NSF REU Site: Swarms of Unmanned Aircraft Systems in the Age of AI/Machine Learning

Ryan Restivo, Saint Bonaventure University
Connor Walsh, University of Tennessee at Martin
Wesley Chase Duclos
Vrushank Mali, University of Tennessee at Martin
Dr. Jian Wang, University of Tennessee at Martin
Prof. Huihui H. Wang, St. Bonaventure University

Dr. Huihui Wang is a tenured Associate Professor in the Department of Computer Science and Cybersecurity at St. Bonaventure University (SBU) since January 2021. She is a rotating program director at the NSF since August 2021. Before SBU, she was a tenured associate professor and the Founding Chair of the Engineering Department at Jacksonville University, FL.

Dr. Thomas Yang, Embry-Riddle Aeronautical University - Daytona Beach

Dr. Thomas Yang received his Ph.D. in Electrical Engineering in 2004 from the University of Central Florida (UCF). He is currently a Professor of Electrical and Computer Engineering at Embry-Riddle Aeronautical University (ERAU)-Daytona Beach. Dr. Yang was a 2013 National Research Council (NRC) Senior Research Fellow supported by Air Force Office of Scientific Research (AFOSR), and a Visiting Faculty Research Fellow at Air Force Research Lab/Information Directorate (AFRL/RI) in 2012, 2017, 2018, 2021 and 2022. Dr. Yang is the recipient of 2017 ERAU Abas Sivjee Outstanding Researcher of the Year Award, 2010 IEEE Florida Council Outstanding Engineering Educator Award, Best of Session and Best of Track (Special Topics & Space Systems) paper awards at 2021 Digital Avionics Systems Conference, and Best Paper Award at 2014 IEEE International Conference on Electro/Information Technology.

Prof. Richard Stansbury, Embry-Riddle Aeronautical University - Daytona Beach

Dr. Richard S. Stansbury is an associate professor of computer engineering and computer science at Embry-Riddle Aeronautical University in Daytona Beach, FL. His research interests include unmanned aircraft systems, field robotics, and applied artificial

Prof. Houbing Herbert Song, University of Maryland, Baltimore County

Houbing Song (M'12–SM'14-F'23) received the Ph.D. degree in electrical engineering from the University of Virginia, Charlottesville, VA, in August 2012.

He is currently a Tenured Associate Professor, the Director of NSF Center for Aviation Big Data Analytics (Planning), and the Director of the Security and Optimization for Networked Globe Laboratory (SONG Lab, www.SONGLab.us), University of Maryland, Baltimore County (UMBC), Baltimore, MD. Prior to joining UMBC, he was a Tenured Associate Professor of Electrical Engineering and Computer Science at Embry-Riddle Aeronautical University, Daytona Beach, FL. He serves as an Associate Editor for IEEE Internet of Things Journal (2020-present), IEEE Transactions on Intelligent Transportation Systems (2021-present), and IEEE Journal on Miniaturization for Air and Space Systems (J-MASS) (2020-present). He was an Associate Technical Editor for IEEE Communications Magazine (2017-2020). He is the editor of eight books, the author of more than 100 articles and the inventor of 2 patents. His research interests include cyber-physical systems/internet of things, cybersecurity and privacy, and AI/machine learning/big data analytics. His research has been sponsored by federal agencies (including National Science Foundation, US Department of Transportation, and Federal Aviation Administration, among others) and industry. His research has been featured by popular news media outlets, including IEEE GlobalSpec's Engineering360, Association for Uncrewed Vehicle Systems International (AUVSI), Security Magazine, CXOTech Magazine, Fox News, U.S. News & World Report, The Washington Times, and New Atlas.

Dr. Song is an IEEE Fellow, an ACM Distinguished Scientist, and an ACM Distinguished Speaker. Dr. Song is a Highly Cited Researcher identified by Clarivate™ (2021, 2022) and a Top 1000 Computer

Scientist identified by Research.com. He received Research.com Rising Star of Science Award in 2022 (World Ranking: 82; US Ranking: 16). Dr. Song was a recipient of 10+ Best Paper Awards from major international conferences, including IEEE CPSCom-2019, IEEE ICII 2019, IEEE/AIAA ICNS 2019, IEEE CBDCom 2020, WASA 2020, AIAA/ IEEE DASC 2021, IEEE GLOBECOM 2021 and IEEE INFOCOM 2022.

NSF REU Site— Drone Swarms in the Age of Artificial Intelligence

Abstract

Drone swarms, the ability of drones to autonomously make decisions based on shared information, create new opportunities with major societal implications. However, future drone swarm applications and services pose new networking challenges. A resurgence of artificial intelligence (AI) and machine learning (ML) research presents a tremendous opportunity for addressing these networking challenges. This REU site focuses on networking research for drone swarms in the age of AI. The first cohort of seven undergraduate students were recruited to participate in a ten-week summer program to perform networking research for drone swarms under the guidance of faculty and research mentors. In this paper, a couple of drone swarm projects were briefly summarized. By the end of the summer program, students was surveyed about their undergraduate research experiences. A couple of months after students were back to their home institutions, a couple of students were interviewed about the impact of their undergraduate research experiences on their continued learning. The faculty who helped to supervise the undergraduate students at the REU also were interviewed. The feedback from the students and reflections from the faculty would provide guidance about the integration of the undergraduate research experiences into the courses to broaden the impacts of undergraduate research on learning and teaching. In the future, at least another two cohorts of students. especially from underrepresented groups, will be recruited. We will have a longitudinal study to explore the impacts of undergraduate research experiences on learning and teaching using a mixed qualitative and quantitative method.

Keywords

Research Experience for Undergraduate, Drone Swarms, Artificial Intelligence.

1. Introduction

Studies showed that interdisciplinary undergraduate research activity efficiently improves students' learning and increases retention rate and graduation rates [1-8]. Research Experience for Undergraduates (REU) Site hosted by University 1 aims to engage undergraduates in various interdisciplinary research projects of drone swarms. The goals of the REU Site are:

1) attract undergraduate students to state-of-the-art drone swarm research, especially those from underrepresented groups, and from institutions with limited opportunities.
2) develop the research capacity of participants by guiding them to perform research on drone swarms.
3) grow the participants' technical skills to enable a wide variety of beneficial applications of drone swarms.
4) promote the participants' integrated AI/machine learning and drone swarm competencies.
5) prepare participants with professional skills for careers.

For the first year, we recruited seven students in this program. The retention rate of this scholarship program is higher than that of the engineering majors at the host university. Additionally, the project successfully recruited several underrepresented minorities and women in engineering related fields to meet the goal. The scholarship program activities and adjustment attribute the success of the REU as well as the faculty support structure.

During the first summer, a variety of activities were planned to enhance the sense of learning community and establish mentorships. These relationships provided students with guidance, support, and feedback as they faced the challenges of academic and professional life. A sense of community was strengthened through orientation activities game nights workshops with guest speakers, undergraduate research projects, and professional presentations. In collaboration with professors from a range of fields, the students in the REU program had the opportunity to work on a variety of research projects, including those related to Drone Swarms in the Age of Artificial Intelligence. The students not only gained practical skills and hands-on project experience, but also developed a deeper interest in research and a desire to continue further study in the future.

In this paper, we introduce a couple of undergraduate research projects at the REU site, conduct surveys and interviews with the REU students and faculty mentors, analyze the impact of research on their professional identities and finally summarize the work and future study.

2. Undergraduate Research Projects

In this section, students share the undergraduate research projects with the faculty's supervision. Project 1 is the topic of one professor's research team and the students joined the team and had outstanding outcomes with other members. Projects 2 and 3 are topics provided by professors and the students in groups mainly made explorations by themselves with the professors' instruction. During the exploration, the professors provided technical support and academic instructions for investigations.

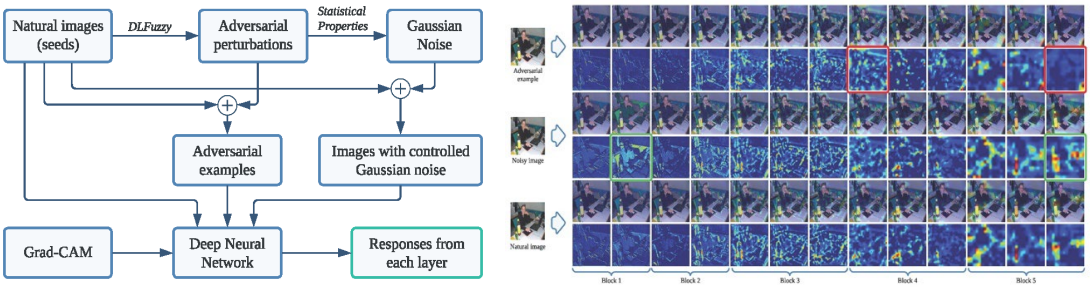

Figure 1 Exploring neural network response against adversarial perturbations and Gaussian noise

1) Exploring Adversarial Attacks on Neural Networks: An Explainable Approach

Deep Learning (DL) is being applied in various domains, especially in safety-critical applications such as autonomous driving. It is important to understand why errors occur due to mutated inputs and to make the decisions of Convolutional Neural Networks (CNNs) explainable and trustworthy. In this paper, heatmaps were generated using Grad-CAM to show which features were used to classify images of the ImageNet dataset by the VGG16 model. In particular, decisions on images with adversarial noise and Gaussian random noise were analyzed layer by layer to determine where errors occurred. In addition, we also explored the possibility of using a Zero-Bias Dense Layer to upgrade VGG16 to increase its robustness under adversarial attacks. Our work could potentially provide useful insights into developing more reliable CNN models. The students participated in the team of deep learning on UAV swarm security and gained many experiences in the security design of UAV swarm networking. Figure 1 shows the framework of the Exploring neural network response against adversarial perturbations and Gaussian noise and a representation of the result for the experiment.

2) The Morris Worm: Overview and Analysis on UAV Security

Students investigated the Morris worm on computer security and extend the discussion on UAV swarm security. They summarized the investigations as follows: One of the most effective ways users can protect themselves from worms, viruses, and simply malware in general is by knowing how these things can infect and exploit their UAV. On top of this, it is also imperative to know which kinds of devices are vulnerable to infection along with the measures users can take to guard themselves against and eliminate harmful malware if a device has already been infected. Malware is extremely dangerous and can cause problems ranging from slowing a computer down to having one's identity stolen by attackers. Figure 2 shows Morris worm exploit options.

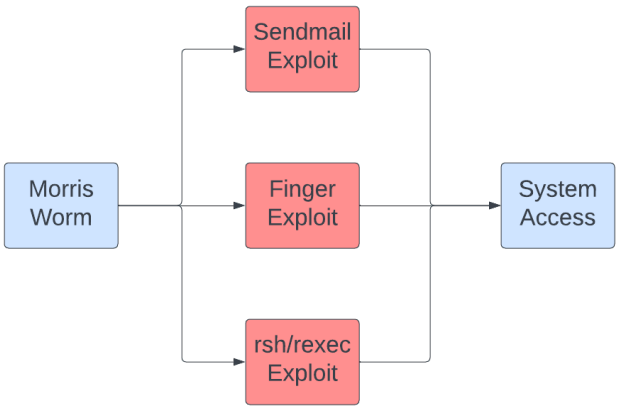

Figure 2 Morris worm exploit options

Overall, using safe browsing practices on the internet, avoiding suspicious websites, and being on the lookout for phishing of any kind are all effective ways to avoid having to deal with a worm, virus, or any other kind of malware. In this day and age, there is really no excuse for not having an antivirus due to the amount of inexpensive and even free options available. By being smart about computer use, disasters like that caused by the Morris Worm, can be reduced or avoided outright.

3) GPS Spoofing on UAV: A Survey

As the core of UAV, Global Positioning System (GPS) is essential to provide the navigation information for UAVs to finish missions. GPS receives satellite signals and calculated localization so UAVs can recognize their positions. However, malicious attackers leverage the mechanism to generate forged GPS signals that can spoof UAV that has wrong positions. The wrong positions can lead to missions' failure and threaten public safety and private security. In this paper, we investigated the overview of GPS spoofing and explored the development of GPS spoofing on UAVs. This work can provide researchers with state-of-the-art GPS spoofing development on UAVs and inspiration for new directions in this field. Figure 3 depicts the processing of GPS spoofing attacks and detection on UAV.

As one implacable part of IoT and CPS, UAV is significant to the processing of massive deployment of IoT and CPS which is fundamental to SAGC development. However, GPS is critical to UAVs which helps remote operators to finish missions precisely and effectively. In this paper, we investigated state-of-the-art GPS spoofing on UAVs and obtained a survey on this topic. We explore the mechanism of GPS spoofing and categorize different technologies. For each category, we have summaries that present an overview of the attacks in each category. We believe

our contributions can affect the development of this topic and more exploration will be made with our work.

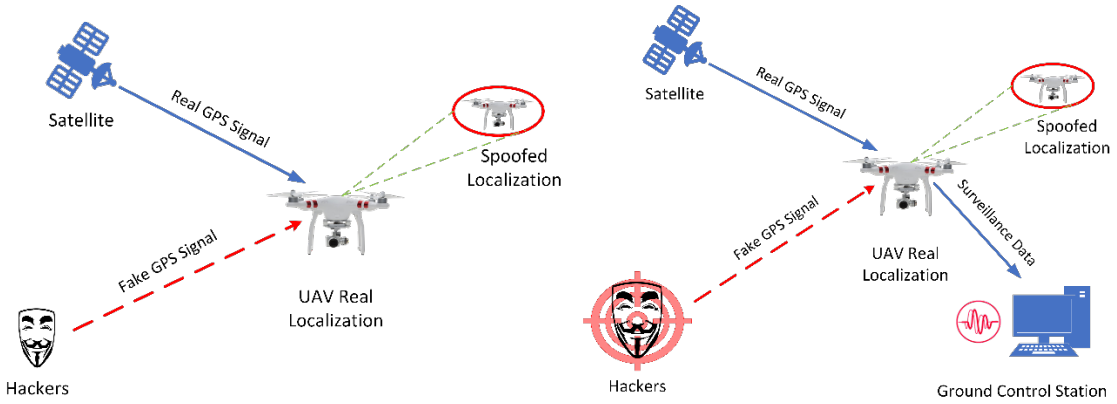

Figure 3 GPS spoofing attacks and detection on UAV

3. Students' reflections about the REU program

We conducted a survey with the REU students by the end of the first summer, to know the impacts of the REU on their research and career goals. All students took the survey. We highlighted some survey questions and the results are summarized as follows:

Question 1: How certain are you that you will pursue a graduate degree? 0-100%,

- 0% means you are certain you will NOT go to graduate school
- 100% means you are absolutely certain you WILL
- anything in between reflects your current confidence about whether or not you'll go

Summary: 7 students chose 100% and certainly will pursue a graduate degree. Participating in the REU program can provide students with valuable research experience and exposure to the field, which can make them more competitive candidates for graduate programs. Additionally, the mentorship and networking opportunities available through the REU can help students to build relationships with professionals in their field, which can be helpful as they explore their career options and make decisions about their future.

Question 2: Are you more or less sure than at the beginning of the summer?

Summary: 5 students choose more; 1 student chose less; 1 student chose not sure. The experiences and insights gained through the REU can be valuable in helping students to clarify their career goals. By participating in research projects, working with mentors, and networking with professionals in their field, students can gain a better understanding of what a career in research entails and whether it aligns with their interests and skills. This can help them to make more informed decisions about their future and can increase their confidence in their career path.

Question 3: What people, events, or other factors this summer impacted any changes in your career goals?

Summary: We categorize the answers as the follows:

Research Experience: Working on a research project during the REU program can give students a taste of what it's like to work in a particular field and can help them to determine if it's a good fit for their interests and skills.

Mentorship: Working with experienced researchers and mentors can provide students with guidance and support as they navigate their academic and professional journeys. Mentors offer advice on how to pursue their career goals and can provide students with valuable insights into their field.

Networking Opportunities: Participating in the REU program can provide students with the opportunity to meet and work with other students, researchers, and professionals in their field. These relationships can help students to build a professional network and can provide them with valuable connections for their future careers.

Conferences and Presentations: the REU provides students with opportunities to present their research at conferences and other events. This can give students a chance to gain valuable presentation skills, receive feedback on their work, and build their professional network. These experiences can help students to build confidence in their abilities and can have a lasting impact on their future careers.

Question 4: List words/phrases you believe describe what research scientists are like (be honest!):

Summary: 1. Curious, 2 Creative, 3. Analytical, 4. Persistent, 5. Methodical, 6. Intense, 7. Inquisitive, 8. Innovative, 9. Driven, 10. Disciplined, 11. Open-minded, 12. Objective, 13. Rational, 14. Knowledgeable
The following list is our collection results. The list shows that our students have more interests in the REU.

Question 5: To what extent do you think of yourself as a potential research scientist? 0-100%.

Summary: The average is 63.5%. It's great to hear that 63.5% of students have an interest in becoming a scientist. Becoming a scientist requires hard work and dedication, but it can also be a highly rewarding and fulfilling career. If these students are committed to pursuing their goals, they should start by building a strong foundation in their field of interest through advanced education and hands-on experience. They can also seek out mentors and networking opportunities to learn from experienced scientists and build relationships with other professionals in the field. With persistence and effort, it is possible for these students to achieve their goal of becoming a scientist.

We also interviewed students and one student told what he gained from the project.

Student: “When I was in the REU program I was responsible for producing a paper that could be submitted for publication by the end of the project. During the project weekly zoom status reports were conducted to ensure that we stayed on track and always had set goals. Much of the time we were responsible for finding research papers that could be used in our project. Through practice and advice from the professors involved, I learned a lot about how to effectively read, summarize, and cite academic papers. I also gained experience writing academic papers. Moreover, the stipend that I got from the REU paid me more than my internship did. Overall, I am very thankful for the opportunity to participate in the REU program.”

Also, the faculty’s comments for the project are very important. One faculty mentor told us:

"The students consistently produced high-quality work, met project deadlines, and actively contributed to group discussions. The students also showed exceptional communication skills, regularly updating project progress and presenting their findings in a clear and concise manner. I was impressed with their dedication, enthusiasm, and outstanding performance with the REU program."

4. Summary and future work

The REU students have built a stronger connection with their chosen majors and developed research skills and experiences. The interactions with faculty mentors helped students to mature intellectually and professionally, build their confidence, and gain a deeper understanding of their majors and career paths. Overall, the REU program provides a valuable opportunity for students to enhance their research experiences and skills.

In the future, we plan on sharing positive testimonials from students and facilitating connections with professors in relevant fields. We will continue our efforts to have a diverse, inclusive, and accessible REU team. According to the interview results, we will consider implementing measures to attract and retain students from underrepresented backgrounds, including those with disabilities. We will investigate establishing partnerships with institutions and organizations that serve diverse student populations. Additionally, we will try to explore ways to provide more personalized support to students, such as mentorship programs or tailored career development workshops. These initiatives can not only enhance the quality of the program but also help to create a more equitable and inclusive STEM community.

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