https://doi.org/10.31256/Br7Bk8O

On-track Localisation based on Object Detection

Masoumeh Rahimi
School of Aerospace, Transport and Manufacturing
Cranfield University
Bedford, UK
masoumeh.rahimi@cranfield.ac.uk

Miftahur Rahman
School of Aerospace, Transport and Manufacturing
Cranfield University
Bedford, UK
miftahur.rahman@cranfield.ac.uk

Isidro Durazo Cardenas
School of Aerospace, Transport and Manufacturing
Cranfield University
Bedford, UK
i.s.durazocardenas@cranfield.ac.uk

Andrew Starr
School of Aerospace, Transport and Manufacturing
Cranfield University
Bedford, UK
a.starr@cranfield.ac.uk

Amanda Hall
Network Rail
Milton Keynes, UK
amanda.hall@networkrail.co.uk

Robert Anderson
Network Rail
Milton Keynes, UK
robert.anderson4@networkrail.co.uk

***Abstract*—Railway vehicle positioning is a task of fundamental importance in providing an accurate and reliable localisation information for railway control and safety operation. Acquiring the vehicle's position in absolute level is also important to the maintenance sector, as it would lead the maintenance tasks to be done more accurate, and faster. In this paper object detection based on feature matching technique is proposed to improve onboard train positioning systems to achieve higher levels of positioning performance. An RGB-D camera is integrated to the front-base of the vehicle for this purpose. This localisation technique examines the vehicle position on the railway track by extracting features from track-side infrastructure and comparing them with a predefined database.**

Keywords*— *localisation, object detection, vision sensor, autonomous systems

I. Introduction

Accurate and reliable railway vehicle positioning plays a prominent role in the safety of the system since this positioning information is critical to rail-system management, for train control. Localising of maintenance vehicles, which do the task of inspection and repair on the railway track, has high importance as well [1], as it leads to specifying the defect positioning in absolute level of accuracy. For railway vehicle positioning, a wide range of sensors and infrastructures have been proposed and deployed, therefore classification is also necessary [2]. These sensors are mostly divided into two classes:

1) Elements in the railway environment (infrastructure-based) including magnetic coils, signal post, cable loops, contacts, track-circuits, axle counters, transponders, and radio Balises.
2) On-board sensors (infrastructure-less) including tachometers, inertial sensors, satellite-based positioning systems, Lidar and vision sensors.

II. Problem Definition

Acquiring high position accuracy for autonomous maintenance vehicles on the railway track would lead to enhancing safety, reliability and quality of the whole railway system which is paramount for passengers, employees, and the entire rail network. At present, widely used on-board positioning systems cannot lead to cm level as required due to drift or accumulated errors over time. In terms of GPS, it might not be available in specific places such as tunnels, near tall buildings, dense forests, and so on. Therefore, for increasing the accuracy and reliability of the vehicle positioning on the railway track, vision sensor is applied [3]. For localising purposes, the trackside elements like signal post, electrical box or track-base objects such as sleepers, Balise, fish plate track joint can be used as a reference. The main criteria about these objects is that they should be easily captured, and also have a fixed size. The scenario in this paper is that a RIRS (robotic inspection and repair system) which is equipped with various on-boards sensors including RTK-GPS, IMU, wheel odometer, and RGB-D camera, is moving on a railway track [4]. The vehicle is aimed to find the defect location which is previously specified on the railway track, based on the on-board sensors and the track-side objects. Figure 1 shows the RIRS on the railway track.

Fig.1. On-track RIRS

III. Method and Result

Track-side object detection is done by processing the captured images from RGB-D camera, which generate depth image-based point cloud. Processing of object recognition consists of two parts: first is teaching that is executed before main operation. During this step, objects are presented to the vision system and then image and extracted set of features are saved as a pattern in the memory of the system. Second step is actual recognition which is executed constantly during robot operation. In this step, every frame of the camera is processed, image features are extracted and compared to the dataset saved in memory, if enough features match the pattern, then the object is recognised. This process is done by applying find_object_2d node from find_object_2d package for both teaching and recognition.

The aim is to extract the 3D position of the detected object through processing the relative depth image point cloud. But as far as the range of the depth image is about 3 to 4 meters, far objects would not provide a reliable distance to the camera.

This is found after evaluating the corresponding RGB and depth image of a frame. Figure 2 demonstrates RGB and depth images of one frame of the camera.

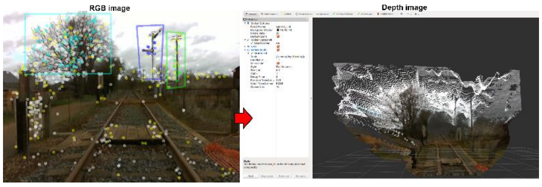

Fig.2. RGB and Depth images

Here the criterion of highest number of features is considered, that upon it is acquired, the vehicle would stop, and then from the related point cloud, a more reliable distance would be acquired. An important point, which needs to be taken into consideration, is the type of the descriptor defined for the system. Feature descriptor is an algorithm which takes an image and encodes interesting information into a series of numbers. Based on the applied feature descriptor, various kinds of interest points would be extracted from the image. The following figures show the function of a number of descriptors on different objects. In figure 3, most of the descriptors failed in feature extraction, while in figure 4 related to a signal post, most of the descriptors including SURF, BRISK, SIFT succeed in features extraction.

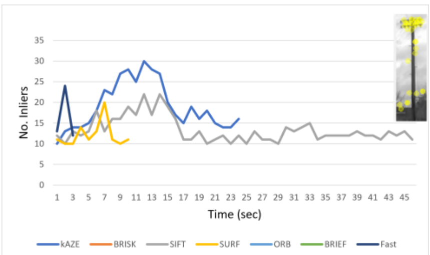

Fig.3. Number of detected features in light post based on different feature descriptor

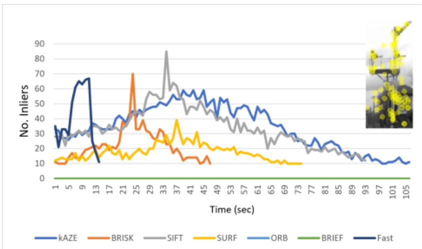

Fig.4. Number of detected features in signal post based on different feature descriptor

Besides the importance of the type of descriptor chosen for feature extraction, the size and dimension of the object considered as a reference is also important. This is clear that if the objects contain more edges, corners, lines, and contrast colors, they would be identified easier.

In the next phase, distance from the detected object to the camera, in x axis, which is along the railway track, is extracted. It is expected that by the movement of the vehicle on the railway rack, distance decrease, but as figures 5 and 6 show, it has an erratic behavior. Based on these outputs, it is not clear which of these values are reliable and indicative of correct distance.

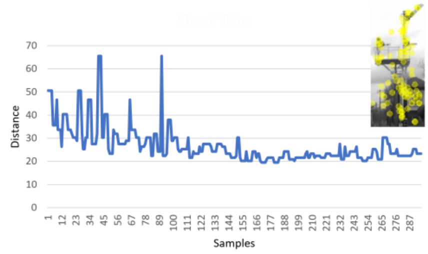

Fig.5. Distance from the signal post to the camera

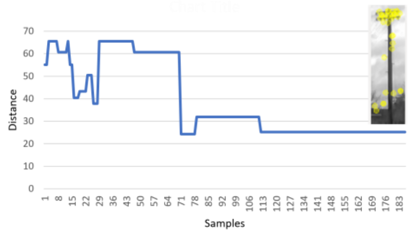

Fig.6. Distance from the light post to the camera

As in figure 2 shown, from RGB image, the objects can be detected, but in the depth image, the point cloud related to the far objects and high-sized ones are not clear enough for distance calculation. Therefore, the more reliable location for estimating the distance is when the highest number of features is detected in the recognised object.

IV. Conclusion and Future Work

The precise, and real-time rail vehicle localisation is essential to the robot command & control, task execution, safety and efficiency. The current study investigates a positioning approach on the railway track based on feature matching technique. It is shown that the type of the descriptor, and the size of the track-side infrastructures considered as reference, impact the results. In future, for achieving a more reliable result, it is aimed to specify distance from the recognised objects to the camera, when the highest number of features is identified. The validation of this result would be done by processing point cloud of the onboard lidar.

Acknowledgment

This project has received funding from the Shift2Rail Joint Undertaking (JU) under grant agreement No 881574. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Shift2Rail JU members other than the Union.

References

[1] M. Rahimi, H. Liu, I. D. Cardenas, A. Starr, A. Hall, and R. Anderson, "A Review on Technologies for Localisation and Navigation in Autonomous Railway Maintenance Systems," *Sensors*, vol. 22, no. 11. p. 4185, 2022, doi: 10.3390/s22114185.

[2] O. Heirich, "Localization of Trains and Mapping of Railway Tracks," Ph.D. Thesis, Technische Universität München, München, Germany, 2020.

[3] W. Zhangyu, Y. Guizhen, W. Xinkai, L. Haoran, and L. Da, "A Camera and LiDAR Data Fusion Method for Railway Object Detection," *IEEE Sens. J.*, vol. 21, no. 12, pp. 13442–13454, 2021, doi: 10.1109/JSEN.2021.3066714.

[4] M. Rahimi, H. Liu, M. Rahman, I. D. Cardenas, A. Starr, A. Hall, and R. Anderson, "Localisation and Navigation Framework for autonomous Railway Robotic Inspection and Repair System," no. November, 2021.