Undergraduate Research Summer Residency Program

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Abstract:

This Work-In-Progress Paper presents an overview of Fairfield University's Undergraduate Research Summer Residency (URSR) program, aimed at promoting undergraduate research. The program offers students the opportunity to engage in voluntary research, receive stipends, and access paid residency dorms. It contributes to academic growth and practical experience, enhancing communication skills, presentation abilities, resilience, teamwork, and problem-solving capabilities.

The program spans eight weeks from June 1st to July 27th. Students are required to dedicate 20 hours per week to their respective research projects and attend weekly seminars organized by the dean's office on important topics such as responsible conduct of research training, intellectual property rights, regulatory aspects of research including Institutional Review Board (IRB) and Institutional Animal Care and Use Committee (IACUC), and grant writing and proposal preparation. Additionally, a session on technology transfer is provided.

A mid-term report is due after 4 weeks, and at the end of the program a presentation poster is to be presented to the public, faculty, and fellow students, with a demonstration of the project designed.

The program has been successfully conducted in the summers of 2022 and 2023, with intentions to proceed into summer 2024. The current year's participation data is encouraging, featuring 31 undergraduate students, which constitutes 10% of the school's undergraduate body. The distribution across academic years includes 3 seniors, 8 juniors, 14 sophomores, and 6 freshmen.

Fairfield University's summer research initiative, supported by the School of Engineering and Computing, advances undergraduate research and demonstrates notable student progress. Future plans include assessing the program's impact via data analysis, targeting enhanced communication, teamwork, problem-solving skills, retention, and readiness for graduate school. This paper describes the program's structure, participant diversity, and offerings, concluding with survey results and a sample drone assembly research project from summer 2023.

1. Introduction

The realm of undergraduate education is continuously evolving, with an increasing emphasis on providing students with not only theoretical knowledge but also practical, hands-on experience in their field of study. In this context, the URSR at Fairfield University emerges as a good initiative, designed to bridge the gap between classroom learning and real-world research [8]. The summer research program is an opportunity for students who wish to conduct research, who have not secured an internship in the industry, and most of our rising seniors will choose the internship unless they are really interested in research.

The core objective of the URSR is to immerse undergraduates in a research-intensive environment, where they can apply academic theories to real-life problems and develop a deeper understanding of their field [9,10]. This program offers a unique platform for students to work

closely with faculty mentors and engage in rigorous research activities, thereby fostering a culture of inquiry and innovation.

At Fairfield University, we recognize the critical role of research in the holistic development of students. Research not only enhances critical thinking and problem-solving skills but also prepares students for the complexities of the professional world. The URSR is structured to provide students with an immersive experience, combining the rigor of academic research with the dynamism of practical application.

This paper aims to present a comprehensive overview of the program's design, including its objectives, structure, and the diverse range of research projects available to students.

1.1 Literature Review:

Undergraduate research (UR) has been extensively studied for its broad impact, encompassing benefits, perceptions from faculty and students, and diverse strategies used by universities [1]. Craney et al. [2] surveyed 465 undergraduate research participants from varied disciplines and backgrounds, discovering high satisfaction and significant gains in professional development, deeper subject understanding, and better preparedness for graduate studies and careers. Similarly, Lopatto [3] found that 85% of UR participants in science continued to postgraduate education, with those not pursuing further studies reporting lesser gains. Haddad and Kalaani [4] introduced a model to integrate research into traditional curriculums via summer workshops and designated courses, aiming to boost participation through the creation of an Undergraduate Research Office. Lopatto's further research [5] confirmed the reliability of students' positive evaluations of their research experiences, noting benefits like readiness for graduate-level research and increased intrinsic motivation. Mabrouk and Peters [6] highlighted a strong preference among students in the USA and Canada for independent learning and societal contributions through research, with 98% recommending UR to their peers. Hoke and Gentile [7] discussed the successes and challenges at the University of Richmond, emphasizing the importance of funding and close faculty mentoring in maintaining student engagement, particularly in STEM fields.

2. Program Structure

The URSR at Fairfield University offers an immersive eight-week research experience, carefully designed to foster engagement in projects while maintaining a balance with summer activities. With a 20-hour weekly commitment, the program ensures meaningful involvement in research while respecting personal time, achieving a balance between academic development and individual interests.

Faculty members are encouraged to volunteer as mentors, proposing one or two projects with detailed summaries. These are then presented to students, highlighting the diversity of research opportunities available.

Recruitment channels include email lists and faculty presentations, with communications clearly detailing program expectations, application procedures, and participant stipends. Applicants provide contact and academic information, a statement of interest, and their preferred faculty mentor choices, ensuring a personalized match in research interests.

The coordination team's efficacy is evident in the program's 100% placement rate last year, successfully pairing students with appropriate mentors and projects, reflecting a keen understanding of both student and faculty needs.

A key aspect of the program is its dual focus on hands-on research and educational seminars. Students engage directly in real-world research under expert guidance, applying classroom theories to practical scenarios, fostering innovation and inquiry. Concurrently, weekly seminars cover essential topics like research ethics, intellectual property rights, IRB and IACUC protocols, and grant writing skills, and technology transfer.

The program’s holistic structure develops not just research skills but also soft skills like communication, teamwork, and time management. The combination of practical research and theoretical learning prepares students for future academic and professional pursuits.

3. Educational Seminars

Each seminar is carefully structured to cover key aspects of research that are vital for any aspiring researcher. These sessions delve into a range of topics, each chosen for its relevance and importance in the field of research. The seminars begin with an introduction to the Responsible Conduct of Research Training, a crucial topic that lays the foundation for ethical research practices. This training encompasses various aspects of research ethics, including data management, conflict of interest, collaborative research, and ethical treatment of subjects. Such training ensures that students are well-versed in the principles of ethical research, a prerequisite in today’s research landscape.

Following this, the seminars focus on Intellectual Property Rights, providing students with crucial knowledge about protecting their research ideas and outputs. This session is particularly relevant in an era where intellectual property plays a significant role in the research and development sector. Understanding these rights not only empowers students to safeguard their work but also educates them about respecting and acknowledging the intellectual property of others.

Regulatory aspects of research form another critical component of these seminars. Sessions on IRB and IACUC protocols offer students insights into the processes and importance of obtaining necessary approvals for research involving human and animal subjects. This knowledge is imperative for conducting responsible research that adheres to legal and ethical standards.

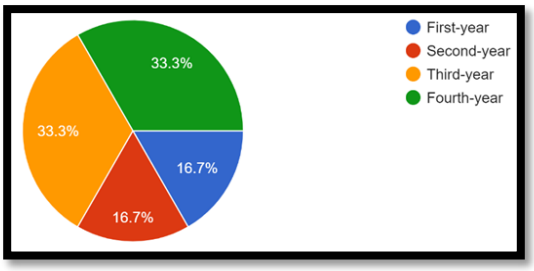
Grant writing and proposal preparation sessions are designed to equip students with the skills necessary to articulate their research ideas convincingly and competitively. These skills are essential for securing funding and support, which are often crucial for advancing research projects. Through interactive workshops and practical exercises, students learn the art of writing effective research proposals, a skill that will benefit them throughout their academic and professional careers.

Finally, a session on technology transfer broadens the students' understanding of how research can be translated into practical applications and commercial products. This seminar explores the

journey from concept to market, highlighting the role of innovation and entrepreneurship in research.

4. Participation and Diversity:

The URSR at Fairfield University stands out for its inclusive nature, drawing a wide array of participants from different academic years and disciplines. The program effectively engages students at any stage of their undergraduate education, offering opportunities for both advanced and novice researchers to enhance their skills or delve into new research areas. This year's participant breakdown showcased the program's broad appeal with 3 seniors, 8 juniors, 14 sophomores, and 6 first-year students. This diverse cohort enriches the research environment with varied perspectives and experiences, fostering a collaborative and dynamic community. The program's ability to attract such a wide demographic underscore its role in promoting research interest and collaboration across different education levels, preparing students for future multidisciplinary teamwork in professional settings.



5. List of offered projects:

Students can choose from these diverse and exciting projects based on their interests and expertise:

- Carbon Nanotube & Graphene Based Polymeric Nanofibrous Scaffolds
- Electrochemical Impedance Spectroscopy
- Drone Assembly and Navigation
- Trust In the Human Brain
- 3d-Printed Growth Module for Tuber Plants and Root Vegetables In Space
- Automated Protein Blotting
- Automated Deburring Equipment
- Bio-3d Printing of Organs.
- Robotic And Automation
- TPMS Composite Structures for Thermal Protection System
- Apparatus To Measure the Friction of Fabric Against Skin
- Machine Learning with Wearable Tech to Understand In-Game Loading Within Achilles Tendon Rupture
- Improving Informal and Formal Education Using AR/VR and AI
- Using Web Log Analysis for Intrusion Detection
- Electropolymerized Biocompatible Substrates
- Simulation Of Advanced Fluidized Bed – Spouted Reactor
- Java App Store

5.1 Sample Project:

"Summer Research Program in Drone Assembly and Navigation"

Program Overview: Welcome to the Summer Research Program in Drone Navigation! This program offers an exciting opportunity for undergraduate students to gain hands-on experience in the field of drone technology, navigation, and research. Throughout the program, you will acquire knowledge, develop practical skills, and foster critical thinking abilities in the domain of drones. This document outlines the goals, objectives, and structure of the program.

Program Goals:

1. Acquire Knowledge about Drone Technology:
    - Understand the components, flight dynamics, sensors, and communication systems of drones.
    - Stay updated on the latest advancements and emerging trends in drone technology.
2. Develop Practical Skills in Drone Building:
    - Gain hands-on experience in building drones from scratch.
    - Learn about different types of drones, materials, assembly techniques, and quality control measures.
    - Emphasize safety and adherence to regulations during the building process.
3. Understand Drone Navigation and Control:
    - Learn the principles of drone navigation, flight modes, stability, and maneuverability.
    - Understand autonomous control systems and programming drones for specific tasks and missions.
4. Enhance Critical Thinking and Problem-Solving Abilities:
    - Analyze and solve complex problems related to drone navigation.
    - Optimize flight paths, address obstacles, and design navigation algorithms.
    - Foster a creative and innovative mindset in approaching drone navigation challenges.
5. Foster Collaboration and Teamwork:
    - Promote teamwork and collaboration among participants, 2 groups of 3 students.
    - Encourage effective communication, cooperation, and sharing of ideas among team members.

6. Promote Ethical and Responsible Use of Drones:
    - Discuss ethical considerations and societal implications of drone technology.
    - Address privacy concerns, legal regulations, and responsible use of drones.
    - Encourage critical thinking about the impact of drones on society and the environment.
7. Develop Research and Presentation Skills:
    - Conduct research related to drone navigation.
    - Learn data collection, analysis, and drawing meaningful conclusions.
    - Refine presentation and communication skills to effectively share research findings.

Program Structure:

- Duration: [June 1] to [July 27]
- Weekly Schedule: [Group meeting every Thursday, short presentation and report, hands-on activities, and project work]

We are excited to have you participate in the Summer Research Program in Drone Navigation. This program will provide a unique opportunity to explore the fascinating world of drones, develop practical skills, and engage in cutting-edge research. We look forward to an enriching and rewarding experience!



Figure 1: Progression of the Drone Project from Soldering to Flight.

During their summer research program, the students achieved significant milestones. Under the guidance of the faculty, they obtained FAA drone licenses and then proceeded to wire, solder, and assemble two fully functional drones. Using the University's 3D printers, they manufactured essential drone components and equipped the devices with specialized software for in-flight data collection.

Once the drones were constructed, the team conducted outdoor maneuverability tests, adhering to FAA and the university guidelines. These flight sessions were instrumental in gathering data to assess each drone's performance and operational coordination. Following each flight, the team conducted structured debrief sessions to review their accomplishments and identify areas for enhancement.

6. Survey Results and Research Highlights

This study aimed to evaluate the impact of the URSR program at Fairfield University. Feedback from participants (in the sample drone project) indicates a high level of satisfaction and learning outcomes The program's success is further exemplified through a showcase of specific research projects, like the drone assembly project, illustrating the practical application of skills acquired during the residency. Survey results from participants in the engineering program indicate overwhelmingly positive responses across various aspects:

- Increased Interest in Engineering: 100% of respondents strongly agree.

- Impact on Confidence to Succeed in Engineering: 100% report a significant increase.
- Understanding of Engineering Design: 83.33% noted an increase, while 16.67% reported a substantial increase.
- Development of Critical Thinking Skills: 83.33% strongly agree, complemented by 16.67% who agree.
- Development of Communication Skills: 83.33% strongly agree, with 16.67% agreeing.
- Ability to Work Independently: 83.33% strongly agree, alongside 16.67% who agree.
- Ability to Work as Part of a Team: 66.67% strongly agree, 16.67% agree, and 16.67% neither agree nor disagree.
- Ability to Conduct a Research Project: 66.67% strongly agree and 33.33% agree.
- Improvement in Relationships with Faculty/Students: 66.67% strongly agree and 33.33% agree.
- Increased Confidence in Research Skills: 83.33% strongly agree, with 16.67% agreeing.
- Increased Confidence in Becoming a Successful Engineer/Professional: 83.33% strongly agree, and 16.67% agree.
- Relevance of Academic Coursework: 83.33% strongly agree, complemented by 16.67% who agree.
- Interest in Pursuing Graduate Studies: 83.33% strongly agree, along with 16.67% who agree.

7. Conclusion

The URSR at Fairfield University, though a resource-intensive and costly endeavor funded by the School of Engineering, has established itself as a robust model for facilitating undergraduate research, particularly within the context of a smaller academic institution. Its comprehensive structure, commitment to diversity, and substantial educational impact demonstrate its potential as an influential template for other universities aiming to foster a culture of research among undergraduate students. Despite being in its nascent stages, with only two iterations so far, the program's success in providing hands-on, experiential learning alongside traditional classroom education has been noteworthy. As we prepare to run this program again, our future goals include not only maintaining the high standards already set but also exploring ways to enhance its accessibility and sustainability. The aspiration is to continue evolving this initiative, making it a beacon for other small institutions seeking to make significant strides in undergraduate research and education.

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Appendix 1: Sample poster at the end of the program

SCHOOL OF ENGINEERING

The Future of Drone Navigation: Autonomous Swarms Using IMU and Optical Flow in GPS Denied Areas

BACKGROUND

With the rapid development and commercialization of drones, a new wave of possible uses for them has emerged. With the possible variety in their new uses, environments where GPS satellites are unreachable by the drone have become an issue. These types of environments can hinder the drones operational capabilities and can require human input. Because of this, the prospect of automating drones can prove to be beneficial in many industries. Reducing the need for human sensory input with the right sensors allows the drone to make the decisions necessary to carry out its mission.

OBJECTIVE

The goal of this project is to research, design, and build an Autonomous First-Person-View (FPV) Drone capable of performing missions without relying on GPS. This can be accomplished by using sensor fusion, or the combination of data the sensors on the drone give us.

HARDWARE/SENSORS

- Flight Controller (STM32F722)
- IMU (BMI270)
- Barometer (BMP280)
- OSD chip (AT7456E)
- GPS (BN-880)
- 500MB Flight Recorder
- Optical Flow
- Magnetometer

METHODOLOGY/CONFIGURATION

We can combine the sensor data to give us more information about the flight. As a result, sensor redundancy can be achieved and the fusion of the data of all the sensors can provide us with the drones position, without a GPS. The drone operates on the ExpressLRS radio protocol with a 500 Hz refresh rate for low latency communication. To achieve autonomous navigation, the drone utilizes the GPS unit and magnetometer. Notwithstanding, the ultimate objective is to eliminate the dependency on GPS.

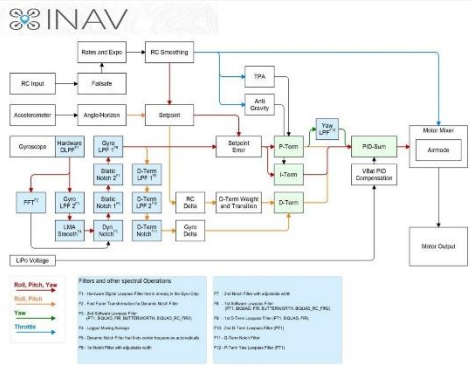
The drone's central component is the flight controller, which integrates all sensor data and controls the drone's operation. The IMU and barometer provide essential information about the drone's attitude and altitude, while the OSD chip overlays crucial flight data on the video feed for the pilot. The flight recorder allows onboard data recording for post-flight analysis. The video feed link provides real-time visuals to the pilot at 500 Hz.

NAVIGATION/AUTONOMY

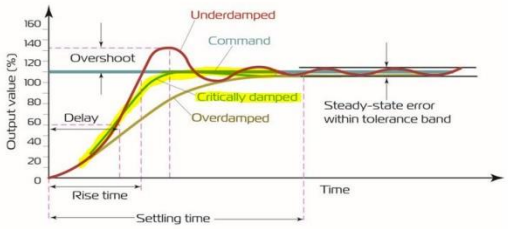
Navigation is initially achieved through the GPS unit with a built-in magnetometer. The drone can follow pre-planned routes and perform missions using GPS data. However, the long-term goal is to develop autonomy that relies less on GPS and more on other onboard sensors and advanced algorithm communication. This will make the drone more resilient in environments where GPS signals may be unavailable or unreliable.

The drone's propulsion system consists of four motors with 46° fixed pitch props, generating approximately 6.4 kg of thrust at full throttle. These motors are controlled by 32-bit electronic speed controllers. The entire system, including all components, will have a total weight of less than 700g, optimizing efficiency and flight performance. Power is provided by 6S LiPo batteries, with a nominal voltage of 23.6V, delivering sufficient energy for extended flight times.

MODEL FORMULATION



RESULTS



CONCLUSIONS

The research and development of an autonomous FPV drone have made significant progress thus far. Two drones have been successfully built and configured, and initial tests have been performed, confirming the drone's flight capabilities. The focus now shifts to tuning and optimizing the drone's performance through software adjustments and data collection flights. The ultimate objective is to achieve autonomy without relying heavily on GPS, enhancing the drone's resilience and expanding its operational capabilities.

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