Course Number
ENGR 4191

Title
Autonomous Vehicle Systems Development–I (AVSD1)

Credits
1

Cross-Listed As
AE 5191 - ADVANCED STUDIES IN AEROSPACE ENGINEERING
CSE 5191 - INDIVIDUAL STUDY IN COMPUTER SCIENCE
IE 5191 - ADVANCED STUDIES IN INDUSTRIAL ENGINEERING
ME 5191 - ADVANCED STUDIES IN MECHANICAL ENGINEERING

Term
Spring Semester 2009

Days & Times
Tuesday 12:00-1:00 PM

Location
Room 315 Ransom Hall

Course Description
AVSD1 is the first course in a two-semester introduction to autonomous vehicle systems (AVS). AVSD1 is broad, conceptual, & theoretical. AVSD2 (worth 2 credits) is focused, practical, & applied.

Introduces AVS (Autonomous Vehicles Systems), their history, missions, capabilities, types, configurations, subsystems, & the disciplines needed for AVS development & operation. Introduces UAVs (unmanned aerial vehicles), UGVs (ground), USVs (surface water), & UUVs (underwater); levels of autonomy; coordinate systems & equations of motion; coordinate systems & transformations for payloads; sensors & actuators; inertial measurement & navigation, Global Positioning System (GPS); PID automatic control, guidance, & navigation; vision-based guidance for ground vehicles; communication & telemetry systems; mission planning, ground control systems & operator interfaces; estimation of vehicle weight, power, & performance; manual remote control technologies & operations; embedded computer system design; & electromagnetic interference (EMI). Provides an environment for designing an autonomous vehicle system for a defined mission such that the developed autonomous systems can be used in national and international competitions. This course is team-taught by faculty in the CSE, MAE, & IE departments.
**Prerequisites**

Undergraduates: Admission into Professional Division in AE, CS, CSE, IE, ME, EE, or SE

Graduates: Admission Status in AE, CS, CSE, IE, ME, EE, or SE

**Instructors:**

Dr. Arthur Reyes  
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Dr. Kamesh Subbarao  
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**Teaching Assistant**

TBD

**Objectives**

- Introduce students to the emerging field of autonomous vehicle systems (AVS).
- Review autonomous vehicle system architectures and enabling technologies.
- Explore emerging applications of AVS technologies.
- Introduce students to obtain hands-on experience with various classes of AVS technologies
- Challenge students to generate system requirements and develop system designs for autonomous vehicles based upon realistic mission scenarios. intended to compete in International Collegiate AVS Competitions
- Provide students with the opportunity to work in multi-disciplinary teams, i.e., make it obvious to each student where their major’s disciplines fit into the development of large, complex system.
- Demonstrate the infrastructure required to coordinate development of a complex system featuring aspects that cross several engineering disciplines.
• Introduce the concept of specifying physical & functional interface requirements that must be satisfied across all disciplines during design refinement.
• Introduce test planning & execution for all levels of the system hierarchy.
• Students majoring in AE, CS, CSE, IE, EE, or ME successfully completing this course & its sequent, Autonomous Vehicle System Development 2, satisfy one Technical Elective.

Outcomes

A. Ability to apply knowledge of mathematics, science and engineering

This will be covered in lectures on mathematical models describing constraints on AVS movement, performance, weight, energy capacity, propulsion & power consumption, sensor capabilities, data links, & human factors.

B. Ability to design and conduct experiments, analyze and interpret data

Design & conduct of experiments will be covered in the lectures on test planning & execution. Analytical models describing fundamental constrains on AVS will be graphed, analyzed, & interpreted. Performance data of real AVS and components will be analyzed for trends & interpreted for applicability, feasibility, & tradeoffs.

C. Ability to design a system, component, or process to meet desired needs

The rules of the intended competition will provide the “desired needs”. The team project assesses the ability to design systems, components, & processes.

D. Ability to function on multi-disciplinary teams

Students majoring in AE, CS, CSE, SE, ME, IE, EE or other academic discipline can come together in this course in inter-disciplinary teams. Together they can develop a shared understanding of high-level requirements, system-wide scope, and functional & physical interfaces from an inter-disciplinary perspective.

E. Ability to identify, formulate, and solve engineering problems

Introductory or overview lectures will cover how to identify AVS engineering problems. Lectures on mathematical models of AVS constraints will cover how to formulate AVS engineering problems. Lectures on solving the mathematical models of AVS constraints & performance data for actual systems & components will cover how to solve AVS engineering problems.

F. Understanding of professional and ethical responsibility

What kind of AVS sensor & resolution is required to distinguish a combatant from a non-combatant? If an AVS has or can deploy sensors that can eavesdrop on a conversation, how do we ensure that privacy laws are not broken? What is the maximum AVS tread pressure that can...
be applied to permafrost without causing damage to the delicate ecosystem? What is the price/performance threshold at which a humanitarian organization will purchase an AVS for landmine remediation? How do you reduce the likelihood of data link exploitation by an adversary? Is an AVS covered by the Geneva Convention? These are relevant questions to address during lectures.

G. Ability to communicate effectively

Students will need to work in a multi-disciplinary team and teams will have to present their projects.

H. Broad education necessary to understand the impact of engineering solutions in a global and societal context

Students will learn about AVS flight operations conducted in public airspace under the auspices of the Federal Aviation Administration (FAA) & the Federal Communications Commission (FCC).

I. Recognition of the need for, and the ability to engage in life-long learning

This course will introduce a number of disciplines that are outside each student’s major. It should be obvious to each student that if they wish to be employed in the AVS industry, they will need to acquire more detailed knowledge & skills in specific areas.

J. Knowledge of contemporary engineering issues

The “Build versus Buy” Issue: Because capable & relatively inexpensive commercial hardware & software components are available for many parts an AVS, e.g., base vehicle, automatic control components, imaging, image processing, etc., this course will discuss and expose students to the pros and cons of both sides of the “Build versus Buy” dilemma.

K. Ability to use techniques, skills, and modern engineering tools necessary for engineering practice

Students will work with the MATLAB/SIMULINK by Mathworks Inc. to develop analytical models of AVS. Students will also have the opportunity to work with sensors, microcontrollers and interface software suitable for use with AVS.

Reference Textbook


Required Software

MATLAB/SIMULINK Student Edition with Control and system ID toolboxes by Mathworks Inc.
Other Material
The instructors will provide handouts on topics not covered in the textbook, such as issues specific to UGVs, USVs, & UUVs.

Course Website
There will be a WebCT website created.

Assessments & Weights

Homeworks: [20%]
Throughout the semester, every instructor will give a homework assignment on the material that he covers in class.

Project Report¹: [30%]
Each team is required to submit a project report that describes the design of their entry and the rationale behind their design choices. Overall Systems engineering implementation, system design features, and expected performance (including test results if available) shall be included. Descriptions are required for the vehicle, ground control station, data link, payload, and method of autonomy and target types supported by autonomous cueing/recognition (if utilized). Specific attention shall be paid to safety criteria. This report shall be no more than 20 pages long (including all figures, references, and appendices). Additionally, each report shall include an abstract of no more than 250 words. The report and abstract shall be printable on standard 8.5 × 11 inch paper, with margins of at least 1 inch on all sides, and all text shall be in 12 point or larger font. Each page shall bear footer with the page number and the team name. The report shall be submitted at the beginning of the class on Dec 5th before the team presentations start.

Project Presentation: [30%]
Each team is required to present their design to the instructors of the course and an external evaluation committee. Each team shall provide a 15 minute presentation which highlights their approach, design, and expected performance. Unique or innovative features and safety approaches shall be included.

Teammate Evaluation: [10%]
An evaluation form will be provided by the end of the semester. Each student is required to provide his/her evaluation of each teammate. Your evaluation will effect your teammates' grade he/she will get from the project according to the policy provided in the evaluation form.

Attendance: [10%]
Attendance in the lectures and weekly project meetings is required

Grading
Final letter grades will be assigned according to the following scale.

¹ Project Report format is copied from 2007 AUVSI Student UAV Competition Rules.
A: 85 <= Grade
B: 70 <= Grade < 85
C: 55 <= Grade < 70
D: 40 <= Grade < 55
F: Grade < 40

We will record numeric grades to the nearest 1/100 of a percentage point. I.e., if your final, numeric grade is 84.99%, your final letter grade is B.

**Tentative Course Schedule**

<table>
<thead>
<tr>
<th>Wk</th>
<th>Monday</th>
<th>Lecture Topics</th>
<th>Lecturer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/20/2009</td>
<td>An introduction to AVS</td>
<td>Huff</td>
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<tr>
<td>2</td>
<td>1/27/2009</td>
<td>Reviewing Rules of Competitions and Developing AVS Requirements</td>
<td>Reyes</td>
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<tr>
<td>4</td>
<td>2/10/2009</td>
<td>Unit/Integration/System testing planning and execution</td>
<td>Reyes</td>
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<tr>
<td>5</td>
<td>2/17/2009</td>
<td>AVS classes, missions and operating scenarios, equipment</td>
<td>Huff</td>
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<tr>
<td>6</td>
<td>2/24/2009</td>
<td>A hands-on laboratory exercise with a ground vehicle and sensors</td>
<td>Huff</td>
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<tr>
<td>8</td>
<td>3/10/2009</td>
<td>Vehicle Localization Methods, Issues, and Technologies</td>
<td>Huff</td>
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<tr>
<td>9</td>
<td>3/17/2009</td>
<td><strong>Spring Break – No Class</strong></td>
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<tr>
<td>10</td>
<td>3/24/2009</td>
<td>MATLAB for Control, Estimation and System Identification</td>
<td>Subbarao</td>
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<tr>
<td>11</td>
<td>3/31/2009</td>
<td>System Identification</td>
<td>Subbarao</td>
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<tr>
<td>12</td>
<td>4/7/2009</td>
<td>Estimation and sensor noise reduction</td>
<td>Subbarao</td>
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<tr>
<td>13</td>
<td>4/14/2009</td>
<td>Introduction to Simulink for dynamic system modeling and simulation</td>
<td>Dogan</td>
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<td>14</td>
<td>4/21/2009</td>
<td>Implementation of a control law in Simulink</td>
<td>Dogan</td>
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<tr>
<td>15</td>
<td>4/28/2009</td>
<td>Performance evaluation of closed-loop system in Simulink</td>
<td>Dogan</td>
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<tr>
<td>16</td>
<td>5/5/2009</td>
<td>Student Presentations</td>
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<tr>
<td>17</td>
<td>5/12/2009</td>
<td>Finals Week – <strong>No Class</strong></td>
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