Project Report: Simulation of Backup Camera with Dynamic Trajectory of Rear Wheels

1. Introduction
The objective of this project is to simulate a backup camera's view with a dynamic trajectory of rear wheels using a 10-second clip from a phone recording. The simulation involves making assumptions about steering geometry, vehicle dimensions, and overlaying the trajectory on the video. The simulation is performed using Python, using OpenCV and NumPy libraries.

2. Vehicle Parameters
The simulation assumes a vehicle (Toyota Corolla [1][2]) with the following parameters:

Height: 1.4351 m
Width: 1.78054 m
Wheelbase: 2.7 m
Wheel Radius: 0.315 m
Front and Rear Track Widths: 1.4351 m and 1.53162 m, respectively
Steering Ratio: 18

The simulation also assumes the the rear axle and the rear wheel are in-line

3. Camera Calibration
The camera matrix and rotation matrix were calibrated to transform the simulated trajectory into the camera frame. The transformation matrix and projection matrix were derived to facilitate the overlay of the rear wheel trajectory on the video.

The projection matrix is derived from the concept of perspective–point problem which projects the pose of an object in 3D space into a 2D image plane. The projection matrix consists of the camera intrinsic matrix and the transformation matrix (where R is the rotational component and T is the translational component)[3].

4. Ackermann Steering and Trajectory Calculation
The steering angles of the left and right wheels are calculated based on Ackermann steering dynamics. The trajectory of the rear axle is then determined using state space equations, considering the vehicle's speed and the pinion angle [4][5].

The pinion angle is used to determine the steering wheel angle by dividing the pinion angle by the steering ratio. This is then used to dynamically change the input angle given to the steering wheel in the video by utilizing a slider.

The trajectory of the wheels is determined by offsetting the rear axle trajectory by half the rear track width. The resulting wheel trajectories are transformed into the camera frame and then to pixel coordinates for overlay.

5. Pixel Coordinates and Visualization

The pixel coordinates of the left and right rear wheels are computed and rounded to integers for visualization. The trajectory is drawn on the video frame in both static (pinion angle = 0) and dynamic (pinion angle adjustable through a trackbar) scenarios. Horizontal lines are drawn to enhance the visual representation of the vehicle's path.

6. Video Processing

The code processes a video file, 'Video.mp4', frame by frame, overlaying the rear wheel trajectory, and saving the output as 'output.avi'. The simulation can be adjusted dynamically using the trackbar to change the pinion angle, providing a flexible and interactive approach to visualize different steering scenarios.

7. Conclusion

This project successfully demonstrates the simulation of a backup camera's view with a dynamic trajectory of rear wheels. The ability to adjust the simulation dynamically adds an interactive element, enhancing the understanding of the impact of steering on the vehicle's trajectory.

References

[1] Toyota Corolla Dimensions & Drawings | Dimensions.com
[2] 2024 Toyota Corolla Features and Specs | Toyota.com
[3] OpenCV: Perspective-n-Point (PnP) pose computation
[4] Dynamic Backup Lines (ti.com)
[5] Ackerman Steering • Computer Science and Machine Learning (xarg.org)