Lone Wolf ATV: Dynamic Model and Model Predictive Control

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Background and Thesis Statement

Project Lone Wolf is a multi-disciplinary project within KONGSBERG's business area, Kongsberg Defence & Aerospace. The project is dedicated to designing and constructing an autonomous all-terrain vehicle (ATV) capable of obstacle avoidance. [1] The thesis statement for the project is:

"Development of a dynamic model of the Lone Wolf ATV and integration of a complementary control algorithm"

Dynamic Model

The dynamic model of the ATV is derived using first principles, advanced tire models and approximations for the engine and drivetrain mechanics. The model, simplified as a bicycle model, describes the ATV's dynamics within the XY-plane, capturing movements along the x-axis, y-axis, and yaw angle, Ψ.

The model features adjustable parameters for later refinement using real-world data, where employing grey box methods can enhance its fidelity to the actual system dynamics.

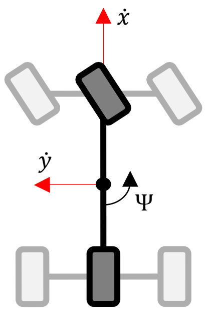

Figure 1: Dynamic Model, simplified

Model Predictive Control

A Model Predictive Controller (MPC) was developed to enable a vehicle to follow a predefined trajectory by predicting future states and optimizing throttle and steering adjustments. The MPC uses a simplified model of vehicle dynamics and an internal state estimator to account for unmeasured system variables.

The controller's objective is to minimize trajectory tracking errors and control effort, quantified by a cost function. To address the nonlinear optimization involved, the controller utilizes the IPOPT (Interior Point OPTimizer) algorithm, known for its effectiveness in nonlinear optimization.

Project Overview

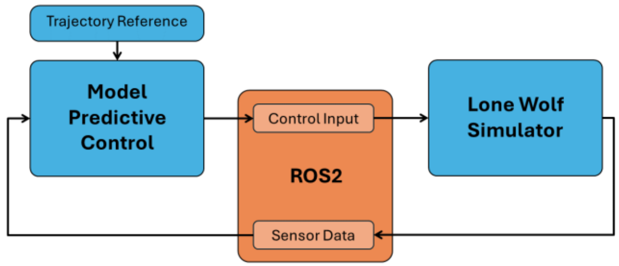

Figure 2: Project Overview

Figure 2 illustrates how the simulator and the MPC developed in the thesis communicate using the ROS2 framework. This is done to mimic the software architecture of the actual Lone Wolf and facilitate easy integration into the real system at a later occasion.

Simulator in Simulink

The dynamic model of the ATV was implemented in the ROS2-compatible software Simulink. A graphical user interface (GUI) simulates the vehicle in real-time, shown in Figure 3. It plots the vehicle's movement in the XY-plane, the reference trajectory, and the velocity, steering angle, and deviation from the reference over time.

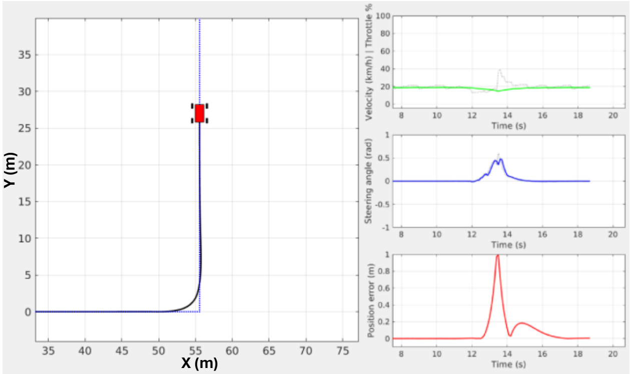

Figure 3: Screenshot from the Lone Wolf simulator in use

Results and Conclusion

The MPC has been tested in the simulator with various reference trajectories, as shown in Figure 4. The MPC proved to be effective in dynamically adjusting the throttle and steering angle to closely match the predetermined trajectories, demonstrating robust performance. This confirms the system's potential for real-world applications.

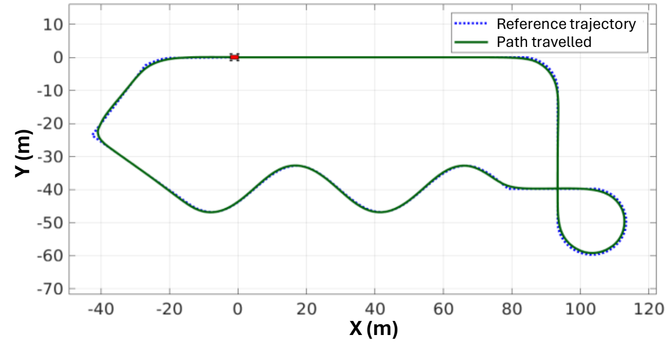

Figure 4: Racetrack reference

Further Work

The work underlaid throughout this thesis has made a foundation for further development on Project Lone Wolf. Recommended tasks for the future, building on the work done in this thesis, include:

- Data collection for model improvements and validation
- Path-/trajectory planning algorithms
- Implementation of an Extended Kalman Filter for signal processing

References

[1] *Join the pack*, KONGSBERG, 2024, www.kongsberg.com/careers/summer-interns/lone-wolf/
[2] E. Bakken, E.N. Bjørnevik, J.V. Knutsen, V. Ohren, *«Lone Wolf ATV: Dynamic Model and Model Predictive Control»*, 2024