BE 385

Precision Observation with Drones

Lecture (Marley 212) – Tues: 11:00AM –12:15PM
Lab (Marley 218): (Section -1) - Th: 11:00 - 1:30
Lab (Marley 218): (Section -2) - Th: 1:30 - 4:00

Description of Course

Precision Observation with Drones is an introductory course about the practical aspects of small-scale multirotor unmanned aerial systems with a strong emphasis on quadcopters. The course aims at introducing the students to the new and evolving field of small multirotor Unmanned Aerial Vehicles/Systems (UAV, UAS, Drones), their electrical and electronics subsystems, how they work, how to size and build a small drone, add useful sensors, use the system for observing the physical and natural environment, and how to manage and process some of the most common data collected by drones.

Upon completing this course, the student should become familiar with small drone technology, be able to understand their potentials and limitations, add different sensors, design and program a simple flight controller, bench test all drone parts and the full drone system, collect and analyze data with the drones.

The course is aimed at all students with basic science and engineering knowledge and a desire to observe, remotely sense, and collect data about the natural environment with high precision.

Course Prerequisites or Co-requisites

MATH. 122B or MATH 124 or MATH 125

Students interested in this course are not required to but having a familiarity with electrical and electronic systems, electronic tools, sensing, image analysis, and computer programming is a plus.

If the student is not sure, please check with the instructor or the BE academic advisor before registering.

Instructor and Contact Information

Kamel Didan, Ph.D.
Associate Professor, Biosystems Engineering
Office: Shantz Building, Room 501A and Forbes Room 134
Phone: 520-621-8514, didan@arizona.edu, https://vip.arizona.edu
Office Hours: - Tuesday 9:00am-11am, Shantz Building Room 501A
Open door policy at Shantz, Room 501A
Web: https://vip.arizona.edu/VIP_Teaching.php

Course Format and Teaching Methods

The course will follow a lecture and lab format. Topics are presented using power point slides, the white board, with emphasis on introducing the various electrical, electronic, mechanical, sensors, and control parts that make up a multirotor UAV/UAS/Drone. During the Lab., the students will explore the drone parts, learn their function, specifications, measure and test the parts during operation, understand the differences, integrate the parts into an operational system, and test under different loads and conditions. During the second half of the

semester, the Lab work will shift to calibrating the drones, planning automatic observation missions, collecting data, and analyzing this data.

Students are encouraged to interact, work in groups, explore and practice what they learn to become efficient and skilled with the topics.

Besides the basic concepts, the course does not require knowledge of electrical or electronic circuits or engineering, however, prior course and experience may help the students grasp the concepts faster and better. If the student is not sure, he/she should check with the instructor before registering for the course.

- Fees = $100: To recover cost of lab. tools, electronic parts, field trip cost, and other course/Lab. expenses.
- Offered each Fall

Course Objectives and Expected Learning Outcomes

Course Objectives

Precision Observations with Drones will introduce the students to small multi-rotors drones, their basic theory and physics, teach them how to size and build a custom small unmanned aerial system, understand their electronics, electrical, navigation systems, how to control their flight, how to calibrate them, how to add instruments and sensors, how to use the combination drones/sensors to collect data and observe the environment with high precision, and how to process and analyze the most common data collected by drones and extract useful, accurate, and scientific data and information.

This unique course brings together multiple fields of expertise and skills (electrical engineering, environmental engineering and science, data science, and natural resources management, and remote sensing). The course is an opportunity for all students of agriculture, life sciences, natural resources, engineering, and remote sensing to quickly acquire the necessary skills to apply small drone technology to any natural resources problem or environmental and engineering outdoor observation.

Course Learning Outcomes

Upon completion of the course students will be able to:

1) Define and Explain the basics of Multirotor UAS/UAV/Drone,
2) Design a drone and estimate the proper thrust and weight requirements,
3) Assemble, Verify, and calibrate a fully functional drone,
4) Describe, develop, and verify the principles of system control and flight controller programming,
5) Integrate various payloads to the drone with emphasis on the most common sensors (RGB/multispectral cameras, thermal cameras, and/or other advanced sensors),
6) Develop, plan, and execute an autonomous drone mission to collect observations,
7) Analyze and Synthesize the collected data with emphasis on 2D and 3D reconstruction of the observed environment,
8) Manage to safely and legally operate drones under current FAA (part 107) regulations.

In addition, the course supports the following ABET Program Educational Learning Outcomes:

- **ABET Criterion 1:** An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- **ABET Criterion 5:** *An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives*
- **ABET Criterion 6:** An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions
- **ABET Criterion 7:** An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Absence and Class Participation Policy

The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop.

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: https://deanofstudents.arizona.edu/absences

Participating in the course and attending lectures, lab. Computer exercises and other course events are vital to the learning process. As such, attendance is required at all lectures and meetings. Students who miss class due to illness or emergency are required to bring documentation from their health-care provider or other relevant, professional third parties. Failure to submit third-party documentation will result in unexcused absences.

Unexcused and reoccurring absence will be a sufficient reason for the instructor to recommend that the student be administratively dropped from the course. You are fully responsible for all course materials, lab. work, reading assignments, and any topic covered during the class or lab. if you miss without prior arrangement.

Makeup Policy for Students Who Register Late

Given the class nature, lab. requirements, and limited space, no late registration will be entertained. However, the instructor may accept a late registration if the student shows a strong and compelling need to take the class during the ongoing semester.

Course Communications

Please use your university email account in all communications regarding this course and lab. Emails from other accounts and services will not be accepted for internet security reasons and due to the strict UA spam filters that may prevent certain emails from reaching the instructor on time or at all.

You can contact the Instructor with any questions regarding the course.

Instructor:

Dr. Kamel Didan
Email: didan@email.arizona.edu
Office: Shantz 501A/Forbes 134

Required Texts or Readings

The instructor will provide handouts, links to online open source/access digital material, and links to relevant papers/documents required by the class.

The following books are recommended but not required.

- *Building Your Own Drones: A Beginners' Guide to Drones, UAVs, and ROVs 1st Edition*
- By John Baichtal

- *DIY Drones for the Evil Genius: Design, Build, and Customize Your Own Drones: Design, Build, and Customize Your Own Drones*
- By: Ian Cinnamon, Romi Kadri, and Fitz Tepper
- McGraw Hill Professional (http://www.diydronebook.com/)

- *Make: Drones: Teach an Arduino to Fly*
- By David McGriffy

Other books are fine also and many are available online.

The instructor will provide necessary course notes and handouts, and Open Access material/Videos.

Required or Special Materials

A personal computer (running Windows 7 or above or iOS) with an internet (WiFi) connection, is highly recommended for this course. Computers are also available throughout the UA campus via OSCR labs. or the library system, but we highly suggest a personal computer. Most software tools required for the class will either be special student licensed commercial software, developed

by the students, provided by the instructor, or freely available online. An external storage device and a digital camera is highly recommended to document your lab work and transfer data.

Required Extracurricular Activities

The course will provide specially built, teaching and learning oriented, Drones/Parts to experiment with, measure, test, dismantle, and rebuild at the lab. However, we highly encourage all students to invest in buying their own drone kit ($250-$300). Students who bring their own kit can work on it instead of using the lab. drones. The instructor can arrange and help purchase these kits for the students to insure they are the right size and will operate properly.

Access to special commercial image processing software licenses will be provided to insure lab. work is completed. A lab monitor and/or teaching assistant will be available during the lab. sessions and can assist the students with their work, clarify concepts, and insure everyone is safe.

In addition, the class will take two field trips to different off or on campus locations (TBD) to experiment with the drones, collect data, and plan observation missions. Information about the field trips will be made available during the class meeting.

Assignments and Examinations: Schedule/Due Dates

Exams: There will be two midterm examinations and one final exam. Exams will be comprehensive and will cover all topics. Exams are meant to reinforce what the students have learned and help them identify areas they may want to explore and review more. All exams are open books and students can use their computers.

Lab. work*:* Lab. activities are designed to let the students explore the parts, build and operate the drone or subsystem in a controlled setup. We will be working with Electronic and Electrical parts, which means safety rules will be fully enforced. No disregard to safety will be tolerated and students who disregard the rule could be dropped form the class.

Homework and other activities: The instructor will post assignments and other class work on D2L or by handouts with specific due dates. Students are highly encouraged to exercise and explore further on their own. Homework assignments will mostly require use of a computer, some drawing and computation activities.

Final Examination and/or Project

The date and time of the final exam or project, along with links to the Final Exam Regulations, https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information, and Final Exam Schedule, http://www.registrar.arizona.edu/schedules/finals.htm

A final comprehensive open book exam will be given to all students.

Grading Scale and Policies

Your final grade will be based on:

Activity	% Contribution to Grade
Homework/Lab. work	50
Midterm exams (2)	25
Final Exam	25
Total	100

Final letter grades for the course are computed as:

Score	Grade
90-100	A
80-89	B
70-79	C
60-69	D

<60	E

Depending on the overall class performance, the scores for the different final letter grades may be curved.

A make-up exam may be scheduled only when a student has a strong valid excuse. The valid excuses for missing an examination are serious personal illness, or serious illness or death in your family, and pre-approved leave of absence signed by the UA Dean of Students (or Dean Designee) to attend a professional event. If you determine that you will be unable to attend an examination, inform the instructor. If you miss any of the exams without a valid excuse or documentation, you will be assigned a score of zero for the exam(s) missed.

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete and http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal respectively.

Dispute of Grade Policy

Work will only be re-graded when there is clear evidence of grading error. A student can dispute his/her grade within a week if he/she believes there was an error.

In general, and during the lecture/lab. your ideas, comments, suggestions, questions, are all welcome. Your discretion in these matters is expected however. No part of your grade will be based on anything other than your coursework, exams, and lab work.

You are encouraged to take advantage of instructor office hours for help with anything related to the course and your progress.

Suggestions for success

For most students with basic math, science, and engineering knowledge and who are interested and motivated, this will be a moderately "difficult" course. The key to succeeding in this course is to keep up and explore on your own outside the class. There are lots of online material, videos, tutorials, etc. about drones so take advantage.

Our research lab. will always be open and all class students are welcome to come spend additional time, explore, or catchup with work, provided proper arrangements are made so as not to interfere with other work.

My suggestions for anyone who wishes to enjoy and succeed in this course is to think of the potential skills you will gain while having fun experimenting with an innovative technology. Grades are also important, but do not let the grade only interfere with your learning experience. This course is designed to provide you with skill that will prepare you for your career and sets you apart from others. If you are organized, work hard, and show interest you should get full grade. If you have any questions do not hesitate to talk to the instructor, we want you to learn and succeed.

Honors Credit

Students wishing to contract this course for Honors Credit should email me to set up an appointment to discuss the terms of the contract. Information on Honors Contracts can be found at http://www.honors.arizona.edu/faculty-and-advisors/contracts.

Scheduled Topics/Activities

Schedule is approximate and will be adjusted as needed but all topics will be addressed.

Week	Topic
Week 1 **AUG**	First session devoted to discussing course format, expectations, establishing class and lab. rules, and miscellaneous.
	Introduction to Drones Market potentials for Drones History and Basic theory of multirotor UAS/UAV/Drones.
Week 2 **SEPT**	Drone shapes, parts descriptions, parts function, sizing and selecting the parts, understanding specifications.
	Lab. 1: Introduction to Lab tools, rules, and safety.
Week 3 **SEPT**	Propellers and Brushless motors specifications, KV/RPM (Revolutions per volts)
	Lab 2: Two Exercise: 1. Design a one arm Drone, test motor spin/RPM, Temp, Noise, and Power analysis 2. Understand the basics or TX-RX
Week 4 **SEPT**	Thrust generation basics Electronic Speed Controllers operation and specifications Flight Controllers and Control Algorithms basics
	Lab. 3: Two Exercises: 1. Bench test Brushless motors and thrust generation 2. Test combination of Motor x Propeller and generate design specifications
Week 5 **SEPT**	Power supply and LiPo Batteries safety considerations Batteries specifications (mAH, S # Cells, C Rating)
	Lab 4. Three Exercises: **1.** Propeller specification **2.** Battery internal resistance and power analysis **3.** PDB Soldering
Week 6 **OCT**	Drone Dynamics & Modelling Drone Equations of Motion Principles of flight control
	Lab. 5. Start the Drone building project 1. Building your own Drone (work in teams) 2. Documenting the process and design considerations 3. Frame and Motors Assembly
Week 7 **OCT**	Exam -1 Review Continue with Drone Dynamics and Principles of Flight Control System Control Theory and PID
	Lab 6: Continue building the drone 1. Focus on Flight Controller installation 2. Initial test of motors (without props)
Week 8 **OCT**	Exam-1
	Lab 7: Continue building the full drone 1. Flight controller and Drone calibration 2. Pairing RC and Receiver 3. Arming/Disarming 4. Telemetry and Communication with the drone

Week 9 **OCT**	From Drone Dynamics and Equations of Motion to System Control Principles of PID system control
	Lab 8: Two exercises: 1. Advanced Automatic flight and Mission planning 2. Adding payloads and sensors (FPV addition, Gimbals, telemetry) 3. Miscellaneous drone design topics: a. Safety, Propeller cages, Parachute kits, kill button, etc.
Week 10 **OCT**	Positional Sensors and Flight Controller Programming (IMUs, Compass, Gyroscopes, Accelerometer, GPS) Safety Checks and Initialization
	Lab 9: Drone Cage/Flight test Evaluation and calibration and readiness for field testing (@ UA SRER)
Week 11 **NOV**	Exam -2 Review Continue with Principles of Flight controller programming
	Lab 10: Two Exercises 1. Hovering Flight controller design, programming, and testing with Arduino and single drone arm. 2. Flight controller programming with collision avoidance (Arduino and Ultrasound sensor)
Week 12 **NOV**	Sensors and instrumentation for Precision observation Types of sensors: RGB, Multispectral, Hyperspectral, Thermal cameras Principles of Missions planning **Exam 2: Take Home**
	Lab 11: Two Exercises: 1. Mission planning and preparation for Post-mission data management and Analysis 2. Geo-referencing data 3. Photogrammetry with WebODM 4. 2D stitching with WebODM
Saturday	• **Field trip (to UofA Santa Rita Experimental Range)** • **Leave Saturday at 8AM and be back 3pm. We will use UA mini vans** • **Test fly the drones and have fun** • **Automatic mission + data collection** • **With licensed pilot**
Week 13 **NOV**	Review of Trip results Structure from Motion basics with 3D reconstruction Value added data, Lidar point clouds, and Data fusion
	Lab. 12: Two Exercises: 1. 3D modeling with Drone images and SfM software 2. Online value-added tools (Vegetation Indices)
Week 14 **NOV**	Safety, Rules, FAA Regulations, Pilot Licensing Weather briefs and introduction to Airspace
	Lab. 13: Continue with data post-processing and analysis
Week 15 **NOV**	Close remaining loose ends and Review Sessions
Week 17 **DEC**	Final Exam

Bibliography

Students will be encouraged to experiment on their own and directed towards additional online and free resources.

Classroom Behavior Policy

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Students are asked to refrain from disruptive conversations with people sitting around them during lecture. Students observed engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave lecture or discussion and may be reported to the Dean of Students.

While Laptops are part of the course work, students are not allowed to use them for activities other than what is assigned or required. Students are not permitted to use other mobile devices during the class period, especially mobile phones, unless instructed to do so or part of the class or lab. activity.

Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

Accessibility and Accommodations

Our goal in this classroom is that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that we can discuss options. You are also welcome to contact the Disability Resource Center (520-621-3268) to establish reasonable accommodations. For additional information on the Disability Resource Center and reasonable accommodations, please visit http://drc.arizona.edu.

If you have reasonable accommodations, please plan to meet with me by appointment or during office hours to discuss accommodations and how my course requirements and activities may affect your ability to fully participate.

Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

The University Libraries have some excellent tips for avoiding plagiarism, available at http://new.library.arizona.edu/research/citing/plagiarism

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

UA Nondiscrimination and Anti-harassment Policy

The University is committed to creating and maintaining an environment free of discrimination; see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Additional Resources for Students

UA Academic policies and procedures are available at http://catalog.arizona.edu/policies

Student Assistance and Advocacy information is available at
http://deanofstudents.arizona.edu/student-assistance/students/student-assistance

Confidentiality of Student Records

http://www.registrar.arizona.edu/personal-information/family-educational-rights-and-privacy-act-1974-ferpa?topic=ferpa

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor. Lab. meetings and field trips may have to be adjusted to synchronize them with the lecture progress. In all cases, the students will be notified ahead of time.