PLANES VERSUS TRAINS

FLAVIEN VIGUIER, PIERRE ASSALI, URSULA RIEGL AND PHILIPP AMON REPORT ON A PROJECT TO DETERMINE WHETHER UAV-MOUNTED LIDAR DATA COULD BE USED TO SUPPLEMENT OR EVEN REPLACE DATA ACQUIRED FROM A UNIT MOUNTED ON A TRAIN

Suppose that one day, you're asked to run a system that partly relies on a structural layout from the mid-19th century and that uses a diversity of material, some of it decades-old, some representing the newest, state-of-the-art technologies. To increase the challenge even further, you also have to provide the utmost safety, efficiency and reliability to a vast number of people who take this for granted every day.

Difficult? Yes. But this is no theoretical problem. You're now running the French national railway company, SNCF (Société Nationale des Chemins de Fer français), and are responsible for 10 million passengers every day, 32,000 track kilometres on the French mainland alone, 17,000 locomotives, 500 high-speed trains and 180,000 people working in 120 countries around the globe.

As you can probably imagine, regular inspection of the track is vital. SNCF Réseau, a member of the SNCF group, employs a dedicated department responsible for the regular, complete and thorough inspection of the track and related infrastructure network. The typical results required from surveying are clearance monitoring, updating of infrastructure maps and inspection of catenary. Safety installations, such as fences, also need to be checked regularly. The condition of important buildings and constructions such as bridges and viaducts is registered for renovation, replacement or maintenance.

These different tasks need to be carried out according to a defined safety and maintenance schedule. Yet environments with elevated risks, such as rock-fall areas, require surveys to be carried out more frequently and sites with sudden damage or construction require immediate survey. Scheduling all the inspection tasks necessary to operate a safe and timely railway network is therefore difficult. This is why different technologies come into play and why different, complementary methods of using them are the most efficient approach.

Technology in action

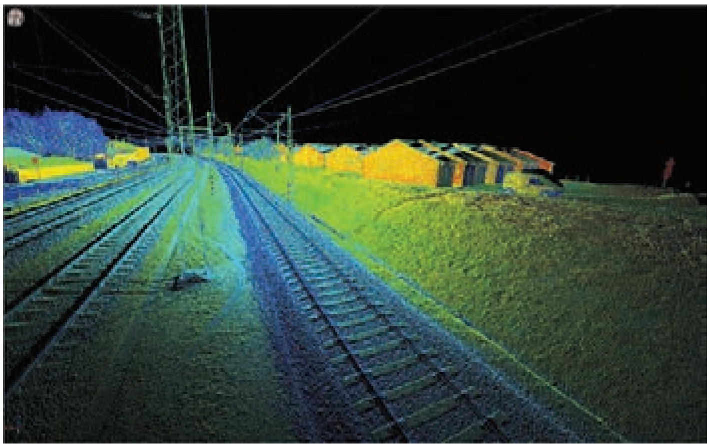
As well as total stations, ground-based stationary LiDAR and photogrammetric cameras, the SNCF engineering team uses a mobile LiDAR system (MLS) for surveying. Data is acquired using a RIEGL VMX-450-Rail, a high-speed scanning system consisting of two RIEGL VQ-450 laser scanners combined with a calibrated camera system, an Applanix high precision inertial measurement unit, an optical odometer and several additional sensors. The mobile system is mounted on the locomotive or on the front or rear of a wagon – potentially on a special scaffold to gain a better perspective on the rails. The operator's equipment is installed in the cabin.

In the past two years, the team has surveyed 18,000 track kilometres of the French railway network with this set-up. The scanning speed of the system can be adapted to the application, at the maximum speed of 2 x 200 scan lines per second at a train speed of typically 60km/h, resulting in one million measurement points per second and an average point density of 1,000 points per square metre in the centre of the track. To improve precision further, the measurement is carried out in two passes.

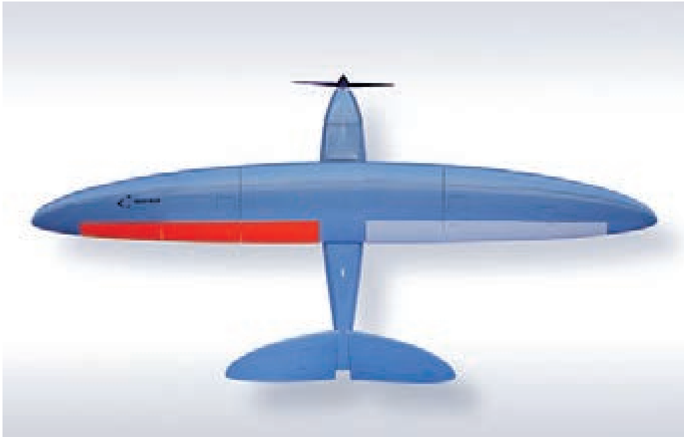
The laser scanners used can receive and process several return signals from a single pulse, and analyse each signal with respect to specific attributes such as reflectance. It is therefore possible to penetrate several layers of even dense vegetation or other complex environments, and to derive digital terrain models (DTMs)

The RIEGL VMX-450 mobile scanning system mounted on an SNCF measuring train

The typical complexity of railway mapping: parallel tracks, turnout/switch section, infrastructure elements (bridge, tunnel entry)



Coloured point cloud from a mobile scan. The field of view of the two scanners enables a wide perspective covering both tracks and the slope, and provides a regular, dense point pattern



Delair Tech DT26X equipped with RIEGL VUX-1 scanning system

from the point cloud. The analysis of the signal's attributes can be used for filtering, detecting objects and classifying surfaces. Single layers of vegetation, such as low vegetation growing in the railway embankment, potentially destabilising the gravel slope, are monitored to decide whether herbicides should be used. Analysing the heights of trees and their distance to infrastructure elements enables potential hazards to be identified so adequate measures can be taken.

UAV-borne LiDAR

These tasks are well defined with regards to density, accuracy and traceability. Yet, it is hard to cover all the different scenarios with one method. While the MLS enables fast, efficient and very precise measurement, urgent, on-demand surveys are hard and sometimes impossible to realise because the units aren't available.

There was therefore a need for a complementary method for particular environments and to gain more operational flexibility. A special research team from SNCF's engineering and projects group, SNCF Pôle Drones, was founded in 2014 to assess the potential of UAV-borne surveying, to test different sensors and aerial platforms and to implement suitable solutions. As a result of the research, SNCF now uses several different models of UAV equipped with photogrammetric cameras. To complement and to some extent replace ground based static and kinematic LiDAR, SNCF opted for the RIEGL VUX-1 miniature laser scanner, the first survey-grade laser scanner adapted for small UAVs.

UAVs are foreseen to be a future standard for the automated monitoring of high-speed rail lines. SNCF therefore commissioned the French UAV company Delair Tech with the development of a fixed-wing UAV to be equipped with the RIEGL VUX-1 complete scanning system.

Fixed wing UAVs are indisputably a reliable, perfectly efficient solution for monitoring routes over longer distances. Yet for complex,

RiCOPTER – an electrically powered octocopter with VUX-1 LiDAR system

narrow conditions where a particularly flexible flightpath or vertical take-off and landing (VTOL) are needed, another type of UAV seems more suitable. Another test was therefore carried out with an electrically powered octocopter.

A practical test

The chosen test site in eastern France featured some of the challenging characteristics of a typical railway survey: very close surrounding vegetation; wire poles and other obstacles; and the margins needed because of operational requirements and to keep personnel safe.

The central study area was surveyed in four separate flight paths at 50m and 100m above ground level at maximum scanning performance (550kHz) and a forward speed of 6m/s.

For the 50m flight, this resulted in 122 lines per second and 290 points per square metre, with a spacing of 5.8cm between single scan lines. For the 100m flight, with the same scanner performance set, the result was 70 lines per second, a point density of 150 points per square metre and a spacing of 8.3cm between scan lines.

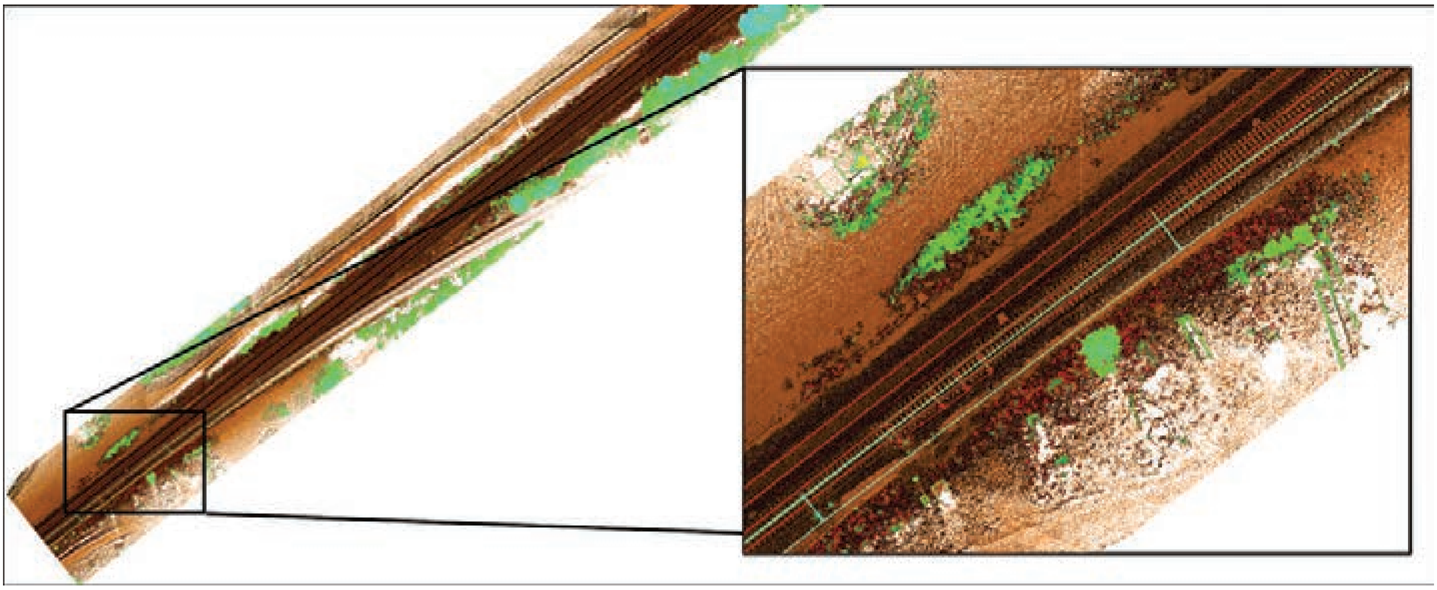
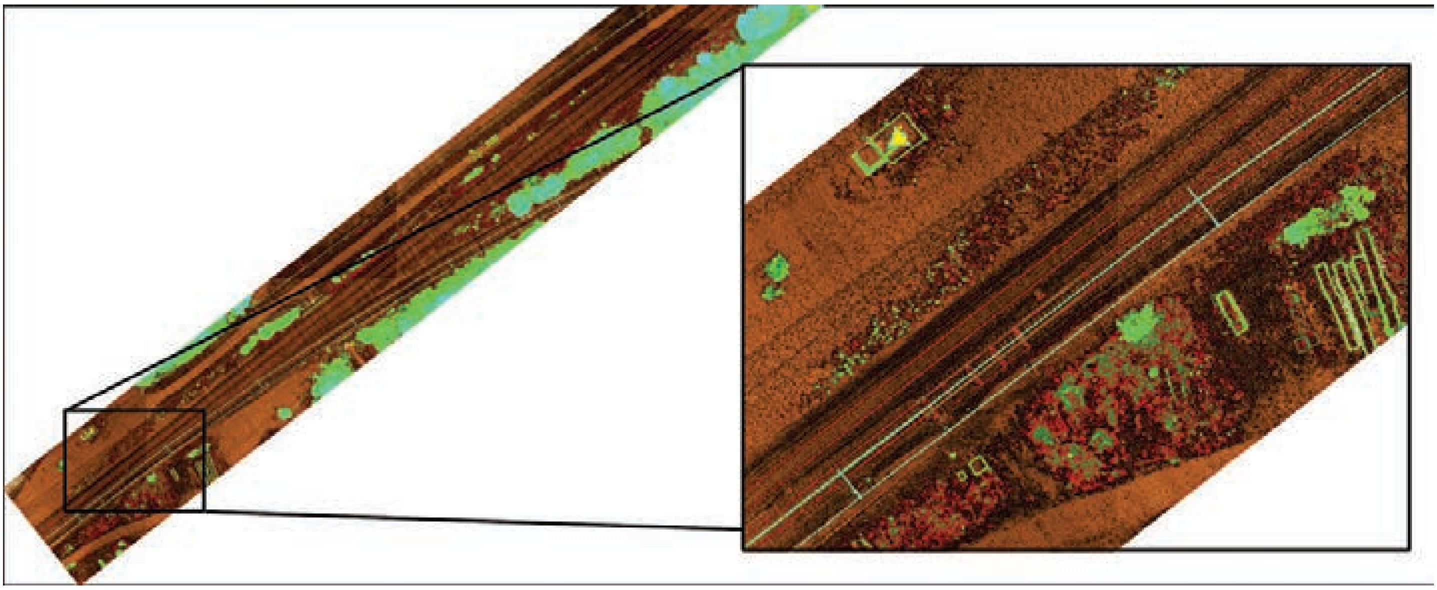


Figure 1. Orthoimages from the normalised digital surface model obtained from VMX-450 data (above) and the VUX-1 point cloud (below)



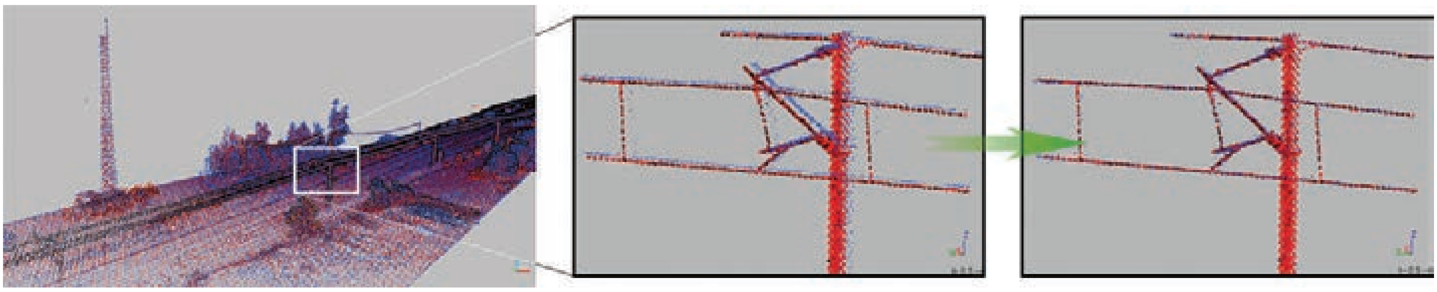


Figure 2. Position offset between VMX-450 (red) and VUX-1 data (blue), and optimisation with a best-fit algorithm; example on a catenary support

Data quality

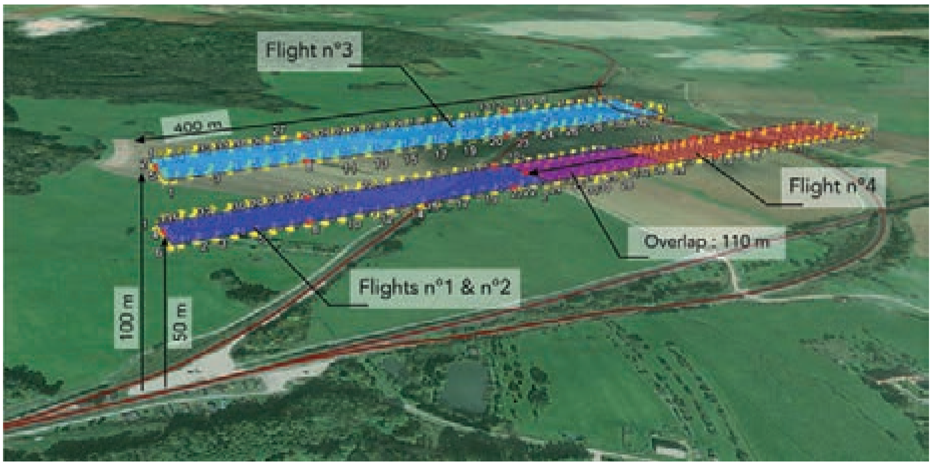
The point cloud density in the UAV dataset allowed for the comparison with previously acquired MLS data for tracking modelling and precision analysis. The following experimental modelling process was tested on a selected track section:

- Point cloud segmentation to extract the railhead. This is easily performed manually on the tangent section. Tests with an automatic algorithm show promising results, too.
- Application of a linear best-fit algorithm to compute the directional axis of the rail.
- Extrusion of the CAD model of the rail along the best line.
- Calculation of cloud-to-model distances.

The process showed that the UAV data met with the monitoring quality requirement of an accuracy better than 1cm. Of course, even higher precision can be expected from the MLS – 8mm for the UAV point cloud versus 4mm for the MLS point cloud.

Comparison of data sets

The first level of comparison concerns the spatial distribution and comprehensiveness of the two datasets. The planar projection of each point cloud and its conversion into an orthoimage representing the normalised digital surface model (DSM) serve as a basis for this comparison. Figure 1 clearly shows that in the VMX-450 data, the fixed perspective of the scanning system means many areas are shielded from view. The UAV point cloud



Four separate flight paths were defined for UAV data acquisition, to provide a comprehensive basis for data quality analysis

overcomes this difficulty, providing a more complete dataset.

The superposition of the two point clouds shows a global offset of less than 10cm, despite there being no ground control points (GCP) in the test field. This offset therefore represents the absolute accuracy of the UAV point cloud. GCPs could improve the absolute accuracy up to 1cm.

Yet even if an offset is observed, no local distortion is detected. Fusion of UAV and MLS datasets is therefore a straightforward procedure. To further improve the data superposition, it is possible to correct the global offset with a best-fit algorithm (see Figure 2), resulting in a very precise and homogeneous point cloud with a global density of more than 1,000 points per square metre.

Based on these results, SNCF decided to continue using MLS point clouds for rail extraction and track alignment analysis and, complementarily, UAV point clouds for environmental studies. Nevertheless, the data quality from these initial tests means UAV data can be reliably used for high accuracy analysis when MLS data is unavailable.

Conclusion

For obvious reasons, UAV-based laser scanning provides more operational flexibility than MLS, as well as complementary perspectives for zones occluded in the track environment. MLS remains unrivalled for continuous, high-precision surveying, route monitoring and mapping large areas; it is also more efficient.

However, for critical zones or situations, when the MLS cannot be booked on short notice, UAV data can be embedded into an existing MLS dataset. The smooth integration of a UAV point cloud into a large project file opens up new potential for intelligent updating of databases.

The positive outcome of the field tests again proves the potential of a complementary surveying approach combining various technologies and different operational methods.

THE SMOOTH INTEGRATION OF A UAV POINT CLOUD INTO A LARGE PROJECT FILE OPENS UP NEW POTENTIAL FOR INTELLIGENT UPDATING OF DATABASES

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