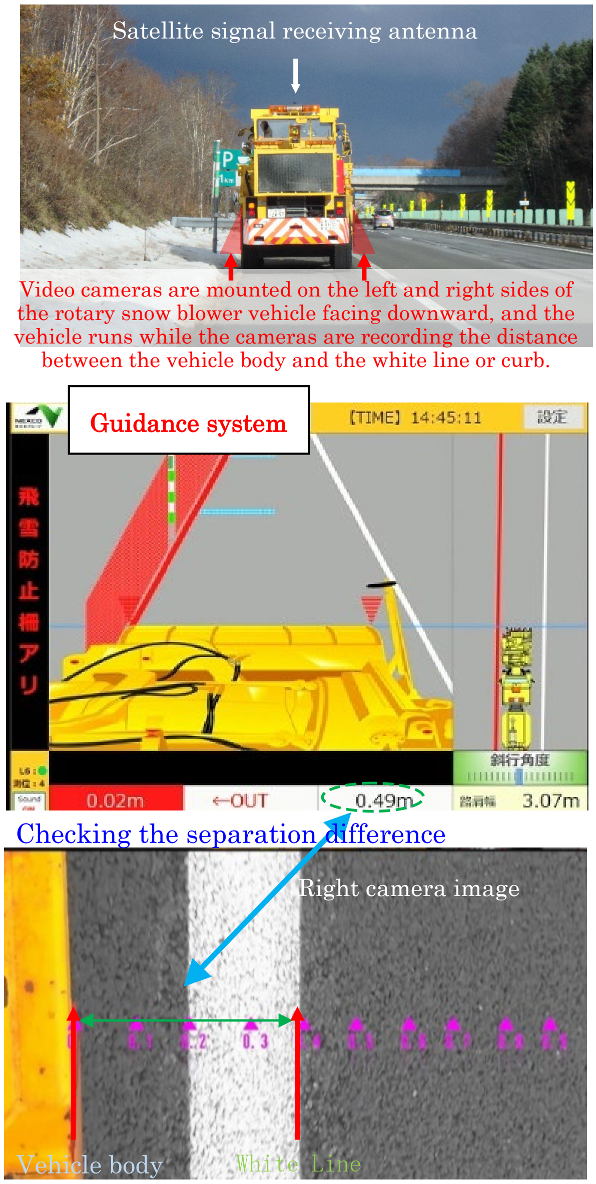
5. Trial test results

A trial test of the system was performed by running the rotary snow blower vehicle equipped with high-precision positioning equipment and a work guidance system on the shoulder of a road. The test was performed on the shoulder of the outbound lane on a section of the Hokkaido Expressway from the Iwamizawa Interchange to the Iwamizawa Service Area. The trial method involved installing the system equipment and video cameras on a rotary snow blower vehicle in the maintenance yard at the Iwamizawa Interchange, then after moving to the shoulder of the main lane (Iwamizawa Interchange to Iwamizawa Service Area), the rotary snow blower vehicle was run at actual working speed, and system log data and video camera images were recorded.

The method used to verify the trial results was to calculate the error between the system and the actual measurement values from the recorded system log data and each video camera image, and extract and verify the evaluation target section as representative points.

The trial test resulted in an average error value of approx. 0.2 m. By road structure, the error for embankments section was 0.19 m, the error for cuttings section was 0.22 m, and the accuracy of embankments was higher due to the better satellite reception environment. (Figure-8)

The target error of this system is set at 0.2 m, and the above results were almost satisfactory. Therfore, operator would trust the system and could keep the vehicle in an expressway shoulder based on the guidance imformation.



Road structure	System error (m)	
	Average value	Sample
Overall	0.22	171
Embankment	0.19	27
Cutting	0.22	144

Figure-8. Trial test verification method and system errors

6. Conclusion

The developed guidance system could provide resonable results to assit snow blowing operation. We are now under additional testing for improving its further accuracy and plan to use the system practically at the end of 2020.

The system can achieve both providing safer winter expressway for drivers and reducing the burden of the snow blower operatiors, so we are making best effort to complete this project. In additon, we are going to challenge to develop an automonous snow blower based on the quasi-zenith satelite system as the second stage of the project.

Acknowledgement

The authors wish to acknowledge Dr Noboru Noguchi, Professor of Hokkaido University -, for his advice on the quasi-zenith satellite based precise position system in this study

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