Advanced GNSS Positioning for Cooperative Adaptive Cruise Control (CACC) Truck Platooning

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Outline

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  – DSRC radio communication
  – CACC algorithms and software
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• Conclusions and Future Work
Background and Motivation
Background/Motivation

• Although combination trucks account for ~1% of all motor vehicles on US roads, these vehicles drive approximately 50,000 more miles than the next vehicle type [1]

• Decline of truck drivers, e.g. in the Canadian forestry industry [2]
• ATRI showed highest operational cost for truck fleets of all sectors was fuel usage, coming in at 38% of the total marginal operating cost [3]

• 36% of all freeway accidents occurred on entrance ramps [4]
CACC System
CACC Overview

- Cooperative Adaptive Cruise Control
- Extension of Adaptive Cruise Control (ACC)
- V2V network to share information
- Auburn’s CACC system
  - Level 1 Autonomy
  - Longitudinal (throttle and braking) control
  - Manual steering

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Hardware Setup

- System components
  - PC for vehicle interface and algorithms
  - DSRC radio
  - GPS receiver
  - Automotive radar
  - By-wire kill switch for disconnect from CAN bus
  - GUI Display
DSRC Radio Communication

• Dedicated Short Range Communication (DSRC)
• Current industry standard
• Developed two implementations
  – Denso
  – Cohda Wireless MK5
• Custom UDP data packet
  – Vehicle state information
  – Raw GPS observables
Range Estimation

• Dynamic-base Real Time Kinematic (DRTK) [6]
  – Differential GPS technique; extension of RTK
  – Uses GPS carrier phase measurements to calculate Relative Position Vector (RPV)
  – High quality (sub-centimeter level accuracy) but low frequency
CACC Algorithms

- **Kalman Filter**
  - Fuses complementary measurements of radar and DRTK
  - Produces reliable estimates of inter-vehicle range, range rate, and bearing
  - Track neighboring vehicles using radar and predict forward path for cut-in detection [7]
CACC Algorithms

Control System

• Longitudinal headway, or gap, controller
• PID with feedforward control
• Feedforward $F_{RR}, F_{air\ drag}, F_{grade}$
CACC Software

- Real time implemented in ROS architecture [8]
  - Sensor/hardware Drivers
    - J1939 CAN
    - Delphi ESR Radar
    - Novatel GPS
    - DSRC V2V communications
  - Controller and Estimation
    - Range Estimation filter
    - DRTK RPV filter
    - CACC control Node
    - Convoy Manager
Testing and Demonstrations
Phase II

Phase IIC

• Blue Water Bridge Crossing
• October 5, 2017 in Port Huron, Michigan
• Convoy across bridge from USA to Canada and back for VIP event
Phase II Cont.

Phase IIB

• Truck Platooning on highway I-69 in Michigan
• October 16-19, 2017
• Convoy tests for controller validation
  – Spacing: 50, 75, 100, and 200 ft.
  – Speed: 55 mph
Phase II Cont.

• Demonstration totals during testing:
  – Operation time: ~3.5 hours
  – Distance: >170 miles
Phase III

- October 22-27, 2018
- Four vehicle platoon
- Longitudinal control, vehicle cut-ins, and connected vehicle merging
Phase III Cont.

- Cut-in detection
  - Track neighboring vehicles
  - Project forward path and determine if vehicle is inside
  - Fall back to safe distance
  - Range off cut-in; maintain DRTK to leader
Phase III Cont.

- **Connected vehicle merging**
  - GPS position/velocity, merge point/speed limit known
  - Estimate time to merge point
  - First In First Out (FIFO) logic

![Images of connected vehicle merging](image-url)
Phase III Cont.
Conclusions and Future Work
Conclusions/Future Work

- Successfully developed and implemented a CACC system
- Demonstrated capabilities that have potential safety, fuel benefits
- Future work:
  - Level 2 Autonomy (lateral control)
  - Fuel testing
  - Optimal platoon configuration and terrain
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Questions?

Thank You!
References


