Drift Initiation via Nonlinear Optimization for Optimal Control

John Alsterda, Qizhan Tam, Mauro Salazar

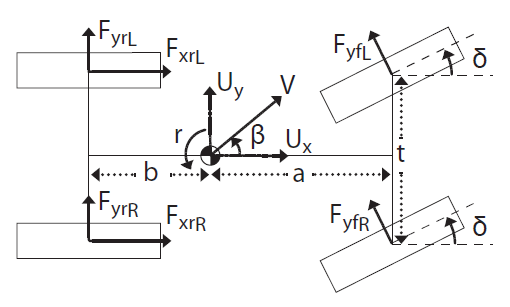
# Introduction

Prior work [1] has focused on autonomous driving in the drift regime while the vehicle is near equilibrium drift conditions. This work has not, however, addressed the problem of transitioning a vehicle into this drift equilibrium from a normal driving state. The goal of this project is to develop an optimal path planner and controller through nonlinear programming to accomplish this transition. The maneuver this project will focus on is the Scandinavian Flick—characterized by the saturation (oversteering) of the rear wheels of the car while its inertia carries the car through a corner [2]. Simulations will be performed as the verification step.

# Vehicle Dynamics Model

## Four-Wheel Model

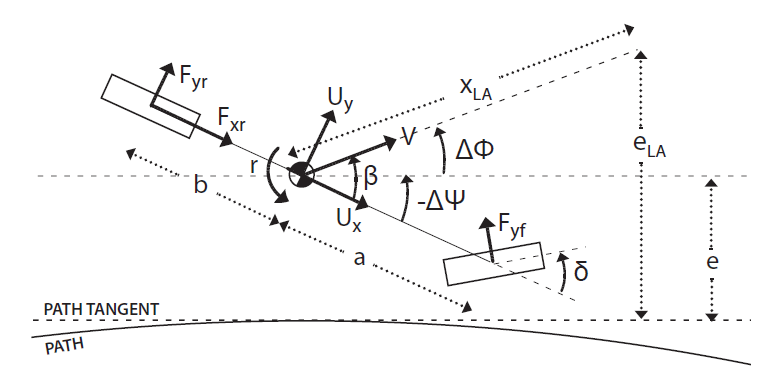
The four-wheel model (Fig. 1) is used to determine the desired final states of the vehicle, just as Goh et al. [1] did for their drift stabilization and tracking work. ­We also employ this model in IPOPT to calculate a state and input trajectory for the Scandinavian Flick via nonlinear optimization. The velocity states in Fig. 1 are sideslip , yaw rate , and vehicle speed .



1. Parameters of the four-wheel model [1].

## Single-Track ‘Bicycle’ Model

A simplified model can be used where each of the front and rear wheel pairs are coupled and assumed to have identical forces acting upon them. We may employ this model for closed loop control around the optimal trajectory, where a simplified model may prove necessary to achieve the speed required for online computation.



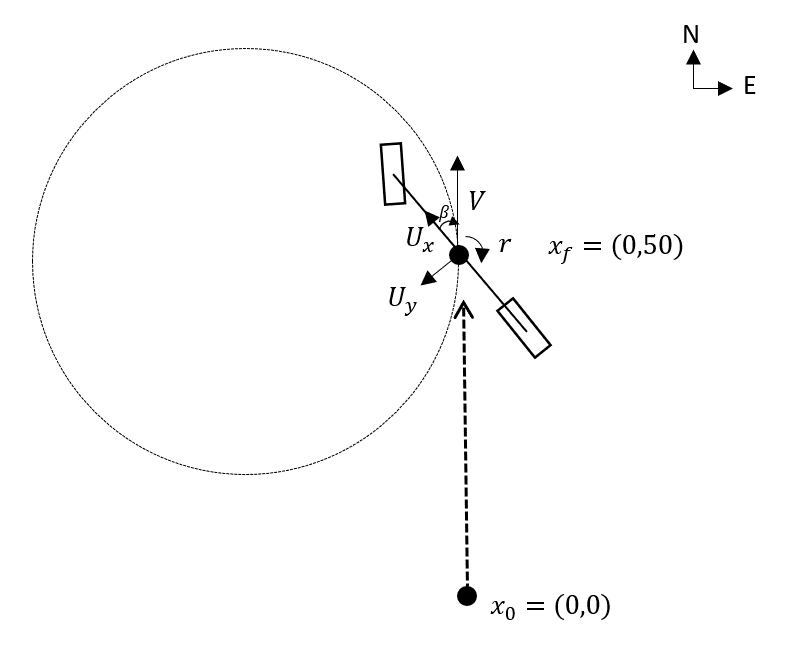
1. Parameters of the simplified single-track model [1]

# Problem Formulation

## States and Control Inputs

The states of this optimization problem are the vehicle position , heading angle relative to North, Φ, longitudinal velocity , lateral velocity , and yaw rate . The control inputs are the steering angle, δ, and the rear-wheel torque, .

The final, or goal states are determined when the vehicle is at an unstable drifting equilibrium. This occurs when the equations of motion, derived from the four-wheel model, equate to . The final states are further constrained by the final position and heading of the vehicle as depicted in Figure 3 for the initialization of drift-tracking a circular trajectory. Additional state and input constraints obtained from Dynamic Design Lab’s MARTY platform will be used for this project.



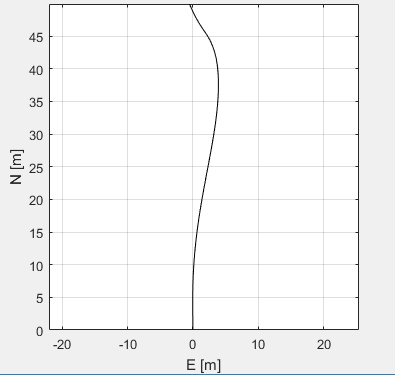
1. Sketch of the desired initial and final positions of the vehicle.

## Cost Minimization

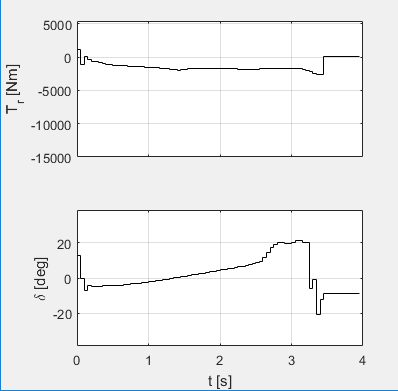
The proposed cost function is the weighted sum of the squaredL2 norms of the final state deviations with the first derivative of the control inputs penalized as a measure of driving comfort.

# Preliminary results

Initial solutions to the state and input trajectories show promise:



1. East-North *optimal* state trajectory



1. *Optimal* torque and steering input trajectories

##### References

* + - 1. J. Y. Goh and J. C. Gerdes, "Simultaneous stabilization and tracking of basic automobile drifting trajectories," 2016 IEEE Intelligent Vehicles Symposium (IV), Gothenburg, 2016, pp. 597-602.
      2. E. Velenis, P. Tsiotras and J. Lu, “Modeling Aggressive Maneuvers on Loose Surfaces: The Cases of Trail-Braking and Pendulum-Turn"Modeling aggressive maneuvers on loose surfaces: The cases of Trail-Braking and Pendulum-Turn," 2007 European Control Conference (ECC), Kos, 2007, pp. 1233-12