Robust Track Following for UAV based Inspection

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IHHA 2025
13TH INTERNATIONAL HEAVY HAUL ASSOCIATION CONFERENCE 2025

November 17-21, 2025 | The Broadmoor, Colorado Springs, CO, USA

Introduction

The safety of rail operations relies on regular and thorough maintenance of track infrastructure. Major events such as earthquakes and floods can render tracks unsafe for use until they can be inspected. Current inspection methods have limitations in terms of time, cost, and safety. Drones have potential to improve inspection work by inspecting at high speeds independently of track conditions, but there are some barriers to effective implementation. These include feasibility of GPS navigation and limited onboard processing power.

This study works on an autonomous drone platform that leverages computer vision for navigation along railroad tracks. Images are processed to identify the track environment, and the drone uses a feedback controller to fly along the center of the track. To ensure a clear and stable view of the track for inspection, multiple tests were done to assess track following efficacy at different altitudes and forward velocities. The main parameters measured are the lateral and directional deviation from the centerline of the track.

System Design

The system is built on DJI's Matrice 100 platform with the Guidance module for improved GPS-denied navigation. An Intel T265 Camera provides both images for track detection as well as vision-based localization. Communication and processing is done on an Intel NUC minicomputer using a Robot Operating System (ROS) software package and flight control commands are sent using DJI's Onboard Software Development Kit. The complete setup is shown in Figure 1. Track detection is performed using a neural network with U-Net architecture [1, 2]. The centerline of the detected track region is then transformed into a set of 3D coordinates, providing a setpoint for a model predictive controller to follow. An example of what the drone sees is shown in Figure 2 with the red line representing the line of interest.

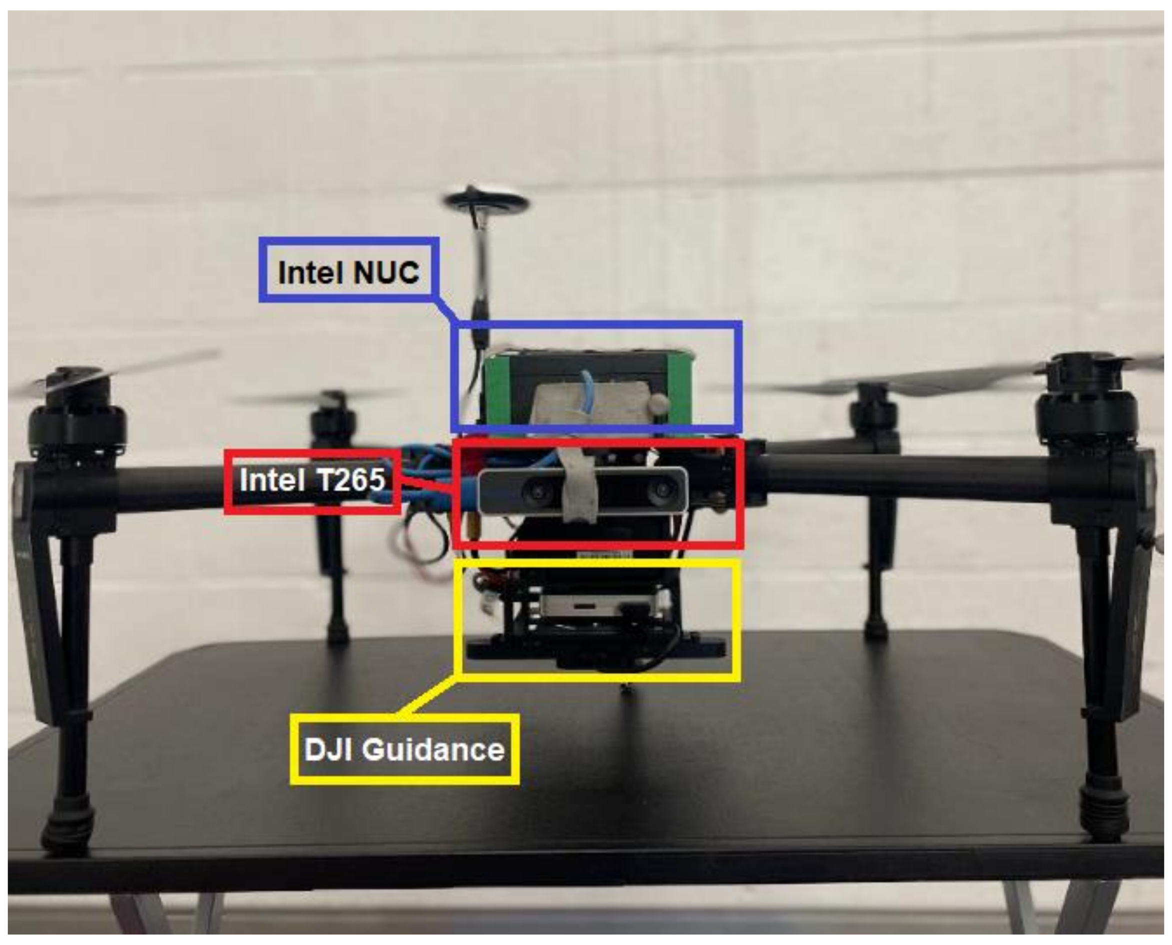

Figure 1. Hardware setup

Experimentation

Flight testing was conducted at the South Carolina Railroad Museum. This site provides a variety of track environments (single vs. multiple tracks, open fields vs. tree-lined corridors, etc.). Tests were carried out altitudes between 3-6 meters and speeds between up to 4 meters per second. These tests included a parallel track in the image to ensure the system can consistently follow a single desired line.

Figure 3 shows the drone's flight path along a straight track. After an initial offset, the drone quickly settles along the track's path. The average distance error at a 2 m/s velocity was 0.21m with an average heading error of about 1.5 degrees. With intentional selection of the line to be followed as well as wind compensation in the drone's flight controller, the system possesses some robustness to external disturbance and complex track environments.

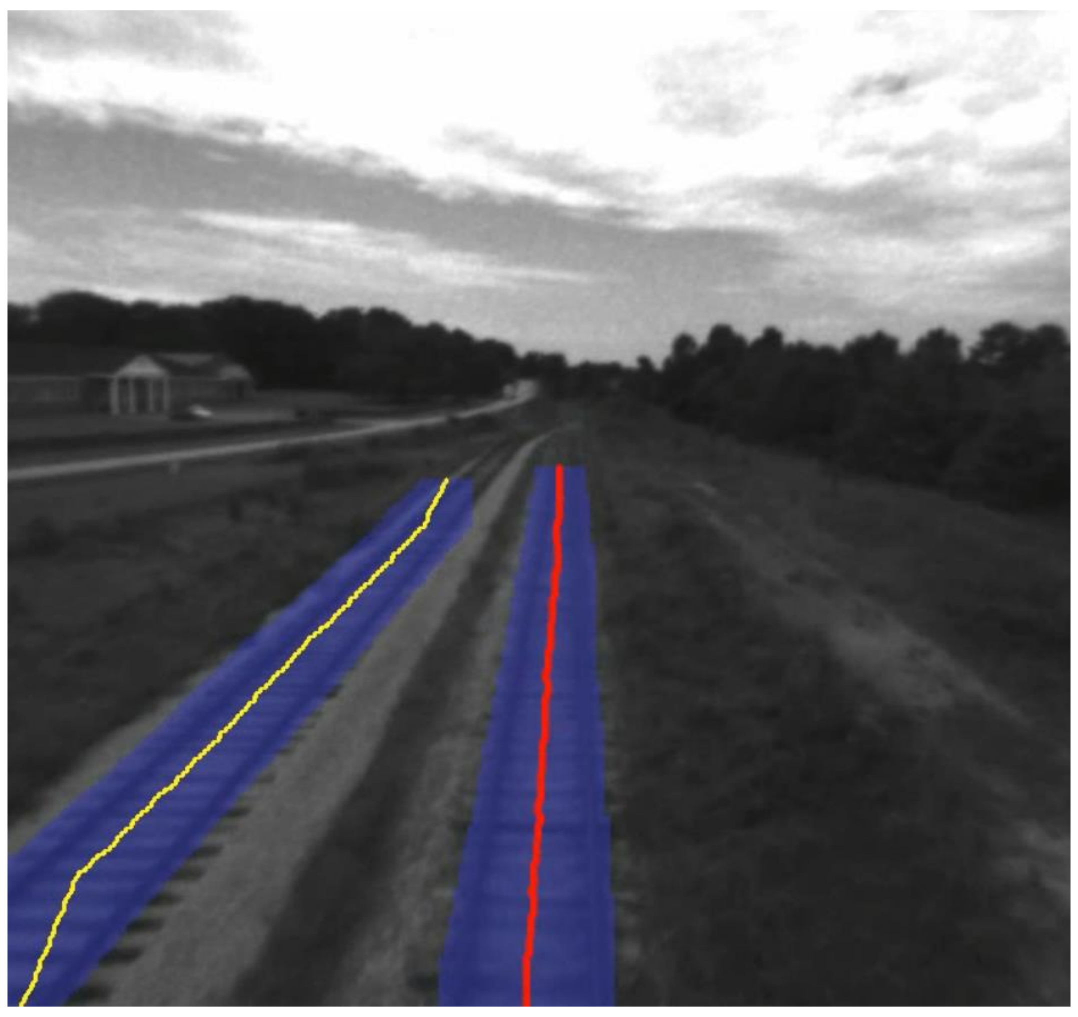

Figure 2. Processed image with two tracks in frame

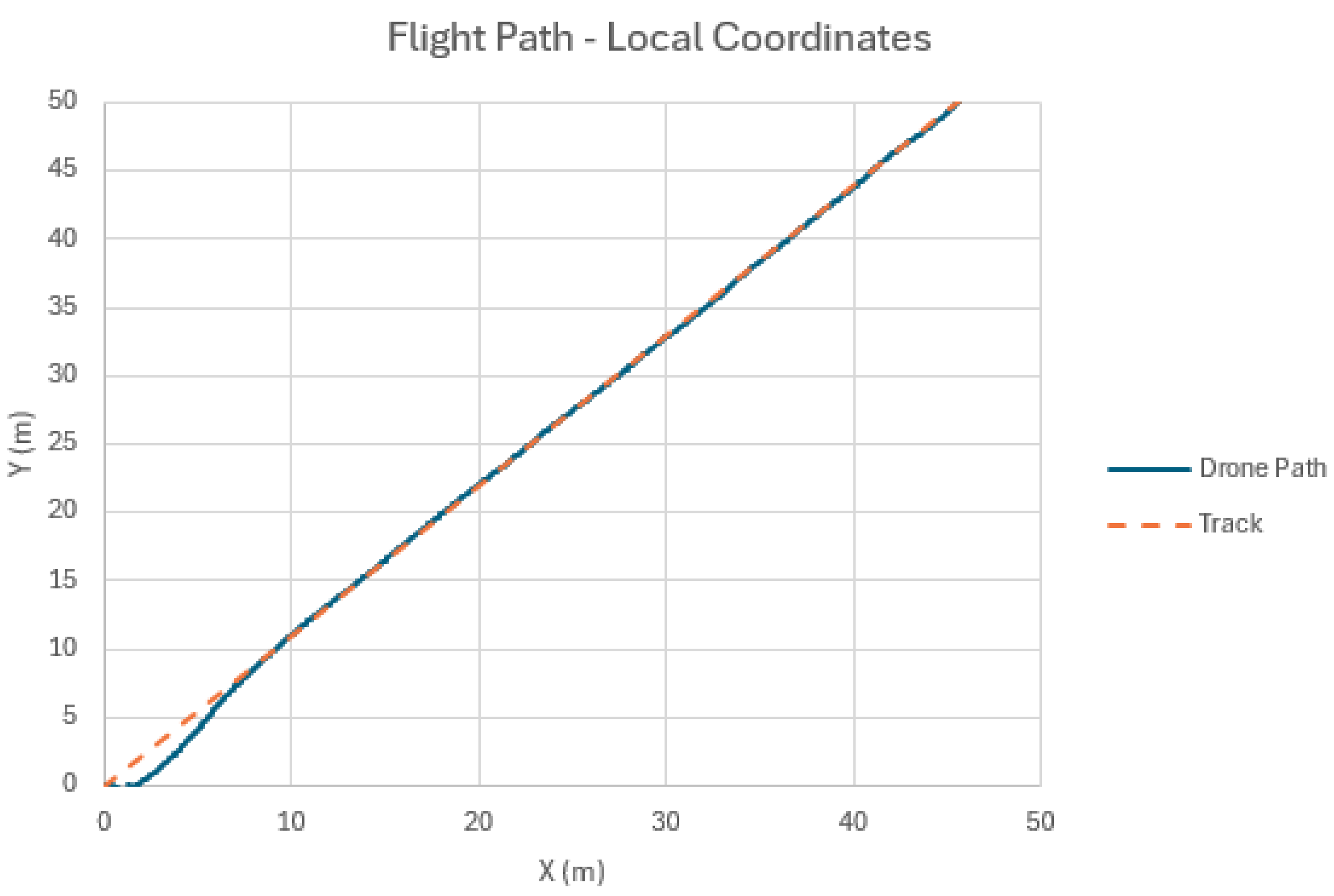

Figure 3. Drone flight path

Conclusions

To aid in the development of new forms of rail inspection, this work presents an autonomous, computer-vision guided drone system. Flight tests confirm the system's ability to follow the tracks and make some basic choices for which line to choose. Future work is being done to improve controller performance and include obstacle detection capability, expanding both safety and utility.

References

[1] K. Lewandowski and N. Vitzilaios, "UAV-Based Railroad Line Detection," in Proceedings of the 2024 ASME Joint Rail Conference, Columbia, SC, USA, May 13–15, 2024, p. V001T01A001.

[2] O. Ronneberger, P. Fischer, and T. Brox, "U-net: Convolutional networks for biomedical image segmentation," in Medical image computing and computer-assisted intervention - MICCAI 2015, Munich, Germany, October 5–9, 2015, pp. 234 - 241.

Acknowledgments

The authors want to acknowledge the University Transportation Center for Railway Safety (UTCRS) at the University of South Carolina for the financial support provided to perform this study through the USDOT UTC Program under Grant No. 69A3552348340.

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