Syllabus: Automated, Connected, and Intelligent Vehicles

Part 1: Course Information

Description:

Automated, Connected, and Intelligent Vehicles is an advanced automotive technology course that should be taken in the last semester of a two-year automotive technology associate degree program or towards the end of an advanced certificate program in modern automotive technology electronic systems. The goal of the course is to introduce students to the various technologies and systems used to implement advanced driver assistance systems. These systems have the overall impact of automating various driving functions, connecting the automobile to sources of information that assist with this task, and allowing the automobile to make autonomous intelligent decisions concerning future actions of the vehicle that potentially impact the safety of the occupants.

The basics of automotive electronics, fundamentals of electronic control systems, and the evolution of these systems will be introduced. After a short review of body, chassis, and powertrain electronics, course attention turns to advanced driver assistance systems (ADAS). The necessary components needed to implement these systems: including advanced location and vehicle surroundings sensors, wireless technology, and the networking and processing of data are presented. The details of various automotive advanced driver assistance systems are covered including the most recent innovations: lane keeping, collision avoidance, automatic emergency braking, and autonomous vehicles. Other course topics include: sensor data fusion, advanced display and driver warning technology, impaired/medical emergency driver sensor technology, vehicle prognostics, and system troubleshooting.

The course lectures, handouts, homework assignments, lab exercises and projects, and exams are designed to train community college students that are in automotive advanced certificate and/or associate degree programs. The materials may also be adapted for use in the training of incumbent workers.

This course is designed to be a 3-credit course that will meet over a period of 16 weeks. In this format, it will consist of 2 meetings per week of 2 hours per meeting. Other formats are possible, such as a duration of 8 week with 8 hours of meeting time per week.

Prerequisites Basic electricity/electronics theory and/or automotive electronics basics

Basic knowledge of the operation of traditional vehicle systems: brakes, suspension and steering, drivetrain, engine, engine electrical, emission controls, fuel and exhaust systems, environmental systems, etc.

Reference Books

- G. Mullett, *Wireless Telecommunications Systems and Networks,* Thomson – Delmar Learning, ISNB#1-4018-8659-0, 2006
- G. Mullett, *Basic Telecommunications : The Physical Layer*, Thomson – Delmar Learning, ISBN#1-4018-4339-5, 2003

Part 2: Course Learning Outcomes (CLOs)

The course learning outcomes are that the students:

1. Understand the rational for and evolution of automotive electronics;
2. Understand which automotive systems have been replaced by electronic control systems and the advantage of doing so;
3. Understand the fundamental theory of operation of electronic control systems;
4. Understand the basics of how automotive ECUs function in conjunction with the vehicle data bus networks and sensors;
5. Become familiar with the various types of advanced driver assistance systems;
6. Understand the concept of cyber-physical control systems and their application to collision avoidance and autonomous vehicles;
7. Understand the concept of remote sensing and the types of sensor technology needed to implement remote sensing;
8. Understand the basic concepts of wireless communications and wireless data networks;
9. Understand the concept of wireless standards and the roll of various organizations in the development and evolution of these standards;
10. Understand the fundamental principles of data networking and its roll in ADAS and future autonomous vehicles;
11. Be familiar with protocols and IP addressing;
12. Understand the fundamentals of on-board vehicle networks;
13. Understand the concept of the connected vehicle and its role in ADAS and automated vehicles;
14. Become familiar with the theory and operation of legacy, new, and

emerging ADAS systems and proposed autonomous vehicle systems;

15. Understand the fundamentals of sensor data fusion as it relates to ADAS;
16. Become familiar with modern vehicle display/cluster technology;
17. Become aware of the possible evolution of vehicle prognostics and impaired driver technology;
18. Become familiar with the concept of fully autonomous vehicles;
19. Become familiar with the concepts of programming of ECUs;
20. Demonstrate effective communication and teamwork skills through technical presentations and reports in course lab projects.

Part 3: Course Topics and Roadmap

Topics covered

1. Introduction to Automated, Connected, and Intelligent Vehicles
   - Introduction to the Concept of Automotive Electronics
   - Automotive Electronics Overview
   - History & Evolution
   - Infotainment, Body, Chassis, and Powertrain Electronics
   - Advanced Driver Assistance Electronic Systems
2. Connected and Autonomous Vehicle Technology
   - Basic Control System Theory applied to Automobiles
   - Overview of the Operation of ECUs
   - Basic Cyber-Physical System Theory and Autonomous Vehicles
   - Role of Surroundings Sensing Systems and Autonomy
   - Role of Wireless Data Networks and Autonomy
3. Sensor Technology for Advanced Driver Assistance Systems
   - Basics of Radar Technology and Systems
   - Ultrasonic Sonar Systems
   - Lidar Sensor Technology and Systems
   - Camera Technology
   - Night Vision Technology
   - Other Sensors
   - Use of Sensor Data Fusion
   - Integration of Sensor Data to On-Board Control Systems
4. Overview of Wireless Technology
   - Wireless System Block Diagram and Overview of Components
   - Transmission Systems – Modulation/Encoding
   - Receiver System Concepts – Demodulation/Decoding
   - Signal Propagation Physics
   - Basic Transmission Line and Antenna Theory
5. Wireless System Standards and Standards Organizations
   - Role of Standards

- Standards Organizations
- Present Standards for Autonomous Applications

6. Wireless Networking and Applications to Vehicle Autonomy
   - Basics of Computer Networking – the Internet of Things
   - Wireless Networking Fundamentals
   - Integration of Wireless Networking and On-Board Vehicle Networks
   - Review of On-Board Networks – Use & Function
7. Connected Car Technology
   - Connectivity Fundamentals
   - Navigation and Other Applications
   - Vehicle-to-Vehicle Technology and Applications
   - Vehicle-to-Roadside and Vehicle-to-Infrastructure Applications
   - Wireless Security Overview
8. Advanced Driver Assistance System Technology
   - Basics of Theory of Operation
   - Applications – Legacy
   - Applications – New
   - Applications - Future
   - Integration of ADAS Technology into Vehicle Electronics
   - System Examples
   - Role of Sensor Data Fusion
9. Connected Car Display Technology
   - Center Console Technology
   - Gauge Cluster Technology
   - Heads-Up Display Technology
   - Warning Technology – Driver Notification
10. Impaired Driver Technology
    - Driver Impairment Sensor Technology
    - Sensor Technology for Driver Impairment Detection
    - Transfer of Control Technology
11. Vehicle Prognostics Technology
    - Monitoring of Vehicle Components
    - Basic Maintenance
    - End-of-Life Predictions
    - Advanced Driver Assistance System Sensor Alignment and Calibration
12. Autonomous Vehicles
    - Driverless Car Technology
    - Moral, Legal, Roadblock Issues
    - Technical Issues
    - Security Issues
13. Present Advanced Driver Assistance System Technology Examples
    - Toyota, Nissan, Honda, Hyundai
    - Volkswagen, BMW, Daimler
    - Fiat Chrysler Automobiles
    - Ford, General Motors
14. Troubleshooting and Maintenance of Advanced Driver Assistance

Systems
- Failure Modes – Self Calibration
- Sensor Testing and Calibration
- Redundant Systems
- Standard Manufacturing Principles

15. Non-Passenger Car Advanced Driver Assistance Systems and Autonomous Operation
- Uber/Lyft – Disruptive Technology
- Trucking
- Farming
- Mining
- Shipping & Rail
- Military

Roadmap

The following roadmap is recommended for instructors (Handouts 1-15 are the PowerPoint lecture slides):

Week and Topic	• **Lecture Topics** • **CLOs**	**Main Concepts, Terms, and Equations**	• **Course Materials,** • **Homework & Projects**
1	• Introduction to Automated, Connected, and Intelligent Vehicles • 1, 2, 5	• Automotive Electronics • Infotainment, Body, Chassis, and Power-Train Electronics • Advanced Driver Assisted Systems	• Handout #1 • EX1 • Discussion of Lab and Course Projects
2	• Connected and Autonomous Vehicle Technology • 3, 4, 6	• Basic Control System Theory • Overview of ECU operation • Concept of Cyber-Physical Control Systems • Remote Sensing Technology • Wireless Networks and Autonomy	• Handout #2 • HW1 & EX2
3	• Remote Sensing Technology • 7	• Radar & Sonar • Lidar – Multiple Beam • Cameras & Night Vision • Model Creation & Sensor Data Fusion	• Handout #3 • HW2 & EX3

4	• Wireless Technology • 8	• Wireless System Block Diagram • Transmission - Modulation/Encoding • Reception - Demodulation/ Decoding • Propagation, Transmission Lines, and Antennas	• Handout #4 • HW3 & EX4
5	• Wireless Standards • 9	• World-Wide Standards • Cellular and IEEE • Examples: DSRC, VANET, IEEE 802.11p • NHTSA and USDOT Roles	• Handout #5 • EX5 • Project 1 Due
6	• Wireless Networking • 8, 10, 11, 12	• Basic Networking Concepts • Wireless Networking Fundamentals • IEEE802.11, 802.15, 802.16, and Cellular • Protocols and IP Addressing • Connection of On-Board Networks to Off-Board • Review of On-Board Networks	• Handout #6 • EX6 • Quiz #1 • Project 2 Discussion
7	• Connected Car Technology • 13	• Connectivity Fundamentals • Navigation and Other Applications • Vehicle-to-Vehicle (V2V) • Vehicle-to-Roadside (V2R) • Vehicle-to-Infrastructure (V2I) • Wireless Security Issue	• Handout #7 • HW4 & EX7
8	• Advanced Driver Assistance Systems • 14, 15	• Basic System Operation • Applications – Legacy, New, & Future • Integration into Vehicle Electronics • System Examples • Role of Data Fusion • Model Construction – Point Cloud	• Handout #8 • Present lab project
9	• Display Technology • 16	• Center Console Technology • Cluster Gauge Technology • Heads-Up Display • Warning/Driver Notification Technology	• Handout #9 • HW5 & EX8
10	• Impaired Driver Technology • 17	• Driver Impairment Problems - Medical • Driver Impairment sensors • Transfer of Control Systems	• Handout #10 • EX9 • Quiz #2

11	• Vehicle Prognostics Technology • 17	• Monitoring of Vehicle Systems – Advanced OBD • Basic Maintenance Functions • End-of-Life Predictions • ADAS Maintenance	• Handout #11 • HW6 & EX10
12	• Autonomous Vehicles • 18	• Driverless Vehicle Technology • Artificial Intelligence and Deep Learning • Implementation Issues	• Handout #12 • HW7 & EX11
13	• ADAS System Examples by Manufacturer • 20	• Major Automobile Manufacturers • Project Presentations by Students	• Handout #13 • Project #2 Due
14	• Troubleshooting and Maintenance of ADAS Systems • 19	• Failure Modes and Self Calibration • Sensor Testing and Calibration • Redundant Systems • Software Upgrades	• Handout #14 • EX12 • Quiz #3
15	• Non-Passenger Car ADAS and Autonomous Operation • 18	• Uber/Lyft Business Model • Trucking, Farming, Mining • Shipping and Rail • Military	• Handout #15 • HW8 & EX13

Part 4: Grading and Assessment

HW Assignments

The 8 homework (HW) assignments are related to the topics described above. They will be collected and graded and are part of the overall course grade. They will be available as a separate document.

Course Projects

Two course projects are to be assigned. The first one is about the evolution of some aspect of legacy automotive technology and is to be submitted as a research project/report. The second project is a group presentation about some modern ADAS for a particular manufacturer. For this second project, the students should consult with a local car dealership to obtain information about the particular ADAS and if possible get photos (use their cell phone camera) of the system components for their presentation if at all possible.

Course Experiments Work and Lab Projects

The student will be assigned 13 laboratory experiments (EX) to complete. These experiments might include Internet research about the course topics, hands-on activities with sensors and microcontrollers, data networks, wireless transceivers, wireless networks, and simple embedded controller projects. More complex laboratory project(s) that create(s) a complete system (e.g. Smart Robot Car Kit, etc.) is also suggested. A list of possible lab exercises and laboratory projects is included as a separate document.

Computer Usage

Students should be able to use a PC, be familiar with a recent Windows OS, and be comfortable accessing information from the Internet

Tools to be used

For the course, students should possess basic PC skills and have a knowledge of Microsoft Office (specifically, Microsoft Word and Power Point). For the lab portion of the course, please refer to the documents that speak to those activities.

Grading Schedule

- Homework (5 out of 7) 10%
- 3 Quizzes 30%
- Final Test 15%
- Course Projects (2) 10%
- Laboratory Work and Projects 35%

Prepared by

Professor, Gary J. Mullett, Electronics Group
Springfield Technical Community College
Email gmullett@stcc.edu
Work Phone 413-755-4600
Office Location Building 17 Room 635

Date 03/2/2017 Rev 1.0
Revised 05/31/2017