Research Interests

The GPS Vehicle Dynamics Laboratory focuses on the robust control of autonomous vehicles using GPS and Inertial Navigation System (INS) sensors. Our research has three main thrusts: sensor fusion/integration, on-line system identification, and adaptive control techniques and their application to vehicle dynamics and transportation. These methods can be used for such things as determining vehicle and driver models. Improved driver models could be used by a number of vehicle monitoring systems, i.e. safety systems that determine the effectiveness of a driver and increase road safety by removing fatigued or intoxicated drivers from the road. Vehicle modeling and state estimation is important in a number of current vehicle safety systems, such as ABS, traction control, and stability control. Additionally, future vehicle safety systems, such as driver assisted systems, adaptive cruise control, and even full autonomous lane-keeping, require precise vehicle models.

The first part of our research is to investigate methods for better calibration of the INS errors while GPS measurements are available. This will improve performance of the INS unit during periods when the GPS signal is obstructed (as well as between GPS measurements). Improved performance will be sought by including dynamic models of the vehicle system and incorporating these dynamic constraints with low-level INS/GPS measurements. Carrier-phase GPS signals, in conjunction with the system model, will be used to accurately calibrate the INS model and its errors. This precise calibration will provide a dead reckoning system, initialized using GPS, capable of providing accurate estimates of the vehicle states (position and attitude) for the continuous control of the vehicle during GPS outages. The integration of INS and GPS can be used to provide an unbiased, high-update estimate of vehicle states such as position, velocity, and attitude. This blended solution thereby provides accurate data for modeling autonomous vehicles. The ability to accurately determine the vehicle states as well as the vehicle model on-line, during changing environments, will in turn lead to an increase in the control performance of a vehicle.

Finally, our research focuses on adaptive control and estimation algorithms for autonomous vehicles. On-line system identification techniques capture the changing parameters of the systems, which can be used to adapt the control and estimation algorithms. Once techniques for using the GPS/INS solution to perform on-line identification have been developed, methods that adapt, or self-tune, optimal controllers and estimators (such as LQR and Kalman filters) can be investigated. The adaptation of the control and estimation algorithms to the continually identified model parameters will lead to accurate and robust performance of these autonomous systems.

Auburn University GPS Vehicle Dynamics Laboratory

The GPS Vehicle Dynamics Laboratory focuses on the control and navigation of vehicles using GPS in conjunction with other sensors, such as Inertial Navigation System (INS) sensors. The laboratory has several research thrusts including: sensor fusion/integration, on-line system identification, adaptive and robust control algorithms, and vehicle state and parameter estimation. These research thrusts are focused towards vehicle dynamics and transportation, including heavy trucks, passenger cars, off-road vehicles, as well as autonomous and unmanned vehicles. The laboratory consists of various GPS receivers (including a software GPS receiver), Inertial Measurement Units (IMUs), an instrumented Chevrolet Blazer, an automatically steered John Deere tractor, and access to an iRobot ATRV. Current projects include ultra-tight GPS/INS coupling (sponsored by the Army), study of vehicle rollover propensity, improved steering control of GPS guided farm tractors (sponsored by John Deere), vehicle and driver monitoring, and navigation and control of unmanned ground vehicles (UGVs).

As part of a current project with U.S. Army Aviation and Missile Command, a GPS receiver capable of performing ultra-tight GPS/INS integration has been acquired. Ultra-tight GPS/INS coupling provides improved anti-jamming resistance, improved satellite tracking, as well as allows for immediate GPS signal reacquisition after short GPS outages. This GPS unit could be valuable in investigating GPS navigation in cluttered environments, where GPS satellite signals become unavailable and available for intermittent periods. The GPS Vehicle Dynamics Laboratory also has access to the National Center for Asphalt Testing (NCAT) test track (http://www.pavetrack.com/). Validation of navigation and parameter and state estimation algorithms can be performed using the vehicles on the NCAT track. GPS and inertial sensors can be mounted on the semi-trucks or our own test vehicles to validate proposed estimation and control algorithms. Additionally, errors such as jamming, multi-path, and other sensor errors can be simulated to test the algorithms ability to reject these disturbances and continue to provide an accurate navigation solution.

GPS Vehicle Dynamics Laboratory
List of Research Interests

- Robust Control algorithms for computationally restricted platforms
  - Simple adaptive algorithms
  - Computationally efficient controllers

- Sensor noise canceling for system identification

- Low level GPS/INS integration for improved navigation
  - Improved dead reckoning through better initial alignment
  - Improved INS error characterization (including INS scale factor estimation)

- Model-free (human-like) driver Control algorithms for autonomous vehicles
  - Controllers that can be moved from one vehicle to another

- Multiple/Redundant sensor fusion for on-line system identification

- Low-level GPS/INS integration using vehicle dynamic constraints for improved vehicle state and parameter estimation

- Two-step on-line parameter identification of non-linear systems in the presence of noise

- Design and control of MEMS actuators

- Control of low-flying UAVs for mine recovery (and forest pesticide delivery)

- Sensor and system fault detection and reconfigurable control and estimation algorithms

- Low-cost MEMS sensor integration with GPS for UGVs and UAVs

Auburn GaVLab Facilities and Equipment

- ## NCAT Test Track

The GPS Vehicle Dynamics Laboratory has access to the National Center for Asphalt Testing (NCAT) test track (http://www.pavetrack.com/). The 1.7-mile oval track has four trucks driving on the track 16 hours a day (each driver performing an 8 hour driving shifts) and is broken into 200-foot sections of different pavement types. Detailed information on each section of the track is monitored including rut depth and coefficient of friction. Eight-hour driver shifts, changing rut depths, and detailed tire logging make the facility an ideal location for testing the algorithms developed in the area of intelligent transportation systems. GPS and inertial sensors can be mounted on the semi-trucks or our own test vehicles to validate proposed navigation and parameter and state estimation algorithms. Additionally, errors such as jamming, multi-path, and other sensor errors can be simulated to test the algorithms ability to reject these disturbances and continue to provide an accurate navigation solution.

- ## Automatically Steered John Deere Tractor

John Deere has loaned an 8420 auto-steer tractor (valued at $160,000) as a research platform for a funded research project with the company. The test tractor is located 20 miles from Auburn University and provides the ability to test various autonomous steering control strategies. Research will be conducted to quantify the variations in the dynamic steering model due to variations in vehicle configurations as well as variations in ground conditions.

- ## Instrumented SUV

Auburn has a fully instrumented Chevrolet Blazer that is used to run experiments at the NCAT test track. Like the tractor, this vehicle is used as a test-bed to validate newly developed algorithms in navigation and state and parameter estimation at highway speeds. Accurate dynamic models of the SUV are available in order compare simulated and measured vehicle responses.

- ## GPS Software Receiver

As part of a current project with U.S. Army Aviation and Missile Command, a GPS receiver capable of performing ultra-tight GPS/INS integration has been acquired. Ultra-tight GPS/INS coupling provides improved anti-jamming resistance, improved satellite tracking, as well as allows for immediate GPS signal reacquisition after short GPS outages. This GPS unit could be valuable in investigating GPS navigation in cluttered environments, where GPS satellite signals become unavailable and available for intermittent periods.

- ## Autonomous ATV

Sciautonics has loaned Auburn University their DARPA Grand Challenge Vehicle for the summer. Auburn was responsible for developing the speed and steering control for the vehicle as well as the GPS/INS navigation system for the vehicle in the 2004 Grand Challenge Race. The vehicle is equipped with a camera, Lidar, Starfire GPS receiver, IMU, wheel speed sensors and is fully autonomous (full x-by-wire capabilities). Auburn will use the vehicle to develop models (both on-road and off-road) and robust control algorithms for the next Grand Challenge Race.