

Use of LiDAR and autonomous mobile robots in safety and inspection applications on railways

Abstract

LiDAR is a remote sensing technology that enables measuring distances using laser beams. Over the last two decades, LiDAR has established itself primarily in the field of Earth observation and has subsequently taken advantage of its capabilities in stationary and mobile platforms, providing real-time solutions for e.g. autonomous driving, robotics, and drone applications. This paper presents two examples confirming applicability of LiDAR sensors in safety and inspection applications on railway infrastructure. SMART2 uses a stationary sensor (or more of them) for accident prevention and detection of dangerous obstacles at level crossings. The second application developed in the InspectRail project introduces a new way of controlling dangerous railway sections threatened by landslides, falling rocks, collapses of buildings, etc. LiDAR sensors and video cameras are utilized to inspect such sections, mounted on the autonomous mobile robots moving along the railway lines on steel cables stretched between catenary masts.

Keywords: LiDAR, robot, railway infrastructure, level crossing, safety

1 Introduction

LiDAR (Light Detection and Ranging) is a remote sensing technology that enables measuring distances using laser beams. It is best known for dedicated and periodic airborne acquisitions of 3D points of the Earth's surface with scanners, which with integrated GPS and IMU systems allow accurate georeferencing of captured points, thus making significant progress in the use of Earth observation (EO) data in meteorology, geodesy, seismology, etc. Besides such scanners, the LiDAR sensors are gaining popularity recently, operating in high resolution and accuracy over shorter distances from stationary or mobile platforms and providing real-time solutions for e.g. autonomous driving, robotics, and drone applications.

This paper presents two examples confirming applicability of LiDAR sensors in safety and inspection applications on railway infrastructure. First, the use of a

stationary sensor for accident prevention and detection of dangerous obstacles at level crossings is presented. In the second application, LiDAR is utilized to inspect dangerous railway sections threatened by landslides, falling rocks, collapses of buildings, etc. This application introduces a new way of controlling the dangerous sections with autonomous mobile robots moving along the railway lines on steel cables stretched between catenary masts. The robots are equipped with LiDAR sensors and video cameras. Each robot autonomously processes the captured data and sends it to the control centre, where the data fusion and decision-making processes take place.

Tests performed in real conditions on the railway show that each application has its own specific requirements, which is reflected in the choice of sensors according to spatial and temporal resolution, and in the complexity of captured data processing. In both cases, the detection of obstacles on the line was performed by adapting the algorithms of the Laboratory of Geospatial Modelling, Multimedia and Artificial Intelligence (GeMMA) [1] from the Faculty of Electrical Engineering and Computer Science of the University of Maribor (UM FER), which has many years of experience in fusion and processing of Earth observation (EO) and other spatial data. The implemented algorithms showed a high level of reliability in real operating conditions.

2 Detection of dangerous obstacles at level crossings with LiDAR in SMART2 project

Level crossing accidents are not just significant economic, but also very depressing social problems for the people involved, their families and society. Advanced new technologies like LiDAR, enable reduction of the risk and reduction of the number of fatal accidents at railway level crossings. In the SMART2 project [2], FOKUS TECH [3] has developed its own 3D LiDAR to detect dangerous obstacles at level crossings. It works on the "Time of Flight" principle, which is presented in Figure 1.

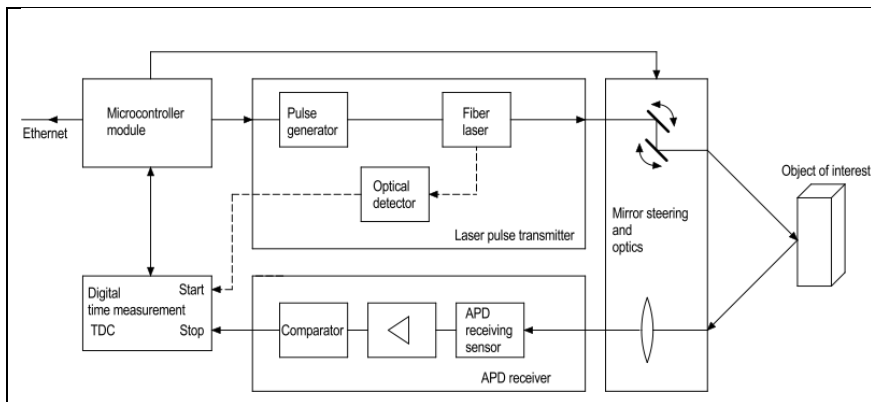


Figure 1. Principle of operation of the 3D "Time of Flight" scanning LiDAR.

LiDAR mounted on a pole near a level crossing is shown in Figure 2. It covers the dangerous area of the level crossing with a laser beam and reports the danger to the signalling system if it detects a dangerous obstacle at the crossing. The sensor covers a spatial angle of $60^\circ \times 30^\circ$ and has a range of 40 m. This is sufficient for most level crossings on double-track lines. However, two systems could be used for larger crossings and more complex situations.



Figure 2. LiDAR sensor installed at the level crossing.

Figure 3 shows a photo and the point cloud acquired on a test polygon. In the 3D view (right), the detected obstacles on the track are clearly visible.

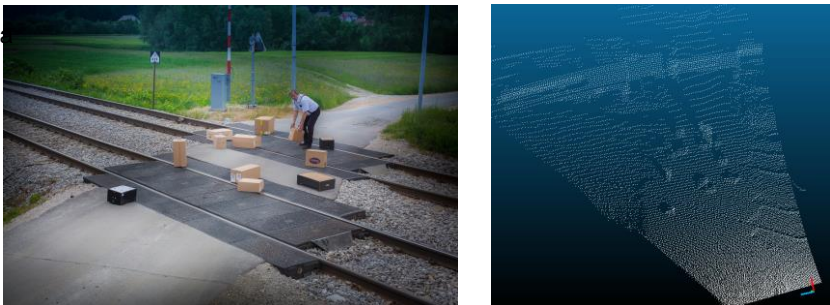


Figure 3. Test scenario and acquired point cloud.

Depending on the requirements set by the Infrastructure Manager, the parameters of the service application determine the minimum size of the hazardous objects that LiDAR must detect. The service application also defines a 3D dangerous area at the level crossing, which must be free of obstacles before the train arrives. The detected objects in the 3D dangerous area are shown by red bounding boxes in the point cloud in the service application (Figure 4). The detected objects outside the dangerous area are shown with green bounding boxes. Their status changes to red if they move so that they reach into the dangerous area. Axis-aligned bounding boxes are utilized in the current application. Object-oriented bounding boxes would expectedly provide more accurate results, but they do not provide

real-time performance yet and, thus, they call for additional studies and improvements.

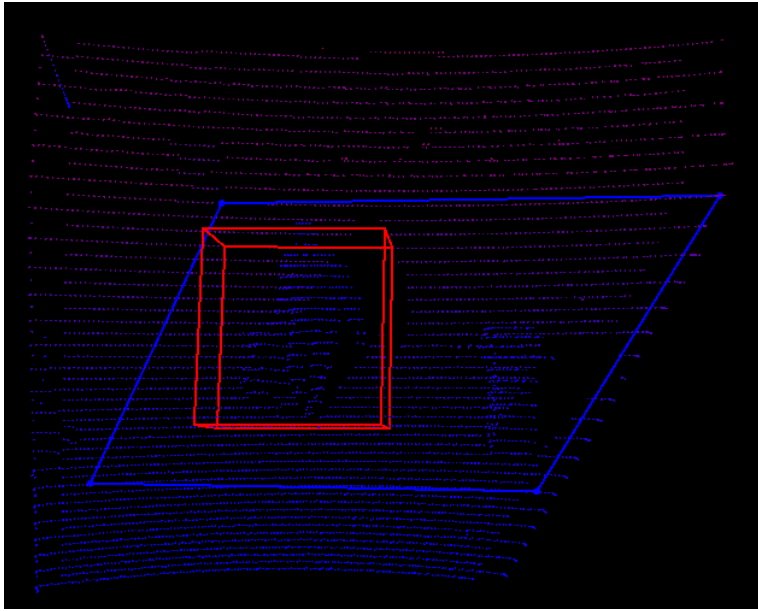


Figure 4. Detected standing human person (red bounding box) in the dangerous area at the level crossing (blue polygon line).

3 Inspection of dangerous railway sections with LiDAR in InspectRAIL project

Railway safety is threatened by landslides, falling rocks and trees, floods, collapses of rail lines and load-bearing structures, torrents, and other hazards as shown in Figure 5. The InspectRAIL project [4] introduces an entirely new concept for inspection of dangerous sections of railway lines with autonomous mobile robots. The robots are equipped with various sensors which inspect the railway tracks. Its data is automatically processed and sent to the Intelligent Control System (ICS), signalling system, traffic control, and maintenance centre for further actions. The robots move through dangerous places along the railway lines on steel cables stretched between the catenary masts and operate in all weather conditions.



Figure 5. Dangerous situations on railway tracks: collapsed stones (left) and torn off super/substructure (right)



Figure 6. InspectRail concept: LiDAR sensor mounted on an autonomous mobile robot that moves along wires on the catenary poles.

A LiDAR sensor plays the central role among the InspectRail sensors. The OS1 LiDAR sensor from Ouster [5] is used. It is mounted on an autonomous mobile robot that moves along wires (Figure 6) on the overhead catenary poles to check the track condition. If LiDAR detects a dangerous situation during the inspection, it reports this to the control centre. The system operates 24 hours a day in all weather conditions. On a longer route, several robots can move simultaneously along the same steel wires. These robots share the control area between them, significantly reducing inspection times. The robots are autonomous and do not need a human operator. However, the latter can view the situation on the ground using a video camera mounted on the robot as well, and then make appropriate decisions.

Contemporary LiDAR devices such as OS1 allow for more advanced object detection. This is no longer based on simple distance measurements based on time-of-flight only. One such additional feature of the OS1 is the measurement of the reflectivity of the target surface. Based on this, it is possible to identify different patterns on the objects from which the LiDAR beams are reflected. Figure 7 shows the recognition of inscriptions on containers loaded on a freight train. This feature is currently not used in InspectRail, but it opens possibilities for further

advancements in the object recognition. The latter is currently designed in a traditional manner, where the real-time point cloud of the current potentially dangerous track condition is compared to the reference point cloud initially acquired in normal conditions. The difference between both projects, STAR2 and InspectRail, is that the latter uses different type of a LiDAR sensor mounted on a mobile robot, combines multiple 3D acquisitions captured by several LiDAR sensors along the trail, and detects other types of dangerous events besides to the discrete obstacles of a given size.



Figure 7. A container with inscription (left) and its recognition with the reflectivity measurements performed by the OS1 LiDAR sensors (right).

4 Conclusions

The paper presents two concepts of LiDAR sensor applications in safety and inspection applications on railway infrastructure. The STAR2 project, being in its final phase, uses a stationary sensor for accident prevention and detection of dangerous obstacles at level crossings. In the second application, the InspectRail project being in the implementation phase, LiDAR is utilized to inspect dangerous railway sections threatened by landslides, falling rocks, collapses of buildings, etc. This project introduces a new way of controlling the dangerous sections with autonomous mobile robots which, equipped with LiDAR sensors and video cameras, move along the railway lines on steel cables stretched between catenary masts. Each application has its own specific requirements according to the spatial and temporal resolution of the utilized sensors and the complexity of acquired data processing which is, however, in both cases based on adaptation of the algorithms for object detection and recognition developed by the Laboratory of Geospatial Modelling, Multimedia and Artificial Intelligence at UM FERl.

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