



Underwater Robot Perception (ENPM808E)

Sections 101, R001

Term: Spring 2024

Professor: Dr. Shahriar Negahdaripour

Pronouns: he/him

Email: segahdaripour@umd.edu

Office Hours: Tues (or Wed) 12:00-3:00pm¹

Thurs 12:00PM-3:00PM (and by appointment with
24-hour advance arrangement)

Credits: 3

Course Dates: From Jan 24, 2024 - May 17, 2023

Course Times: Thursday 4:00-6:40PM

Classroom: JMP 2216

Teaching Assistant: TBD

Pronouns: ###

Email: ###

Office Hours: ###

Canvas/ELMS: TBD

Course Description

The course deals with robot perception in marine environments, exploring how to address 2 key questions:

- 1) positioning and navigation: where am I, where to go and how?
- 2) terrain mapping: building 2-D/3-D visual record of surrounding environment or individual 3-D objects.

These generic issues are also encountered by terrestrial and aerial robots, but marine environments pose unique challenges. Among them, turbidity limits visibility range of optical imaging systems - key sensors commonly employed by land robots - leading to deterioration of visual information in underwater images. The course explores the application of various computer vision techniques to images of 2-D forward-look sonar systems (or through integration with information from optical images). It is shown that the same sonar projection geometry applies to certain 2-D radar imaging devices, allowing their utilization for autonomous driving cars.

Prerequisites

1. ENPM673: Perception for Autonomous Robots;
2. Basic Knowledge of Matlab is recommended in order to write scripts utilizing key functions within Computer Vision Toolbox for fundamental CV methods. However, students are free to use any other resource of their choice, including but not limited OpenCV.

Learning Outcomes

Upon successful completion of the course and the understanding of key underlying concepts, the students would be able to:

- Analyze 3D-to-2D projection geometries of optical and sonar imaging in terms of ambiguities, visual cues and relationship to selected reconstruction problems (trade-offs, advantages, and shortcomings);
- Perform feature detection (corners, edges, circles);

¹ First period (Tues. or Wed.) will be finalized after the first class based on students' availability. Students **MUST** provide **advanced notification by 9am of the**

same day that they plan to attend the office hour in the afternoon. I may not be found in my office, if you stop by without the required advanced notice.

- Apply image transformation techniques for optical and sonar modalities;
- Analyze advantages in integration of visual cues from optical and sonar images modality in key application: object tracking, target classification, and 3-D reconstruction;
- Apply 3-D object reconstruction techniques using a single 2-D imaging sonar, sonar stereo, and opti-acoustic (integration of optical and sonar) stereo imaging;
- Perform visual motion analysis from video sequences;
- Explain how computer vision methods for optical images may be adapted to process sonar images.

Course Materials

The course has no assigned textbook, however, students will use the following resources:

- posted material on the course website, comprising of lecture slides and monograph document covering instructor’s own research work on various topics (also available online as published scientific manuscripts);
- references to other technical manuscripts describing other methods and approaches (available online);
- suggested supplementary computer vision textbooks as references:
 1. Computer Vision: Algorithms and Application, Richard Szeliski Online: <http://szeliski.org/Book/>
 2. Multiple View Geometry in Computer Vision, Richard Hartley and Andrew Zisserman University Press, 2004;
 3. Visual 3D Modeling from Images, Marc Pollefeys (Tutorial Notes) (<https://inst.eecs.berkeley.edu/~ee290t/fa11/tutorial.pdf>)
 4. CV Models, Learning, and Inference, Simon J.D. Prince (<http://web4.cs.ucl.ac.uk/staff/s.prince/book/book.pdf>);
 5. <https://www.youtube.com/user/ttttamaki/videos>
 6. Matlab Image Processing and Computer Vision Toolboxes

Course Structure

This course includes both on-campus and online sections. To attend synchronously online, log into ELMS-Canvas at the time of the Section 0101 class (Thursdays 4pm-6:40pm in JMP 2216) and select “Video Conference” from the left side menu. This will open a Zoom link to the live classroom.

For asynchronous online students, all lectures are recorded and made available on ELMS-Canvas under “Panopto Recordings/Video Lectures” within 24 hours of class time. Be sure to review the recorded lecture in a timely manner.

On-campus students come to class prepared to engage with the lecture and materials. Online students, be sure to log into Canvas regularly and participate in discussions and activities. Regardless of the section you are enrolled in, participation is expected.

Please note that F1 students enrolled in the on-campus section are required to attend in person. If you have a conflict on a particular day, please reach out to me in advance to discuss.

Communication Guidelines

Communicating with the Instructor

My goal is to be readily available to you throughout the semester. I am primarily reached at snegahda@umd.edu (by email). Please DO NOT email me with questions that are easily found in the syllabus or on ELMS-Canvas (e.g., When is this assignment due? How much is it worth? etc.), but please DO reach out about personal, academic, and intellectual concerns/questions.

When constructing an email to me, please put “ENPM 808E (Section 0101): your topic” in the subject line. This will draw my attention to your email and enable me to respond to you more quickly. On week days from 9:00am to 5:00pm EST, you will more likely receive email responses from me within an hour or two. At other times, a response can be expected within 24 hours. If I do not respond within these time frames, I may have not received your message, for some reason. Feel free to resend and include “(resend)” after your topic.

Additionally, please review [These tips for 'How to email a Professor'](#). By following these guidelines, you will be ensured to receive a timely and courteous response.

Finally, if you need to discuss issues not appropriate for the classroom and/or an email, we can arrange to talk by phone, over Zoom, or in person. Send me an email asking for a meeting and we can set something up.

Announcements

I will send IMPORTANT messages, announcements, and updates through ELMS-Canvas. To ensure you receive this information in a timely fashion, make sure your email and announcement notifications (including changes in assignments and/or due dates) are enabled in ELMS-Canvas ([How to change notification settings in CANVAS](#)).

Log in to our ELMS-Canvas course site at least once every 24-hour period to check your inbox and Announcements page.

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. Visit trans.umd.edu to learn more.

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.

Communicating with your 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.

Netiquette Policy

Netiquette is the social code of online classes. Students share a responsibility for the course's learning environment. Creating a cohesive online learning community requires learners to support and assist each other. To craft an open and interactive online learning environment, communication has to be conducted in a professional and courteous manner at all times, guided by common sense, collegiality and basic rules of etiquette.

Grading

Grade Breakdown

Assignment	Points
Bi-Weekly Projects (4-5)	75
Term Project (1)	25
Extra Credit Opportunities	25
Total	125

Course Assignments

The course (biweekly and term) projects are to be completed by teams of 3-4 students, to be established during the first week of the course. While each team will submit a single project report, it is expected that all team members make roughly equal contributions, both to the entire work towards completion of the assignment and the written report. I reserve the right to randomly select and question any one or all members of various teams on the technical content, results, or any other aspect of the work. To ensure fairness, the discussions may be recorded for later review and grade adjustment, if necessary.

Bi-Weekly (Matlab) projects

- To give students practical experience with the theoretical concepts and methodologies presented during lectures, generally utilizing distributed data.

- Being the first-time offering of the course and due to diverse students' backgrounds, details and deliverables of biweekly projects will be finalized, when each project is assigned. Selecting of either all or 4 (out of 5 topics) from the following list provides flexibility and feasibility to extend the duration of one or two projects, where suitable.
 - Analysis/comparison of featured detection in optical and sonar images;
 - 2-D image transformations and registration;
 - single camera and opt-acoustic stereo calibration;
 - visual motion analysis;
 - multiple-view 3-D reconstruction, using sonar only or integrated opti-acoustic cues;
- Matlab is the recommended programming environment, but students are free to select other means to complete each project.

Term Project

- Opportunity to apply knowledge gained during the entire course to explore practical applications, capabilities, or alternative approaches. Alternatively, teams can explore and compare 3 or more different solutions/approaches to a particular problem through computer implementation, experimentation, and analysis of the results. In either case, a key component demonstrating deep understanding of relevant concepts is the collection of suitable data for the experimental component of the project.
- Topics are selected by each team (but must be approved for feasibility and suitability to the course).
- Each project requires brief 5-minute presentation to inform the entire class of proposed work, and 15-minute presentation (plus Q&A) of completed work (on final class day).

Extra Credit Opportunities:

- *Creative Component 10-12.5 pnts*: Biweekly projects provide opportunity for creative component(s), where teams present results from exploring non-trivial issues beyond explicitly assigned tasks. To promote highest level of creativity, top 3 teams with best contributions receive 2.5, 1 and 0.5 pnts (for max. total 10-12.5 pnts over 4/5 projects).
- *Quizzes (12.5-15 pnts)*: Lectures will start with a 15-minute quiz, testing students on concepts from past lecture(s). In some cases, this involves listing *the steps* in coding a particular task. Students registered for asynchronous online attendance *may be* given a different quiz.

Grading of Assignments

All assignments will be graded according to a predetermined set of criteria (i.e., rubric) which will be communicated to students before the assignment is submitted.

To progress satisfactorily in this class, students need to receive timely feedback. To that end, we intend to grade all assignments *generally within one week of their due date, and no later than two weeks in rare occasion(s)*. In the highly unlikely event that an assignment would take any longer to grade, students will be informed of why and when they can expect to see their grade.

Grade Computation

All assessment scores will be posted on the graded report and/or ELMS/Canvas page. If you would like to review any of your grades (including the exams), or have questions about how something was scored, please email me to schedule a time for us to meet and discuss.

You will submit your work electronically by the deadline listed in the syllabus, and/or assignment sheet, and/or on ELMS-Canvas. Late work will be penalized according to the late work policy described in the **Course Policies and Procedures** section below.

Grade Disputes: I am happy to discuss any of your grades with you, and if a mistake has been made, I will immediately correct it. Any formal grade disputes must be submitted in writing and within one week of receiving the grade.

What you learn in this course should take precedence over other means of performance assessment. However, the aim is to ensure high correlation between students' degree of learning and their final grade. With possible minimal adjustment, where necessary to ensure fairness*, the following grades will be assigned based on final scores (out of **maximum possible 125 points**):

Final Grade Cutoffs									
+	115 pnts	+	100 pnts	+	85 pnts	+	70 pnts	+	
A	110 pnts	B	95 pnts	C	80 pnts	D	65 pnts	F	<60 pnts
-	105 pnts	-	90 pnts	-	75 pnts	-	60 pnts	-	

*Establishing grade boundaries is not science. Separation by small differences above and below a boundary grade (say, 100.1 and 99.9) should not lead to different grades (B+ and B). This is one example where adjustment to the above schedule may become necessary.

Course Schedule

<u>Week</u>	<u>TOPIC</u>	<u>ASSIGNMENT and DUE DATE</u>
01: (1/22/2023)	Course Overview; Review of Background Material from 673; Mathematical Tools Linear algebra - LS Estimation; Eigen Decomposition; SVD Optical Image Projection Homogeneous Coordinates	
02: (1/29/2023)	Feature Detection; Hough transform and detection of structural features point, line and edge detection Hough transform detection of lines, circles and structural features.	
03: (2/05/2023)	Intrinsic Parameters and Calibration Perspective projection and camera intrinsic parameters; impact of parameter accuracy sonar projection and parameters intrinsic sonar calibration	Project 1 (Feature Detection); two-week duration, due 2/05/23 - 15%
04: (2/12/2023)	Image Transformations Projective, affine, Euclidean and Similarity Transformations and Computations sonar image transformation	

	optical-to-sonar & sonar-to-optical transformations (application to opti-acoustic stereo)	
05: (2/19/2023)	Opti-Acoustic Stereo Imaging and Calibration epipolar geometry of calibrated stereo, and application to opti-acoustic stereo reconstruction performance assessment Calibration	
06: (2/26/2023)	Opti-Acoustic Stereo Imaging Appl's: Tracking, Classification & Reconstruction correspondence problem reconstruction and application to image Enhancement coincident cameras and reconstruction of occluding boundaries	Project 2 (Transformations, intrinsic and opti-acoustic stereo calibration); three-week duration, due 2/26/23 - 20%
07: (3/04/2023)	Visual Motion (1)	
08: (3/18/2023)	Visual Motion (2) sonar video and 3-D reconstruction opti-acoustic motion sequences and bundle adjustment	Project 3 (2-D motion estimation); 3.5-week duration, due 3/21/23 - 20%
09: (3/25/2023)	Shape from Shading & 3-D Reconstruction from Single/Multiple Image(s) reflectance map - optical images reconstruction from single image and photometric stereo reconstruction from sonar image	
10: (4/01/2023)	Sonar Stereo epipolar geometry ambiguous and ideal configurations reconstruction from sonar stereo	
11: (4/08/2023)	Multi-View Geometry (1) reconstruction from optical views reconstruction from sonar views - space carving	
12: (4/15/2023)	Multi-View Geometry (2) and Term Proj Presentations (1) 5-minute presentation of term projects reconstruction from sonar views - shadow boundaries & other methods	Project 4 (Matching and Stereo 3-D reconstruction); 3.5-week duration, due 4/15/23 - 20%
13: (4/22/2023)	Selected topics	
14: (4/29 /2023)	Selected topics	
15: (5/06 /2023)	Term Proj Final Presentations (2)	
16: (5/13/2023)		Term Project; 4-week duration, due 5/13/23 - 25%

Note: This is a tentative schedule, and subject to change as necessary – monitor ELMS-Canvas 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.

Course Policies and Procedures

The University of Maryland's conduct policy indicates that course syllabi should refer to a webpage of course-related policies and procedures. For a complete list of graduate course related policies, visit the [Graduate School website](#). Below are course-specific policies and procedures which explain how these Graduate School policies will be implemented in this class.

Satisfactory Performance

The Graduate School expects students to take full responsibility for their academic work and academic progress. The student, to progress satisfactorily, must meet all the academic requirements of this course. Additionally, each student is expected to complete all readings and any preparatory work before each class session, come to class prepared to make substantive contributions to the learning experience, and to proactively communicate with the instructor when challenges or issues arise.

Questions about Assignments

Please ask all of your questions about an assignment as early as possible but by no later than **2:00pm two days prior** to assignment is due. Any question after this deadline may not receive a timely response to enable proper changes to your work.

Late Work Policy

Assignments (project reports) should be completed by the due date and time listed with the assignment, on the syllabus, and/or in the course calendar. If you are unable to complete an assignment by the stated due date, it is your responsibility to discuss an extension with me, at least 48 hours BEFORE the assignment is due. Extensions are not guaranteed, will be rare and up to the instructor's discretion.

Unless deadline is extended to the entire class, late project report submissions are accepted up to 24 hours delay with 20% penalty. No credit is given beyond extended deadline.

Religious Observance

It is the student's responsibility to inform the instructor of any intended absences for religious observances in advance. Notice should be provided as soon as possible but no later than the end of the schedule adjustment period.

Academic Integrity

For this course, *some of your assignments will be collected via Turnitin on ELMS/Canvas*. I have chosen to use this tool because it can help you improve your scholarly writing and help me verify the integrity of students' 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, or AI generated content 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 or biased 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 among teams on any project is strictly prohibited unless otherwise stated**. Examples of prohibited collaboration include: asking classmates for answers on quizzes, asking for access codes to clicker polls, etc. Please visit the [Office of Graduate Studies' full list of campus-wide policies](#) and reach out if you have questions.

Finally, on each quiz or project report, you must write out the following pledge: **"I pledge on my honor that I have not given or received any unauthorized assistance on this quiz/assignment,"** which is signed by all team members.

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, **you must ask!**

To help you avoid unintentional violations, **the following table** lists levels of collaboration that are acceptable for each graded work. Each assignment will contain more specific information regarding acceptable levels of collaboration.

	 OPEN NOTES	 USE BOOK	 LEARN ONLINE	 GATHER CONTENT With AI	 ASK FRIENDS	 WORK IN GROUPS
Quizzes	✓	---	✓	---	---	---
Biweekly Projects	✓	✓	✓	---	---	✓
Term Project	✓	✓	✓	---	---	✓

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. By completing all of your evaluations each semester, you will have the privilege of accessing through Testudo the evaluation reports for the thousands of courses for which 70% or more students submitted their evaluations.

Copyright Notice

Course materials are copyrighted and may not be reproduced for anything other than personal use without written permission.

Tips for Succeeding in this Course

1. **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 professor. Participation can also help you articulate your thoughts and develop critical thinking skills.
2. **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.
3. **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.
4. **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.
5. **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.
6. **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.

Student Resources and Services

Taking personal responsibility for your 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 the [Counseling Center's Academic Resources](#) to learn more about the wide range of resources available to you. Below are some additional resources and services commonly used by graduate students. For a more comprehensive list, please visit the Graduate School's [Campus Resources Page](#).

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. Information about [sharing your accommodations with instructors, note taking assistance](#) and more is available from the [Counseling Center](#).

Writing Center

Everyone can use some help sharpening their communication skills (and improving their grade) by visiting [The Graduate School's Writing Center](#) and schedule an appointment with them. Additionally, international graduate students may want to take advantage of the Graduate School's free [English Editing for International Graduate Students \(EEIGS\) program](#).

Health Services

The University offers a variety of physical and mental health services to students. If you are feeling ill or need non-emergency medical attention, please visit the [University Health Center](#).

If you feel it would be helpful to have someone to talk to, visit [UMD's Counseling Center](#) or [one of the many other mental health resources on campus](#).

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's](#) website at ocrsm.umd.edu.

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 supports 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.