Pedestrian Emergency Braking in Ten Weeks

Steven Nguyen
University of California, Santa Barbara
Dept. of Mechanical Engineering

Zillur Rahman and Brendan Tran Morris
University of Nevada, Las Vegas
Dept. of Electrical and Computer Engineering

1950872

Outline

- **Motivation and Background**
- Methods
  - Longitudinal/Lateral Control
  - Pedestrian Detection
- Experimental Evaluation
  - Simulation Environment
  - Vehicle Platform Setup
  - Pedestrian Detection
  - In-vehicle Test
- Concluding Remarks

Overview

- 10 week research program as part of UNLV’s NSF REU: Smart Cities site

- Develop a control algorithm for pedestrian emergency braking system in autonomous vehicles
  - Implement the controller in a real vehicle and test its safety
  - Demonstrate ability for safe braking
- Establish UNLV’s first autonomous vehicle platform

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Background

- Existing control approaches include PID, MPC, fuzzy logic, neural networks, etc.
  - PID used in this work for rapid implementation and computational speed
  - Sufficient for basic maneuvers
- Past works in implementation for autonomous vehicles commonly use ROS
  - Alternatively, some researchers have used User Datagram Protocol (UDP)
  - ROS more widely used and was selected for ease of implementation
- Goal was to use widely available resources for this project
  - ROS, Linux, Logitech webcam

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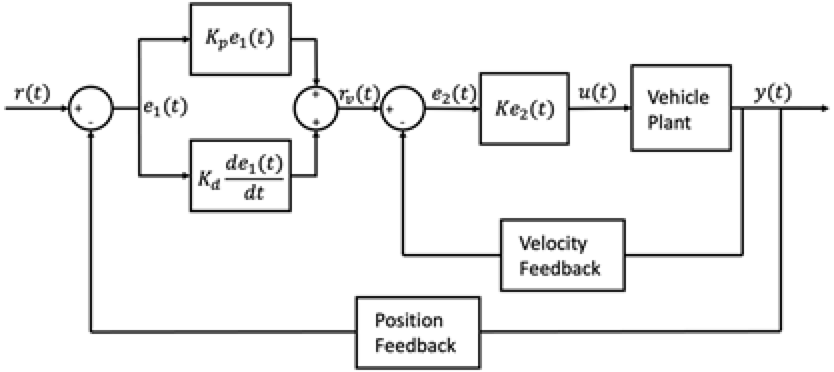
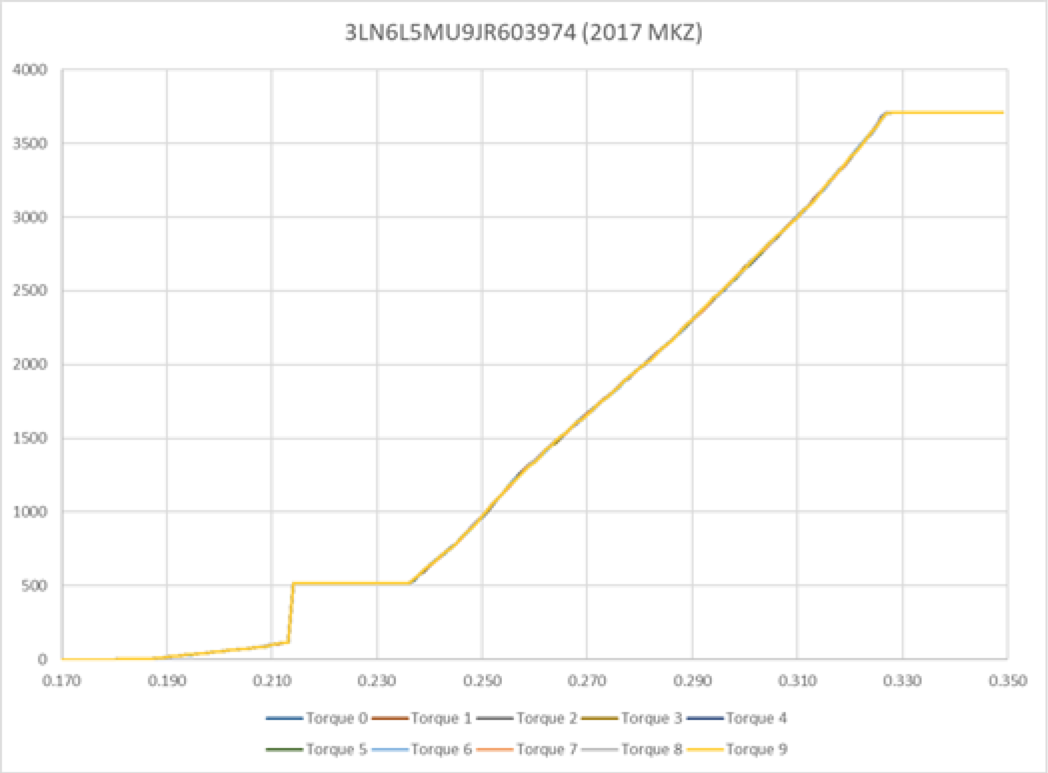
Longitudinal Control Design

- Applied PID approach
- Important considerations were safety and comfort
- Velocity and position feedback used to prevent overshoot, increase safety
- Reference position provided is distance from pedestrian minus headway
- Vehicle plant used brake data from Dataspeed



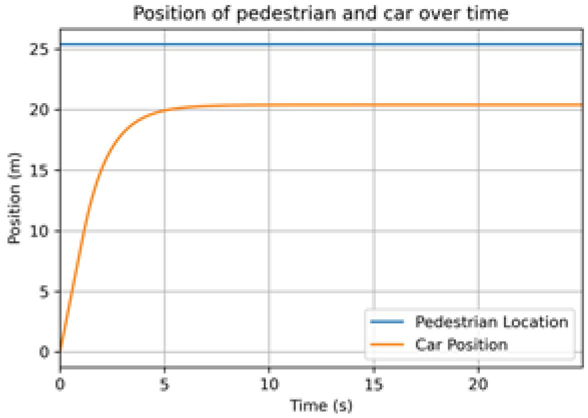
Longitudinal Control Design - cont.

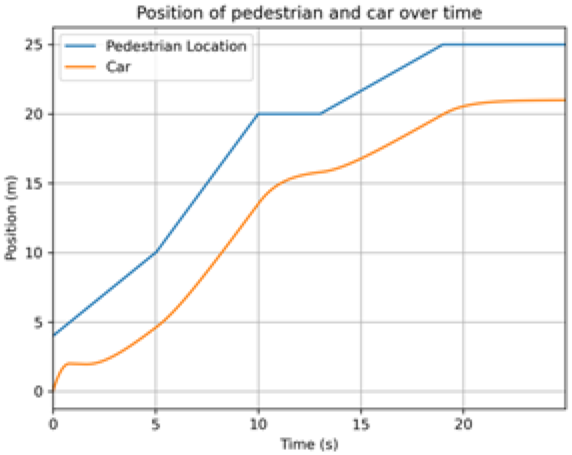
- Vehicle datasheet only showed data up to brake values ~0.35
    - Due to this and for comfort, brake values limited to 0.4 in controller



Longitudinal Control Design - cont.

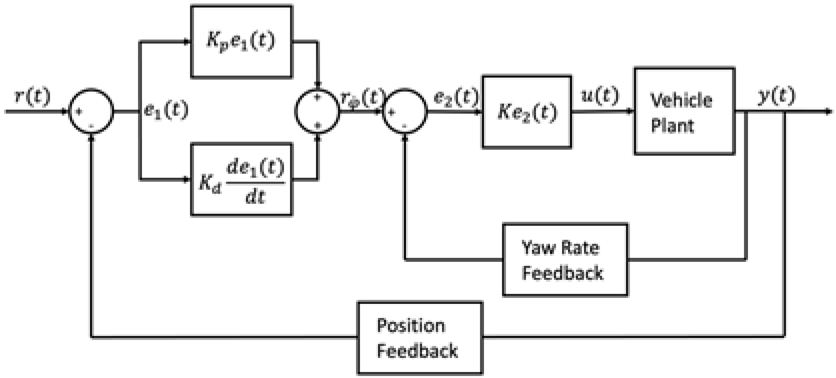
- Simulations verified controller safety
- Tested step inputs and arbitrary pedestrian reference
- Implemented in vehicle after verification





Lateral Control Design

- Similar approach to longitudinal controller
- Purpose is to steer for lane tracking or vehicle following
- Reference position is the center of lane to follow or a lead vehicle
- Instead of velocity feedback, used yaw rate feedback



Pedestrian Detection Algorithm: 2D Detection

- YOLOv5 was used to detect 2D objects from video frames.
- Trained on MS COCO dataset and customized to infer only on relevant classes
- Provides 2D bounding box coordinates for each object. No depth information.

Pedestrian Detection Algorithm: 3D Detection

- VGG-16 network trained on KITTI dataset estimates the 3D object properties
- Geometric constraints provided by YOLOv5 were combined with those estimations to get depth information
- Ped. distance used in controller feedback
- Implemented using webcam on vehicle

Sample detection from camera

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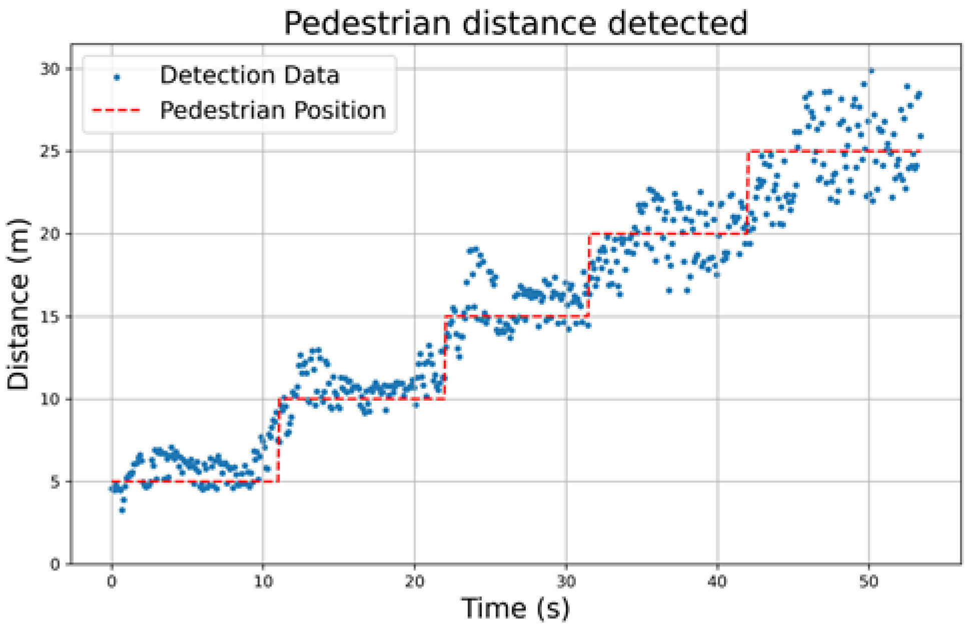
Vehicle Platform

- 2017 Lincoln MKZ Hybrid with Dataspeed drive-by-wire system
- Logitech C920 camera
  - Offset position for safety
- Computer specifications
  - Intel Xeon E5-2603
  - Nvidia RTX 2070 GPU
  - Ubuntu 20.04
- ROS1 to read and write CAN messages
  - Sensor data from CAN
  - Communication between hardware and code

Vehicle Platform - cont.

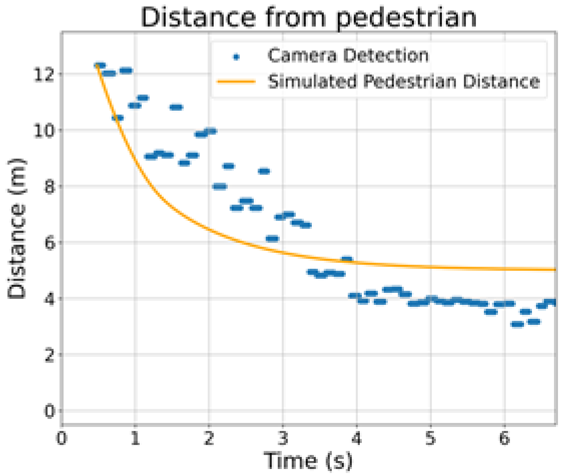
Pedestrian Detection Accuracy

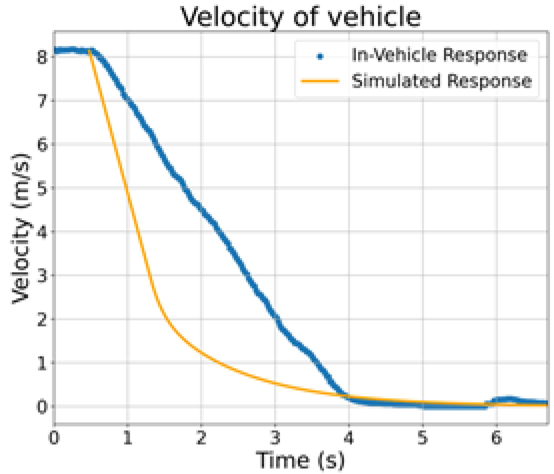
- Stationary pedestrian moving 5 meters every ~10 seconds
- Vision-based detection is noisy
- Detection is less precise at farther distances



Brake Testing with Pedestrian

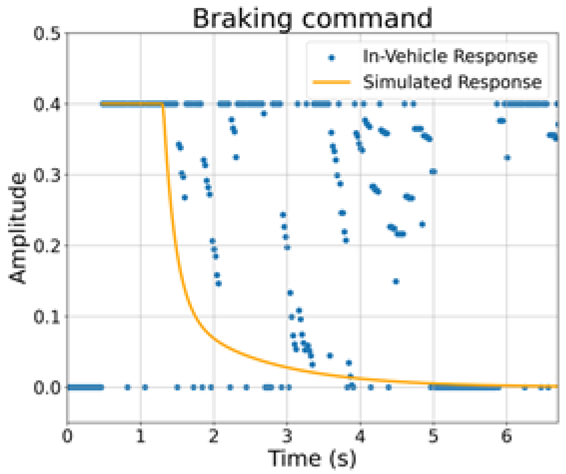
- Longitudinal controller safely brakes at variable distance from pedestrian
- Vehicle response not as fast as simulation
- Discrepancy in test and sim motivates investigation of brake response model





Brake Testing with Pedestrian

- Controller saturates in live testing
- Noise in pedestrian signal likely causes jumps in control signal
- Control response is sometimes abrupt for passengers
- Tuning control gains can create more gradual braking



In-Vehicle Testing

In-Vehicle Testing - cont.

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Discussion of Results

- The designed controller was successful and safe in braking tests
- Began from scratch and achieved autonomous testing within ten weeks
  - Demonstrated rapid implementation and basic testing of autonomous vehicle functionality
- Vehicle platform enables further research at UNLV for autonomous vehicles

Future Work

- Use sensors that can generate smooth pedestrian signal (lidar) through sensor fusion
- Implement filters to track pedestrian position more smoothly
- Further investigate reliability of controller at varying speeds and smoothness of braking with smoother pedestrian signal
- Incorporate lateral control for testing

Thank you.

Questions?