DEVELOPMENT OF FUZZY LOGIC BASED MODEL PREDICTIVE CONTROL FOR PATH TRACKING OF AUTONOMOUS VEHICLE

By
Nada Awad Sadek Mogoda

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electrical Power and Machines Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

Development of Fuzzy Logic Based Model Predictive Control for Path Tracking of the Autonomous Vehicle

Key Words:

Autonomous Vehicles; Model Predictive Control; Fuzzy Logic Switching; Linear Quadratic Regulator; Kalman Filter.

Summary:

The present thesis explains a path tracking control technique for autonomous ground vehicles. It develops a control technique based on the linear constrained model predictive control for the autonomous vehicle to follow a given path. The system architecture includes the; path planning model, fuzzy switching system, path tracking controller, and the nonlinear vehicle model. A detailed vehicle model is developed with three degrees of freedom and the Pacejka tires model. The fuzzy logic switching module is used for online switching between the linearized vehicle models. Further approaches are developed on the vehicle model, such as the discrete linear quadratic regulator as a tracking controller and the Kalman filter.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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Nomenclature

Symbols:

F_y	Lateral force of the vehicle
F_x	Longitudinal force of the vehicle
C_α	Lateral stiffness of the tires
C_σ	Longitudinal stiffness of the tires
α	Side slip angle
R_{eff}	Effective wheel radius,
ω	Angular velocity
V_x	Linear velocity
μ	Friction coefficient
F_z	Vertical load of the vehicle
m	Mass of the vehicle
g	Gravitational acceleration
X	Coordinate system in the reference planar frame in the x direction
Y	Coordinate system in the reference planar frame in the y direction
φ	Heading angle
β	Slip angle
v	Magnitude of the velocity vector.
l_r	Rear distances from the center of mass.
l_f	Front distances from the center of mass
δ	Steering angle
$F_{x,i}$	Force generated at the wheel contact surface with the ground in the x-axis, where i indicates front or rear wheel
$F_{y,i}$	Force generated at the wheel contact surface with the ground in the y-axis direction, where i indicates front or rear wheel
V_g	Vehicle speed at the car center of gravity
α_f	Vehicle front slip angle
I_z	Moment of inertia around the z-axis
$V_{wx,f}$	Linear velocities of the wheels front and rear, in the x-axis direction
$V_{wy,f}$	Linear velocities of the wheels front and rear, in the y-axis direction
$\dot{x}$	Velocity component in the vehicle frame in the x-axis direction
$\dot{y}$	Velocity component in the vehicle frame in the y-axis direction
$F_{x,r}$	Forces in the x directions for the rear wheels
F_{yf}	Forces in the y directions for the front wheels
v_x	Longitudinal velocity,
v_y	Lateral velocity,
r	Yaw rate
a_x	Longitudinal accelerations of the vehicle
a_y	Lateral accelerations of the vehicle
J_z	Vehicle yaw inertia
b_f and b_r	Front and rear track width.

V_{w1}	Speed of the vehicle wheel number 1
c_W	Aerodynamic drag coefficient
ρ	Air density
A	Frontal area of the vehicle
λ_i	Slipe ratio of the ith wheel
F_{zi}	Normal force of the ith wheel
h	Height of the center of gravity of the vehicle from the ground
ω_i	Angular velocity of the ith wheel
x	State space vector
u	State space input vector
y	State space output vector
A_i, B_i, and C_i	Discrete state space model matrices
Q_i and R_i	MPC tracking controller design parameters
K_{dlqr}	Gain matrix of the DLQR
N_p	Prediction horizon of the MPC
N_c	Control horizon of the MPC
X_{ref_i}	Reference states at sample time i
u_{ref_i}	System inputs reference signals
N	Number of the Laguerre terms
a	Pole of the discrete-time Laguerre network
η	Laguerre parameter vector
u_{min} and u_{max}	Minimum and the maximum input values
Δu_{min} and Δu_{max}	Minimum and the maximum values of the rate of change of the inputs
x_{min} and x_{max}	State's minimum and the maximum values
R_L	Optimization problem input increments
L(i)	Laguerre functions at time sample i
N_{in}	Inputs number in the state space representation
N_S	States number
ω_{min}	Minimum value of the angular velocity
ω_{max}	Maximum value of the angular velocity
δ_{min}	Stearing angle minimum value
δ_{max}	Stearing angle maximum value
$\Delta\delta$	Rate of change of the steering angle
$\Delta\delta_{max}$	Maximum value of the rate of change of the steering angle
$\Delta\delta_{min}$	Minimum value of the rate of change of the steering angle