PURDUE UNIVERSITY | College of Engineering

Engineering Faculty Document No. **87-24]**
February 9, 2024

TO: The Engineering Faculty

FROM: The Faculty of the Lyles School of Civil Engineering

RE: New graduate course – CE 50502: UAS-based LiDAR Mapping

The Faculty of the Lyles School of Civil Engineering has approved the following new graduate course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM:

CE 59700 UAS-based LiDAR Mapping, 1 credit

Spring 2024 (16), Spring 2022 (11)

No Prerequisites

TO:

CE 50502: UAS-based LiDAR Mapping, Spring

One total credit

Prerequisite: CE 50500 UAS-Based Mapping: Basic Principles

Course Description: This 1-credit module covers the principles and mathematical details of laser scanning-based 3D reconstruction using ranging sensors onboard UAVs.

RATIONALE:

The continuous developments in direct georeferencing (i.e., integrated Global Navigation Satellite Systems – GNSS – and Inertial Navigation Systems – INS) and remote sensing (i.e., passive and active imaging sensors in the visible and infrared range – RGB cameras and laser scanning) technologies are providing the professional geospatial community with ever-growing opportunities to provide accurate 3D information with rich set of attributes. These advances are also coupled with improvement in the sensors' performance, reduction in associated cost, and miniaturization of such sensors. Aside from the sensing systems, we are also enjoying the emergence of promising platforms such as Unmanned Airborne Vehicles (UAVs). UAVs equipped with consumer-grade imaging/ranging sensors and direct georeferencing systems have been proven as a potential remote sensing platform that could satisfy the needs of a wide range of civilian applications. The advantages of UAV-based mapping can be attributed to the following facts: a) they can fly at lower elevation and slower speed than manned aircrafts, thus

providing high quality spatial data; b) they can be cost-effectively stored and deployed, which make them optimal for rapid response mapping applications; c) they are easy to use with minimal training; d) they can provide repetitive mapping at higher frequency with minimal cost; and e) they are less affected by weather conditions (e.g., they can fly under cloud cover). In spite of the proven potential of UAVs, the nature of their use in mapping applications can be described as ad-hoc at best. This course will be discussing LiDAR mapping using the imaging systems and ranging sensors onboard the UAVs

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Head/Director of the Lyles School of Civil Engineering

Link to Curriculog entry: https://purdue.curriculog.com/proposal:27539/form

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UAS-Based LiDAR Mapping

Course Information

Course number: CE50502
Meeting time: Online
Course credit hours: 1 credit
Prerequisites: CE597 UAS-Based Mapping: Basic Principles
Description: Learn the fundamentals of UAS-based mapping from laser scanning systems with emphasis on point positioning, system calibration, and quality control of derived point clouds/products.

How does this program support your institutional goals?

The continuous developments in direct georeferencing (i.e., integrated Global Navigation Satellite Systems – GNSS – and Inertial Navigation Systems – INS) and remote sensing (i.e., passive and active imaging sensors in the visible and infrared range – RGB cameras and laser scanning) technologies are providing the professional geospatial community with ever-growing opportunities to provide accurate 3D information with rich set of attributes. These advances are also coupled with improvement in the sensors' performance, reduction in associated cost, and miniaturization of such sensors. Aside from the sensing systems, we are also enjoying the emergence of promising platforms such as Unmanned Airborne Vehicles (UAVs). UAVs equipped with consumer-grade imaging/ranging sensors and direct georeferencing systems have been proven as a potential remote sensing platform that could satisfy the needs of a wide range of civilian applications. The advantages of UAV-based mapping can be attributed to the following facts: a) they can fly at lower elevation and slower speed than manned aircrafts, thus providing high quality spatial data; b) they can be cost-effectively stored and deployed, which make them optimal for rapid response mapping applications; c) they are easy to use with minimal training; d) they can provide repetitive mapping at higher frequency with minimal cost; and e) they are less affected by weather conditions (e.g., they can fly under cloud cover). In spite of the proven potential of UAVs, the nature of their use in mapping applications can be described as ad-hoc at best. This course will be discussing LiDAR mapping using the imaging systems and ranging sensors onboard the UAVs.

The course is part of a series.

- Module 1: UAS-Based Mapping: Basic Principles
- Module 2: UAS-Based Photogrammetric Mapping
- **Module 3: UAS-Based LiDAR Mapping (this course)**

Any learner interested in taking "*UAS-Based Photogrammetric Mapping*" and "*UAS-Based LiDAR Mapping*" will need to successfully complete Module 1: "*UAS-Based Mapping: Basic Principles*" or equivalent as a prerequisite for these courses.

Information About the Instructor

Name of the instructor(s): Dr. Ayman Habib
Office Location: CIVL 4108
Phone number: (765) 496-0173
Email Address: ahabib@purdue.edu

Course Description

This 1-credit module covers the principles and mathematical details of laser scanning-based 3D reconstruction using ranging sensors onboard UAVs.

Learning Outcomes

By the end of the course, you will be able to:

1. Explain the principles of LiDAR-based mapping.
2. Identify/select systems/sensors/platforms and design flight plan to meet the needs of a specific application.
3. Conduct a UAS-based mapping project using a LiDAR system.
4. Evaluate the quality of UAS-based ranging products.

How to Succeed in this Course

If you want to be a successful student:

- Be self-motivated and self-disciplined.
- Be willing to "speak up" if problems arise.
- Be willing and able to commit to 6 to 15 hours per week per module.
- Be able to communicate through writing.
- Be able to meet the minimum requirements for the course.
- Accept critical thinking and decision making as part of the learning process.

In contrast, here are some common behaviors that lead to failing the course.

- Not viewing the lecture videos.
- Wait until the last day to begin assignments.
- Forget about deadlines.
- Ignore emails from the instructor and/or your peers regarding course activities.
- Don't get familiar with the syllabus.

Learning Resources, Technology, & Texts

- Optional Textbooks:
  - Shan, J., & Toth, C. K. (Eds.). (2018). *Topographic laser ranging and scanning: principles and processing*. CRC press.
  - Wujanz, D. (2016). Terrestrial laser scanning for geodetic deformation monitoring. Technische Universitaet Berlin (Germany).
  - Maune, D. F. (Ed.). (2007). Digital elevation model technologies and applications: the DEM users manual. Asprs Publications.

- Software/web resources.
  - CloudCompare (free download): https://www.danielgm.net/cc/
  - Matlab: https://www.mathworks.com/products/matlab.html

- Octave (free download): https://www.gnu.org/software/octave/index

Course Logistics

- You are encouraged to "mentally enroll" in this course as if it occurred on Monday mornings. In other words, our weeks will run from Monday to Sunday.
- Deadlines are an unavoidable part of being a professional and this course is no exception. Course requirements must be completed and posted or submitted on or before the specified due date and delivery time deadline. Due dates and delivery time deadlines are defined as Eastern Standard Time (as used in West Lafayette, Indiana).
- All homework, quizzes and final exam will be submitted to BrightSpace. Please be sure to include your name on each sheet. Further instructions for submitting your documents to BrightSpaceare listed with each homework, quiz and final exam in BrightSpace.

Instructor's Email Availability and Policies

I will be available via email daily, and try to respond as soon as possible (generally within 24-48) hours. When emailing me, please place the course number/section and the topic in the subject line of the email (*e.g.,* XXX 240 – Assignment 2 Question). This will help me tremendously in locating and responding to your emails quickly.

Virtual Office Hours

Virtual Office Hours are a synchronous session (*https://purdue.webex.com/meet/ahabib. Office hours to TBD*) to discuss questions related to weekly readings and/or assignments.

Assignments and Points

Your learning will be assessed through a combination of participation, homework and quizzes spread throughout the course. Details on these assignments and exams and guidelines on discussion and evaluation will be posted on the course website.

Assignments	Due	Points
2 Homework Assignments	○ Assignment 1: 11:59 pm ET on April 3rd, 2022 ○ Assignment 2a: 11:59 pm ET on April 17th, 2022 ○ Assignment 2b & 2c: 11:59 pm ET on May 1st, 2022	40 points (10 and 30 points)
2 Timed Quizzes	○ Quiz 1: 11:59 pm ET on April 17th, 2022 ○ Quiz 2: 11:59 pm ET on May 1st, 2022	50 points (25 points each)

Missed or Late Work

No late homework accepted or lowest score dropped.

Grading Scale

- A+: 95-100
- A: 90-95
- A-: 85-90
- B+: 80-85
- B: 75-80

- B-: 70-75
- C+: 65-70
- C: 60-65
- C-: 55-60
- D+: 50-55
- D: 45-50
- D-: 40-45
- F: 40 or below

- Class participation: 10%
- Homework: 40%
- Timed Quizzes: 50%

Course Schedule

Course Start Date: Monday, March 21, 2022 at 12:00 am ET (05:00 am UTC)
Course End Date: Friday, April 29, 2022 at 11:59 pm ET (04:59 am UTC)
Certificate Release Date for Verified and Audit Learners: Monday, May 9, 2022

Section	Section Release Dates	Topics	Homework, Quizzes, Final Exam Release and Due Dates
Section 1	1. LiDAR Mapping Principles **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Videos: LiDAR Mapping Principles	Assignment 1: Mobile Laser Scanning Systems **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC) **Due Date:** Sunday, April 3, 2022 at 11:59 pm ET (Monday, April 4, 2022 at 04:59 am UTC)
	2. LiDAR Point Positioning **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Video: LiDAR Point Positioning	
	3. LiDAR Error Sources and their Impact **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Videos: LiDAR Error Sources and their Impact	
	4. LiDAR System Calibration **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	LiDAR System Calibration	

Section	Section Release Dates	Topics	Homework, Quizzes, Final Exam Release and Due Dates
	5. LiDAR Data Quality Control **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Video: LiDAR Data Quality Control	Quiz 1 (50-minutes) **Release date:** Monday, April 11, 2022 at 12:00 am ET (Monday, April 11, 2022 at 05:00 am UTC) **Due Date:** Sunday, April 17, 2022 at 11:59 pm ET (Monday, April 18, 2022 at 04:59 am UTC)
Section 2	6. LiDAR Data Structuring **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Video: LiDAR Data Structuring	Assignment 2a: LiDAR Point Cloud Processing **Release date:** Monday, April 4, 2022 at 12:00 am ET (Monday, April 4, 2022 at 05:00 am UTC) **Due Date:** Sunday, April 17, 2022 at 11:59 pm ET (Monday, April 18, 2022 at 04:59 am UTC)
	7. LiDAR Data Characterization **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Video: LiDAR Data Characterization	
	8. LiDAR Data Downsampling **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Video: Camera and System Calibratio LiDAR Data Downsampling n	
	9. LiDAR Data Segmentation **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Video: LiDAR Data Segmentation	
Section 3	10. Digital Terrain Model Generation **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Video: Digital Terrain Model Generation	Assignment 2b and 2c: LiDAR Point Cloud Processing **Release date:** Monday, April 4, 2022 at 12:00 am ET (Monday, April 4, 2022 at 05:00 am UTC) **Due Date:** Sunday, May 1, 2022 at 11:59 pm ET (Monday, May 2, 2022 at 04:59 am UTC)

Section	Section Release Dates	Topics	Homework, Quizzes, Final Exam Release and Due Dates
	11. Point Cloud Registration **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Video: Point Cloud Registration	
	12. Applications **Release date:** Monday, March 21, 2022 at 12:00 am ET (Monday, March 21, 2022 at 05:00 am UTC)	Video: Applications	Quiz 2 (50-minutes) **Release date:** Monday, April 25, 2022 at 12:00 am ET (Monday, April 25, 2022 at 05:00 am UTC) **Due Date:** Sunday, May 1, 2022 at 11:59 pm ET (Monday, Monday 2, 2022 at 04:59 am UTC)

Netiquette

Your instructor and fellow students wish to foster a safe online learning environment. All opinions and experiences, no matter how different or controversial they may be perceived, must be respected in the tolerant spirit of academic discourse. You are encouraged to comment, question, or critique an idea, but you are not to attack an individual. Our differences, some of which are outlined in the University's nondiscrimination statement below, will add richness to this learning experience. Please consider that sarcasm and humor can be misconstrued in online interactions and generate unintended disruptions. Working as a community of learners, we can build a polite and respectful course ambience. Please read the Netiquette rules for this course:

- Do not dominate any discussion. Give other students the opportunity to join in the discussion.
- Do not use offensive language. Present ideas appropriately.
- Be cautious in using Internet language. For example, do not capitalize all letters since this suggests shouting.
- Avoid using vernacular and/or slang language. This could possibly lead to misinterpretation.
- Keep an “open-mind” and be willing to express even your minority opinion.
- Think and edit before you push the “Send” button.
- Do not hesitate to ask for feedback.

Discussion Guidelines

This course will use the discussion board for student-to-student and student-to-instructor communication. Discussion forums are where you can express thoughts, develop ideas, and engage with classmates and instructors. Each week has Q&A sections to help you apply the material of the course. You can also access these discussions on the Discussion page.

Here are some friendly guidelines to help you successfully participate in the discussions:

1. Review discussion postings before posting your own to avoid redundancy. Make sure you’re in the right topic before posting.
2. When adding a post, mark it as a Question or a Discussion. Questions raise issues that need answers, whereas Discussions share ideas and start conversations.
3. Do not post answers to quiz questions.
4. Give your message a meaningful title. Be descriptive, specific, and succinct. This will make it easier for readers to notice your post.

5. Use common writing practices for online communication. For example:

- Avoid TYPING IN ALL CAPS. It's difficult to read and is associated with shouting.
- Be careful with humor and sarcasm - both can be easily misunderstood.
- Check your writing for errors before posting.
- Avoid excessive use of acronyms (LOL), emojis, and repeating punctuation (!!!!)
- Offer sincere and constructive feedback. Please don't be overly critical of others.
- Do not post short comments or responses like "Great" or "Makes sense," as these tend to clutter up the discussion forums and add little to the conversation.

1-Credit Module contribution to meeting the professional component

- This course integrates science and engineering principles to understand, design, and evaluate the basics, protocol, and products of/from LiDAR mapping, respectively. The application of scientific and engineering knowledge in solving engineering problems associated with the quality assurance and quality control of UAS-based LiDAR mapping is a key objective of this course. The following subjects are addressed: (i) LiDAR point positioning, (ii) quality assurance and quality control of LiDAR mapping, (iii) LiDAR data characterization and processing, and (iv) UAS LiDAR mapping applications.

The following information explains the policies and resources specific for our Purdue students:

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern.

The Honor Pledge Task Force, a student organization responsible for stewarding the mission of the Honor Pledge and encouraging a culture of academic integrity, asks all instructors to prominently include the student-initiated Purdue Honor Pledge on their syllabus, as well as exams and key assignments:

The Purdue Honor Pledge "As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue"

You may also want to refer students to Purdue's student guide for academic integrity.

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. Link to Purdue's nondiscrimination policy statement.

Students with Disabilities

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: **drc@purdue.edu** or by phone: 765-494-1247.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Guidelines regarding ensuring access to emergency information:

- *Keep your cell phone on to receive a Purdue ALERT text message.*
- *Log into a Purdue computer connected to the network to receive any Desktop Popup Alerts.*
- *If you have a "no cell phone" in class policy allow one or two students who have signed up for Purdue ALERT to keep their phones on to receive any alerts*
- *Further emergency information and details here.*

Mental Health Statement

- **If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack.** Sign in and find information and tools at your fingertips, available to you at any time.
- **If you need support and information about options and resources**, please see the Office of the Dean of Students for drop-in hours (M-F, 8 am- 5 pm).
- **If you're struggling and need mental health services**: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Violent Behavior Policy

Below is Purdue's policy prohibiting violent behavior.

Purdue University is committed to providing a safe and secure campus environment for members of the university community. Purdue strives to create an educational environment for students and a work environment for employees that promote educational and career goals. Violent Behavior impedes such goals. Therefore, Violent Behavior is prohibited in or on any University Facility or while participating in any university activity.

See the University's full violent behavior policy for more detail.

Diversity and Inclusion Statement

In our discussions, structured and unstructured, we will explore a variety of challenging issues, which can help us enhance our understanding of different experiences and perspectives. This can be challenging, but in overcoming these challenges we find the greatest rewards. While we will design guidelines as a group, everyone should remember the following points:

- We are all in the process of learning about others and their experiences. Please speak with me, anonymously if needed, if something has made you uncomfortable.

- Intention and impact are not always aligned, and we should respect the impact something may have on someone even if it was not the speaker's intention.
- We all come to the class with a variety of experiences and a range of expertise, we should respect these in others while critically examining them in ourselves.

Course Evaluation

During the last two weeks of the course, you will be provided with an opportunity to evaluate this course and your instructor. Purdue uses an online course evaluation system. You will receive an official email from evaluation administrators with a link to the online evaluation site. You will have up to two weeks to complete this evaluation. Your participation is an integral part of this course, and your feedback is vital to improving education at Purdue University. I strongly urge you to participate in the evaluation system.

Disclaimer

This syllabus is subject to change.