



MARYLAND APPLIED
GRADUATE ENGINEERING

On-Road Automated Vehicles (ENPM818Z)

Term: Fall/2026

Instructor: Zeid Kootbally

Pronouns: He/Him

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Email: zeidk@umd.edu

Office Hours: Appointments

Credits: 3

Course Dates: From Sep 3, 2026 - Dec 10, 2026

Course Times: Thursdays, 7 pm – 9:40 pm

Classroom: JMP 2121

Course Description

ENPM818Z is a graduate course on the software that makes on-road automated vehicles work. Across fourteen lectures it follows the autonomous driving stack end to end, from raw sensor data through perception, localization, prediction and planning to the control commands that move the vehicle, and then asks how those pieces fail and how the industry manages that risk.

The course is organized around a single running project. Teams of four students build an autonomous driving pipeline in the CARLA simulator across four cumulative group projects, then evaluate the completed system on scenarios it has never seen: urban intersections, highway merges, pedestrian crossings, adverse weather and construction zones. What is lectured in a given week is what the current project needs next.

The deep learning content is not decoration. GP2 carries the largest weight of the four projects because it requires training, evaluating and comparing two object detection architectures, YOLO and DETR, and deploying the chosen model as a ROS 2 node. Real time goes into data, training runs and quantitative comparison, not only into integration.

Prerequisites are ENPM605 or equivalent, for strong Python, object-oriented design and ROS 2 development, and ENPM673 or equivalent, for camera models, image processing, CNN fundamentals and state estimation. Familiarity with robotics kinematics and control theory is assumed, as are linear algebra, probability and calculus. Students arriving without ENPM673 should review CNN fundamentals before Lecture 4 and camera calibration before Lecture 2.

A note on what makes this course hard. The difficulty is rarely one difficult concept. It is the number of moving parts and the fact that four people have to make them work together on a three-week clock, four times in a row.

A note on pace. The course moves quickly and each week depends on the one before it. Students who fall behind in Week 3 usually feel it in Week 9. Anyone who begins to struggle should contact the instructor early rather than late.

Learning Outcomes

After successfully completing this course, students will be able to:

- Explain the architecture of a modern autonomous driving stack and justify where a given capability belongs within it.
- Configure and calibrate a multi-modal sensor suite in CARLA and build a ROS 2 pipeline that delivers synchronized sensor data to downstream components.
- Train, evaluate and compare deep learning object detection models, and deploy the selected model as a real-time ROS 2 perception node.
- Implement camera-LiDAR fusion and probabilistic localization, and quantify the accuracy of each against ground truth.
- Design and implement a planning and control layer, and evaluate the integrated pipeline on unseen driving scenarios using quantitative metrics.

Required Resources

- **Course website:** ELMS-Canvas (elms.umd.edu). Announcements, project submissions, quizzes and grades. Required.
- **Course documentation:** enpm818z-fall-2026-docs.readthedocs.io. Lecture notes, CARLA exercises, quizzes, the CARLA setup guide, pre-read material and the glossary. Required. Free.
- **Textbook:** None required, and nothing to buy. The reference list on each lecture page, the CARLA documentation at carla.readthedocs.io and the ROS 2 documentation are the primary sources.
- **Operating system:** Ubuntu 22.04 LTS or Ubuntu 24.04 LTS. Required. Note that CARLA 0.9.16 is officially built for Ubuntu 20.04 and 22.04. It runs on 24.04 for many users, but 24.04 is not an officially supported CARLA platform, so students who choose it should expect to resolve dependency problems themselves.
- **Simulator:** CARLA 0.9.16. Required. Free. Roughly 20 GB of disk space. Setup instructions are in the CARLA Simulator section of the course documentation.
- **Middleware:** ROS 2 Humble with Ubuntu 22.04, or ROS 2 Jazzy with Ubuntu 24.04. Required. Free.
- **Language and libraries:** Python 3.10 or newer, plus the deep learning stack named in the GP2 specification. Required. Free.
- **Editor and accounts:** Visual Studio Code and a GitHub account. Required. Free.
- **Hardware:** An NVIDIA GPU, GTX 1060 minimum and GTX 1070 or better recommended; a quad-core CPU; 8 GB of RAM minimum and 16 GB or more preferred; 20 GB of free disk space. Be aware that CARLA's own documentation recommends a GPU equivalent to an NVIDIA RTX 2070 or better with 8 GB of VRAM. A GTX 1060 will run the simulator but will run it slowly, and GP2 model training on 6 GB of VRAM will constrain batch size and training time. Students whose hardware falls short should contact the instructor early rather than in Week 5.
- **Total estimated cost of required course materials:** \$0.00

Setting up this environment is not optional preparation, it is the first thing the course depends on. Students should follow the CARLA Simulator and Pre-Read sections of the course documentation before the first lecture and contact the instructor if anything does not work.

Course Structure

The course meets in person once a week for a single long lecture on Thursdays. There are fourteen lectures. Week 15 has no class meeting; that slot is the submission window for the final report.

Each lecture has a companion page in the course documentation containing the lecture notes, CARLA exercises, a self-check quiz and references. The exercises are not graded, but they are the bridge between a lecture and the project code that depends on it, and they are best attempted in the days immediately after class.

The spine of the course is the team project. Teams of four students are formed in Week 2 and stay together for the semester, building one autonomous driving pipeline through four cumulative group projects of three weeks each, followed by a final report evaluating the integrated system. Because the projects are cumulative, a weakness left unresolved in one project is inherited by the next.

Two topics are assigned as pre-read rather than lectured. The development environment material is assumed from ENPM605 and should be read before Lecture 1, since every group project depends on it. The automotive cybersecurity material should be read before Lecture 14, which it supports.

Students should expect to spend roughly six to ten hours per week outside class, more during GP2, where the training runs themselves are largely unattended but the data preparation, evaluation and comparison are not. Time for environment and simulator problems should be built into that estimate rather than treated as an interruption to it.

Tips for Success in this Course

- **Participate.** I invite you to engage deeply, ask questions, and talk about the course content with your classmates. You can learn a great deal from discussing ideas and perspectives with your peers and instructor. Participation can also help you articulate your thoughts and develop critical thinking skills.
- **Manage your time.** Students are often very busy, and I understand that you have obligations outside of this class. However, students do best when they plan adequate time that is devoted to course work. Block your schedule and set aside plenty of time to complete assignments including extra time to handle any technology related problems.
- **Login regularly.** I recommend that you log in to ELMS-Canvas several times a week to view announcements, discussion posts and replies to your posts. You may need to log in multiple times a day when group submissions are due.
- **Do not fall behind.** This class moves at a quick pace and each week builds on the previous content. If you feel you are starting to fall behind, check in with the instructor as soon as possible so we can troubleshoot together. It will be hard to keep up with the course content if you fall behind in the pre-work or post-work.
- **Use ELMS-Canvas notification settings.** Pro tip! Canvas ELMS-Canvas can ensure you receive timely notifications in your email or via text. Be sure to enable announcements to be sent instantly or daily.
- **Ask for help if needed.** If you need help with ELMS-Canvas or other technology, IT Support. If you are struggling with a course concept, reach out to me and your classmates for support.

Policies and Resources for Graduate Courses

It is our shared responsibility to know and abide by the University of Maryland's policies that relate to all courses, which include topics like:

- Academic integrity
- Student and instructor conduct
- Accessibility and accommodations
- Attendance and excused absences
- Grades and appeals
- Copyright and intellectual property

Please reference and review the [Graduate School's Course Related Policies](#) and follow up with me if you have questions.

Course Guidelines

Names/Pronouns and Self-Identifications

The University of Maryland recognizes the importance of a diverse student body, and we are committed to fostering inclusive and equitable classroom environments. I invite you, if you wish, to tell us how you want to be referred to in this class, both in terms of your name and your pronouns (he/him, she/her, they/them, etc.). Keep in mind that the pronouns someone uses are not necessarily indicative of their gender identity. For more information about names and gender markers, visit the [LGBTQ+ Equity Center](#).

Additionally, it is your choice whether to disclose how you identify in terms of your gender, race, class, sexuality, religion, and dis/ability, among all aspects of your identity (e.g., should it come up in classroom conversation about our experiences and perspectives) and should be self-identified, not presumed or imposed. I will do my best to address and refer to all students accordingly, and I ask you to do the same for all of your fellow Terps.

Video or Audio Recording

Video or audio recording of class sessions, activities, or discussions is prohibited without advance permission from the instructor. Maryland is one of 11 U.S. states that require [two-party, or all-party, consent](#) before it is permissible to record or otherwise intercept and/or capture communications (such as phone calls, in-person conversations, video conferences). This means that everyone participating in a conversation must give their consent before any communication is recorded. Read this UMD article on [Audiovisual Recording](#) for more information.

Communication with Instructor

Email: If you need to reach out and communicate with me, please email me at zeidk@umd.edu. Please DO NOT email me with questions that are easily found in the syllabus or on ELMS (i.e. When is this assignment due? How much is it worth? etc.) but please DO reach out about personal, academic, and intellectual concerns/questions. While I will do my best to respond to emails within 24 hours, you will more likely receive email responses from me on Mondays, Wednesdays and Fridays from 8:00am-10:00am EST

ELMS: I will send IMPORTANT announcements via ELMS messaging. You must make sure that your email & announcement notifications (including changes in assignments and/or due dates) are enabled in ELMS so you do not miss any messages. You are responsible for checking your email and Canvas/ELMS inbox with regular frequency.

Communication with Peers

With a diversity of perspectives and experience, we may find ourselves in disagreement and/or debate with one another. As such, it is important that we agree to conduct ourselves in a professional manner and that we work together to foster and preserve a virtual classroom environment in which we can respectfully discuss and deliberate controversial questions. I encourage you to confidently exercise your right to free speech—bearing in mind, of course, that you will be expected to craft and defend arguments that support your position. Keep in mind, that free speech has its limit and this course is NOT the space for hate speech, harassment, and derogatory language. I will make every reasonable attempt to create an atmosphere in which each student feels comfortable voicing their argument without fear of being personally attacked, mocked, demeaned, or devalued.

Any behavior (including harassment, sexual harassment, and racially and/or culturally derogatory language) that threatens this atmosphere will not be tolerated. Please alert me immediately if you feel threatened, dismissed, or silenced at any point during our semester together and/or if your engagement in discussion has been in some way hindered by the learning environment.

Major Assignments

Final Project: Group Projects (GP1 to GP4)

- The central assessment of the course. Teams of four students build one autonomous driving pipeline in CARLA across four cumulative projects of three weeks each. Teams are formed in Week 2 and stay together for the semester.
- **GP1: Sensor Suite and Data Pipeline.** Posted September 10, due October 1. CARLA sensor configuration and the ROS 2 data foundation. 15 percent of the group-project portion, 10.2 percent of the course grade.
- **GP2: Perception, YOLO versus DETR.** Posted October 1, due October 22. Train, evaluate and compare two object detection architectures and deploy the chosen model as a ROS 2 node. 40 percent of the group-project portion, 27.2 percent of the course grade. This is the largest single component of the course.
- **GP3: Fusion and Localization.** Posted October 22, due November 12. Camera-LiDAR fusion and EKF localization. 25 percent of the group-project portion, 17 percent of the course grade.
- **GP4: Planning and Control.** Posted November 12, due December 10. Path planner, controller and decision logic. 20 percent of the group-project portion, 13.6 percent of the course grade.
- Collaboration within a team is expected on every part of these projects. Every team member is responsible for understanding the whole submission, not only the portion they wrote.
- Full specifications, rubrics and team assignments are posted on ELMS-Canvas and on ReadTheDocs.

Final Report and Evaluation

- Posted December 10, due December 17. 15 percent of the final project grade, 12 percent of the course grade.
- Teams evaluate the completed pipeline on instructor-provided scenarios that were not available during development: urban intersection navigation, highway merging with traffic, pedestrian crossing detection, adverse weather and construction zone navigation.
- Deliverables are the integrated pipeline, quantitative metrics across all scenarios, a written report of 8 to 10 pages, and peer evaluations.
- There is no class meeting in Week 15. That week is the submission window.

Quizzes

- Five quizzes, worth 20 percent of the course grade in total, given in Weeks 3, 6, 9, 11 and 14 (September 17, October 8, October 29, November 12 and December 10).
- Quizzes cover the preceding lectures and are individual work. They are short, and students who have kept up with the lectures and exercises are already prepared.
- Generative AI assistance is not permitted on quizzes.

Final Exam

- There is no final exam in this course. The final report and evaluation is the capstone assessment.

Grading Structure

Assignment	Percentage %
GP1: Sensor Suite and Data Pipeline	10.2%
GP2: Perception, YOLO versus DETR	27.2%
GP3: Fusion and Localization	17.0%
GP4: Planning and Control	13.6%
Final Report and Evaluation	12.0%
Quizzes (5)	20.0%
Total	100%

Academic Integrity

For this course, some of your assignments will be collected via Turnitin on our course ELMS page. I have chosen to use this tool because it can help you improve your scholarly writing and help me verify the integrity of student work. For information about Turnitin, how it works, and the feedback reports you may have access to, visit [Turnitin Originality Checker for Students](#).

The University's Code of Academic Integrity is designed to ensure that the principles of academic honesty and integrity are upheld. In accordance with this code, the University of Maryland does not tolerate academic dishonesty. Please ensure that you fully understand this code and its implications because all acts of academic dishonesty will be dealt with in accordance with the provisions of this code. All students are expected to adhere to this Code. It is your responsibility to read it and know what it says, so you can start your professional life on the right path. **As future professionals, your commitment to high ethical standards and honesty begins with your time at the University of Maryland.**

It is important to note that course assistance websites, such as CourseHero, are not permitted sources unless the instructor explicitly gives permission. Material taken or copied from these sites can be deemed unauthorized material and a violation of academic integrity. These sites offer information that might be inaccurate, and most importantly, relying on restricted sources will hamper your learning process, particularly the critical thinking steps necessary for college-level assignments.

Additionally, students may naturally choose to use online forums for course-wide discussions (e.g., Group lists or chats) to discuss concepts in the course. However, collaboration on graded assignments is strictly prohibited unless otherwise stated. Examples of prohibited collaboration include: asking classmates for answers on quizzes or exams, asking for access codes to clicker polls, etc. Please visit the [Office of Undergraduate Studies' full list of campus-wide policies](#) and reach out if you have questions.

Finally, on each exam or assignment you must write out and sign the following pledge: ***"I pledge on my honor that I have not given or received any unauthorized assistance on this exam/assignment."*** If you ever feel pressured to comply with someone else's academic integrity violation, please reach out to me straight away. Also, ***if you are ever unclear*** about acceptable levels of collaboration, ***please ask!*** To help you avoid unintentional violations, ***the following table*** lists levels of collaboration that are acceptable for each graded exercise. Each assignment will contain more specific information regarding acceptable levels of collaboration.

Permitted Resources and Collaboration by Assessment

Assessment	 OPEN NOTES	 USE BOOK	 LEARN ONLINE	 GATHER CONTENT With AI	 ASK FRIENDS	 WORK IN GROUPS
Final Project (GP1 to GP4 and Final Report)	✓	✓	✓	✓	✓	✓
Quizzes	✓	✓	✓	---	---	---

AI policy for this course

This is a course about artificial intelligence, so the policy has to separate two different things. Training, evaluating and deploying deep learning models such as YOLO and DETR is the coursework itself, and pretrained weights, public datasets and standard libraries are expected tools. What follows concerns generative AI assistants (TerpAI, ChatGPT, Claude, Gemini, GitHub Copilot and similar) used to produce the submitted work.

Permitted, with disclosure. On the group projects, the final report and the lecture exercises, generative AI assistants may be used to explain concepts, interpret errors, review code the team has already written, suggest debugging strategies and generate small illustrative examples. When such a tool has contributed to submitted code, analysis or prose, the submission must carry a short disclosure naming the tool and describing how it was used. Two or three sentences is enough. Disclosure carries no penalty. Undisclosed use is a violation of the Code of Academic Integrity.

Not permitted. Generative AI assistants may not be used during quizzes. Submitting generated code, results or written analysis that the team cannot read, explain and defend is not acceptable, and generated prose presented as the team's own analysis in the final report is plagiarism rather than assistance.

Reported results must be real. Every metric, plot and comparison in a submission must come from a run the team actually performed. Fabricated or model-invented numbers are a serious academic integrity violation, and they are straightforward to detect because they do not reproduce.

The standard applied. Every team member is responsible for the whole submission. The instructor may ask any member, in class or in office hours, to walk through any part of it: why it works, what would break it, and what would be changed. Work that cannot be explained does not count, regardless of whether it runs or how it was produced. This is the same standard a future employer will apply.

A caution worth taking seriously. These tools are strongest on the patterns most common on the public internet, and that body of code skews old. Confident answers using deprecated CARLA API calls, ROS 1 idioms and superseded model architectures should be expected. Anything a tool produces must be verified against the CARLA and ROS 2 documentation for the versions this course uses before it is relied upon.

Students unsure whether a particular use is permitted should ask the instructor before using it rather than after submitting.

[See the University of Maryland guidelines on Generative AI for Teaching & Learning](#) for more information

Grades

Final grades are computed from the weights shown in the Grading Structure table above: the four group projects total 68 percent of the course grade, the final report and evaluation 12 percent, and the five quizzes 20 percent.

Final letter grades include plus and minus descriptors and are assigned from the percentage of total points earned, using the cutoffs below.

All assessment scores are posted on the course ELMS-Canvas page as they are graded, so standing in the course can be tracked throughout the semester. Requests to review graded work, or questions about how something was scored, should be sent by email to the instructor, who will arrange a time to go through it.

Late work. Group projects and the final report are accepted up to 48 hours after the deadline with a 20 percent penalty, after which they are not accepted. Quizzes cannot be made up. Extensions are granted for documented excused absences under University policy, and the instructor should be contacted before a deadline rather than after it. Because each project builds on the one before it, a late submission also costs the team time on the next project.

Peer evaluation. Peer evaluations are collected with the final report and may be used to adjust individual grades within a team. A student who does not contribute does not receive the team's grade.

Regrade requests. A request to correct a score must be submitted in writing within one week of receiving the grade. Errors will be corrected immediately.

Final letter grades are assigned from the percentage of total points earned. Clear standards are applied consistently to every student, so being close to a cutoff is not the same as making the cut (89.99 is not 90.00). Exceptions are not made for some and not others.

Final Grade Cutoffs

Letter Grade	Cutoff
A+	97%
A	94%
A-	90%
B+	87%
B	84%
B-	80%
C+	77%
C	74%
C-	70%
D+	67%
D	64%
D-	60%
F	<60%

Course Outline

The schedule below maps each week to its lecture topic and the work due that week, including the pre-read deadlines. Lectures meet on Thursdays. There is no class during the Thanksgiving recess, and Week 15 has no lecture: that slot is the submission window for the final report.

Tentative Schedule

Week #	Topic	Deliverable
Before Sep 3	Pre-read: development environment (Ubuntu, ROS 2, Git, VS Code, shell)	Complete before the first lecture
1 (Sep 3)	L1: Course introduction and the AV landscape	Course and project overview
2 (Sep 10)	L2: Sensor technologies and calibration	Team formation; GP1 posted
3 (Sep 17)	L3: Probabilistic state estimation and fusion	Quiz 1
4 (Sep 24)	L4: Perception I, object detection (YOLO to DETR)	GP1 in progress
5 (Oct 1)	L5: Perception II, BEV, occupancy and segmentation	GP1 due; GP2 posted
6 (Oct 8)	L6: Perception III, tracking, temporal reasoning and deep fusion	Quiz 2
7 (Oct 15)	L7: Localization and SLAM	GP2 in progress
8 (Oct 22)	L8: Navigation and route planning	GP2 due; GP3 posted
9 (Oct 29)	L9: Prediction and behavior modeling	Quiz 3
10 (Nov 5)	L10: Motion planning	GP3 in progress
11 (Nov 12)	L11: Trajectory generation and control	Quiz 4; GP3 due; GP4 posted
12 (Nov 19)	L12: End-to-end driving, VLA and imitation learning	GP4 in progress
Nov 26	No class: Thanksgiving recess	No deliverable
13 (Dec 3)	L13: World models and simulation	Pre-read: automotive cybersecurity, complete before L14
14 (Dec 10)	L14: System integration, safety and industry outlook	Quiz 5; GP4 due; final report posted
15 (Dec 17)	No class: final report submission window	Final report due

Note: This is a tentative schedule, and subject to change as necessary. Monitor the course ELMS page for current deadlines. In the unlikely event of a prolonged university closing, or an extended absence from the university, adjustments to the course schedule, deadlines, and assignments will be made based on the duration of the closing and the specific dates missed.

Resources & Accommodations

Accessibility and Disability Services

The University of Maryland is committed to creating and maintaining a welcoming and inclusive educational, working, and living environment for people of all abilities. The University of Maryland is also committed to the principle that no qualified individual with a disability shall, on the basis of disability, be excluded from participation in or be denied the benefits of the services, programs, or activities of the University, or be subjected to discrimination. The [Accessibility & Disability Service \(ADS\)](#) provides reasonable accommodations to qualified individuals to provide equal access to services, programs and activities. ADS cannot assist retroactively, so it is generally best to request accommodations several weeks before the semester begins or as soon as a disability becomes known. Any student who needs accommodations should contact me as soon as possible so that I have sufficient time to make arrangements.

For assistance in obtaining an accommodation, contact Accessibility and Disability Service at 301-314-7682, or email them at adsfrontdesk@umd.edu.

Emergency Preparedness

Emergencies on campus can happen at any time. To prepare, visit prepare.umd.edu or use the emergency symbol in the UMD App to review information. Resources for persons with disabilities are available on the [emergency preparedness page of the ADA Coordinator's website](#).

Student Resources and Services

Taking personal responsibility for your own learning means acknowledging when your performance does not match your goals and doing something about it. I hope you will come talk to me so that I can help you find the right approach to success in this course, and I encourage you to visit [UMD's Student Academic Support Services website](#) to learn more about the wide range of campus resources available to you.

In particular, everyone can use some help sharpening their communication skills (and improving their grade) by visiting [UMD's Writing Center](#) and schedule an appointment with the campus Writing Center.

You should also know there are a wide range of resources to support you with whatever you might need ([UMD's Student Resources and Services website](#) may help). If you feel it would be helpful to have someone to talk to, visit [UMD's Counseling Center](#).

Basic Needs Security

If you have difficulty affording groceries or accessing sufficient food to eat every day, or lack a safe and stable place to live, please visit [UMD's Division of Student Affairs website](#) for information about resources the campus offers you and let me know if I can help in any way.

Veteran Resources

UMD provides some additional support to our student veterans. You can access those resources at the office of [Veteran Student life](#) and the [Counseling Center](#). Veterans and active duty military personnel with special circumstances (e.g., upcoming deployments, drill requirements, disabilities) are welcome and encouraged to communicate these, in advance if possible, to the instructor.

Notice of Mandatory Reporting

Notice of mandatory reporting of sexual assault, sexual harassment, interpersonal violence, and stalking: As a faculty member, I am designated as a "Responsible University Employee," and I must report all disclosures of sexual assault, sexual harassment, interpersonal violence, and stalking to UMD's Title IX Coordinator per University Policy on Sexual Harassment and Other Sexual Misconduct.

If you wish to speak with someone confidentially, please contact one of UMD's confidential resources, such as [CARE to Stop Violence](#) (located on the Ground Floor of the Health Center) at 301-741-3442 or the [Counseling Center](#) (located at the Shoemaker Building) at 301-314-7651.

You may also seek assistance or supportive measures from UMD's Title IX Coordinator, Angela Nastase, by calling 301-405-1142, or emailing titleIXcoordinator@umd.edu.

To view further information on the above, please visit the [Office of Civil Rights and Sexual Misconduct](#).

Course Evaluation

Please submit a course evaluation through Student Feedback on Course Experiences in order to help faculty and administrators improve teaching and learning at Maryland. All information submitted to Course Experiences is confidential. Campus will notify you when Student Feedback on Course Experiences is open for you to complete your evaluations at the end of the semester. Please go directly to the [Student Feedback on Course Experiences](#) to complete your evaluations. You may access the evaluation reports for courses for which 70% or more students submitted their evaluations.

Copyright Notice

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