Next Generation Vehicle Positioning in GPS-Degraded Environments for Vehicle Safety and Automation Systems

Auburn University

Penn State University

Sarnoff Corporation

Kapsch

Navteq (hopefully)

Team Overview

- Auburn (David Bevly)
  - Lead Systems Integrators
  - Overall Team Management
  - Sensor Integration
- Penn State University (Sean Brennan)
  - Road signature based positioning
- Sarnoff Corporation (Supun Samarasekera & Chetna Bindra)
  - Visual Odometry
- Kapsh (Steve Sprouffske & Dmitri Khijniak)
  - DSRC Ranging
- Navteq (Bob Denaro)
  - Map databases

Automotive Review Panel

- External review panel has been assembled to monitor progress and provide direction and feedback
- Current list of participants:
  - Ford Motor Company (Tom Piluti)
  - Mercedez-Benz (Michael Maile)
  - Honda (Jim Keller)
  - Volkswagen (Dirk Langer)
  - Volvo (Paul Schmitt)
  - Nissan (Hiroshi Tsuda)
  - Bosch (Kyle Williams)
  - Eaton Corporation
  - GM
  - Richard Bishop

Project Management

- Monthly teleconferences
  - Provide the team an opportunity to report status and resolve integration
- Quarterly Reviews
  - More in depth reviews (to coincide with quarterly reports due to FHWA)
  - At least one will be on-site, coinciding with Automotive Panel Reviews
- Quarterly Reports

Literature Review (Vision)

- Previous work done in lab
  - J. Clanton, "GPS and Inertial Sensor Enhancement for Vision-Based Highway Lane Tracking," M.S. thesis, Auburn University, Auburn, Alabama, US, 2006
- Current navigation filter technology
  - P. Groves. *Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems*. Boston, Massachusetts: Artech House, 2008.
- Current research on vision based navigation
  - A. Soloviev, D. Eaton, M. Uijt de Haag, Z. Zhu, "Integration of Ladar, Vision and Inertial Data for GPS-denied Navigation," presented at the 2009 ION GNSS, Savannah, Georgia, 2009.
  - D. Venable, J. Campbell, D. Hooper, J.T. Kresge, M.J. Veth, G.L. Peterson, "Performance Evaluation of Tight Coupling Between Vehicle Guidance and Vision Aided Navigation," presented at the 2009 ION GNSS, Savannah, Georgia, 2009.

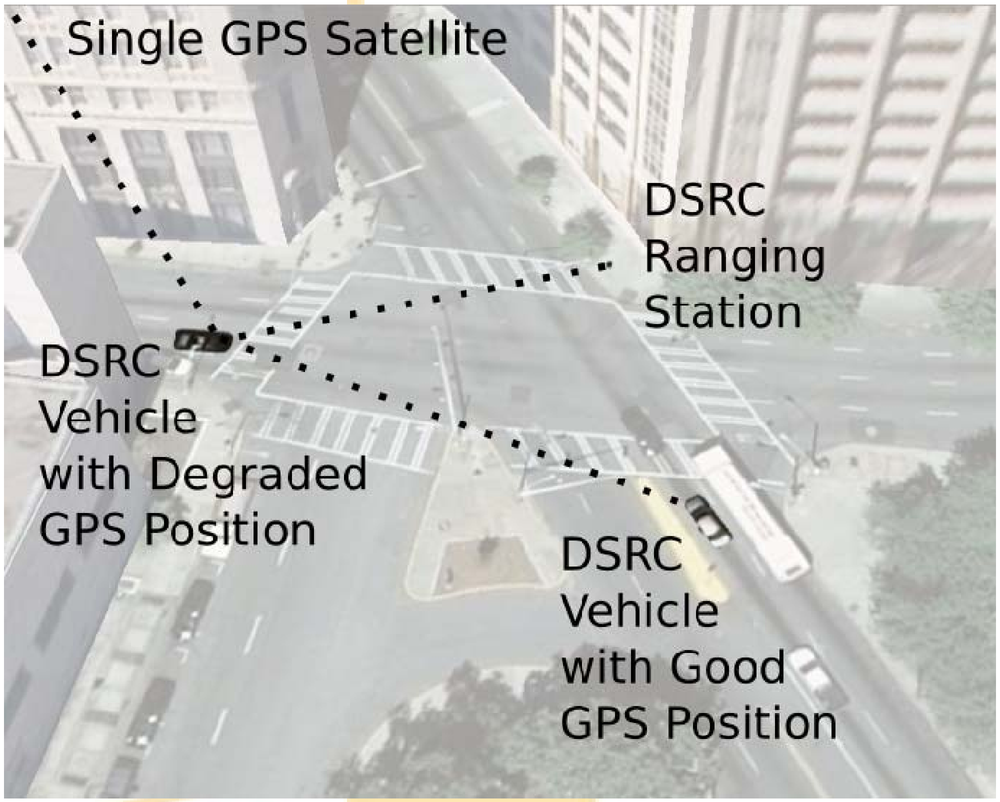
Literature Review (Lane Navigation)

- C.R. Jung and C.R.Kelber, “A lane departure warning system based on a linear-parabolic lane model”, in *IEEE Intelligent Vehicles Symposium*, June 2002, vol. 1, pp. 154-159.
  - Models the lane based on a line in the near field and a parabola in the far field of the image
- C.R. Jung and C.R.Kelber, “A lane departure warning system using lateral offset with uncalibrated camera”, in *Intelligent Transportation Systems*, September 2005, pp. 102-107.
  - Lateral offset is determined by the linear part of the linear-parabolic model to predict lane departure based on an analysis on offset across time.
- Y. Feng, W. Rong-ben, and Z. Rong-hui, “Based on digital image lane edge detection and tracking under structure environment for autonomous vehicle”, in *IEEE International Conference on Automation and Logistics*, August 2007, pp. 1310-1314.
  - Road edges are tracked using a dynamic area of interest based on the prediction result of the Kalman filter
- F. Mirzaei and S. Roumeliotis, “A Kalman Filter Based Algorithm for IMU-Camera Calibration: Observability Analysis and Performance Evaluation” in *IEEE Transactions on Robotics*, October 2008, vol. 24, no. 5, pp. 1143-1156.
  - An extended Kalman filter is used to determine the unknown transformation between a camera and an IMU using the time correlation of the IMU measurements and provide a figure of merit for the estimated transformation.

Current State of the Art (LiDAR)

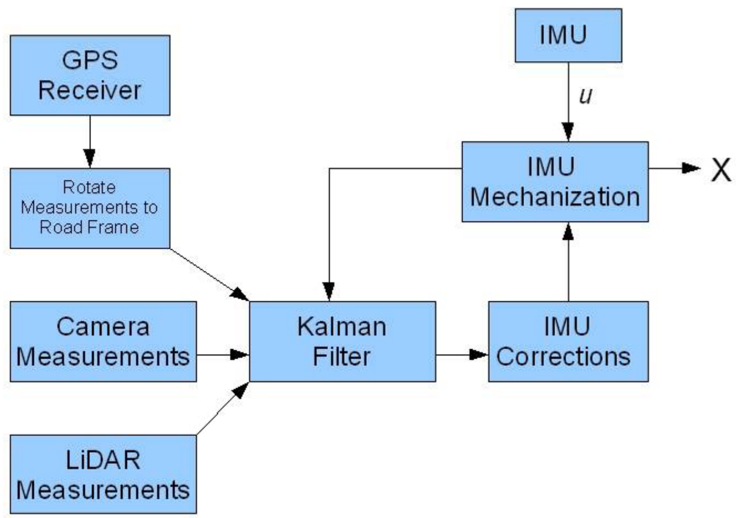
- J. Kibbel, W. Justus, K. Furstenberg. “Lane Estimation and Departure Warning using Multilayer Laserscanner”, *Proceeding of the 8th international IEEE Conference on Intelligent Transportation Systems.* September, 2005.
- K. Dietmayer, N. Kampchen, K. Furstenberg, J. Kibbel, W. Justus, R. Schulz. “Roadway Detection and Lane Detection using Multilayer Laserscanner”, *International Conference on Intelligent Transport Systms.* 2001.
  - Uses Histograms and thresholding to detect lane markings.
- T. Ogawa, K. Takagi. “Lane Recognition Using On-vehicle LiDAR”*, Intelligent Vehicles Symposium*. June, 2006.
  - Uses a Hough transform to create a select a region of interest and EKF to track the lanes.
- S. Kammel, B. Pitzer, “Lidar-based lane marker detection and mapping”, *2008 IEEE Intelligent Vehicles Symposium.* June, 2008
  - Uses thresholding, Radon transform, and feature map creation.

Project Overview

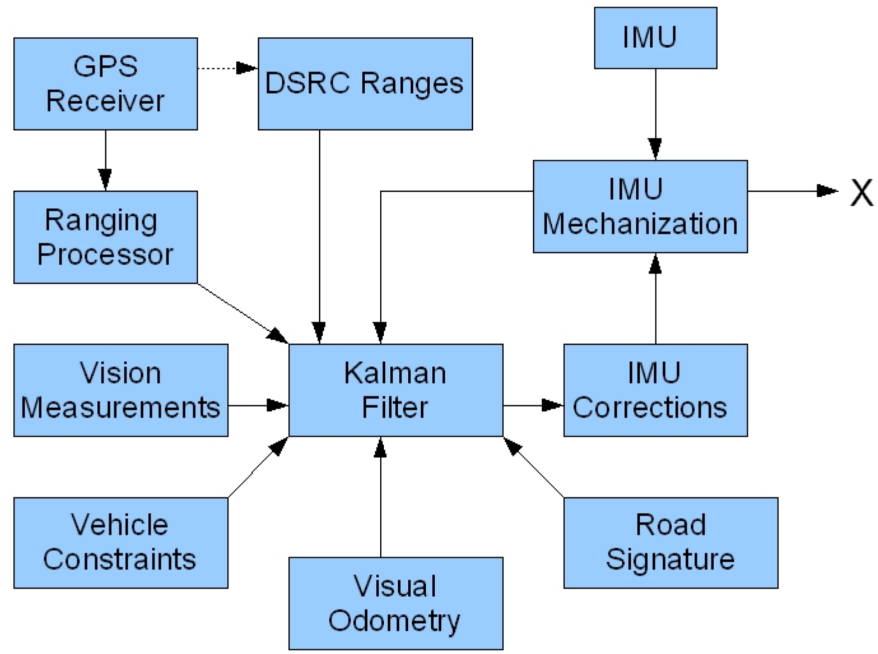


- Use vehicles with GPS availability as nodes
- Combines Measurements from:
  - Camera
  - Lidar
  - DSRC
  - GPS
  - IMU
  - Road Signature

System Integration



Sensor Integration Based on Current EAR Work

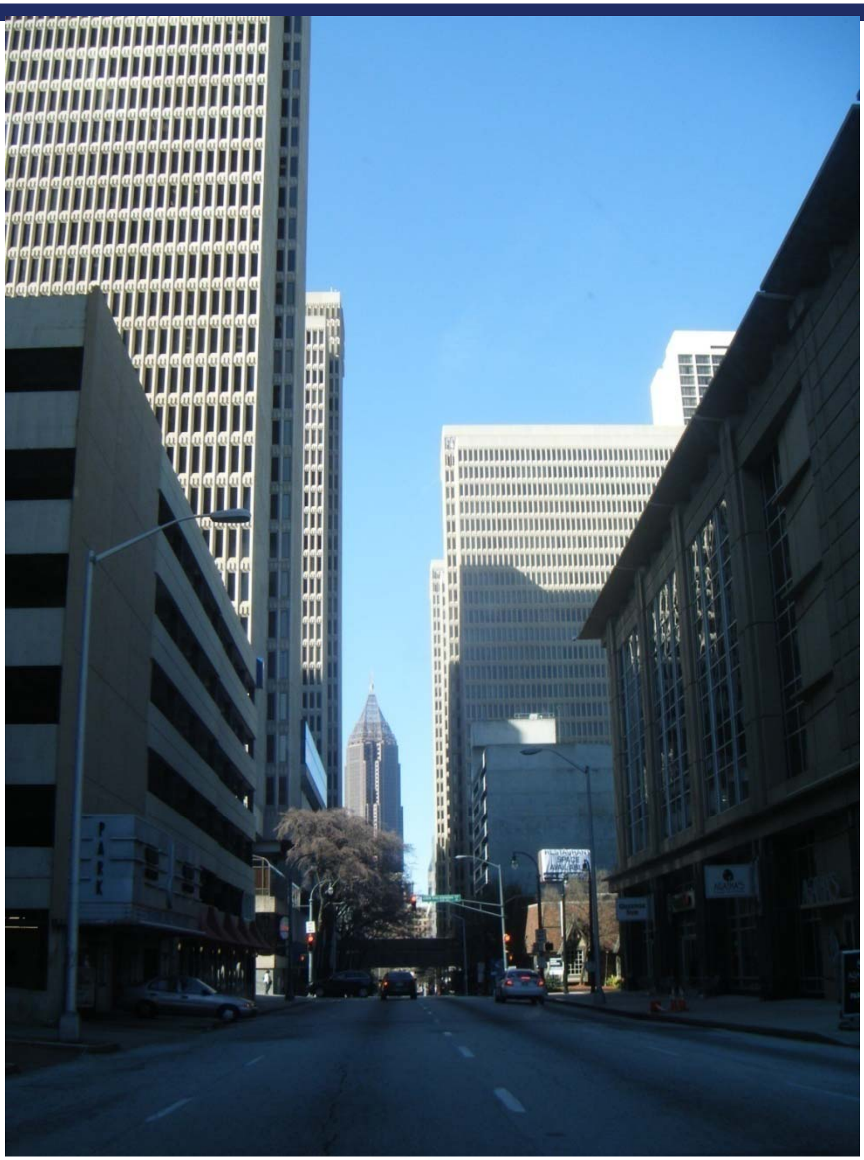


Initial Concept for Including Additional Inputs

System Interfaces

- Auburn will work with subs to ensure known interface protocols from all sub-systems
- Auburn will also provide data out as needed (for example vehicle IMU data to various sub-systems)

Integration of DSRC Ranges



- Utilize DSRC ranges similar to GPS pseudoranges
- Current tightly coupled filter allows for “raw” range measurement inputs

Year One Schedule

Next Generation Vehicle Positioning in GPS-Degraded Environments for Vehicle Safety and Automation Systems – YEAR ONE												
FY2010	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1.0 Project Management	■	■	■	■	■	■	■	■	■	■	■	■
1.1 Team Meetings	■						■					
1.2 Conduct Expert Panel Mtgs		■									■	
2.0 Literature Survey	■	■										
3.0 Investigate Terrain-Based Localization		■	■	■	■	■	■	■	■			
3.1 Install on Test Vehicle		■	■									
3.2 Define Test Protocol			■	■								
3.3 Collect Characterization Data and Analyze Results				■	■	■	■	■	■			
4.0 Investigate Visual Odometry Based Positioning		■	■	■	■	■	■	■	■			
4.1 Install on Test Vehicle		■	■									
4.2 Define Test Protocol			■	■								
4.3 Collect Characterization Data and Analyze Results				■	■	■	■	■	■			
5.0 Investigate DSRC-based RF Ranging		■	■	■	■	■	■	■	■			
5.1 Install DSRC Equipment on Test Vehicle and Test Track		■	■									
5.2 Define Test Protocol			■	■								
5.3 Collect Characterization Data and Analyze Results				■	■	■	■	■	■			
Milestone 1: Testing and Analysis Completed For Each Positioning Technique									▲			
6.0 Define Integrated Positioning System										■	■	
6.1 Define Initial IPS										■		
Milestone 2: Define Initial Integrated Positioning System										▲		
6.2 Revise IPS Definition Based on Expert Panel Feedback											■	
7.0 Demonstration and Final Report												■
7.1 Demonstrate Vehicle Capability												■
7.2 Develop Transition Plan												■
7.3 Deliver final report.												■

Year Two Tasks

- Determine current status and re-evaluate goals and schedule
- Evaluate Integrated Positioning System (IPS) at NCAT Test Track
- Evaluate IPS on Roadway Scenarios
  - Scenarios to be specified by FHWA and Automotive Panel?
- Data Characterization and Analysis of Results
- Final Demonstration/Report

Demonstrations at NCAT

- The NCAT test track in Opelika, AL was surveyed to obtain a detailed lane map of the track.
- RTK Differential GPS is available for “truth” measurements.

Google Earth

Year Two Schedule

Next Generation Vehicle Positioning in GPS-Degraded Environments for Vehicle Safety and Automation Systems – YEAR TWO (optional)												
FY2011	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1.0 Project Management												
1.1 Team Meetings												
1.2 Expert Panel Three												
2.0 Evaluate Integrated Positioning System (IPS) on Test Track												
2.1 Develop Integrated Software Algorithms												
2.2 Install on Test Vehicle												
2.3 Define Test Protocol												
2.4 Collect Characterization Data and Analyze Results												
Milestone One: Integrated Positioning System Installed and Validated on Test Track				▲								
3.0 Evaluate Integrated Positioning System (IPS) in Roadway Scenarios												
3.1 Install on Test Vehicles												
3.2 Define Test Protocol												
3.3 Collect Characterization Data and Analyze Results												
Milestone Two: On-Road Testing Completed										▲		
4.0 Demonstration and Final Report												
4.1 Demonstrate Vehicle Capability to FHWA and Expert Panel												
4.2 Develop Transition Plan												
4.3 Deliver final report.												

Closing Comments

- Questions?
- Action Items?