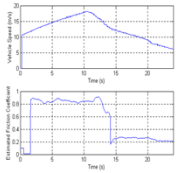
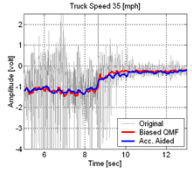
Novel Sensors, New Estimation Algorithms and Advanced Controls:
Solutions for Improving Highway Vehicle Safety and Mobility

Real Time Estimation of Tire-Road Friction Coefficient

- Goal: Develop an on-board friction measurement system for a snow plow
  - Continuously estimate friction between the tires and the road while the snowplow travels
  - Track and provide estimated friction values to the vehicle operator
  - Automated application of sand, salt and deicing material to the roadway

- Vehicle based friction estimation system
  - Uses on-board vehicle motion sensors such as GPS, accelerometers, gyroscope and wheel speed
  - Tests conducted at skid pad with transition from dry asphalt to icy road





- Wheel based friction estimation system
  - Uses a small redundant wheel on the snowplow
  - Novel system with no actuation and minimal moving parts
  - Closed-loop control of applicator for winter road maintenance

Battery-Less Wireless Traffic Sensors

- Novel sensors based on energy harvesting from piezoelectric element embedded in the roadway

Design
- 1 inch wide beam installed in the lane – does not require battery, power supply or any wiring
- Data from multiple sensors can be received by a single wireless transceiver located up to 500 feet from sensors

- Advantages over inductive loop detectors
  - Low cost (eventual cost expected to be less than $100)
  - Easy installation, no wiring
  - No electrical power supply or batteries required
    - Suitable for rural roads

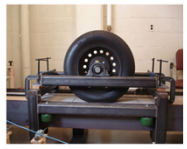
Narrow Tilt-Controlled Commuter Vehicles

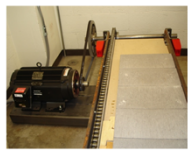
Goal: To develop a traffic and environment friendly commuter vehicle that
- Requires only a half-width lane on the highway
  - 6 feet instead of 12 feet wide
- Provides high fuel economy (100 miles per gallon)
- Is as safe and as easy to drive as a regular passenger sedan
- Incorporates automatic tilt control to help the driver balance the vehicle and provide enhanced stability
  - Control system keeps the vehicle balanced while driving straight
  - Control system tilts the vehicle into curves while cornering

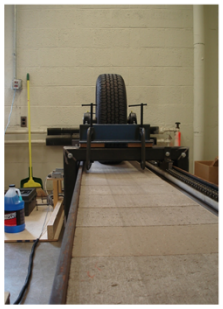
Wireless Tire Sensors for Measurement of Slip Angle, Slip Ratio and Friction Coefficient

- Development of sensors to measure tangential, radial and lateral tire deformations in the contact patch
- Development of algorithms to estimate slip angle, slip ratio and tire-road friction coefficient from tire deformation measurements

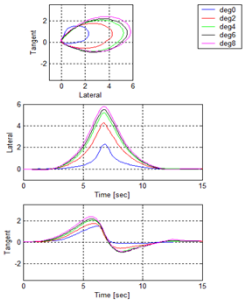
Tire test rig







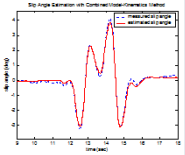
Tire deformations



Observer Design and Fault Diagnostics

- Observer Design for Nonlinear Systems
  - State and unknown input estimation for Lipschitz and bounded Jacobian nonlinear systems
  - Systematic time-varying observer design method for parameter varying systems

- Slip angle estimation for electronic stability control



- Fault Diagnostics
  - NSF CAREER Award
  - Fault detection and identification for nonlinear dynamic systems
  - Fault diagnostics for radar and inter-vehicle measurements

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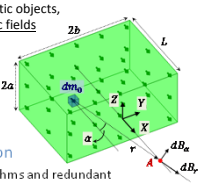
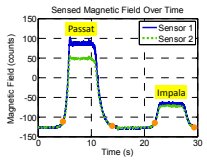
Nature-Inspired Magnetic Sensors for Accurate Position Measurement

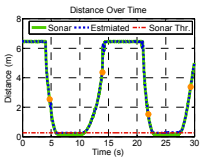
- Sensing Principles
  - Many creatures, including butterflies, newts and dolphins use Earth's magnetic field lines for navigation
  - Likewise, this work seeks to extend the same ideas to measure distances to ferromagnetic objects, exploiting their inherent magnetic fields
  - Example of a magnetic field model for a ferromagnetic object

$$B_x \cong \frac{p}{x_A} + q$$



- Imminent Collision Prediction
  - Use of adaptive estimation algorithms and redundant magnetic sensors to eliminate need for calibration
  - Sample data with two different vehicles





- Non-Intrusive Measurement of Piston Position
  - Applications to hydraulic, pneumatic and IC engine cylinders
  - Adaptive algorithms, auto calibration and automatic disturbance rejection