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RESEARCH RESULTS

FRA OFFICE OF RESEARCH, DEVELOPMENT & TECHNOLOGY

AUTOMATED TRACK CENTERLINE FOLLOWING FOR DRONE FLIGHT AUTOMATION

SUMMARY

VisioStack Inc. completed initial research to automate drone inspection flights over railroad track using real-time rail detection and track centerline following to simulate flight control without Global Positioning System (GPS) information. Uncrewed Aerial Systems (UAS, or drones) are platforms that may enable more frequent and safer track inspection compared to traditional methods, augmenting human inspection and increasing safety on the railroads. This report highlights Phase 1 of this Federal Railroad Administration (FRA)-sponsored project. VisioStack completed this work between September 2021 and March 2022.

VisioStack used commercially available equipment for this research, including a DJI Matrice 300 aircraft and a DJI H20T camera payload. The development efforts included manufacturing a custom, on-board computer system to process track images in real-time for track centerline location as well as software to control the drone's flight path. Researchers used DJI's software development kit (SDK) to capture track imagery and to issue flight commands. VisioStack performed field testing under controlled conditions within line-of-sight limits.

The project's Phase 1 results successfully demonstrated this approach to flight automation. The drone flew autonomously for 600 feet at 5.6 mph without GPS guidance. The test flight overflew tangent track, a grade crossing, and part of a curve. Goals for Phase 2 include flying at higher speeds over a variety of track conditions, establishing a safety case to support a beyond visual line of sight (BVLOS) waiver, and creating an application programming interface (API) to permit other developers to use this technology.

BACKGROUND

UAS are becoming more common across the railway and transportation industries for a variety of inspection purposes. Due to the efficiencies that they provide, drones can be used to inspect unsafe or hard-to-reach areas while also decreasing the time spent on track. Drone applications are generally limited to line-of-sight activities due to safety concerns for flights that extend beyond the sight of the pilot.

Figure 1: Onboard Track Centerline Detection

Railways are long linear infrastructures that require regular inspection. To be completely successful, drone-based railway inspections must achieve BVLOS compliance with federal regulations. The ability to precisely control the drone flight over track without the aid of GPS is a key technical objective that will support a BVLOS safety case. Following the centerline of the track (white line in Figure 1) autonomously demonstrates a high level of flight command and control capability and will enable expanded use of drones for railroad inspections.

OBJECTIVES

The objective of Phase 1 of this project was to develop technology to support autonomous drone flight over the centerline of the track without the aid of GPS position information. Achieving this objective required developing hardware and software systems to capture track images, processing these images to determine the track centerline, and controlling the drone's flight path over the track. All flights were conducted within line-of-sight limitations and at very low altitudes, i.e., less than 60 feet above ground level.

METHODS

VisioStack selected the DJI Matrice 300 aircraft and the DJI H20T camera payload for this research. DJI's onboard and payload SDKs are very flexible and provide adequate precision to meet the project objective. The use of a mature SDK is important because the drone is in constant communication with both the onboard computer and the payload to perform image capture and to issue flight control commands. The control system and software developed by VisioStack is designed to be adapted to other hardware systems.

VisioStack selected the Nvidia Jetson Nano for the onboard computer. The Nano is a low cost, lightweight, low power consumption computer system that includes a developer kit. The system is designed for neural processing of images, image segmentation and classification, and related operations. The form factor of this computer was well-suited to the DJI Matrice platform. Figure 2 shows the onboard computer box attached to the Matrice 300.

Figure 3 displays the workflow that runs while the drone flies down the track. The automated flight starts once the drone is positioned above the track. At this point, the onboard computer sends a command to the DJI H20Tcamera to take a picture. This image data is transferred to the onboard computer for processing. The software-based detection model processes the image, finds each rail, and determines the centerline of the track.

Figure 2: DJI Matrice with Onboard Computer

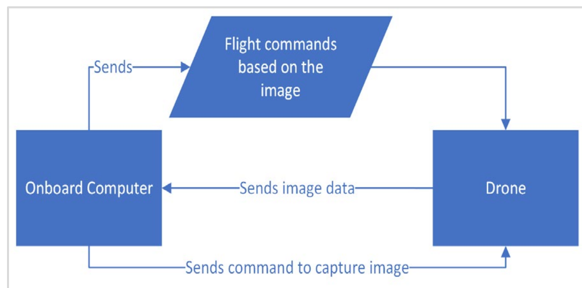

Figure 3: Drone Flight Processing Workflow

The software model compares the position of the track centerline relative to the drone's heading and lateral position over the track and determines if any adjustments to the flight path are needed. The model outputs flight adjustments to guide the drone down the track centerline with the track centered in the camera's field of view.

The onboard computer saves high resolution track pictures for off-board, post-processing purposes. This process repeats until the pilot signals the end of the inspection flight.

For safety, the drone flight is paused if the onboard computer is unable to detect the track centerline. The pilot can then use the image feed available on the flight controller to adjust the drone's flight manually until the track is captured by the camera and the automatic process can continue.

Figure 4 depicts how the detection algorithm functions with respect to changes in the track position. The smaller gray dashed lines show the straight-line path of the drone. The blue line shows the adjusted path that the onboard computer dictates to control the flight over the track. The red lines are configurable flight boundaries. If the drone reaches an outer boundary, the flight is paused.

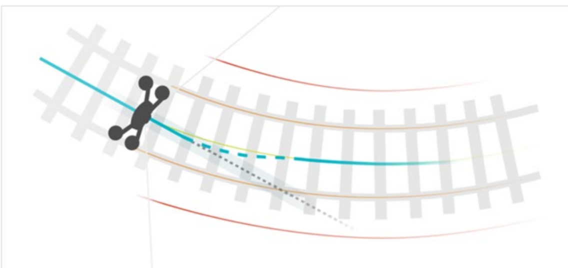

Figure 4: Flight Control Schematic

The team performed iterative testing in a controlled environment throughout the project to test the efficiency and accuracy of the program. VisioStack completed over 20 test flights to develop the correction model and to test the system's performance at various speeds. VisioStack made refinements to the detection process that enabled flight speeds up to 5.6 mph during the final test.

RESULTS

The software, hardware and testing activities concluded with a successful autonomous flight of over 600 feet without using GPS position information. The test flight started on tangent track and flew over a crossing and into the body of a curve. The 5.6 mph test flight speed enables approximately three miles of testing given the current battery limitations of the DJI Matrice 300.

Figure 5 displays 3 sequential images from this flight to illustrate the flight path adjustment process. The slope (angle of flight relative to the track centerline) stayed very close to 90 degrees and the flight control system adjusted the horizontal position of the drone to less than 1 percent off-center.

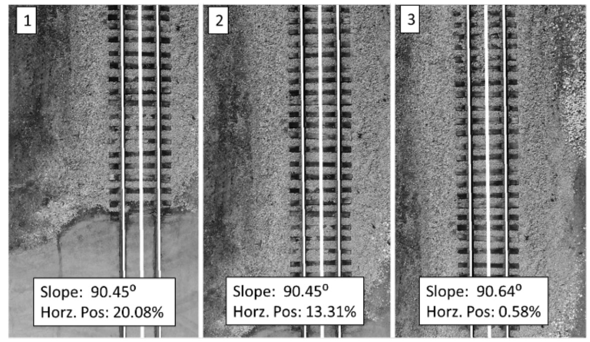

Figure 5: Flight Test Results

CONCLUSIONS

The project results demonstrated the ability to control drone flight over railroad track without GPS position information. VisioStack successfully integrated an onboard computer system onto the DJI drone and used this computer to automatically control image data acquisition to process these data, determine the position of the track relative to the drone, and issue flight commands to the flight control system to adjust the flight path.

These results provide a glimpse of the potential for fully autonomous, BVLOS drone flights over railroad track. With addition of inspection payloads, such as thermal and LiDAR sensors, important track features can be inspected without requiring employees to occupy the track. The onboard computer can save these data for post-processing and there is the potential to detect and inspect some track features in real-time.

The VisioStack team spoke with several potential end-users for this technology who had different use cases for autonomous inspection flights. One such case is the need to fly the system over six miles of hard-to-reach track. This feedback shows that there is a large potential market for this system as it is further developed.

FUTURE ACTION

There are three specific areas that the team has identified for future development to create a safety case for BVLOS authorization. The first is to provide a better feedback loop to the pilot-in-command through a dedicated mobile app. This mobile app will provide direct feedback of the image processing routine results to the pilot.

Secondly, additional development of the detection algorithm will help the system fly over a variety of on-track environments, e.g., in yards, over double main, on double main when a train is on the parallel track, and over features such as switches.

Lastly, improving the speed of the detection algorithm is critical for improving the flight speed Current battery limitations make faster flight speeds necessary for longer BVLOS missions. This system was designed to be system agnostic, so it will be possible to adapt it to drones with better battery life. However, the team is currently limited by options on the market that provide both a drone and payload SDK.

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