JACKSON STATE UNIVERSITY

Department of Industrial Systems and Technology

Course Syllabus and Lesson Plans

Course Number & Title:	IT 312 – Navigation techniques used in connected and automated vehicles
Credit hour(s):	3.00
Semester and Year:	Summer 2016
Instructors:	Dr. James A. Ejiwale
Office Location:	JYW Building, Room 209
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Textbooks:

Groves, P. D. (2004). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems. Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356 http://www.robotee.com/EBooks/Introduction_to_Autonomous_Mobile_Robots.pdf

Required Readings/ Resources:

Anderson, J., N., Kalra, K., Stanley, P., Sorensen, C. S., & Oluwatola, O. (2014). Autonomous Vehicle Technology: A Guide for Policy Makers. Santa Monica: RAND Corporation.

Autonomous vehicle Navigation: Path Planning & Navigation. http://www.swri.org/4org/d14/aerospace/path/auto.htm

Autonomous Driving and ADAS (advanced driver assistance systems).

http://www.hamamatsu.com/us/en/community/optical_sensors/applications/autonomous_driving_adas/index.html?gclid=CI2CosaZ9c8CFQQcaQode8gMrw

Borenstein, J., Everettm H. R., Feng, L., & Wehe, D. (2012). Mobile robot positioning - sensors and techniques. Journal of Robotic Systems-special issue on mobile robots. 14(4), p. 231–249. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.17.8943&rep=rep1&type=pdf

Dixon, J. (1997). Mobile robot navigation. http://www.doc.ic.ac.uk/~nd/surprise_97/journal/vol4/jmd/

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Preparing a nation for Autonomous vehicles: Opportunities, barriers and policy recommendations. https://www.caee.utexas.edu/prof/kockelman/public_html/ENOReport_BCAofAVs.pdf

Glancy, D. J. (2015). Autonomous and automated and connected cars----Oh My! First generation Autonomous cars in the legal ecosystem. Minn. J. L. Sci. & Tech., 16(2). http://conservancy.umn.edu/bitstream/handle/11299/174406/619%20Glancy.pdf?sequence=1

Gilbert, F. & Zallone, R. (2016). Connected Cars Recent Legal Developments. http://robots.law.miami.edu/2016/wp-content/uploads/2015/07/GILBERT-ZALLONE-Connected-Cars-REVISED_2016-03-29.pdf

Gyimesi, K. (2015). Automated and autonomous cars: Looking under the hood of the hype. http://www.ibmbigdatahub.com/blog/automated-and-autonomous-cars-looking-under-hood-hype

Isaac, L. (2016). Driving Towards Driverless: A Guide For Government Agencies http://www.wsp-pb.com/Globaln/USA/Transportation%20and%20Infrastructure/driving-towards-driverless-WBP-Fellow-monograph-lauren-isaac-feb-24-2016.pdf

Lee, H. (2010). An Integration of GPS with INS Sensors for Precise Long-Baseline Kinematic Positioning. Sensors 2010, 10, 9424-9438; doi:10.3390/s101009424. Retrieved from file:///C:/Users/James/Downloads/sensors-10-09424.pdf

Ozkil, A. G. (2009)Technical Report on Autonomous Mobile Robot navigation. Technical University of Denmark. http://orbit.dtu.dk/files/9811555/report.pdf

Noureldin, A., Karamat, T. B. & Georgy, J. (2012). Fundamentals of inertial navigation, satellite-based positioning and their integration. Springer Science & Business Media.

Ozguner, U., Acarman, T., & Redmill, K. (2011). Autonomous Ground Vehicles. Norwood, MA ISBN-13: 978-1608071920 ISBN-10: 1608071928

Schwarz, C., G. Thomas, K. Nelson, M. McCrary, & N. Schlarmann. 2013. "Towards Autonomous Vehicles." *Final Reports and Technical Briefs,* Mid-America Transportation Center. Lincoln: University of Nebraska, Lincoln.

Vehicle Sensors and Actuators: ISBN: 978-0-7680-2125-7; 2009

Vikas, K. N. (2004). Integration of Inertial Navigation System and Global Positioning System Using Kalman Filtering. Dissertation Submitted in fulfillment of the requirements for the Dual Degree Program in Aerospace Engineering

Werries, A. & Dolan, J. M. (2016). Adaptive Kalman Filtering Methods for Low-Cost GPS/INS Localization for Autonomous Vehicles **https://www.ri.cmu.edu/pub_files/2016/5/awerries_written_qualifier.pdf**

Course Description: This course introduces students to principles of navigation techniques used in connected and automated vehicles. Topics include autonomous navigation and connected vehicles, basic navigational mathematics, mobile robot positioning, inertial sensors and navigation systems, global positioning system, kalman-fitering techniques, integrated navigation system, multisensory integrated navigation, fault detection and integrity monitoring, and communication among connected vehicles.

Course Objectives:

Upon completion of this course students will be able to:

1. Explain the importance of navigation systems.

2. Evaluate the levels of automated vehicles.
3. Recognize and apply laboratory safety procedures.
4. Explain the principles of a navigation system.
5. Explain the fundamentals of basic navigational mathematics.
6. Determine the detailed kinematic relationships between the 4 major frames of interest
7. Explain the fundamental basics navigational mathematics.
8. Demonstrate the understanding of the relationship between specific force, inertial acceleration, and gravitational attraction.
9. Demonstrate the understanding of mobile robot positioning.
10. Demonstrate the understanding of mobile robot positioning with respect to Sensors and techniques applications.
11. Describe the basics of performing INS computations
12. Describe the integration of the inertial navigation system (INS) with other sensors.
13. Discuss various examples of practical INS applications.
14. Describe the fundamentals of satellite navigation
15. Explain the fundamentals of GPS
16. Explain how to set up and operate the components of a mapping-grade GPS system
17. Identify levels of GPS accuracy.
18. Explore the integration of GPS with other technologies
19. Identify sources of GPS errors
20. Measure GPS accuracy
21. Demonstrate understanding of the material covered by the learning outcomes in Lessons 1 through 6 on a mid-term exam.
22. Demonstrate the ability to apply different Kalman filter (KF) techniques to combine noisy sensor outputs to estimate the state of a system with uncertain dynamics.
23. Apply KF to estimate the errors introduced into the unaided INS system due to gyros and accelerometers.
24. Discuss the fundamentals of the integrated navigation system (INS).
25. Describe the different INS/GNSS integration architectures.
26. Describe different integration architectures
27. Combine different navigation sensors for different applications.
28. Explain the limitations of incorporating terrestrial radio navigation
29. Differentiate between loosely coupled integration and tightly coupled integration.
30. Explain what a dead-reckoning reference incorporates.
31. Describe feature matching techniques
32. Discus the failure modes that can occur in navigation systems.
33. Describe the certification that an integrity monitoring system fulfills.
34. Demonstrate the understanding of robotic motion planning problems.
35. Discuss collision avoidance methods.
36. Demonstrate the understanding of robotic motion planning problems.
37. Explain the legal outlook for automated (autonomous) and connected cars.
38. Demonstrate basic understanding of the material covered in the course.

Course Content and Assignment Schedule

Note: H_1 = Handout_1
L_1 = Lecture_1

Week **Topic** **Assignments**

Part I. Towards Autonomous Navigation and connected vehicle

1. Overview of Autonomous Navigation and Connected vehicles
   a. Introduction to the history of autonomous and connected vehicles
   b. Levels of vehicle automation
   c. Difference between automated and autonomous vehicles.
   d. Preparing a nation for autonomous vehicles:
      i. Opportunities – potential benefits
      ii. Barriers to implementation, and
      iii. Policy recommendation.
   e. Introduction to navigation

H_1 (p. 1 – 18)
H_2 (p. 1 – 19)
H_3
H_4
L_1A
L_1B
L_1C
L_1D
(Groves 2008, CH 1, p. 1-15)
Homework #1 assigned
Group Assignment

Part II. Fundamentals of navigation systems

2. Fundamentals of basic navigation mathematics
   a. Coordinate frames
   b. Transformation frames

L_2

Read: (Groves 2008, CH 2, p. 15 - 34)

3. Basic navigational Mathematics (continued)

    a. Earth surface and gravity models
    b. Frame transformation

L_3

Read: (Groves 2008, CH 2, p. 35 - 53)
Homework #1 due

4. Mobile robot positioning
    a. Overview of mobile robot positioning– Sensors and techniques
    b. Relative and absolute position measurements
    c. Characteristics of each category

H_5
H_6
L_4A
L_4B

Test#1

5. Introduction to Inertial Sensors and Navigation Systems
    a. Inertial sensors
        i. Gyroscopes: Error and Characteristics
        ii. Accelerometers: Error and Characteristics
    b. Introduction to Inertial Navigation
    c. Inertial system equations
    d. Initialization and alignment
    e. INS Error propagation
    f. Platform INS

H_7 (p. 7 - 13)
H_8
L_5A
L_5B

Groves (2008), CH 4 & 5, p. 95 – 160*)*
Homework #2 assigned

6. Introduction to GPS
    a. Overview of Global Positioning System
        i. Introduction to fundamentals of satellite navigation

ii. Introduction to global Positioning System
iii. Errors in GPS
iv. Implementation of GPS Module

H_7 (p. 15 –19)
H_9 (p. 212 – 249)
L_6
Groves (2008, CH 6 & 7, p. 161 – 277)
Homework #2 due

7. ***Review for Mid-term Exam #1***
   Review material from Lesson 1 – 6.

8. ***Mid-term Examination (#1)***
   Mid-term examination on lesson 1 – 6.

9. Introduction to Kalman filtering Techniques
   a. Overview of Kalman Filtering
      i. Discrete Kalman Filter
      ii. Kalman filter and navigation
      iii. Implementation of Kalman Filter Module

H_7 ***(p. 15 - 19)***
H_9 ***(p. 227 – 249)***
H_10
H_11
H_12
H_13
L_9A
L_9B
Groves (2008), Ch 3, p. 55 - 93

10. Introduction to integrated navigation systems
    a. INS/GNSS Integration
    b. Integration Architectures
    c. System Model and State selection
    d. Measurement models
    e. Advanced INS/GNSS Integration

H_5
H_14
L_10

Groves, P. (2008). CH 12, p. 361 - 406

11. Multisensor Integrated Navigation
    a. Integration Architectures and Measurement Models
    b. Dead Reckoning, Attitude, and Height Measurement
    c. Feature Matching

H_9 ***(p. 291 – 305)***
H_15
L_11A
L_11B
Groves (2008, CH. 14, p. 419 – 448)
Homework #3 assigned

12. Fault detection and integrity monitoring
    a. Failure modes
    b. Range checks
    c. Kalman filter measurement innovations
    d. Direct consistency checks
    e. Certified integrity monitoring

H_16
H_17
H_18
H_19
H_20
L_12A
L_12B
L_12C
L_12D

Groves (2008, CH. 15, p. 451 – 469)

Part III Fundamentals of Autonomous Planning and Navigation in vehicles

13. Competences for Navigation: Planning and Reacting
    a. Robotic motion planning problems.
    b. Difference between physical space and configuration space.
    c. Collision avoidance methods.
    d. Overview of Multiple-Robots

H_9 (p. 257 – 291).
H_21
H_22
L_13A
L_13B
L_13C

L_13D
L_13E

Project assigned/Team formation
Test #2

Part IV. Legal Outlook, Challenges and Research Needs

14. Legal outlook for autonomous, automated and connected cars
    a. Legal environment for first generation autonomous cars
    b. Legal outlook down the road
    c. Challenges and research needs: Technical, Human factors, Societal and Economic.

H_2 ***(p. 19 – 53)***
H_23 - 30
Homework #3 due

15. Review for final examination and Project presentation
    a. Project presentation
    b. Review materials from 1 – 14

16. ***Final Examination*** (#2)
    a. Final review of materials with students
    b. Final examination

Instructional Strategies

The course content will be presented through a blend of instructional methods to include:

- Lecture - Face-to-face
- Discussion/Questioning
- Independent Learning/Self-Instruction
- Problem-Solving
- Multimedia presentations
- Guest Speaker (s)
- Library Referencing and Resources
- Computer and Internet Research

STUDENT ACTIVITIES:

- 16 class meetings - Class attendance and participation in class discussion
- 3 homework assignments – Read (study), complete and turn in assignments at the scheduled time (*usually* at the *beginning* of class periods on the due dates)
- 2 Tests
- Laboratory exercises/ Project – Complete a robotic building project during lab periods
- Mid-term Examination
- Final Examination

Class attendance and participation
There will be a total of 16 class meetings, including final examination day. During these meetings, class attendance and participation in class discussions are essential. Students should be prepared to discuss all required readings before each scheduled class.
Homework assignments
The assignments are designed primarily to increase your familiarity with sensors used in autonomous robots, automated and connected vehicles and make it easier for you to use it in our projects and research work. There will be 3 homework assignments and will generally be based on materials covered in the class. The remaining two parts will require a lot more effort and may require you to refer to material outside the lectures. Students should read (study), complete and turn in assignments at the scheduled time.

Quizzes and Tests
During the semester, all students are required to successfully pass two (2) tests and participate on at least 10 quizzes. These tests will come from your lectures, readings and writing assignments and will consist of multiple choices, fill in the blank, essays and true/false.

Examinations
During the semester, all students are required to successfully pass two (2) examinations (midterm and final). These examinations will come from your lectures, reading and writing assignments and will consist of multiple choices, fill in the blank, essays and true/false.

Laboratory Exercises/ Project
Laboratory exercises measure skills and abilities relating to knowledge learned in class. These laboratory exercises will aid the in the design, building and examination of the navigation techniques used in robotics. It is anticipated that this laboratory exercises will result in the creation of a software tool kit that can allow for the immediate use of these navigation techniques without the need for an in-depth knowledge of the physics behind the sensors as the final project.

Students are required to complete a project involving team collaboration. As such a complete involvement and contribution in all phases of the project is expected from each team member. For the duration of the course, each team is expected to work together and produce a professional quality response to a problem in the form of a written report. In addition, each team will make a 10 – 15 minutes oral presentation. Final reports are due on the day of the presentation and each member of the team, regardless of input, will receive the same grade for the team project. The projects will be judged by a panel consisting of the course faculty and external experts in automated and connected vehicle

Written Report (Format)

I. Executive Summary.
II. Table of Contents, List of Team members, and Specific Team Member Contribution.
III. Problem Statement, Design Objectives and Development of Requirement.
IV. Methods and Discussion Leading to Proposed Design.
V. Schedule.

VI. Results Including the Measures of Success (speed, range, conservation of energy).
VII. Equipment List for robotic project.
VIII. Lesson Learned.
IX. Power Point Presentation Slides.
X. References

Methods of Student Evaluation:

Grading will consist of the following criteria and percentages:

3 Homework assignments 15%
10 Quizzes ……………….………………. 05%
2 Tests ……………………………………10%
1 Mid-term Examination ………………… 20%
1 Final Examination ………………………. 20%
1 Laboratory exercises/ Project……………. 20%
1 Presentation ………………………………10%

Total 100

Grading Scale:

A	B	C	D	F
90-100	**80-89**	**70-79**	**60-69**	**< 60**

<u>Methods of Course Evaluation</u>

A. Jackson State University Student Instructional Rating System (SIRS)

Special Needs Learners:

"It is the University policy to provide on a flexible and individualized basis, reasonable accommodations to students who have disabilities that may affect their ability to practice in course activities or to meet course requirements. Students with disabilities are encouraged to contact their instructors to discuss their individual needs for accommodation." Contact Information:

ADA Coordinator, Disability Services & ADA Compliance
2100 Student Center, 2nd Floor, P.O. Box 17156, Jackson, MS 39217
Phone: (601.979.3704), Fax: (601.979.6918), TTY: (601.979.6919)
Website: http://www.jsums.edu/disability/

Diversity Statement:

Jackson State University is committed to creating a community that affirms and welcomes persons from diverse backgrounds and experiences and supports the realization of their human potential. We recognize that there are differences among groups of people and individuals based on ethnicity, race, socioeconomic status, gender, exceptionalities, language, religion, sexual orientation, and geographical area. All persons are encouraged to respect the individual differences of others.

Class Attendance Policy:

All students at Jackson State University must fully commit themselves to their program of study. One hundred percent (100%) punctual class attendance is expected of all students in all scheduled classes and activities. Instructors keep attendance records and any absence for which a student does not provide written official excuse is counted as an unexcused absence. Students must understand that even with an official excuse of absence, they (students) are responsible for the work required during their absence.

Students may be officially excused from class for attendance at University approved functions, provided the sponsor properly executes a Student Affairs Leave Form. Such excuses shall be accepted by the instructor. Students may also be officially excused by the Dean of their School or the Vice President for Academic Affairs for certain campus activities. Students must submit written documentation to Student Affairs to obtain official excuses for absences due to illness or other emergency situations.

Students who willfully miss class face serious consequences. After being absent three times in a 50-minute class, three hours in a class that meets longer than one hour, or one time immediately before or after a scheduled recess/holiday, the instructor shall report the next unexcused absence to the Dean of University College for freshman and sophomores and to the school dean and department chair for juniors and seniors. The dean/chair or designee will counsel with the student and in concert with the instructor, may require the student to complete complementary course assignments. If a student does not respond well to the counselor with the assignments, the instructor may impose a grade penalty on the student. Unexcused absences that exceed the equivalency of six 50-minute Sessions may lead to an "F" for the course. Students who do not maintain the minimum grade point average required for retention over two semesters are suspended from the University.

At the discretion of the school dean and with approval of the Office of Academic Affairs, there may be additional class attendance policies stipulated in school handbooks and other official school documents.

Academic Dishonesty Statement:

Academic dishonesty will be rewarded with a grade of zero for the assignment or exam and may possibly lead to failure of the course.

References

Anderson, J., N. Kalra, K. Stanley, P. Sorensen, C. Samaras, & O. Oluwatola. 2014. *Autonomous Vehicle Technology: A Guide for Policy Makers*. Santa Monica: RAND Corporation.

Brugeman, V., R. Wallace, J. Cregger, M. Smith, & W. Tansil. 2012. *Expert Opinion Forecast of Connected Vehicle Technology*. September. Detroit: Michigan Department of Transportation and Center for Automotive Research.

Childress, S., B. Nichols, B. Charlton, & S. Coe. 2015. *Using an Activity-Based Model to Explore Possible Impacts of Automated Vehicles*. Presented at the 94th Annual Meeting of the Transportation Research Board, Washington, DC.

DiClemente, J., S. Mogos, & R. Wang. 2014. *Autonomous Car Policy Report*. Pittsburgh: Carnegie Mellon University, New Technology Commercialization Project Class.

Ernst & Young. 2014. "Deploying Autonomous Vehicles: Commercial Considerations and Urban Mobility Scenarios." Detroit: EYGM Limited.

Eno Center for Transportation. 2013. *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations*. Washington, DC: Eno Center for Transportation.

European Technology Platform on Smart Systems Integration (EPoSS). 2015. *European Roadmap: Smart Systems for Automated Driving*. Berlin, German: EPoSS.

Gareffa, P. 2014. "2015 BMW i3 with Remote Valet Parking Coming to 2015 CES." *Edmunds.com.* December 16. Accessed August 13, 2015. http://www.edmunds.com/car-news/2015-bmw-i3-with-remote-valet-parking-coming-to-2015-ces.html.

Goodin, G. 2014. Automated Vehicles and Public Policy: State and Local Public Policy. Presentation at the 2014 Automated Vehicle Symposium, sponsored by the Transportation Research Board and the Association for Unmanned Vehicle Systems International San Francisco, CA, July 16, 2014.

Government Accountability Office (GAO). 2012. "Intelligent Transportation Systems: Improved DOT Collaboration and Communication Could Enhance the Use of Technology to Manage Congestion." Report to Congressional Requesters GAO-12-308. March. Washington, DC: US GAO.

Government Accountability Office (GAO). 2013. "Intelligent Transportation Systems: Vehicle-to-Vehicle Technologies Expected to Offer Safety Benefits, But a Variety of Deployment Challenges Exist." Report to Congressional Requesters GAO-14-13. November. Washington, DC: US GAO.

Hendrickson, C., A. Biehler, & Y. Mashayekh. 2014. *Connected and Autonomous Vehicles: 2040 Vision*. Philadelphia: Pennsylvania Department of Transportation.

IHS Automotive. 2014. *Emerging Technologies: Autonomous Cars—Not If, But When*. January. Englewood, CO: IHS Inc.

J.D. Power and Associates. 2014. U.S. Automotive Emerging Technologies Study. Press Release, May 1. J. D. Power and Associates and McGraw-Hill Financial. Accessed July 28, 2015. http://www.Jdpower.com/sites/default/files/2014057_US%20_Auto_ET.pdf.

Katkoori, S., S. Barbeau, P. Lin, & J. Bittner. 2013. *Technology Barriers to Deployment of Automated Vehicles in Urban Environment*s. November. Tampa, FL: Center for Urban Transportation Research, University of South Florida.

KPMG LLP and Center for Automotive Research. 2014. "Self-Driving Cars: The Next Revolution." Accessed December 3, 2014. http://www.kpmg.com/US/en/issuesandInsights/ArticlesPublications/Documents/self-driving-cars-next-revolution.pdf.

Levin, M., & S. Boyles. 2015. *Effects of Autonomous Vehicle Ownership on Trip, Mode, and Route Choice*. Presented at the 94th Annual Meeting of the Transportation Research Board, Washington, DC.

McComb, G. (2013). Arduino Robot Bonanza Paperback. McGraw Hill Education, NY: New York. ISBN-13: 978-0071782777; ISBN-10: 007178277X. Edition: 1st

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Bcg.perspectives. April 21, Boston: Boston Consulting Group.
National Highway Traffic Safety Administration (NHTSA). 2013. "Preliminary Statement of Policy Concerning Automated Vehicles." Washington, DC: NHTSA.
Pillkahn, U. 2008. *Using Trends and Scenarios as Tools for Strategy Development.* Erlangen, Germany: Publicis Corporate Publishing.
Shladover, S. & R. Bishop. 2015. *Road Transport Automation as a Public-Private Enterprise.* White Paper 1. April 14–15, Washington, DC: EU-US Symposium on Automated Vehicles.
Shladover, S., & Gettman, D. (2014). *Connected / Automated Vehicle Roadmap for AASHTO*. Deliverable 2. NCHRP 20-24(98). Washington, DC: Transportation Research Board.
Stanley, K., & J. Wagner. Forthcoming. "Data Privacy." College Station: Texas A&M Transportation Institute (Policy Research Center).
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Thierer, A., & R. Hagemann. 2014. *Removing Roadblocks to Intelligent Vehicles and Driverless Cars*. Mercatus Working Paper. September. Arlington, VA: Mercatus Center, George Mason University.
Wagner, J. 2015. *Automated Vehicle Testing: Policy Considerations for Texas*. College Station: Texas A&M Transportation Institute (Policy Research Center).
Wagner, J., T. Baker, G. Goodin, & J. Maddox. 2014. *Automated Vehicles: Policy Implications Scoping Study*. Report 600451-00029-1. College Station: Southwest Region University Transportation Center, Texas A&M Transportation Institute.
Williams, K. 2013. *Transportation Planning Considerations for Automated Vehicles*. November. Tampa: Center for Urban Transportation Research.
Wright, J., J. Garrett, C. Hill, G. Krueger, J. Evans, S. Andrews, C. Wilson, R. Rajbhandari, & B. Burkhard. 2014. *National Connected Vehicle Infrastructure Footprint Analysis: Final Report*. Washington DC: FHWA.
Zhang, T. & Delgrossi, L. (2012). Vehicle safety Communications: Protocol, security, and privacy. John Wiley & Sons. ISBN 978-1-118-13272-2
Zmud, J., I. Sener, & J. Wagner. Forthcoming. "Impact on Travel Behavior of Self-Driving Vehicles." College Station: Texas A&M Transportation Institute (Policy Research Center).

IT 312 – Navigation techniques used in connected and automated vehicles

Course Safety Confirmation

This course is an introductory course in navigation techniques used in automated and connected vehicles. Students will work in teams and apply Android Software Operation and sensors technology to create a software tool kit that can allow for the immediate use of these navigation techniques without the need for an in-depth knowledge of the physics behind the sensors and overall robotic vehicle structure in a hands-on laboratory environment. Each student team will design and build an autonomous robot by selecting various components and system configurations, and integrating the systems for optimal vehicle performance.

SAFETY: ***This course may involve the use of laboratory and/or shop equipment, and no student is allowed to utilize methods/techniques without the supervision of course instructors. This safety requirement includes all aspects of the development, construction, assembly, transportation and operation of all components of the robot. As a rule, once the robot is capable of self-contained movement, the robot may not be powered if anyone is within 15 feet of its direction of movement (i.e. don't turn it on until there is no one standing in front of the vehicle). Any student who chooses to disregard ANY safety rules, or conducts himself/herself in a manner that places anyone in danger, will be dismissed from the course immediately, and the case will be turned over to the Dean of Students.***

The first imperative of the automated and connected Vehicle Systems course is personal and property safety. As a student in this course, I have read the course outline. I understand the course safety imperative and have asked all questions regarding safety and safety expectations. I will abide by all safety requirements placed upon us as part of the conduct of the course. Further, I will abide by safety practices common to laboratories as well as customary transportation safety.

I ____ (have/ do not have) a valid

operators license in ____ (state).

Signature: __________________________________ Date: ___________________________

Assignments

For both of the assignments below use Times New Roman, 12 font, and document your references using APA format.

Assignment #1 -

Write a paper on different localization approaches. Explain the need for localization, different approaches, limitations, environments (indoors and outdoors). This is a very important paper that will assist in completing your project. You will need to spend enough time to look at different approaches and this will help you chose the best approach for your project.

Assignment #2

Write a paper on different area searching approaches. How do you search a given area efficiently and in the minimum time possible?

Assignment #3

Write a paper on "Preparation for the integration of a community automated mass transit bus in my state capital."

Project Requirements and Design Specifications

I. Total cost of final product must not exceed $500.00
II. Budget provided by the IS&T dept. is $400.00
III. Programmable EV3 Brick - serves as the control center and power station for your robot.

Project A

Accident Detection and Messaging System using GSM and GPS

The aim of this project **Accident Detection and Messaging System** is to inform the emergency response teams (Ambulance and Police) and immediate family members of the accident site and arrange for necessary steps to control the situation. This system is not only efficient but also worthy to be implemented. The Accident Detection and Messaging System can be fitted in the vehicle of the emergency responders: (Ambulance, the Police), immediate family members and they are informed about any such untoward incident at the go.

http://www.engineersgarage.com/contribution/accident-detection-and-messaging-system-using-gsm-and-gps

How it Works

Accident Detection and Messaging System is easy and the components used are Vibration Sensor, which detects the accident and in turn sends the signals to Arduino. At this point the Arduino takes control and starts collecting the coordinates received from the GPS which are later sent to the Central Emergency Monitoring Station by using the GSM Module.

Internet Resources for Parts

Distributors

- Allied Electronics
- Arrow Electronics
- AVNET Electronics
- Digikey
- Edmund Scientific's
- Electronix Express
- Future Electronics
- Jameco Electronics
- Mouser Electronics
- Newark Electronics
- Radio Shack
- Sullivan Products (hobby products: wheels, ...)

Manufacturers

- Allegro MicroSystems Inc. (H-bridges, ...)
- Amp Incorporated (connectors: Pittman motor and encoder connectors, ...)
- Hamamatsu Co. (photo-optical systems: UV flame detector, ...)
- Molex (connectors)
- Motorola (HC12 microcontroller, ...)
- National Semiconductor (H-bridges, ...)
- Sharp Electronic Components Group (optical devices: GP2D12's, GP2D120's, ...)
- Sharp USA (microelectronics group)
- ST Microelectronics (H-bridges, ...)

Surplus

- All Electronics
- American Science & Surplus
- B.G. Micro
- C and H Sales Company
- Electronic Goldmine
- Herbach and Rademan
- Marlin P. Jones & Assoc. Inc.
- Mendelson's Electronics Co.

- Wirz Electronics (Robotics parts: An H-bridge design, IR tutorial, ...)

Parts Order
Select one member of your group to be in charge of purchasing. This person will submit the completed order forms to the IS&T secretary and maintain subsequent communication with her concerning the order.

IT 312 - Course Learning Objectives (*red ink*)/Outcomes mapped out for weekly lessons

	Course Learning Objectives/Outcomes mapped out for lessons	***LESSONS***														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	Explain the importance of navigation systems.	X														
2	Evaluate the levels of automated vehicles.	X														
3	List and discuss the abilities of an autonomous robots	X														
4	Describe how to prepare a nation for autonomous vehicles.	X														
5	Describe fundamental methods that most navigational techniques are based upon	X														
6	*Recognize* and *apply* laboratory safety procedures.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	*Explain* the principles of a navigation system.		X													
8	*Explain* the fundamentals of basic navigational mathematics.		X													
9	*Determine* the detailed kinematic relationships between the 4 major frames of interest		X													
10	Discuss the fundamental concepts of integrated navigation systems		X													
11	Explain the fundamentals of basic navigational mathematics.		X													
12	Demonstrate the understanding of basic navigation mathematical techniques		X													
13	Explain the coordinate frames and coordinate transformations supporting various driving functions.		X													
14	Explain the fundamental basics navigational mathematics.			X												
15	Demonstrate the understanding of the relationship between specific force, inertial acceleration, and gravitational attraction.			X												
16	Demonstrate the understanding of geometry of the earth			X												
17	Demonstrate the understanding of the types of			x												

	coordinates in the ECEF frames.															
18	Access the position vectors to the origin of the body frame			X												
19	Discus earth and gravity models			X												
20	Demonstrate the understanding of the relationship between specific force, inertial acceleration, and gravitational attraction.			X												
21	Demonstrate the understanding of mobile robot positioning.				X											
22	Demonstrate the understanding of mobile robot positioning with respect to Sensors and techniques applications.				X											
23	Discuss relative and absolute position measurements				X											
24	Explain the characteristics of relative and absolute position measurements.				X											
25	Describe the basics of performing INS computations					X										
26	Describe the integration of the inertial navigation system (INS) with other sensors.					X										
27	Discuss various examples of practical INS applications.					X										
28	Demonstrate the understanding of the current trends for practical applications of inertial navigation technology					X										
29	Apply INS computations to solve navigation problems.					X										
30	Identify INS limitations					X										
31	Specify inertial sensor characteristics for your application area.					X										
32	Explain the strategies for integrating inertial systems with other sensors.					X										
33	Describe the fundamentals of satellite navigation						X									
34	Explain the fundamentals of GPS						X									
35	Explain how to set up and operate the components of a mapping-grade GPS system						X									
36	Identify levels of GPS accuracy						X									
37	Describe the understanding of the fundamentals of GPS						X									
38	Practice the workflow of a typical GPS project						X									
39	Explore the integration of GPS with other technologies						X									
40	Identify sources of GPS errors						X									
41	Measure GPS accuracy						X									
42	Use differential GPS to increase accuracy						X									
43	Demonstrate understanding of the material covered by the learning outcomes in Lessons 1 through 6 on a mid-term exam.	X	X	X	X	X	X	X	X							
44	Demonstrate the ability to apply different Kalman filter (KF) techniques to combine noisy sensor									X						

	outputs to estimate the state of a system with uncertain dynamics.															
45	Apply KF to estimate the errors introduced into the unaided INS system due to gyros and accelerometers.									X						
46	Apply the different Kalman filter (KF) techniques to estimate the state of a system.									X						
47	Apply Kalman filter to combine noisy sensor outputs to estimate the state of a system with uncertain dynamics.									X						
48	Integrate the GPS with other sensors via a Kalman filter to improve navigation availability									X						
49	Apply Kalman filter to estimate the errors introduced into the unaided INS system due to gyros and accelerometers.									X						
50	Discuss the fundamentals of the integrated navigation system (INS).										X					
51	Describe the different INS/GNSS integration architectures.										X					
52	Discuss the fundamentals of the integrated navigation system (INS).										X					
53	Describe and compare the different integration architectures.										X					
54	Discuss state selection for INS/GNSS integration Kalman-filters.										X					
55	Describe system and measurement models.										X					
56	Discuss advanced INS/GNSS Integration and implementations.										X					
57	Describe different integration architectures											X				
58	Combine different navigation sensors for different applications.											X				
59	Explain the limitations of incorporating terrestrial radio navigation											X				
60	Differentiate between loosely coupled integration and tightly coupled integration.											X				
61	Explain what a dead-reckoning reference incorporates.											X				
62	Describe feature matching techniques											X				
63	Describe different integration architectures and their benefits and drawbacks											X				
64	Combine different navigation sensors for different applications based on the environment, dynamics, budget, accuracy requirements, and the degree of integrity required.											X				
65	Compare the different architectures that may be used to integrate measurements from three or more different navigation systems.											X				
66	Discus the integration issues related to navigation sensors.											X				
67	Explain the limitations of incorporating											X				

	terrestrial radio navigation															
68	Differentiate between loosely coupled integration and tightly coupled integration.											X				
69	Explain what a dead-reckoning reference incorporates.											X				
70	Describe feature matching techniques											X				
71	Discus the failure modes that can occur in navigation systems.												X			
72	Describe the certification that an integrity monitoring system fulfills.												X			
73	Discus the failure modes that can occur in navigation systems.												X			
74	Discuss fault detection through range checks												X			
75	Describe Kalman-filter innovation monitoring												X			
76	Describe integrity monitoring through direct consistency checks between quantities calculated from different combinations of measurements.												X			
77	Describe the certification that an integrity monitoring system fulfills.												X			
78	Demonstrate the understanding of robotic motion planning problems.													X		
79	Discuss collision avoidance methods.													X		
80	Demonstrate the understanding of robotic motion planning problems.													X		
81	Explain the difference between physical space and configuration space.													X		
82	Discuss collision avoidance methods.													X		
83	Explain the legal outlook for automated (autonomous) and connected cars.														X	
84	Explain the legal outlook for autonomous, automated, and connected cars.														X	
85	Describe the legal environment for first generation autonomous cars														X	
86	Demonstrate the understanding of how to pave the way for fundamental legal changes needed before the first generation autonomous cars will be permitted to operate on United State roadways.														X	
87	Demonstrate basic understanding of the material covered in the course.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

IT 312 - Course Content and Assignment Schedule – Summer 2016			
Wk	**Topics/Readings/Study** **Note: H_1 = Handout_1** **L_1 = Lecture_1**	**Assignments**	**Due Date**
Part I. Towards Autonomous Navigation and connected vehicles			
1 **7/13**	Overview of autonomous navigation and connected vehicles - Introduction to the history of autonomous and connected vehicles - Levels of vehicle automation - Differences between automated and autonomous vehicles - Preparing a nation for autonomous vehicles: i. Opportunities – potential benefits ii. Barriers to implementation, and iii. Policy recommendation. - Introduction to navigation	**Read:** **H_1 (p. 1 – 18)** **H_2 (p. 1 – 19)** **H_3** **H_4** **L_1A** **L_1B** **L_1C** **L_1D** (Groves 2008, CH 1, p. 1-15) ***Homework #1 assigned*** ***Group Assignment***	
Part II. Fundamentals of navigation systems			
2 **7/14**	Fundamentals of basic navigation mathematics a. Coordinate frames c. Transformation frames	***(Groves 2008, CH 2, p. 15 - 34)*** **L_2**	
3 **7/15**	Basic navigational Mathematics (continued) a. Earth surface and gravity models b. Frame transformation	***(Groves 2008, CH 2, p. 35 - 53)*** **L_3** ***Homework #1 due***	
4 **7/18**	Mobile robot positioning a. Overview of mobile robot positioning– Sensors and techniques b. Relative and absolute position measurements c. Characteristics of each category	**H_5** **H_6** **L_4** ***Test#1***	
5 **7/19**	Introduction to Inertial Sensors and Navigation Systems a. Inertial sensors i. Gyroscopes: Error and Characteristics ii. Accelerometers: Error and Characteristics b. Introduction to Inertial Navigation c. Inertial system equations d. Initialization and alignment e. INS Error propagation f. Platform INS	**H_7** **H_8** **L_5A** **L_5B** **Groves (2008), CH 4 & 5, p. 95 – 160*)*** ***Homework #2 assigned***	

6 **7/20**	Introduction to GPS a. Overview of Global Positioning System - Introduction to fundamentals of satellite navigation - Introduction to global Positioning System - Errors in GPS - Implementation of GPS Module	**H_7 (p. 15 – 19)** **H_9 (p. 212 – 249)** **L_6** **Groves (2008, CH 6 & 7, p. 161 – 277)** ***Homework #2 due***	
7 **7/21**	**Review for Mid-Term Exam** Review material from lesson 1 - 6		
8 **7/22**	**Mid-Term Exam** Material from lesson 1 – 6		
9 **7/23**	Introduction to Kalman filtering Techniques b. Overview of Kalman Filtering i. Discrete Kalman Filter ii. Kalman filter and navigation iii. Implementation of Kalman Filter Module	**H_7 *(p. 15 - 19)*** **H_9 *(p. 227 – 249)*** **H_10** **H_11** **H_12** **H_13** **L_9A** **L_9B** ***Groves (2008), Ch 3, p. 55 – 93***	
10 **7/25**	Introduction to integrated navigation systems a. INS/GNSS Integration b. Integration Architectures c. System Model and State selection d. Measurement models e. Advanced INS/GNSS Integration	**H_5** **H_14** **L_10** *Groves, P. (2008). CH 12, p. 361 - 406*	
11 **7/26**	Multisensor Integrated Navigation a. Integration Architectures and Measurement Models b. Dead Reckoning, Attitude, and Height Measurement c. Feature Matching	**H_9** ***(p. 291 – 305)*** **H_15** **L_11A** **L_11B** *Groves (2008, CH. 14, p. 419 – 448)* ***Homework #3 assigned***	
12 **7/27**	Fault detection and integrity monitoring a. Failure modes b. Range checks c. Kalman filter measurement innovations d. Direct consistency checks e. Certified integrity monitoring	**H_16** **H_17** **H_18** **H_19** **H_20** **L_12A** **L_12B** **L_12C** **L_12D** *Groves (2008, CH. 15, p. 451 – 469).*	
Part III Fundamentals of Autonomous Planning and Navigation in vehicles			

13 **7/28-30**	Competences for Navigation: Planning and Reacting a. Robotic motion planning problems. b. Difference between physical space and configuration space. c. Collision avoidance methods. d. Overview of Multiple-Robots	**H_9 (p. 257 – 291).** **H_21** **H_22** **L_13A** **L_13B** **L_13C** **L_13D** **L_13E** ***Project assigned/Team formation.*** *Test#2*	
Part IV. Legal Outlook, Challenges and Research Needs			
14 **8/1-3**	Legal outlook for autonomous, automated and connected cars a. Legal environment for first generation autonomous cars b. Legal outlook down the road c. Challenges and research needs: Technical, Human factors, Societal and Economic.	**H_2** ***(p. 19 – 53)*** **H_23 - 30** **Homework #3 due**	
15 **8/4-5**	Review for final examination and Project presentation a. Project presentation b. Review materials from 1 – 14		
16 **8/6**	***Final Examination*** a. Final review of materials with students b. Final examination		

Weekly Lesson Plans

Note: H_1 = Handout_1
L_1 = Lecture_1

Lesson Plan for week #1

Lesson 1: Introduction to navigation systems in connected and automated vehicles

Delivery Time: 180 minutes of lecture and 60 minutes of lab

Course Objective

1. Explain the importance of navigation systems.
2. Evaluate the levels of vehicle automation

Lesson Learning Outcomes

Following this lesson, the student will be able to:

3. List and discuss the abilities of an autonomous robots
4. Describe how to prepare a nation for autonomous vehicles.
5. Describe fundamental methods that most navigational techniques are based upon
6. *Recognize* and *apply* laboratory safety procedures.

Required Texts:

Groves, P. D. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems. Second Edition.
Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Groves (2008), CH 1, p. 1-15.
Handouts:

H_1 (p. 1 – 18)
H_2 (p. 1 – 19)
H_3
H_4
L_1A
L_1B
L_1C
L_1D

Homework #1 assigned

Group Assignment

Preparation and Setup

- Prepare a first day handout: course syllabus, Lab 1 – safety rules and regulations, Homework 1 – Lab handout and reading assignment.
- Prepare Lecture 1: Concept and the importance of navigation techniques used in automated (autonomous) and connected vehicles.
- Describe how to prepare a nation for autonomous vehicles.
- This lecture includes: 1) instructor introduction and qualifications, 2) discussion of First Day Handout, including course content, schedule, and grading policies, 3) assign reading of chapter in textbook, and, 4) lecture on:
    1. Concept and the importance of navigation techniques used in automated (autonomous) and connected vehicles.
    2. Preparing a nation for autonomous vehicles.
- Prepare Lesson 1 Quiz and a scoring rubric for the quiz. Alternatively, wait until the end of Lesson 2 and give a comprehensive quiz on Lessons 1 and 2.

Lesson Delivery

Topics Covered

1. Introduction to the course: Syllabus, structure, expectations, policies, and procedures
2. Overview of the concept and the importance of integrated navigation systems in automated and connected vehicles.
3. Classification of automated (autonomous) and connected vehicles
    a. NHTSA Levels of vehicle automation
    b. Difference between automated and autonomous vehicles
4. Preparing a nation for Autonomous vehicles
    a. Opportunities - Potential benefits
    b. Barriers to implementation
    c. Policy recommendation
5. Lab 1 is on personal, property and safety practices common to laboratories as well as customary transportation safety.

Read Handout: **Schwarz, C., et al. (2013, p. 1 – 13).**
Read Handout: Technology Assessments
Read Handout: Eno Center for transportation **(2013, p. 3 – 10).**
Homework #1 assigned
Group assignment

Lecture/Discussion

- Introduce yourself and review your qualifications; encourage students to introduce themselves, take notes during lectures, and ask questions anytime.
- Provide an overview of the topics to be covered in the course, the textbook to be used, and any online resources associated with the textbook.
- Discuss the concept and history of automated (autonomous) and connected vehicles.
- Discuss the levels of automations
- Discuss associated technical, social and ethical issues
- Introduce the fundamentals of integrated navigation systems
- Discuss Lab 1 on personal, property and safety practices common to laboratories as well as customary transportation safety.
- Define some basic terminologies needed in discussing automated and connected vehicles.
- Have students complete the Lab handout.
- Assign homework for Lesson 1. For this first week only, the homework is due at the end of the week. Alternatively, student may be able to complete the homework online.
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

- First day handout including syllabus, polices, procedures, and grading information.
- Homework from textbook for next week.
- Groves 2008, Ch. 1.
- Lab 1 on personal, property and safety practices common to laboratory.
- Lesson 1 Quiz.

Lab Activities

- Students gain experience on related laboratory safety procedure:
    - Lab 1 on personal, property and laboratory safety practices.
    - Students will learn to abide by safety practices common to laboratories as well as customary transportation safety.

Homework

Explain expectations and grading policy on the homework. Have the students complete the homework prior to the lecture, based on their reading of the textbook chapter and assigned handouts. This will reinforce the message in the chapter reading, prepare the students to better understand the lecture, and ask questions on things they did not understand.
Assign the following homework:

- Have students read chapter(s) and handouts on navigation techniques used in automated (autonomous) and connected vehicles.
- Lab 1 assignment is due at the end of Lesson 1.

Assessment

Learning Question 1

- **Question:** Evaluate the levels of vehicle automation
- **Assessment:** Lesson 1 Quiz.
- Evaluation: Score quiz using grading guidelines.

Learning Question 2

- **Question:** List five abilities of a fully autonomous robot
- **Assessment:** Lesson 1 Quiz.
- **Evaluation:** Score quiz using grading guidelines.

Learning Question 3

- **Outcome:** Recognize and apply laboratory safety procedures.
- **Assessment:** Student demonstration of safety practices in the laboratory.
- **Evaluation:** Verification (read, understood and signed) of course safety confirmation form.
- **Standard:** Successful signing the course safety confirmation form.

Lesson Plan for week #2

Lesson 2: Fundamentals of basic navigational mathematics

Delivery Time: 240 minutes of lecture

Course Objective

7. *Explain* the principles of a navigation system.
8. *Explain* the fundamentals of basic navigational mathematics.
9. *Determine* the detailed kinematic relationships between the 4 major frames of interest

Lesson Learning Outcomes

Following this lesson, the student will be able to:

10. Discuss the fundamental concepts of integrated navigation systems
11. Explain the fundamentals of basic navigational mathematics.
12. Demonstrate the understanding of basic navigation mathematical techniques
13. Explain the coordinate frames and coordinate transformations supporting various driving functions.

Required Texts:

Groves, P. D. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems. Second Edition.

Siegwart, R., Nourbakhsh, I. R., & Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Lesson Delivery

Topics Covered

1. Lesson 2 Quiz and Lab Activity Review.
2. Fundamentals of basic navigational mathematics
   d. Overview of basic navigational mathematics
   e. Coordinate frames
   f. Kinematics

Lecture/Discussion

- Introduce the basic navigational mathematics
- Discuss coordinate frames –ECI, ECEF, Local navigation frames, body frames other frames
- Discus Kinematics
- Discus Euler attitude,
- Discus coordinate transformation matrix
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

Groves (2008), Ch 2, p. 17 – 54.

- L_2
- Homework for Lesson 2.
- Lesson 2 Quiz.

Lab Activities

- Lab 1 on personal, property and laboratory safety practices.
    - Students will learn to abide by safety practices common to laboratories as well as customary transportation safety.

Homework

1. Students read textbook chapter(s) on Lesson 3.

Assessment

Learning Question 1

- **Question:** In what two ways can a coordinate frame may be defined?
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 2

- **Question:** List the kinetic quantities that involve three coordinate frames?
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #3

Lesson 3: Basic navigational mathematics (continued)

Delivery Time: 240 minutes of lecture

Course Objective

14. Explain the fundamental basics navigational mathematics.
15. Demonstrate the understanding of the relationship between specific force, inertial acceleration, and gravitational attraction.

Lesson Learning Outcomes

Following this lesson, the student will be able to:

16. Demonstrate the understanding of geometry of the earth
17. Demonstrate the understanding of the types of coordinates in the ECEF frames.
18. Access the position vectors to the origin of the body frame
19. Discus earth and gravity models
20. Demonstrate the understanding of the relationship between specific force, inertial acceleration, and gravitational attraction.

Required Texts:

Groves, P. D. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems. Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Lesson Delivery

Topics Covered

1. Lesson 3 Quiz and Lab Activity review.
2. Introduction to fundamentals of basic navigation mathematics
    a. The understanding of geometry of the earth
    b. Types of coordinates in the ECEF frames.
    c. Earth and gravity
    d. The relationship between specific force, inertial acceleration, and gravitational attraction.

Lecture/Discussion

- Demonstrate the understanding of geometry of the earth.
- Demonstrate the understanding of the types of coordinates in the ECEF frames.
- Discus earth and gravity
- Describe the relationship between specific force, inertial acceleration, and gravitational attraction.
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

- L_3
- Homework for Lesson 3.
- Read: Groves 2008, CH 2, p. 53 – 67.
- Lesson 3 Quiz.

Lab Activities

None.

Homework

2. Students read textbook chapter(s) on Lesson 4.

Assessment

Learning Question 1

- **Question:** A rotation may be represented using a quaternion, explain.
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 2

- **Question:** What is the essential feature of navigation mathematics?

- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #4

Lesson4: Mobile robot positioning

Delivery Time: 240 minutes of lecture

Course Objective

21. Demonstrate the understanding of mobile robot positioning.

Lesson Learning Outcomes

Following this lesson, the student will be able to:

22. Demonstrate the understanding of mobile robot positioning with respect to Sensors and techniques applications.
23. Discuss relative and absolute position measurements
24. Explain the characteristics of relative and absolute position measurements.

Required Texts:

Borenstein, et al. (2012). Mobile robot positioning– Sensors and techniques

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Handouts:

Mobile Robot Positioning-Sensors & Techniques (Borenstein, Everett, Feng, & Wehe).
Autonomous and advanced navigation techniques.
Borenstein, et al. (2012). Mobile robot positioning– Sensors and techniques
Sensing with autonomous mobile robots
Simple autonomous robot diagram

Lesson Delivery

Topics Covered

Lesson 4 Quiz and Lab Activity Review.
Mobile robot positioning

a. Overview of mobile robot positioning– Sensors and techniques
b. Relative and absolute position measurements
c. Characteristics of each category

Lecture/Discussion

- Introduce mobile robot positioning – sensors and techniques
- Discuss relative and absolute position measurements
- Discuss the characteristics of relative and absolute position measurements
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

- H_5
- H_6
- L_4A
- L_4B
- Homework for Lesson 4.
- Test#1

Lab Activities

None.

Homework

3. Students read textbook chapter(s) on Lesson 5.

Assessment

Learning Question 1

- **Question:** What two major groups can mobile robot positioning be categorized into?
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 2

- **Question:** What is the difference between systematic and non-systematic errors?
- **Assessment:** Quiz.

- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #5

Lesson 5: Introduction to Inertial navigation systems

Delivery Time: 240 minutes of lecture

Course Objective

25. Describe the basics of performing INS computations
26. Describe the integration of the inertial navigation system (INS) with other sensors.
27. Discuss various examples of practical INS applications.

Lesson Learning Outcomes

Following this lesson, the student will be able to:

28. Demonstrate the understanding of the current trends for practical applications of inertial navigation technology
29. Apply INS computations to solve navigation problems.
30. Identify INS limitations
31. Specify inertial sensor characteristics for your application area.
32. Explain the strategies for integrating inertial systems with other sensors.

Required Texts:

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Lesson Delivery

Topics Covered

1. Lesson 5 Quiz and Lab Activity Review.
2. Introduction to Inertial Sensors and Navigation Systems
    a. Inertial sensors

        i. Gyroscopes: Error and Characteristics
        ii. Accelerometers: Error and Characteristics
    b. Introduction to Inertial Navigation
        i. Inertial system equations
        ii. Initialization and alignment
        iii. INS Error propagation
        iv. Platform INS

Lecture/Discussion

- Describe the strategies for integrating inertial navigation systems (INS) with other sensors.
- Discuss various examples of practical INS applications with other navigation technologies.
- Demonstrate the understanding of basic INS computations.
- Describe INS error behavior and limitations
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

H_7 (p. 7 - 13)

H_8

L_5A

L_5B

Groves (2008), CH 4 & 5, p. 95 – 160*)*

Homework #2 assigned

Lesson 5 Quiz.

Lab Activities

None.

Homework

4. Students read textbook chapter(s) on Lesson 6.

Assessment

Learning Question 1

- **Question:** Inertial sensors that comprise of accelerometers and gyroscopes is commonly abbreviated to?
- **Assessment:** Quiz.

- **Evaluation:** Score quiz using prepared answer key.

Learning Question 2

- **Question:** Explain an inertial navigation system (INS)
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 3

- **Question:** What are the two processes that self-alignment is comprised of
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #6

Lesson 6: Introduction to Introduction to GPS

Delivery Time: 240 minutes of lecture

Course Objective

33. Describe the fundamentals of satellite navigation
34. Explain the fundamentals of GPS
35. Explain how to set up and operate the components of a mapping-grade GPS system
36. Identify levels of GPS accuracy

Lesson Learning Outcomes

Following this lesson, the student will be able to:

37. Describe the understanding of the fundamentals of GPS
38. Practice the workflow of a typical GPS project
39. Explore the integration of GPS with other technologies
40. Identify sources of GPS errors
41. Measure GPS accuracy
42. Use differential GPS to increase accuracy

Required Texts:

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Lesson Delivery

Topics Covered

1. Lesson 6 Quiz and Lab Activity review.
2. The fundamentals of satellite navigation
3. Introduction to Global Positioning System (GPS)
4. Fundamentals of GPS (GLONASS, Galileo, Beidou)

5. Regional and Augmentation Systems and System Compatibility
6. Errors in GPS
7. Implementation of GPS Module

Lecture/Discussion

- Introduce fundamentals of satellite navigation
- Introduce Global Positioning System (GPS)
- Discuss fundamentals of GPS (GLONASS, Galileo, Beidou)
- Describe Regional and Augmentation Systems
- Discuss errors in GPS
- Explain the implementation of GPS module
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

Groves (2008, CH 6 & 7, p. 161 – 277)

Siegward, et al. (p. 212 – 249)

H_7 (p. 15 –19)

H_9 (p. 212 – 249)

L_6

Homework #2 due

Homework for Lesson 6.
Lesson 6 Quiz.

Lab Activities

None.

Homework

5. Students read textbook chapter(s) on Lesson.

Assessment

Learning Question 1

- **Question:** What are the two navigation services offered by NAVSTAR GPS?
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 2

- **Question:** Describe the two main types of augmentations systems that supplement GPS with additional ranging signals?
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 3

- **Question:** What are the four navigation services offered by Galileo?
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #7

Lesson 7: Review for Midterm Examination/ Open lab

Delivery Time: 240 minutes of lecture

Course Objectives

1. Explain the importance of navigation systems.
2. Evaluate the levels of automated vehicles.
3. List and discuss the abilities of an autonomous robots
4. Describe how to prepare a nation for autonomous vehicles.
5. Describe fundamental methods that most navigational techniques are based upon
6. Recognize and apply laboratory safety procedures.
7. Explain the principles of a navigation system.
8. Explain the fundamentals of basic navigational mathematics.
9. Determine the detailed kinematic relationships between the 4 major frames of interest
10. Discuss the fundamental concepts of integrated navigation systems
11. Explain the fundamentals of basic navigational mathematics.
12. Demonstrate the understanding of basic navigation mathematical techniques
13. Explain the coordinate frames and coordinate transformations supporting various driving functions.
14. Explain the fundamental basics navigational mathematics.
15. Demonstrate the understanding of the relationship between specific force, inertial acceleration, and gravitational attraction.
16. Demonstrate the understanding of geometry of the earth
17. Demonstrate the understanding of the types of coordinates in the ECEF frames.
18. Access the position vectors to the origin of the body frame
19. Discus earth and gravity models
20. Demonstrate the understanding of the relationship between specific force, inertial acceleration, and gravitational attraction.
21. Demonstrate the understanding of mobile robot positioning.
22. Demonstrate the understanding of mobile robot positioning with respect to Sensors and techniques applications.
23. Discuss relative and absolute position measurements
24. Explain the characteristics of relative and absolute position measurements.
25. Describe the basics of performing INS computations
26. Describe the integration of the inertial navigation system (INS) with other sensors.
27. Discuss various examples of practical INS applications.
28. Demonstrate the understanding of the current trends for practical applications of inertial navigation technology
29. Apply INS computations to solve navigation problems.

30. Identify INS limitations
31. Specify inertial sensor characteristics for your application area.
32. Explain the strategies for integrating inertial systems with other sensors.
33. Describe the fundamentals of satellite navigation
34. Explain the fundamentals of GPS
35. Explain how to set up and operate the components of a mapping-grade GPS system
36. Identify levels of GPS accuracy
37. Describe the understanding of the fundamentals of GPS
38. Practice the workflow of a typical GPS project
39. Explore the integration of GPS with other technologies
40. Identify sources of GPS errors
41. Measure GPS accuracy
42. Use differential GPS to increase accuracy
43. Demonstrate understanding of the material covered by the learning outcomes in Lessons 1 through 6 on a mid-term exam.

Lesson Learning Outcomes

Following this lesson, the student will be able to:

43. Demonstrate their understanding of the material covered by the learning outcomes in Lessons 1 through 6 on a midterm exam.

Required Texts:

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Preparation and Setup

- Prepare a summary of the first six Lessons
- Return all graded homework, lab activities, and quizzes.
- Prepare a comprehensive mid-term exam covering the first seven lessons.
- Prepare Handouts/References.

Lesson Delivery

Topics Covered

1. Review Lesson 1 - 6 Quiz and Lab Activity.
2. Review for midterm examination.

Lecture/Discussion

- Review for midterm examination.
- Encourage students to ask questions on the review, and students should organize all returned materials and any handouts in preparation for the mid-term exam.
- Answer student questions on lecture topics.

Handouts/References

- Lesson 1 - 6 Quizzes.
- Read: Textbook chapter and handouts assigned for lesson 1 – 6.

Lab Activities

Work on assigned project

Homework

- Students read textbook chapter(s) on Lesson 1 – 6 and complete lab assignments.

Assessment

Learning Question

- **Question:** Demonstrate basic understanding of material covered in lessons 1 – 6.
- **Assessment:** Mid-term Exam.
- **Evaluation:** Score quiz using prepared answer key.
- **Standard: M**inimum score of 70%

Lesson Plan for week #8

Lesson 8: Midterm Examination

Delivery Time: 240 minutes of lecture

Course Objectives

1. Explain the importance of navigation systems.
2. Evaluate the levels of automated vehicles.
3. List and discuss the abilities of an autonomous robots
4. Describe how to prepare a nation for autonomous vehicles.
5. Describe fundamental methods that most navigational techniques are based upon
6. Recognize and apply laboratory safety procedures.
7. Explain the principles of a navigation system.
8. Explain the fundamentals of basic navigational mathematics.
9. Determine the detailed kinematic relationships between the 4 major frames of interest
10. Discuss the fundamental concepts of integrated navigation systems
11. Explain the fundamentals of basic navigational mathematics.
12. Demonstrate the understanding of basic navigation mathematical techniques
13. Explain the coordinate frames and coordinate transformations supporting various driving functions.
14. Explain the fundamental basics navigational mathematics.
15. Demonstrate the understanding of the relationship between specific force, inertial acceleration, and gravitational attraction.
16. Demonstrate the understanding of geometry of the earth.
17. Demonstrate the understanding of the types of coordinates in the ECEF frames.
18. Access the position vectors to the origin of the body frame
19. Discus earth and gravity models
20. Demonstrate the understanding of the relationship between specific force, inertial acceleration, and gravitational attraction.
21. Demonstrate the understanding of mobile robot positioning.
22. Demonstrate the understanding of mobile robot positioning with respect to Sensors and techniques applications.
23. Discuss relative and absolute position measurements
24. Explain the characteristics of relative and absolute position measurements.
25. Describe the basics of performing INS computations
26. Describe the integration of the inertial navigation system (INS) with other sensors.
27. Discuss various examples of practical INS applications.
28. Demonstrate the understanding of the current trends for practical applications of inertial navigation technology.
29. Apply INS computations to solve navigation problems.
30. Identify INS limitations
31. Specify inertial sensor characteristics for your application area.

32. Explain the strategies for integrating inertial systems with other sensors.
33. Describe the fundamentals of satellite navigation
34. Explain the fundamentals of GPS
35. Explain how to set up and operate the components of a mapping-grade GPS system
36. Identify levels of GPS accuracy
37. Describe the understanding of the fundamentals of GPS
38. Practice the workflow of a typical GPS project
39. Explore the integration of GPS with other technologies
40. Identify sources of GPS errors
41. Measure GPS accuracy
42. Use differential GPS to increase accuracy
43. Demonstrate understanding of the material covered by the learning outcomes in Lessons 1 through 6 on a mid-term exam.

Lesson Learning Outcomes

Following this lesson, the student will be able to:

43. Demonstrate understanding of the material covered by the learning outcomes in Lessons 1 through 7 on a mid-term exam.

Instructional Resources

Recommended Textbook(s)

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Preparation and Setup

- Prepare a summary of the first seven Lessons
- Prepare a comprehensive mid-term exam covering the first seven lessons.
- Administer mid-term examination.

Lesson Delivery

Topics Covered

1. Lesson 1 – 7 Review
2. Midterm exam

Lecture/Discussion

- Review the major topics in the first seven Lessons

- Encourage students to ask questions on the review, and students should organize all returned materials and any handouts in preparation for the mid-term exam.
- Administer the midterm exam.

Handouts/References

- Homework for Lesson 9.
- Midterm exam.

Lab Activities

None.

Online Component

- Post the summary review and midterm handout for Lesson 7 prior to class so the students can preview it.
- Post grades for homework, lab activities, and quizzes on the Blackboard.

Homework

- Students read textbook chapter(s) and handouts on Lesson 9 topics.

Assessment

Learning Outcome 43

- **Outcome:** Demonstrate basic understanding of the material covered in lessons 1 – 7.
- **Assessment:** Midterm exam.
- **Evaluation:** Score exam using prepared answer key.
- **Standard:** Minimum score of 70%.

Lesson Plan for week #9

Lesson 9: Introduction to Kalman Filtering Techniques

Delivery Time: 240 minutes of lecture

Course Objective

44. Demonstrate the ability to apply different Kalman filter (KF) techniques to combine noisy sensor outputs to estimate the state of a system with uncertain dynamics.
45. Apply KF to estimate the errors introduced into the unaided INS system due to gyros and accelerometers.

Lesson Learning Outcomes

Following this lesson, the student will be able to:

46. Apply the different Kalman filter (KF) techniques to estimate the state of a system.
47. Apply Kalman filter to combine noisy sensor outputs to estimate the state of a system with uncertain dynamics.
48. Integrate the GPS with other sensors via a Kalman filter to improve navigation availability
49. Apply Kalman filter to estimate the errors introduced into the unaided INS system due to gyros and accelerometers.

Required Texts:

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Lesson Delivery

Topics Covered

1. Lesson 9 Quiz and Lab Activity review.
2. Introduction to Kalman filtering Techniques
    a. Overview of Kalman Filtering techniques
    b. Discrete Kalman Filter
    c. Kalman filter and navigation
    d. Implementation of Kalman Filter Module

Lecture/Discussion

- Introduce Kalman filter-based estimation
- Discuss elements, steps and applications of the Kalman filter
- Discuss Kalman filter algorithm and models
- Discuss implementation issues
- Describe extensions to the Kalman Filter
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

H_7 (p. 15 - 19)
H_9 (p. 227 – 249)
H_10
H_11
H_12
H_13
L_9A
L_9B
Homework for Lesson 9.
Groves (2008), Ch 3, p. 55 - 93
Siegward, et al. (p. 212 – 249)
Lesson 9 Quiz.

Lab Activities

None.

Homework

- Students read textbook chapter(s) on Lesson 9.

Assessment

Learning Question 1

- **Question:** A common technique foe getting the best performance out of an error-state Kalman filter with a linearity approximation applied to the system model is called?
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 2

- **Question:** What are the three main ways to account for time-correlated measurement noise in a Kalman filter?
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 3

- **Question:** The Kalman filter is designed for real time applications. What is the Kalman smoother?
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #10

Lesson 10: Introduction to Integrated Navigation systems

Delivery Time: 240 minutes of lecture

Course Objective

50. Discuss the fundamentals of the integrated navigation system (INS).
51. Describe the different INS/GNSS integration architectures.

Lesson Learning Outcomes

Following this lesson, the student will be able to:

52. Discuss the fundamentals of the integrated navigation system (INS).
53. Describe and compare the different integration architectures.
54. Discuss state selection for INS/GNSS integration Kalman-filters.
55. Describe system and measurement models.
56. Discuss advanced INS/GNSS Integration and implementations.

Required Texts:

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Lesson Delivery

Topics Covered

1. Lesson 10 Quiz and Lab Activity review.
2. Fundamentals of the integrated navigation system (INS).
3. Integration architectures.
4. State selection for INS/GNSS integration Kalman-filters.
5. System and measurement models.
6. Advanced INS/GNSS Integration and implementations.

***Read handouts*:**
Groves, P. (2008). CH 12, p. 361 - 406
Introduction to integrated navigation systems
Mobile Robot Positioning-Sensors & Techniques (Borenstein, Everett, Feng, & Wehe)
Autonomous and advanced navigation techniques

Innovation: Getting closer to everywhere
Benefits of using a tactical-grade IMU for high-accuracy positioning
Read handout: self-driving and connected Cars: fooling sensors and Tracking drivers (Jonathan petit)
Read handout: Improving navigation for groups of autonomous guided vehicles
Read: Chapter 5 (Siegwart, et al., p. 250 - 257).

Lecture/Discussion

- Lesson 10 Quiz and Lab Activity review.
- Introduce the fundamentals of the integrated navigation system (INS).
- Describe and compare the different INS/GNSS integration architectures.
- Discuss state selection for INS/GNSS integration Kalman-filters.
- Describe system and measurement models.
- Discuss advanced INS/GNSS Integration and implementations.
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

H_5
H_14
L_10
Groves, P. (2008). CH 12, p. 361 - 406
Homework for Lesson 11.
Lesson 10 Quiz.

Lab Activities

None.

Homework

- Students read textbook chapter(s) on Lesson 10.

Assessment

Learning Question 1

- **Question:** Inertial navigation has a number of advantages. Name them.
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #11

Lesson 11: Multisensor Integrated Navigation

Delivery Time: 240 minutes of lecture

Course Objective

57. Describe different integration architectures
58. Combine different navigation sensors for different applications.
59. Explain the limitations of incorporating terrestrial radio navigation
60. Differentiate between loosely coupled integration and tightly coupled integration.
61. Explain what a dead-reckoning reference incorporates.
62. Describe feature matching techniques

Lesson Learning Outcomes

Following this lesson, the student will be able to:

63. Describe different integration architectures and their benefits and drawbacks
64. Combine different navigation sensors for different applications based on the environment, dynamics, budget, accuracy requirements, and the degree of integrity required.
65. Compare the different architectures that may be used to integrate measurements from three or more different navigation systems.
66. Discus the integration issues related to navigation sensors.
67. Explain the limitations of incorporating terrestrial radio navigation
68. Differentiate between loosely coupled integration and tightly coupled integration.
69. Explain what a dead-reckoning reference incorporates.
70. Describe feature matching techniques

Required Texts:

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Lesson Delivery

Topics Covered

1. Lesson 1 Quiz and Lab Activity review.
2. Multisensor Integrated Navigation
3. Integration Architectures and Measurement Models

4. Terrestrial radio navigation
5. Dead Reckoning, Attitude, and Height Measurement
6. Feature Matching

Read: Groves (2008, CH. 14, p. 419 – 429)
INS/GPS Integrated Architectures (Schmidt & Phillips, 2010)
Read: Chapter 6 (Siegwart, et al., p. 291 – 305)

Lecture/Discussion

- Introduce multisensor integrated navigation
- Describe and compare the different architectures that may be used to integrate measurements from three or more different navigation systems.
- Explain how to combine different navigation sensors for different applications based on the environment, dynamics, budget, accuracy requirements, and the degree of integrity required.
- Discus the integration issues related to navigation sensors.
- Introduce terrestrial radio navigation
- Explain what a dead-reckoning reference incorporates.
- Describe feature matching techniques
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

H_9 (p. 291 – 305)
H_15
L_11A
L_11B

- Groves (2008, CH. 14, p. 419 – 448)
- Homework #3 assigned
- Lesson 11 Quiz.

Lab Activities

None.

Homework

- Students read textbook chapter(s) on Lesson 12.

Assessment

Learning Question 1

- **Question:** Discus the benefits and drawbacks of these different integration architectures: least squared integration, cascaded, centralized, and federated architectures.
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #12

Lesson 12: Fault detection and integrity monitoring

Delivery Time: 240 minutes of lecture

Course Objective

71. Discuss the failure modes that can occur in navigation systems.
72. Describe the certification that an integrity monitoring system fulfills.

Lesson Learning Outcomes

Following this lesson, the student will be able to:

73. Discuss the failure modes that can occur in navigation systems.
74. Discuss fault detection through range checks.
75. Describe Kalman-filter innovation monitoring
76. Describe integrity monitoring through direct consistency checks between quantities calculated from different combinations of measurements.
77. Describe the certification that an integrity monitoring system fulfills.

Required Texts:

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Lesson Delivery

Topics Covered

1. Lesson 13 Quiz and Lab Activity review
2. Fault detection and integrity monitoring

    a. Failure modes
    b. Range checks
    c. Kalman filter measurement innovations
    d. Direct consistency checks
    e. Certified integrity monitoring

Lecture/Discussion

- Introduce fault detection and integrity monitoring
- Discus the failure modes that can occur in navigation systems.
- Discuss fault detection through range checks.
- Describe Kalman-filter innovation monitoring
- Describe integrity monitoring through direct consistency checks between quantities calculated from different combinations of measurements.
- Describe the certification that an integrity monitoring system fulfills.
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

H_16
H_17
H_18
H_19
H_20
L_12A
L_12B
L_12C
L_12D
Groves (2008, CH. 15, p. 451 – 469)
Homework for Lesson 12.
Lesson 12 Quiz.

Lab Activities

None.

Homework

- Students read textbook chapter(s) on Lesson 13.

Assessment

Learning Question 1

- **Question:** What are the four categories that GNSS failure modes can be divided into?
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 2

- **Question:** Describe the certification that an integrity monitoring system fulfills.
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #13

Lesson 13: Competencies for navigation

Delivery Time: 240 minutes of lecture

Course Objective

78. Demonstrate the understanding of robotic motion planning problems
79. Discuss collision avoidance methods.

Lesson Learning Outcomes

Following this lesson, the student will be able to:

80. Demonstrate the understanding of robotic motion planning problems.
81. Explain the difference between physical space and configuration space.
82. Discuss collision avoidance methods.

Required Texts:

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Lesson Delivery

Topics Covered

1. Lesson 13 Quiz and Lab Activity review
2. Robotic motion planning problems.
3. Difference between physical space and configuration space.
4. Collision avoidance methods.
5. Overview of Multiple-Robots

Lecture/Discussion

- Introduce robotic motion planning problems
- Explain the differences between physical space (where robots and humans operate in) and configuration space (where motion planning usually takes place).
- Discuss collision avoidance methods
    - Dynamic Window Approach
    - Reciprocal Velocity Obstacles
    - Potential Field methods.

- Overview of multiple robots
- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

H_9 (p. 257 – 291).
H_21
H_22
L_13A
L_13B
L_13C
L_13D
L_13E
Homework for Lesson 13
Project assigned/Team formation
Test #2

Lab Activities

None.

Homework

- Students read textbook chapter(s) on Lesson 14.

Assessment

Learning Question 1

- **Question:** Name the three different navigation data messages that GPS satellites broadcast
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #14

Lesson 14: Legal outlook and challenges for autonomous, automated and connected cars

Delivery Time: 240 minutes of lecture

Course Objective

83. Explain the legal outlook for automated (autonomous) and connected cars.

Lesson Learning Outcomes

Following this lesson, the student will be able to:

84. Explain the legal outlook for autonomous, automated, and connected cars.
85. Describe the legal environment for first generation autonomous cars.
86. Demonstrate their understanding of how to pave the way for some of the more fundamental legal changes needed before the first generation autonomous cars will be permitted to operate on United State roadways.

Required Texts:

Glancy, D. J. (2015). Legal outlook for autonomous, automated, and connected cars: A preview of first generation autonomous cars. Federation of Defense & Corporate Counsel Annual Meeting, Fairmont Banff Springs, CA.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356.

Lesson Delivery

Topics Covered

Lesson 14 Quiz and Lab Activity review.
Legal outlook and the challenges for autonomous, automated and connected cars

Legal environment for first generation autonomous cars
Legal outlook down the road
Challenges and research needs: Technical, Human factors, Societal and Economic.

Lecture/Discussion

- Introduce legal outlook and the challenges for autonomous, automated and connected cars.
- Discuss the legal environment for first generation autonomous cars.
- Discuss the legal outlook down the road
- Discuss the challenges and research needs: Technical, Human factors, Societal and Economic.

- Define any new terms.
- Answer student questions on lecture topics.

Handouts/References

- H_2 (p. 19 – 53)
- H_23 - 30
- Homework #3 due
- Homework for Lesson 14.
- Lesson 14 Quiz.

Lab Activities

None.

Homework

- Students read textbook chapter(s) on Lesson 14 and complete the end of chapter questions.
- ***Homework #3 assigned***

Assessment

Learning Question 1

- **Question:** Describe the legal outlook and the challenges for autonomous, automated and connected cars.
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 2

- **Question:** Discuss the challenges facing automated and connected vehicles with regard to the technical, human factors, societal and economic.
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Learning Question 3

- **Question:** Discuss the research needs on automated and connected vehicles with regard to the technical, human factors, societal and economic.
- **Assessment:** Quiz.
- **Evaluation:** Score quiz using prepared answer key.

Lesson Plan for week #15

Lesson 15: Review for the final Exam

Delivery Time: 240 minutes of lecture

Course Objective
Following successful completion of this course, the student will be able to:

87. Demonstrate basic understanding of the materials covered in the course.

Course Learning Outcomes:
Following successful completion of this course, students will be able to:

87. Demonstrate understanding of the material covered in the course.

Instructional Resources

Recommended Textbook(s):

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

All Handouts

Preparation and Setup

- Prepare to review material from previous lessons.
- Identify topics that may have confused students.
- Prepare Assessment tools, such as tests and related scoring guide.
- Review Lab Activities, Homework, and projects.
- Prepare Handouts/References
- Engage students in lab activities.

Lesson Delivery

Topics Covered

1. Review of the Sensors used in connected and automated vehicles course material for final exam.
2. Lab activities

Lecture/Discussion

- Briefly review the material covered in the previous Lessons.
- Focus on topics that have confused students throughout the course.
- Students should be encouraged to ask questions on the topics covered in the course.

Handouts/References

- Course review handout.

Lab Activities

Continue working on lab assignments.

Online Component

- Post the review handout prior to Lesson 15.

Homework

- Study for the comprehensive final exam.

Assessment

Learning Question 1

- **Question:** Demonstrate understanding of course learning outcomes on a comprehensive final exam.
- **Assessment:** Attendance at course review session.
- **Evaluation:** Answer questions and assess discussions about the course material.
- **Standard:** Students receive 100% for attending the review.

Lesson Plan for week #16

Lesson 16: Final Exam

Delivery Time: 240 minutes of lecture

Course Objective
Following successful completion of this course, the student will be able to:

87. Demonstrate basic understanding of the material covered in the course.

Course Learning Outcomes:
Following successful completion of this course, students will be able to:

87. Demonstrate basic understanding of the material covered in the course.

Instructional Resources

Recommended Textbook(s):

Groves, P. (2008). Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, Second Edition.

Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D. (2011). Introduction to Autonomous Mobile Robots, 2/ed., MIT Press, ISBN: 978-0262015356

Preparation and Setup

- Prepare Final Exam and related scoring guide.
- Review Lab Activities and Homework.
- Prepare Handouts/References.

Lesson Delivery

Topics Covered

1. Final exam.

Lecture/Discussion

- Administer final exam.

Handouts/References

None.

Lab Activities

None.

Online Component

- Post the first and second-half handouts Online, along with all of the lectures
- Instructor should post grades for final exam on the Blackboard.

Homework

None.

Assessment

Learning Questions

- **Questions:** Demonstrate basic understanding of the material covered in the course.
- **Assessment:** Final exam.
- **Evaluation:** Score exam using prepared answer key.
- **Standard:** Minimum score of 70%.