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AXIS: An Automated, Drone-based, Grade Crossing Inspection System

SUMMARY

The Federal Railroad Administration (FRA) has engaged in several initiatives to help improve the safety of highway-rail crossings. To that end, FRA recently funded research through the Small Business Innovation Research (SBIR) program to encourage development of a drone-based inspection system for highway-rail grade crossings.

Phase 1 of this SBIR project supported VisioStack, Inc. of Greenville, South Carolina, to begin the development of AXIS: Aerial Crossing Inspection System. AXIS uses UAVs (unmanned aerial vehicles, i.e., drones) to perform grade crossing safety inspections with a high level of accuracy and efficiency. AXIS will determine the risk profile of a crossing based on several factors, such as crossing profile (humped condition), sight lines available to automotive traffic, and the location of signage, gates, and other safety appliances.

AXIS integrates the major elements of an inspection, from planning to analysis and reporting. Figure 1 displays the AXIS dashboard that provides a convenient user interface to the system.

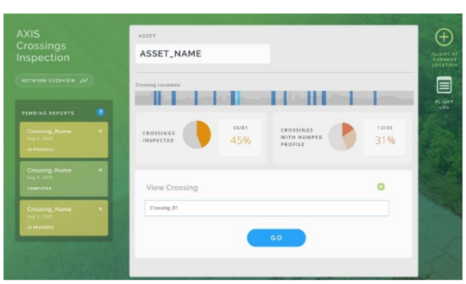

Figure 1. AXIS Dashboard and Planning Center

BACKGROUND

There are more than 200,000 railroad grade crossing locations in the U.S. In the past 5 years, there was an annual average of 2,100 incidents and 264 deaths at these locations (1). Vehicle hang-ups are a common risk at crossings. A hang-up can occur when a low-clearance vehicle encounters a high-profile (or "humped") grade crossing and becomes stuck in the railroad right-of-way, and may be struck by a train.

Guidelines from the American Association of State Highway and Transportation Officials require that a grade crossing's change in elevation should *"be [no] more than 3 [inches] higher or lower from the top of the nearest rail at a point 30 [feet] from the rails"* (2). While the original configuration of crossings can satisfy guidelines, the profile of a grade crossing is often altered by railway or roadway maintenance. Inspections are usually performed just once every 2 to 3 years, during which conditions at the crossing can change drastically. This presents a potentially dangerous safety gap.

OBJECTIVES

VisioStack is developing AXIS to provide the industry with an efficient, accurate method to inspect crossings using emerging UAV and data processing technologies. The objective of Phase 1 was to demonstrate the feasibility of AXIS for grade crossing inspections.

The main challenge in Phase 1 was to demonstrate the ability to collect data using a UAV and to automate the image process to determine the grade crossing profile efficiently.

The goal being to calculate the clearance between long wheelbase vehicles and the crossing surface.

METHODS

AXIS leverages VisioStack's RailLinks® infrastructure to achieve high performance and to integrate the major components of the inspection process. RailLinks Infrastructure currently stores nearly 100,000 miles of track data. Track centerline data and crossing features from RailLinks are the base data used for planning grade crossing inspection flights. The AXIS dashboard (Figure 1) stores key metrics for each subdivision in a network and is the user interface through which crossing inspections are planned. Crossing attributes are displayed on this page and can be selected one at a time or through filtering specific subdivision locations. Additionally, when used in the field, the AXIS application can filter for nearby crossings using GPS, further simplifying the planning process. Once one or more crossings are selected, flight plans are generated automatically.

A grade crossing inspection can be performed by a single, FAA-licensed UAV pilot in less than 10 minutes. Images are captured automatically, allowing users to focus solely on the operational safety of the drone at all times. An initial snapshot of the crossing profile can be created from several images, and the results are returned to the user by the time the inspection is completed. To further simplify user interaction, images are automatically uploaded to the cloud as they are captured and processed using clustered-computing.

Figure 2 displays a 3D mesh created by AXIS. Advanced photogrammetry techniques are applied to the imagery to create this high-density point cloud. One of the challenges faced during development was bridging the gap between the drone's estimate of its location stored in the image exchangeable image file (EXIF) and the location returned from the photogrammetry process. The team developed a flight plan that helps AXIS accurately combine each of the images to create a mesh that minimizes this variation between the point cloud and real-world coordinates. Each mesh contains over 5 million points.

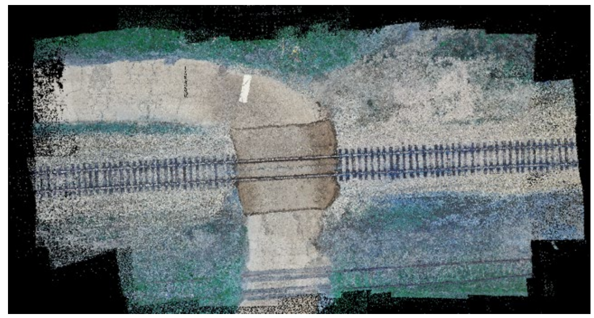

Figure 2: AXIS 3D Mesh

The primary use case considered during development was the maximum clearance required for a vehicle with a 30-foot wheelbase to pass safely over the crossing. After creating a mesh, AXIS iterates dozens of trip paths that vehicles could take while traversing the crossing. Figure 3 displays an elevation profile calculated from a 3D mesh for one of the test sites used during this project. The blue line represents the maximum clearance (4 inches, in this case) required over any 30-foot span to safely traverse this grade crossing. AXIS can also calculate the required clearance for vehicles with different wheelbase lengths, such as 21.3 feet for a standard school bus (2).

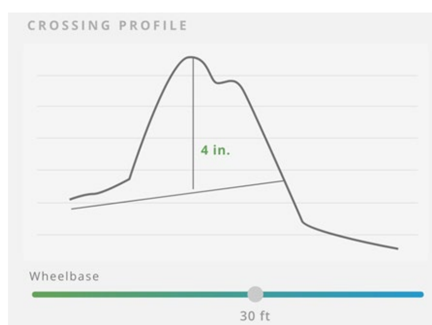

Figure 3: Crossing Elevation Profile

To evaluate a crossing's risk profile in more detail, AXIS also analyzes the imagery to determine lines of sight and the presence of key signage such as crossbucks, crossing gates, and stopping bars. The RailLinks artificial intelligence (AI) platform allows users to define machine learning models that can be taught to look for each of these features at a crossing. These models improve as more crossings are inspected, and users interact with the results during a process called “re-learning.”

Users can prioritize the AXIS risk profile calculation to focus on their particular safety factors. For example, databases containing the number of daily school bus crossings, average train speed, and lanes of traffic can be integrated to determine the final risk-profile. This provides valuable flexibility as railways and State DOTs alike have different evaluation techniques to measure highway-rail crossing safety.

To achieve high levels of efficiency, AXIS leverages cloud services and clustered-computing to help process the heavy data captured during inspections. Results can be provided to decision makers the same day, regardless of how many inspections are performed.

RESULTS

VisioStack tested AXIS at several crossings to provide multiple points of comparison. Each grade profile calculation was compared to calculations made from Phoenix LiDAR data sourced from rail partner CSX. Variations in flight parameters were introduced to help find the ideal flight plan for inspections. AXIS performed hundreds of tests flights at different altitudes and path overlap percentages to find ideal flight conditions to balance both operational efficiency and data accuracy.

The results from AXIS’ automated process were within 5 percent of the measurements calculated from LiDAR data (example shown in Figure 4). These results show the reliability of using a drone-based system for such inspections. Drones provide much greater flexibility for inspection planning and at a fraction of the cost of LiDAR systems. Furthermore, LiDAR data requires more processing time than UAV imagery.

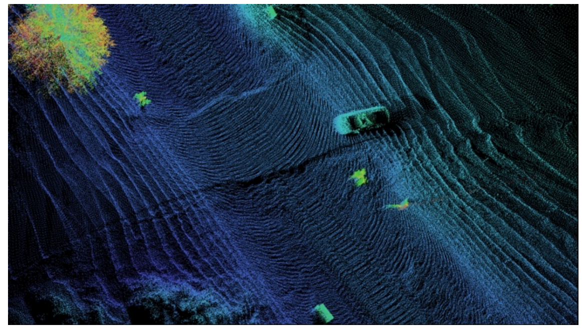

Figure 4: LiDAR Mesh

CONCLUSIONS

Phase 1 demonstrated that AXIS can be a highly efficient and accurate inspection system for grade crossing safety assurance activities. AXIS will enable users to inspect crossings across their networks more frequently to determine if vehicles are at-risk for hang-ups or if other safety-related issues are present at a crossing. Inspection planning and reporting can all be performed within a single application, helping to improve the workflow between back-office and the field. Furthermore, inspection results can be communicated to decision makers quickly so that improvements can be made, or proper signage installed in a timely manner. These results all point to the improvement AXIS provides over existing inspection methods.

Safety is improved not just by understanding current conditions but also by reducing the time personnel spend on the track. As UAVs continue to play a more substantive role in the transportation industry, there is the possibility of further developing AXIS for use on highways and railways to help automate additional inspection processes.

FUTURE ACTION

Phase II, set to begin in fall 2020, will continue the development begun in Phase I. Phase II will focus on improving the efficiency and accuracy of AXIS while moving toward commercialization.

The team will continue conversations with key railway partners and engage state DOTs to build a product that suits users' needs. Immediate feedback from these engagements in Phase I reflected the importance of improving safety at grade crossings and the need to easily inspect them for key safety features. Furthermore, there is the possibility of implementing AXIS outside the U.S., as VisioStack has partnered with railways on several continents. Specific technical objectives for Phase II include:

- Improve the repeatability and reproducibility of risk profile calculations.
- Integrate RailLinks AI models into the risk profile to help detect signage and line of sight.
- Develop a standalone mobile application for flight planning and operation.
- Refine the turnkey approach so that the system can handle the challenges associated with performing inspections across an entire rail network.

REFERENCES

1. FRA Office of Safety Analysis. Ten Year Accident/Incident Overview.

2. American Association of State Highways and Transportation Officials. (2004). A Policy on Geometric Design of Highways and Streets. Washington, DC.

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