Fugro vegetation control: A remote solution for lineside vegetation management

INTRODUCTION

In 2019, Fugro was tasked by Network Rail to conduct a lineside vegetation analysis study in Scotland along 620 km of railway corridors using the FLI-MAP based helicopter lidar system.

Lineside vegetation management is a process that uses risk assessment to contribute to the safe running of the railway infrastructure; the risk is controlled by inspection works, management and maintenance operations. The results of the study led to automatic identification of vegetation-related threats. These activities protect the Network Rail workforce and third parties from harm (NR/L2/OTK/5201).

NETWORK RAIL'S CHALLENGE

Fugro's objective for the study was to develop a solution that could support Network Rail in remotely assessing and/or mitigating vegetation related risks and be as automated as possible.

Such risks include the identification of individual trees of falling distance (trees classed as "falling distance" are those which pose a risk to the safe operation of trains if they were to fall) and zones of vegetation encroachments. This was by no means straightforward, as Scotland has one of the most complex forest types globally. Algorithm success rates depend highly on vegetation type, eg detection and delineation are more accurate for coniferous forests than deciduous ones. It is also important to make a holistic assessment of the wider adjacent infrastructure, including third-party vegetation that may affect the safe operation of the network.

FUGRO VEGETATION CONTROL SOLUTION

Fugro Vegetation Control, part of the overarching Fugro RailData solution for safer railway networks, has been developed specifically to meet these challenges from a Network Rail Asset Manager's perspective. The intention is to provide asset managers with a tool that can help them monitor, plan and implement the relevant vegetation management operations, while increasing efficiency, mitigating risk and reducing operational costs.

Data acquisition was performed by Fugro through its patented FLI-MAP sensor system mounted on a helicopter. The survey flight was conducted between September and October 2019 and covered 930 km of corridor lines.

The FLI-MAP 1000 OMG system consists of the following sensors:

- FM1000 laser scanner
- IMU LN200
- Applanix PosBox 510-v5
- Classified lidar
- GPS/INS
- PhaseOne -IXU-RS- RGB Colour and Near Infrared Camera

The acquired data was processed through Fugro Vegetation Control's highly automated algorithm to identify risk locations such as sites where vegetation impacts on overhead line equipment, signal sightings, railway access and positions of safety. Risk locations also include areas where there has been damage to railway infrastructure and/or third-party assets, and areas of invasive vegetation and / or weeds.

Risk maps based on falling distance tree (and crown) locations, tree canopy coverage, tree distance from the railway, tree encroachment coverage and volume, and tree risk class are just a few of the generated vegetation analysis outputs of this study, as detailed in the following section.

DETAILED METHODOLOGY

Fugro Vegetation Control consists of a series of automatically executed steps, the first of which is the classified point cloud processing to generate a Canopy Height Model (CHM). This CHM eventually forms the input data for the tree segmentation element, which outputs unique geometric information for each tree-to-railway asset relationship. This information is stored in an Individual Tree Database (ITD). The ITD information is further processed and directly compared with the Network Rail intervention zones, for both non-electrified and electrified railways (Figure 1).

From this analysis, the required outputs are subsequently generated for each Engineers' Line Reference (ELR) under review. Figure 2 presents a typical risk map visualisation. The risk map shows three colours:

- Red: vegetation in the immediate action zone;
- Yellow: vegetation in the action zone;
- Green: vegetation in the alert zone.

The risk map tiles are in line with the ORBIS file naming convention. An accompanying vector file includes all falling distance trees and tree crowns. All deliverables can be loaded into any GIS system, such as Geo-RINM, to provide the user

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Dennis is responsible for airborne survey projects for Fugro and a driving force in the creation of Fugro's RailData Vegetation Control solution. An expert in airborne survey acquisition and surveying, Dennis has over 10 years' management experience and has performed many roles including: management of aerial survey operations (imagery and LiDAR); project design and management; and strategic planning. He has a deep understanding of the infrastructure sector and the challenges faced by clients, helping to shape innovative asset management strategies.

Fugro is the world's leading Geo-data specialist, collecting and analysing comprehensive information about the Earth and the structures built upon it. Adopting an integrated approach that incorporates acquisition and analysis of Geo-data and related advice, Fugro provides solutions. With expertise in site characterisation and asset integrity, clients are supported in the safe, sustainable and efficient design, construction and operation of their assets throughout the full lifecycle.

with a quick and clear overview of trees and vegetation potentially in falling distance.

Since the quality of the CHM plays an important role in the holistic accuracy and vision of the tree segmentation results, strong emphasis is placed on the generation of a model that separates individual trees as much as possible, even in cases of dense non-coniferous forests. To achieve this, several CHMs are generated for each different tree coverage within the project area and the results compared. By characterising the interpolation parameters per case, the resulting CHM separates most of the individual trees, even where parts of their branches are close or intertwined.

Once the generation of the CHM is complete, the tree segmentation utilises a variable window function to define the treetops and the tree crowns. During the 2019 study, the complexity and the diversity of the natural vegetation in Scotland introduced various computational challenges at this stage.
For example, the function that successfully segments the coniferous trees had issues segmenting overlying trees in dense forests where small trees were located under the heavy top canopy. For this reason, it became necessary to run several tests for various types of different vegetation coverage before it was possible to conclude the final parameters for the project. The complexity of the characterisation of the segmentation function was further compounded by the fact that some tree species had already started to lose their leaf cover.

On completion of the segmentation, an ITD was generated to define the falling distance tree locations and their canopy crowns.

The next step was to conduct analysis while combining the ITD information with the intervention zone geometries and generate the risk maps for the falling distance trees and the falling distance tree canopy crowns per ELR. These risk maps can be loaded into any GIS system, such as GeoRINM, to give the user a quick and clear overview of the analyses made by the Fugro Vegetation Control algorithms.

Where falling distance trees exist, a point shape with the location of the highest point of the tree is identified using the following displayed attributes:

- Tree ID: unique identification number;
- ELR: ELR ID;
- Start/end mileage of the 1/8th of a mile section;
- Lineside, showing the up or downside of the track.

An area shape that depicts the crown of the tree, which is an extraction of the ITD, is displayed with the following attributes:

- Tree ID: Unique tree identification number;
- Tree Height: difference between the highest point of the tree and the ground level;
- Tree Basal* Distance: 2D distance (metres) to the rail track and falling distance encroachments;
- Tree Encroachment Distance: 2D distance (metres) from the nearest encroachment point to the track;
- Tree Basal Location: if located on Network Rail or third-party owned land;
- Tree Crown Area: crown coverage (square metres);
- ELR: ELR ID;
- Mileage: in (miles, yards);
- ELR lineside: up or down side of the track;
- Earthworks Classification: type of earthworks;
- Slope: the slope of the ground under the tree.

*Tree Basal is a term used to describe the average amount of an area occupied by tree stems and defined as the total cross-sectional area of all stems in a stand measured at chest height and expressed as per unit of land area. Fugro has compiled a comprehensive end-user ITD manual that explains all the applications and more detailed information on the attributes.

COMPLEMENTARY TRAIN-BORNE RILA DATA

Fugro also deploys its state-of-the-art, train-mounted, survey measurement RILA technology, which simultaneously acquires track scan, lidar and imagery data of the entire rail corridor. This highly accurate and information-rich infrastructure model helps rail asset owners to maximise safety and efficiency on their networks. RILA has been used extensively by Network Rail and, to date, approximately 45% of the network has been

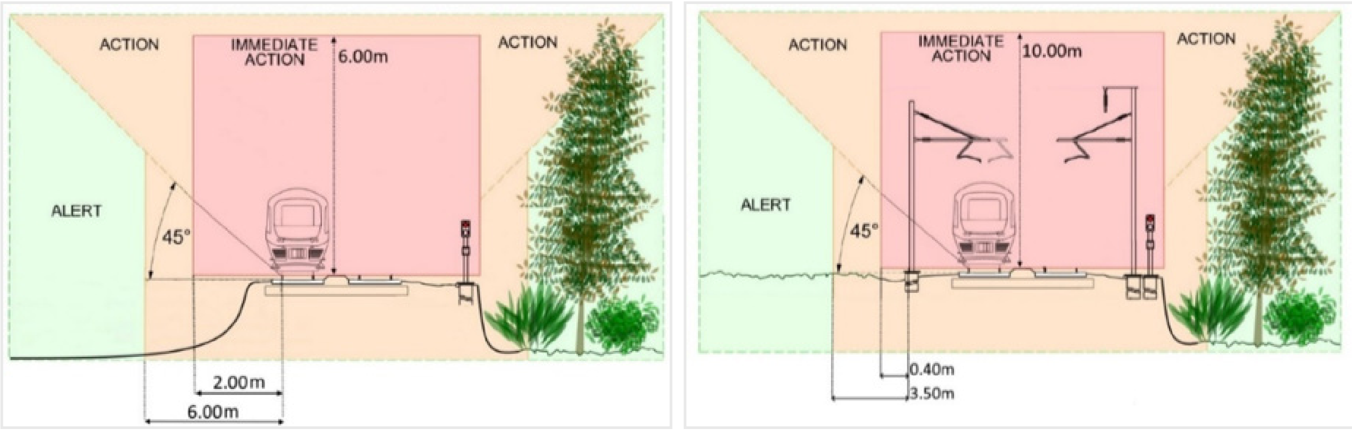

Figure 1: Left - Non-electrified intervention zones; Right - electrified intervention zones as detailed in NR/L2/OTR/5201_01, issue 3.

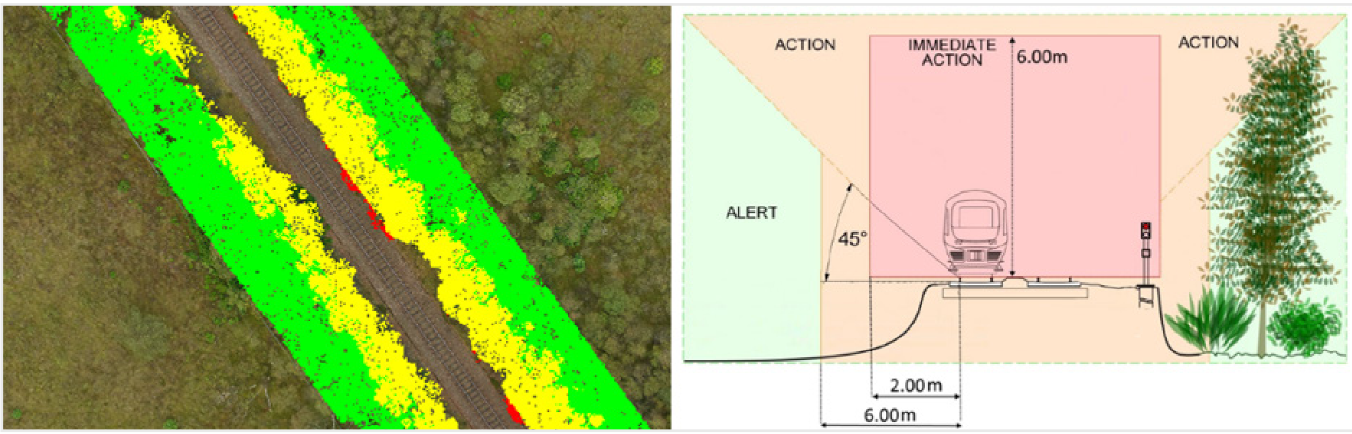

Figure 2: Left - Example risk map showing vegetation in the immediate action zone (in red), in the action zone (yellow), and in the alert zone (green). Right - Intervention zone profile used.

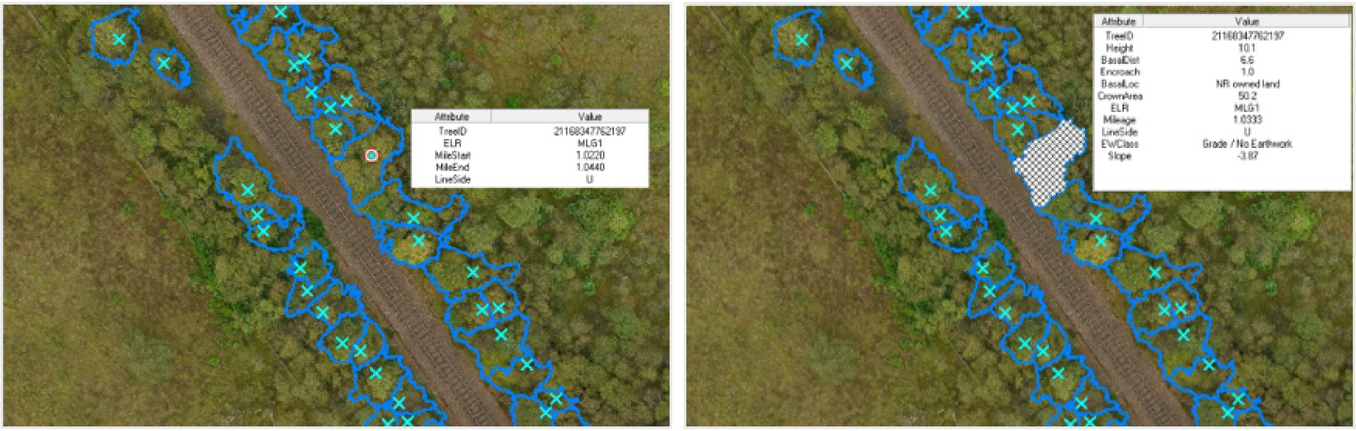

Figure 3: Left - Falling distance trees point shape; Right - Falling distance trees crown area shape.

surveyed using RILA mounted on in-service passenger trains or freight locomotives operating within the regular timetable.

Fugro has developed a process that effectively and accurately combines train-borne RILA and aerial FLI-MAP data sources to provide a holistic and immersive view of the track corridor. All images are positionally merged with the processed point cloud, which is then categorised into feature classes such as rails, sleepers, vegetation, ground etc. The vegetation class is used as an input for vegetation analysis and the volume of vegetation is calculated from the number of reflection points in the point cloud and reported for each zone in the vegetation structure gauge.

The RILA data augments the FLI-MAP data to provide a track-level perspective of the asset. It also reduces the dependency on seasonal aerial survey, as RILA can view the vegetation beneath the upper canopy and provide detailed information on tree bole (trunk) position and girth of individual trees.

By combining these two kinds of data, it is not only possible to characterise the trees and vegetation but to also calculate the height of trees and their likely "falling" radius should they become unstable.

Using the same process, it is also possible to analyse other objects such as signal posts, telegraph poles and other lineside features that may adversely affect the rail corridor.

It is also possible to calculate whether the reported vegetation is the property of the rail asset owner or a third party. The property boundary is derived from information regarding land ownership near the tracks and supplied by the track owner. The amount of vegetation which is not owned by the client is separately reported in the data deliverable.

THE TRACK AHEAD

Fugro's vision is to create a baseline vegetation model from FLI-MAP data, which is subsequently updated and refreshed through regular deployment of RILA in conjunction with scheduled route-wide RILA surveys. These surveys will support a wider range of track recording and asset management applications, including OLE monitoring of heights and staggers; upper and lower sector, 6ft passing clearance, and platform gauging; and monitoring of ballast profile.

Further developments will include species identification and predicted growth patterns for targeted and optimum pruning and clearance activities. Subsequent refreshes will monitor the maintenance regime and contractors' performance. Similarly, the health of an individual tree can indicate an increased risk of failure that could cause a tree branch or limb to fall and impact the safe operation of the railway. Fugro is investigating if this risk can be mitigated using the imagery and/or point cloud with machine-learning algorithms to identify dead or decaying vegetation or through the implementation of additional multi and hyperspectral sensors to the current survey systems.

As the lidar point cloud represents the real world in 3D, theoretical locations such as the train driver's eye position can be calculated and entered into the model, thus allowing line-of-sight analysis, as encroaching vegetation also has the potential to block lines of sight between the driver and approaching signals or speed restriction signs.

A recently reported near-miss incident involving track workers undertaking lineside photographic monitoring of vegetation highlights the risk of working on or near the track; remote systems such as FLI-MAP and RILA offer a clearly defined health and safety benefit to the industry that cannot be ignored.

Network Rail's increased use of the Fugro RailData solution incorporating FLI-MAP and RILA technologies has reinforced the ethos of "survey once, use many times" and there is a growing archive of data available to Network Rail and their supply chain to use at no additional cost. Fugro has developed a secure web portal where users can browse the archive to check if data already exists, including metadata pertaining to survey date, processing status and derived products.

Fugro's commitment is to continue innovating sustainable survey methods and combining technologies to support railway asset owners in their engineering, management and maintenance requirements, for a safer and more liveable world.

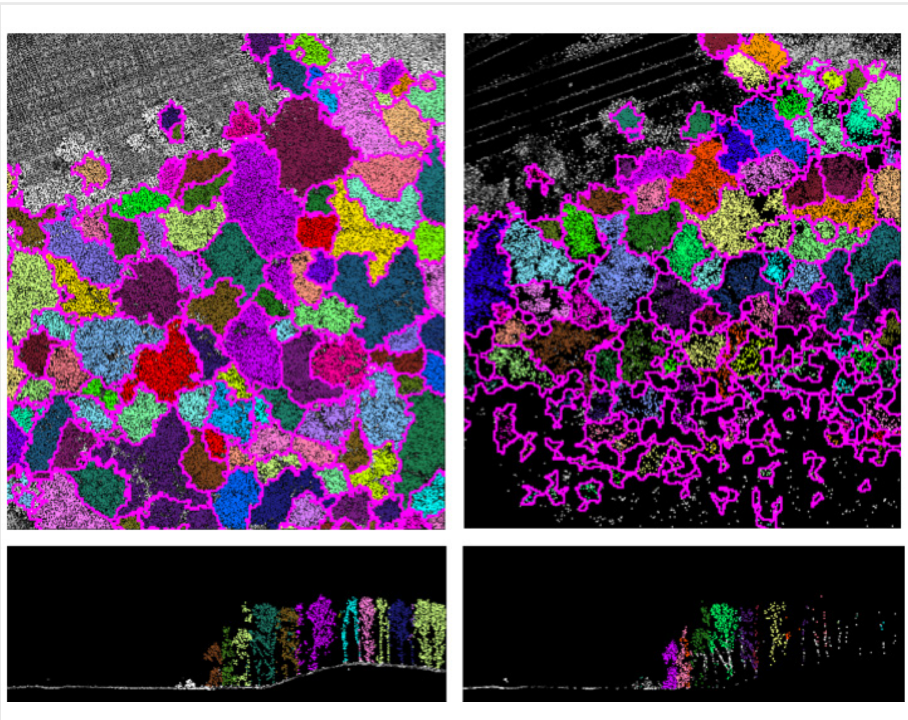

Figure 4: Left - FLIMAP plan and elevation; Right - RILA plan and elevation.