

How to Develop a Culture of Coding for the Future: A Case Study of the megaGEMS Coding Academy

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Abstract

Girls in Engineering, Mathematics, and Science (GEMS) is a free after-school club and summer camp for girls interested in exploring their career in various Science, Technology, Engineering, and Mathematics (STEM) fields. GEMS is the outreach program for the Autonomous Vehicle Systems Research and Education Laboratories. GEMS programs are designed to educate young women about STEM by providing hands-on experiential learning in robotics, programming, and research [1]. GEMS is divided into two main programs: miniGEMS for rising fifth through eighth-grade middle school students, and megaGEMS for rising ninth through twelfth-grade high school students [2]. miniGEMS focuses on robotic challenges and innovative STEM curricula. In contrast, megaGEMS focuses on independent research through two programs: Research Camp (RC), a 4-week program for ninth and tenth-grade students, and the Apprenticeship Program, an 8-week college-level research program for eleventh and twelfth-grade students. All GEMS programs prioritize serving Title I schools, rural, and students from low-income [3], [4] areas of San Antonio and Bexar County. All participants in GEMS explore and investigate hands-on lab experience in the science of autonomy through ground and air robotics, which helps them build the important skills essential to obtaining college-level degrees and readiness for workforce development [5]. GEMS aligns its foundation to address the lack of opportunities for marginalized groups such as race/ethnicity, gender, language, and socioeconomic status but not limited to. GEMS equitable and inclusive practices provide engineering and computer science opportunities to communities in need.

This paper will highlight Coding Academy, a feature of the megaGEMS program that looks to empower its students with the coding knowledge necessary to complete their faculty-guided research projects. Coding Academy supplies daily 1-hour coding lessons to all participants within the megaGEMS program [2]. Focusing specifically on teaching the fundamentals of the Python Programming Language. The function of Coding Academy under the GEMS program; however, is to supply early and effective exposure to coding and programming skills through student-led instruction, and project-based learning. As coding has become significantly important to the next generation of workforce this program provides beyond what is available in a typical classroom. With these methods in mind, the Coding Academy hopes to encourage analytical thinking, effective communication, and foster a problem-solving mindset in all its students which will extend from their studies into their professional lives and encourage pursuing of STEM degrees in a 2 year or 4-year program [1], [5].

Coding Academy is managed by the Computational Intelligence Lab (CIL), part of the Autonomous Vehicle Systems Research and Education Laboratories, consisting of undergraduate student research assistants. The undergraduate students are made up of engineering and computer science majors from the university. These students are referred to the PI of the lab based on their level of professionalism in the classroom, self-efficacy, time management, and overall well-

rounded student. The undergraduate students are interviewed and then finally hired as student employees of the lab. In addition, the research assistants receive aid from the GEMS director. The curriculum of Coding Academy has traditionally centered around the basics of programming in Python, with emphasis on the development of solid fundamental programming skills [6], [7]. In the latest iteration of Coding Academy, the curriculum emphasized multiple-day projects and teamwork to capitalize on the student's ability to teach one another and help them keep information learned in these sessions. For example, the curriculum draws inspiration from popular studying methods, the Feynman technique, and spaced repetition as well as aligning with Texas educational standards for high school students.

Alongside highlighting Coding Academy, this paper will also explore the GEMS programs for females to investigate STEM pathways, the effectiveness of the teaching techniques, exploration of the importance of teaching coding to students, surveying the outcomes, and the continued work of the GEMS programs.

Introduction

Background of GEMS

GEMS (Girls in Engineering, Mathematics, and Science) is a free all-female STEAM (Science, Technology, Engineering, Art, and Mathematics) and Programming Summer Camps and Afterschool Robotic and STEAM clubs. All GEMS programs focus on educating young girls about the fields of STEAM and the careers in each field. GEMS was established in 2015 as the community outreach [5], of the Autonomous Vehicle System (AVS) Research and Education Laboratories (GNC, CIL, and GEMS) as a 1-week summer camp for middle school students but has grown to multiple year-round programs for middle school and high school aged females [2].

GEMS is divided into two programs: miniGEMS and megaGEMS. miniGEMS is for middle school girls and megaGEMS is for high school girls. GEMS recruits' students from Title I, underserved, and rural areas of Bexar County, Guadalupe County, and Medina County in south Texas. Title I schools are defined as a designation based on the number of low-income students who are at risk for school achievement. To be considered a Title 1 school, a minimum of 40% of the students must qualify for free or reduced lunch. GEMS currently partners with schools in San Antonio ISD, Judson ISD, Southwest ISD, and Southside ISD to host miniGEMS After-School STEAM and Robotics clubs.

Each summer camps are held at the University of the Incarnate Word (UIW) and hosted by the AVS Labs. UIW is recognized as a Hispanic-serving institution under federal guidelines [2] which promotes the GEMS community outreach. San Antonio's demographics include 17.7 % living in poverty compared to the 12.5% average of the United States and San Antonio's poverty rate ranks second among the five largest cities in Texas. San Antonio is comprised mostly of 64.2% Hispanic, 24.8% White, and 6.4% African American. The GEMS programs create

equitable and inclusive hands-on curricula that allow female students to spark their intellectual curiosity.

GEMS' *mission* is to inspire and empower young girls to be innovative with their future in the STEM/STEAM fields. GEMS covers diverse topics of education that the students would not normally be exposed to, supporting each other, developing teamwork skills, learning how to better the community with their knowledge, being creative, and developing self-efficacy [1], [4]. GEMS' *goal* is to increase the number of female students interested in STEM careers, especially in engineering and computer programming [5].

In the United States, women make up 14% of the engineering workforce (15% internationally) and in 2020, 24% of bachelor's degrees in engineering were earned by women, and women of color earned 10% of the total engineering degrees [8], [9]. Knowing these statistics GEMS' *objective* is to increase the number of female students from underrepresented communities [4] choosing STEM-related pathways in high school, STEM-related vocations, or STEM-related majors upon graduation from high school [5].

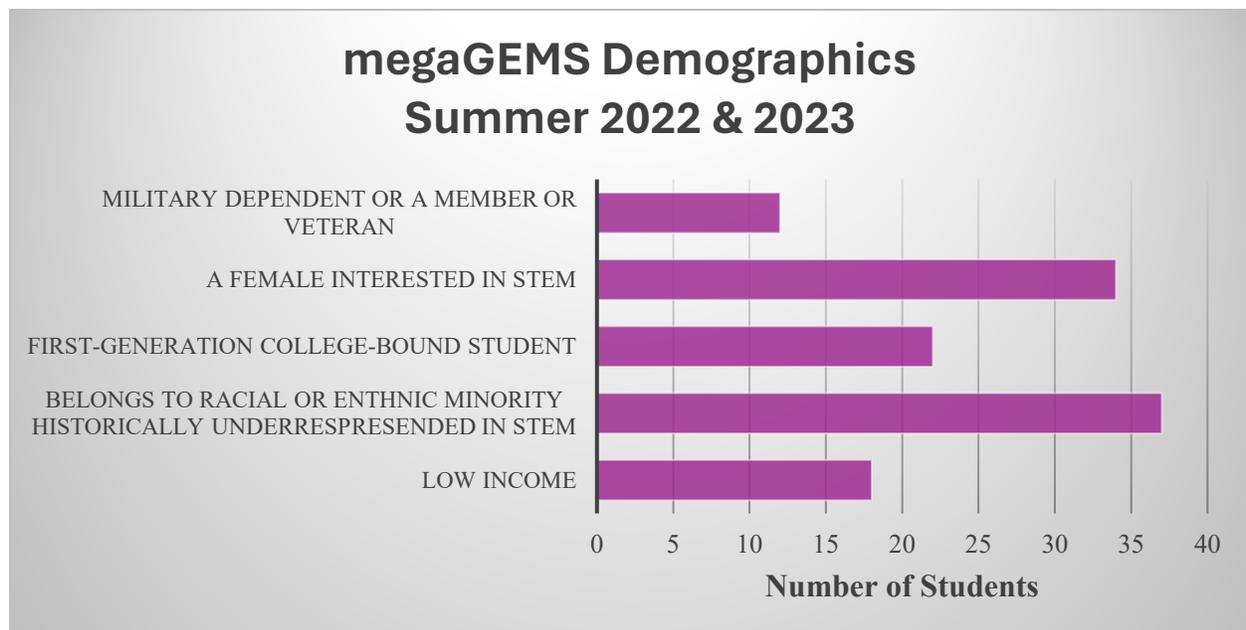


Figure 1, Demographics of megaGEMS Students for the Summer of 2022 & 2023

Additionally, as GEMS recruits from under-resourced [5], rural, and urban areas of San Antonio, and surrounding counties, the megaGEMS summer programs provide stipends which in turn increases the incentive to attend and help provide a small yet necessary income for many our students. Figure 1 depicts the demographics of the megaGEMS students for the summer of 2022 and 2023. megaGEMS Unite serves as a pipeline for students graduating from the miniGEMS middle school programs wishing to continue to explore their intellectual curiosity through hands-

on STEM research. Additionally, the students are then encouraged to apply for the 8-week megaGEMS High School Internship Program for juniors and seniors [2], [5] upon completion of the megaGEMS Unite program.

As all of GEMS' programs are funded through grants, GEMS is privileged to work with the AEOP Consortium. More specifically, GEMS has received funding from the Army Education Outreach Program High School Apprenticeship Program and through the Technology Student Association through grant submissions.

The Army Education Outreach Program (AEOP) offers a collaborative and cohesive portfolio of STEM programs that engage, inspire, and attract the next generation of STEM talent [10] administered through the AEOP consortium. The consortium consists of the Rochester Institute of Technology, the Technology Student Association (TSA) [5], [11], Battelle Memorial Institute, and various other organizations and partners. Each provides funding resources to create, and host programs to empower the next generation of the workforce with the tools and skills that are highly sought out. The AEOP focuses efforts on racial or ethnic minorities, low-income, first-generation [12], English as a second language, a female interested in STEM, and military dependent or a member or veteran [4], [5]. Additionally, GEMS recruits' students with similar demographics as seen in Figure 1 further noting the cohesive partnership.

The AEOP High School Apprenticeship Program (HSAP) is a career development initiative to conduct real-world research through internships and fellowships with a vision of "STEM-inspired change makers, problem solvers, and innovators" [13]. The mission is to provide an accessible pathway of STEM opportunities to attract, develop, and mentor the next generation of our nation's diverse talent through the U.S. Army Educational Outreach Program [13]. The AEOP high school program offers a Learning Hub and Speaker Series through an e-learning platform providing an added resource for students to expand their network and STEM interest during their internships. Essentially, providing a well-rounded foundation and support for all learning styles to experience, learn, and gain STEM knowledge, school pathways, and careers [5]. The HSAP program funds the megaGEMS 8-week Summer Research Program [2].

Unite, administered by TSA, is a nationwide summer program for talented high school students from groups historically underrepresented in STEM [5]. TSA offers various competitions and programs for middle school and high school students to explore fields of forensic science, biotechnology, structural engineering, and building solar-powered race cars [11]. The Unite program funds the megaGEMS 4-week Summer Research Program.

The AEOP consortium provides financial resources to fund GEMS summer high school programs for underrepresented and underserved students. The students can experience career opportunities, develop soft skills, and broaden their STEM skills while earning an education stipend and building a competitive Curriculum Vitae [10]. All students highlight their final

research in poster and presentation format at the End of the Summer Showcase and submit a research abstract to the AEOP to be published in the AEOP Research Journal.

Demand for Coding Academy

The need for Coding Academy lies within the very principles of the GEMS program, specifically in its goal of workforce development as well as improving social justice for female minorities. The National Center for Science and Engineering Statistics (NCSES) said that in 2021 “about two-thirds of those employed (65%) in STEM occupations were men and about one-third (35%) were women [14].” Coding Academy is essential for addressing the basis of this issue and empowering female students who will enter the workforce with strong skills and knowledge in computer sciences. Essentially showing the next generation of female students the feasibility of a career in STEM [4] and allows the students to approach learning STEM safely and encouragingly.

Coding Academy came to be through the request of GEMS participants. Students realized the importance of learning coding skills as they needed the skill to fully conduct their research projects. In 2021, the initial pilot program of teaching Python coding to high school programs was explored. The students received a similar curriculum that discussed foundational concepts through 1-hour teaching sessions. Since the inaugural program, the curriculum has been altered to align with Texas standards as well as adjusted to ensure all concepts can be covered throughout the duration of the program as well as challenge those who have attended the program previously.

Curriculum

The basis for the Coding Academy is the Python Programming Language. Python was selected as the language of choice for its ease of use, wide community support, and demand in the workforce as previously stated [6],[7].

Python is an interpreted beginner-friendly open-source programming language. The flow of this language is similar to how it is written in plain English. The linguistic similarities to English make the language easily readable, thus syntax becomes remarkably simple for users to understand. The Python programming language is also the basis for many introductory-level programming and computer science courses in institutions of higher learning [6], [7]. One such popularly discussed example is Harvard’s CS50 Introduction to Computer Science. By establishing an early relationship with this language students become familiar with the basics of programming, from simple concepts like syntax to more advanced topics such as object orientation. This familiarity gives students a considerable advantage in both the classroom and the job market [15].

In addition to the programming usage of Python, the software is easily accessible. Because of the open-sourced nature of the language and its supporting community, many resources are available to the students for free or at a low cost [6], [7]. This enables all students a means of learning freely without hindrance of references or resources.

An important feature of the curriculum is the undergraduate instructor, who conveys “relatability” to the high school students. As stated previously, they are undergraduate students with similar interests and career paths as the high school students as well as similar backgrounds. Coding Academy is led by undergraduate Research Assistants from the Autonomous Vehicle Systems Laboratory. This is particularly important as they bring an interesting perspective from daily interactions with code. These instructors bring a wealth of on-the-job experience and fundamental theory which the students benefit from. This blend of practical and theoretical knowledge is beneficial especially when students seek to understand how code interacts with their research. Students learning from instructors who similarly interact with code helps to positively reinforce the lessons that the students learn in class.

With both quality instruction and a very beginner-friendly language the curriculum then centers itself around ensuring that students retain and apply knowledge given.

megaGEMS Pedagogy

To support this mission, the megaGEMS summer programs are to enhance learning in STEM topics that are aligned with Texas Education Agency (TEA) Texas Essential Knowledge and Skills (TEKS) [16] requirements for high school students. Students will understand the STEM fields and possible career pathways.

1. Students will be introduced to basic computer programming using the Python Programming Language,
2. Students will be introduced to Artificial Intelligence using Python,
3. Students, through the applied control of robots, will learn about why math and sciences are important,
4. Students and Parents will learn about the high school STEM endorsement and about the necessary courses to take in high school to be ready for STEM study in college, and
5. Students and Parents will learn how to apply to college and about several types of financial aid.

The curriculum of megaGEMS summer programs will incorporate project-based learning group activities and focus on robotics as well as computer programming [2]. Additionally, the students will learn to integrate sensors, such as GPS, so that their robot can make decisions and explore their environment. The Python Programming curriculum was introduced in the Summer of 2019 in the megaGEMS research camps where they learned to create video games. The course got an

incredibly positive review! The curriculum has been refined and aligns with TEKS standards [16], providing teachers and students with innovative relevant material. Python is being taught as it has been consistently ranked among the most popular programming languages and has already been used in Texas high school coding courses [6], [7]. The Python curriculum encourages students to learn fundamental concepts of coding through creative projects which in turn are relatable to their research [2]. The curriculum is designed to be taught throughout the research camp for one hour each day and build upon the previous days' concepts.

Coding Academy Course Structure

Each 1-hour session consists of lessons that develop basic skills in programming, as seen in Figure 2. Throughout the last session of Coding Academy students were able to cover syntax, data types (string, list/array, dictionary), classes and functions, and object-oriented programming basics [7]. The amount of curriculum covered throughout this course can be attributed to the nature of how it was instructed. The structure of the course features an interactive review at the beginning of each session to solidify lessons learned prior, followed by instructor-led examples of the usage of concepts covered, and then group/project work. In the first review at the beginning of each session, students were made to answer review questions collaboratively. For example, they are each assigned a data type and then called on to give an example and make the class guess what data type they have. Students benefitted from the repetition of concepts, and the ability to interact/connect with the lessons from previous sessions in a fun way which solidified confidence in the subject.

During the instructor-led portion of the session, students followed along with coding examples and newer concepts as they were introduced. This entailed having students write the code, and or modify older codes using newer concepts. These parts of the session laid the foundation for group work and projects. Students were responsible in groups of two to three for the development of codes related to some of the bigger lessons. For example, when covering functions students were to write a code for a restaurant menu in which users can select options and display their total at the end of ordering. The benefit of this practice was the students' interactions with each other [6]. With the ability to discuss and work in teams, the students were able to bridge gaps in understanding. When the students were surveyed, 95% of the students found the group work was helpful during the Coding Academy. As some students understood the project and concepts would help students for whom it was unclear. The teams also came with different approaches based on knowledge.

An interesting part of the group work portion of the class is that it mirrored the student's research project teams. Students who worked in teams together for their projects were paired with each other, expanding the extension of the coding fundamentals beyond the classroom. The culmination of which was the student's research projects. With the knowledge obtained in the Coding Academy sessions students were able to begin exploring integrations of code within their

summer research projects. Some of the student even decided to devote themselves to doing the coding parts of their projects exclusively as their confidence increased.

	6/12 MONDAY	6/13 TUESDAY	6/14 WEDNESDAY	6/15 THURSDAY	6/16 FRIDAY
8:45 AM	Drop-off	Drop-off	Drop-off	Drop-off	Drop-off
9:00 AM	Research Time	Drone Session	Revise Poster Outline	Research Time	UIW Garden
9:30 AM	Research Time	Drone Session	Revise Poster Outline	Research Time	UIW Garden
10:00 AM	Coding Academy	Coding Academy	Coding Academy	Coding Academy	Rest period/Research Time
10:30 AM	Coding Academy	Coding Academy	Coding Academy	Coding Academy	Research Time
11:00 AM	Research Time	Research Time	Research Time	One-on-one Conferences/Research Time	Research Time
11:30 AM	Research Time	Research Time	Research Time	One-on-one Conferences/Research Time	Research Time
12:00 PM	Lunch	Lunch	Lunch	Lunch	Lunch
12:30 PM	Research Time/Drone Session	Go over Poster Outline	Research Time	Research Time	Weekly GEMS Meeting
1:00 PM	Research Time/Drone Session	Create Poster Outline	Research Time	Research Time	Weekly GEMS Meeting
1:30 PM	Research Time/Drone Session	Mega Meditation	Research Time	Drone Session	Weekly GEMS Meeting
2:00 PM	Create Poster Outline	Mega Meditation (Until 2:45)	Revise Outline/Research Time	Drone Session	Research Time
2:30 PM	Create Poster Outline (snack @ 2:45)	Work on Poster Outline (Snack at 2:45)	Revise Outline/Research Time (Snack at 2:45)	Drone Session (Snack at 2:45)	Research Time
3:00 PM	Create Poster Outline	Work on Poster Outline	Revise Outline/Research Time	Work on Wkly Slide	Mega Meditation (snack @ 2:45)
3:30 PM	Create Poster Outline	Work on Poster Outline	Revise Outline/Research Time	Work on Wkly Slide	Mega Meditation (snack @ 2:45)
4:00 PM	Journal	Journal (Poster Outline Due)	Journal (Poster Outline Revision Due)	Journal (Wkly Slide Due)	Journal
4:15 PM	Goodbye!	Goodbye!	Goodbye!	Goodbye!	Goodbye!

Figure 2, Example of Weekly Schedule

Implementing Python into research projects

The megaGEMS high school summer research programs require each student to complete a high-caliber college-level project with a focus on air and ground robotics. The students are placed in small groups of 2-3 based on their interests in the provided ongoing research topics. As each member comes from a varying grade level, educational background, and/or interest this creates a cohesive measure to link the students. The final deliverable for each project is a scientific poster and oral presentation displayed at the End of Summer Symposium. The students in the 8-week research program are additionally required to write a 5-page scientific paper.

As the students begin their research the initial step is learning about the hardware and software they will be operating throughout the duration of their research. Coding Academy ties all the projects together as each of the areas of focus requires some coding to achieve the desired goals of the overall projects. For example, the students have various small unmanned aerial vehicles (sUAVs) that they use to determine object detection, and color detection, by implementing code that they find through research, or that they write specifically for the platform they are using.

This “trial and error” allows the groups to brainstorm with each other and then have an open discussion. Each “error” stimulates critical thinking for the students to solve issues that arise in the code they wrote or why a previously written code for another platform does not translate to a new platform.

Another example is seen in Figure 3A with students employing Python code to swarm DJI Tello drones. In this case, a swarm is defined as more than one drone flying together. The students in this group had one student who grasped the coding very well and successfully wrote a working code. This was a huge deal among the students as they then used pieces of her working code for their projects. Successes like this brought the students together and created an overall team among the various groups. This was pointed out by the students, showing how multiple departments of an organization work together to achieve their goals in business.



The Application of Tello Swarm Using Python To Allow More User Creativity

Girls in Engineer, Math, and Science
Army Education Outreach Program, UNITE



Abstract

Tello Drone EDUs are excellent drones for this project. The type of drone that will be used is a Tello EDU. The Tello EDUs are best for this project because it's one of the few drones that can swarm. After making the Python code, two Tello Edu's were paired to a Packet sender Wi-Fi router so they would synchronize in the Tello swarm process. It was difficult to start swarming the Tello because of a lack of resources and experience. Overall, this project. The objective of the project is to swarm Tello drones using Python.

Challenges

It was a challenge to code the Tello drone with Python, this was a challenge because in order to swarm, the drones needed to stay on track the entire time, and with the wrong command the drone could be damaged. The Tello breaking and coming apart multiple times was also a challenge. The Tello is very flimsy/ made of cheap material, so it kept breaking and parts of it needed to be swapped out multiple times. The biggest challenge was trying to connect the Tello drone to an iPhone. The Tello easily connects to Androids better than iPhones so the set-up process to fly with an iPhone takes longer.

Introduction

The quadcopter Tello is a small inexpensive drone with a camera that is able to take SMP photos and stream 720p HD videos. It is commonly used for beginner drone pilots, entertainment purposes, and swarming. Experimenting with Python code is needed to program several Tello drones to fly in autonomous synchronization. Python is a computer programming language used to provide the Tello drone directions to follow. Using Python is beneficial because it allows the user to program specific creative directions that can not be done with the basic Tello flying functions found in the Tello app. Currently, the Tello App functionality is limited to a virtual remote control and lacks the ability to create a drone swarm. The objective of the experiment is to create a quadcopter Tello drone swarm using python coding. This experiment used UIW Tello drones, a lightweight and affordable quadcopter, and the python programming language to enable the drones to do more than what can be done with an iPad controller. Currently, the Tello App functionality is limited to a virtual remote control and lacks the ability to create a drone swarm.

Conclusion

Overall, this project was good. The drones were definitely a challenge, but the research team worked it out. The Tello drones were somewhat easy to work with but takes a while to get started. Once the Tello is doing what it needs to there really is no other struggles. The Tello drones are pretty much straightforward. The swarming process can be very confusing, but everything worked out perfectly fine.

Methods

After making the Python code, two Tello Edu's were paired to a Packet sender Wi-Fi router so they would synchronize in the Tello swarm process. In order to pair the Tellos to the router, the IP address needed to be found for both Tellos. To do this the computer needed to connect to the Tellos Wi-Fi and a command prompt was opened on the Windows computer. After inputting a command in the command prompt, the Tello IP addresses were found. With the IP addresses, the packet sender was able to send commands to the Tello so that they would pair with the router. The Tello drone app was connected to two iPhones to experiment with flying the drones. After successfully connecting, the flying capabilities on the app were tested. Aside from manual flying, the Tello app also offers additional features such as bounce mode, throw and go, and 8D flips. After testing these features, it was decided to make a program that had autonomous flying capabilities as well as a swarm feature that could not be done with the app. Python code (Fig. 3) was used to design a code for the two Tello drones to autonomously synchronize and go up, down, turn clockwise, and counterclockwise at certain angle degrees.

Future Work

The Tello drone has the potential for significant improvement in several key areas:

- Enhance the user experience by developing a more user-friendly drone application to improve the flying process
- Improve the connectivity between the Tello drone and iPhones
- Improve the connectivity between the Tello drone and the router
- Enhance the construction of the Tello drones by incorporating a sturdy and lightweight material
- Increase utilization of metal components to contribute to a more durable and reliable drone design

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```

from djitellotapp import Tello

tello = Tello()
tello.move(0)
tello.rotate(0)

frame_read = tello.get_frame_read()

tello.takeoff()

# while True:
# img = frame_read.frame
# cv2.imshow("drone",img)
tello.move_back(30)
tello.move_forward(30)
tello.move_forward(30)
tello.rotate_yaw_right(90)
tello.rotate_yaw_left(90)
tello.move_back(30)
tello.flip_forward()
tello.flip_right()
tello.flip_left()
tello.land()
                    
```



Fig 1: Top Tello Drone



Fig 2: Tello Drone

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Figure 3A, Example of Poster Presentations from students implementing Python Coding language to conduct their research

Additionally, one group of students had previous background knowledge of JavaScript, an object-oriented computer programming language commonly used to create interactive effects within web browsers. Java is another popular language, well documented, has good community

backing, and with similar features to Python. Despite learning Python, this group of students wanted to challenge their Java skills to mimic the project of object detection and color detection previously mentioned. This unique situation had the groups compare coding languages and discuss how to translate code to achieve similar tasks.

Other research topics included implementing image filters in Python to improve the applications of an autonomous car seen in Figure 3B. and adding Python to a Donkey Car to determine functionalities and capabilities.



Application of Image Filtering to Improve Autonomous Vehicle Training

Autonomous Vehicle Systems (AVS) Research Laboratories, GEMS
Army Educational Outreach Program (AEOP) High School Apprenticeship



ABSTRACT

This project was designed to explore the possibility of using different image filtering techniques to improve the training of an autonomous vehicle (AV) within a simulated 3D environment. The lab used Quanser's QCAR—a sensor-rich car designed for research—as a small-scale model of a vehicle. A variety of OpenCV filters were evaluated to find the ones that would be best suited for this project, then applied to a dataset to be fed into a model. The results of the model were evaluated and compared to determine the best image filtering techniques.



Fig. 2: Virtual (left) versus real (right) camera

CONCLUSION

Many difficulties were encountered within this research, causing the initial goals to shift and change. With certain time and resource constraints, the lab was unable to complete a thorough analysis. Despite this, many things were learned and gained from the conducting of this project:

- Driving around a single circle track is best for collecting data. However, it is important that when manually driving for data collection, the car is driven around the circle in a consistent curve, rather than moving forward to be and turning repeatedly. How the dataset is collected heavily impacts the results of the training and testing.
- The QCAR runs much more smoothly at lower battery voltages or lower speeds. The smoothness of the driving also depends on the dataset collected.
- Visually, image filters make the virtual and real cameras look much more similar. The application of image filters allows promise in decreasing the virtual-reality gap. Out of the filters examined, morphological gradient seems to be the best choice.
- If applying image filters when both training and testing in the real world, there is not much improvement. Compared to without filters, the application of the opening and closing filters actually did worse. The morphological gradient seemed more consistent, but not much **BETTER** than the model trained with unfiltered images.

INTRODUCTION

A virtually simulated environment allows for the replication of autonomous driving within a computer-generated environment, and thus the ability to test an autonomous vehicle on a computer rather than in the real world. The ability for an AV to be tested in a simulation helps save time and money and allows for increased repeats of the same scenarios, improving vehicle reliability. However, there exists a virtual-reality gap. A simulated world allows for the replication of scenarios which do not exist in the real world, such as a car flying car to avoid an obstacle. Additionally, virtual simulations do not contain the imperfections and noise found within images a real-world sensor would obtain. This research explores the use of image filtering to increase the likeness of virtual and real camera images. Image filtering is an image processing technique in which the appearance of an image is altered through manipulation of its pixels. With use of image filtering, an AV's training and driving can be greatly improved.

THE EXPERIMENT

To begin the experimentation, a deep learning (DL) network was needed to build a model for the QCAR to use. A previously built convolutional neural network (CNN) from a past research study was adapted and used. It was chosen for its easy implementation and relevance to this study.

The next step was to collect a dataset of images, throttle signals, and steering angles, either using the real-world camera or virtual camera in the Quanser Interactive Lab application. On the real track, this was done by manually driving the QCAR around the track. In the virtual environment, this was done by running a pre-written Quanser program for autonomously driving the QCAR.

It was noticed that the autonomous driving in the virtual environment for collecting data was inconsistent and inaccurate; oftentimes, the car would go out of its lane, causing faulty data. Until it could be figured out how to improve the autonomous-driving program or how to manually drive the car within the Interactive Lab, this lab was unable to continue training in the virtual environment. Because of the limited time, it was decided to shift the research to simply improve the model trained in the real-world.

Once the data collection was complete, if needed, the dataset would first be cleaned to create a better-quality dataset. Then, the data would be fed into the CNN, training a model to then be tested on the real track. The same process was repeated with different filters applied.



Fig. 1: Quanser's QCAR

SELECTING IMAGE FILTERS

The OpenCV library provides a variety of filters that can be easily applied to images. After a thorough evaluation and examination of the available filters, four were selected for this research:

- **Canny edge detection** (isolated the edges within an image, drawing focus to only such and ignoring the rest)
- Three **morphological processes** (processes that use a structuring element to remove the imperfections of the image and exaggerate its best structures):
 - **Opening** (good for noise reduction and closing gaps)
 - **Closing** (good for image smoothing)
 - **Morphological gradient** (showed both defined edges and outlines of objects and their proximity of them, helping draw attention, especially to lights and objects closer to the QCAR)

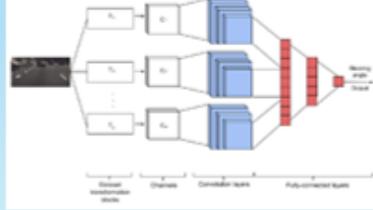


Fig. 4: Example of a neural network

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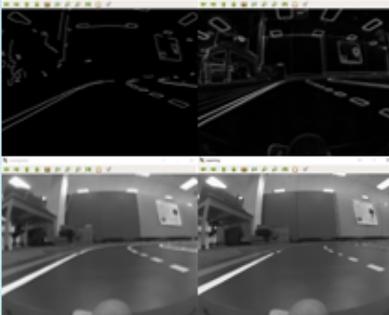


Fig. 3: The four selected filters

FUTURE WORK

- Model improvements can be done through neural network development, data collection refinement, and image filtering variation.
- Data collection within the virtual environment can be improved upon to allow for the completion of this research's initial goal.
- Implementation of stop sign detection and response
- Increased efficiency of model training and testing to require less computer power
- Application of speed control, rather than just steering

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Quanser: <https://www.quanser.com/en/Products/Software/Quanser-Interactive-Lab>

Python: <https://www.python.org/>

TensorFlow: <https://www.tensorflow.org/>

The OpenCV Library: https://docs.opencv.org/4.x/d2/d80/tutorial_python_canny_detector.html

The OpenCV Library: https://docs.opencv.org/4.x/d2/d80/tutorial_python_canny_detector.html

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Figure 3B, Example of Poster Presentations from students implementing Python Coding language to conduct their research

Surveying and Outcomes

Workforce Development and GEMS

Although GEMS serves primarily as a catalyst for STEM/STEAM exposure and preparation, another important function of the program is workforce development [5], [6], [7]. The students learn alongside their research how to develop a resume and cover letter, appropriate dress and

business mannerisms, and advice on how to pursue and continue an education and career across the STEM/STEAM fields. The importance of this practice lies in the ability to cultivate professionalism. The research camp attendees are exposed to professional practice and given a baseline for how a research experience works [1]. For example, research students are given an orientation on day one as well as a job description and expectations. This exemplifies how GEMS begins a “workplace-like environment” and lays the foundation of workplace culture. This allows the students to learn a new structure of communication that differs from that of a typical classroom. If a student is unable to attend, it is required for them specifically to contact the director through email notification of their absence versus their parents. Additionally, when high-level guests or presentations require “business attire,” the students are asked to wear proper clothing. GEMS strives to prepare students for post-secondary school and workforce.

Given these needs and the importance of K–STEM preparation and the opportunities available to students who excel in STEM subjects, it is important to continue to focus on efforts that will increase the number and diversity of students interested in STEM and broaden opportunities for all students to succeed and thrive in STEM [3].

The image on the right shows the U.S. need for an increase in female engineers in the workforce as the global statistic is only 1% greater than the U.S. [9]. A study done by the University of Massachusetts Amherst stated that the United States will need to increase STEM degree completion



for first-generation students by 34% annually to meet its goal of 1 million degrees over the next decade [12] further emphasizing the importance and need for programs like GEMS.

Expected Results

The expected results from the megaGEMS summer programs are to generate a collaborative and creative applied learning environment that will help research students build a solid foundation in

2 topics: (1) understanding how math and science relate to engineering and computer science, (2) understanding the importance of mathematics to science [1], [2], [5]. GEMS expects to provide hands-on experience to teach students STEM career pathways through basic computer programming using Python scripting languages.

The expected results from the megaGEMS summer programs teachers are: (1) introduce teaching skills that can support teachers in gaining hands-on experience in teaching block coding and Python scripting languages to control robots, (2) and provide a supportive professional development for teachers to network with other STEM teachers throughout San Antonio and (3) recruit students, help student management, and help with the research camp learning process. The expected results for the families of the students/campers are to teach about necessary STEM courses in high school that will benefit and prepare students for both college readiness and workforce development. Providing students and families with a foundation of knowledge and expectations going into high school and post-secondary school with maintain the pipeline into STEM careers [1], [2].

Metrics

Metrics are used initially introduced at the start of each program, during the application process, and continue throughout the camp to track the math/science maturation of the students. A pre-survey is administered to the students within their application. GEMS utilizes daily and final program surveys to assess the effectiveness of the program which are discussed further in subsection *Results from Student Surveys*.

Students' progression

“The curriculum of Coding Academy is based upon concepts that build upon each other giving the students the tools they need to write working code for their research. Regardless of the student's level of coding knowledge, each student can learn new skills and/or refresh their skills. The interesting thing to note is that no matter what level the students have, each one struggles at different points throughout the summer, and by the end of the summer they all understand the material. Watching the students from day one of class to the last day of class, it is palpable to see the level of confidence gained by the students from the Coding Academy.

On occasion the students would even ask to extend class beyond the hour so they can continue to work on their codes and complete daily projects. And when the students were able to code the wanted product, the mentors could see their excitement of their success with their eagerness to help others,” said the GEMS Director Stephanie Weiss-Lopez.

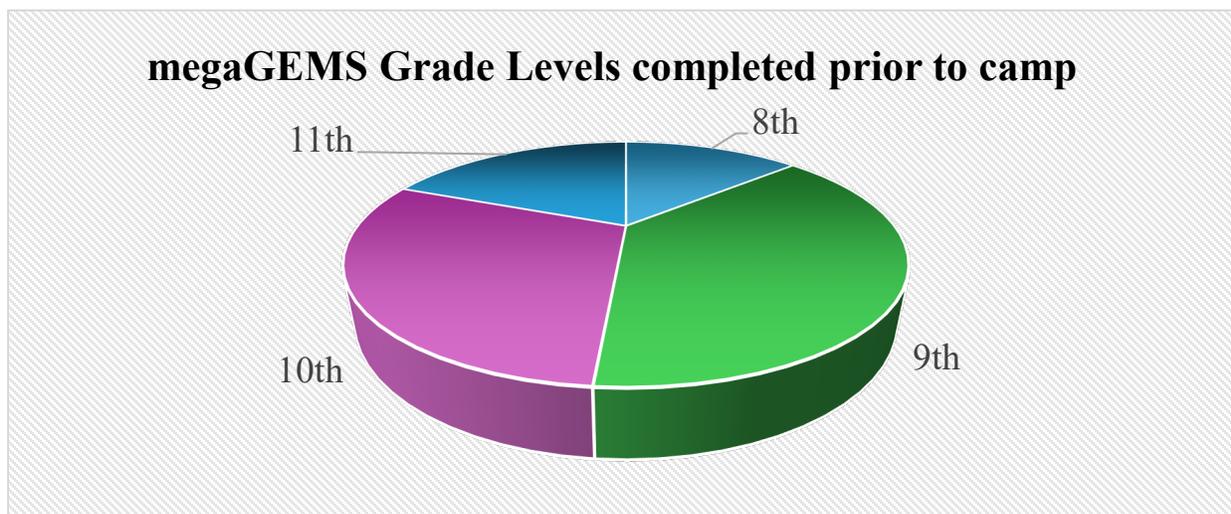


Figure 4, megaGEMS Grade Levels completed prior to the start of summer programs

The metric of student success is also understood from the perspective of the instructor. Students began the camp at various levels. Different grade levels, education levels, backgrounds in coursework, and even interest levels in STEM. Coding Academy provides a level playing field for each student to learn and acquire a new skill.

“In Coding Academy, not only did students have different understandings concerning code, but they came from different grades and academic backgrounds (Figure 4). These differing backgrounds proved to be the basis upon which students’ growth was observed. Seeing students who had no more common ground than the fact of attendance in the program grow to collaborate over a previously unfamiliar programming language was rewarding. This speaks a testament not only to the proficiency of students by the end of camp but to the nature of instruction and how it fostered interpersonal connections,” said Coding Academy Instructor George Sikazwe.

Results from Student Surveys

The student surveys were conducted through a Google Form which allowed the students to read and answer each question at their own pace. The data was collected and analyzed by GEMS leadership.

Figure 5, Common Responses from Student Surveys

What did you find most intriguing about Coding Academy?	What did you find the most challenging in Coding Academy?
"Challenged me and made me learn new things which I enjoyed"	" Syntax and methods specific to Python"
"The process of writing code was entertaining. Talking about what code does is also always fun"	"How specific the code needed to be. If you were to forget an indent or a colon the whole code would not work correctly, and you would need to go back and fix your mistake"
"I liked learning about coding. Coding is something I do enjoy, although I do not know much about it, and I would like to learn more about it, and the coding academy helped with that"	"The syntax, I always either spelled something wrong or forgot to space something"
"Making fun games out of code like tic tac toe"	"Solving the errors was difficult but we solved them together as a team, so if we failed, we did it together"
"The activities! I thought they were fun and thought-provoking!"	"Trying to figure out how to fix it"
"I think that while challenging, the concept of coding is really interesting in the sense that you can create something out of completely nothing"	" Understanding the code at first"

For both summers of 2022 and 2023, the students were asked the same ten questions asking for feedback focusing specifically on Coding Academy. For this section, the analysis will focus on the common responses seen in Figure 5 from what the students considered the most intriguing and the most challenging about Coding Academy. The students consistently enjoyed the flexibility of coding. (i.e., game-making, coding activities) and “creating something out of nothing” was the most intriguing while the most challenging was syntax. Just like learning any new language, the students struggled to fix errors or to understand the code at first but as the syntax became familiar, they were able to write line after line of code.

Besides surveying the students for feedback on the varying aspects of the megaGEMS summer programs, a true testament is noticeable in student retention.

Student Retention

As previously mentioned, GEMS is divided into two programs: miniGEMS and megaGEMS. miniGEMS is for middle school girls and megaGEMS is for high school girls. GEMS has students who have been involved in GEMS programs dating back to 2017. In looking at the summers of 2022 and 2023, just under 25% of the students attended both summers (Figure 6) By the end of Summer 2023, four of the students had attended three years of miniGEMS and three years of megaGEMS.

Additionally, the megaGEMS Unite program began in summer of 2022 and provided the opportunity for a larger number of students for summer research programs.

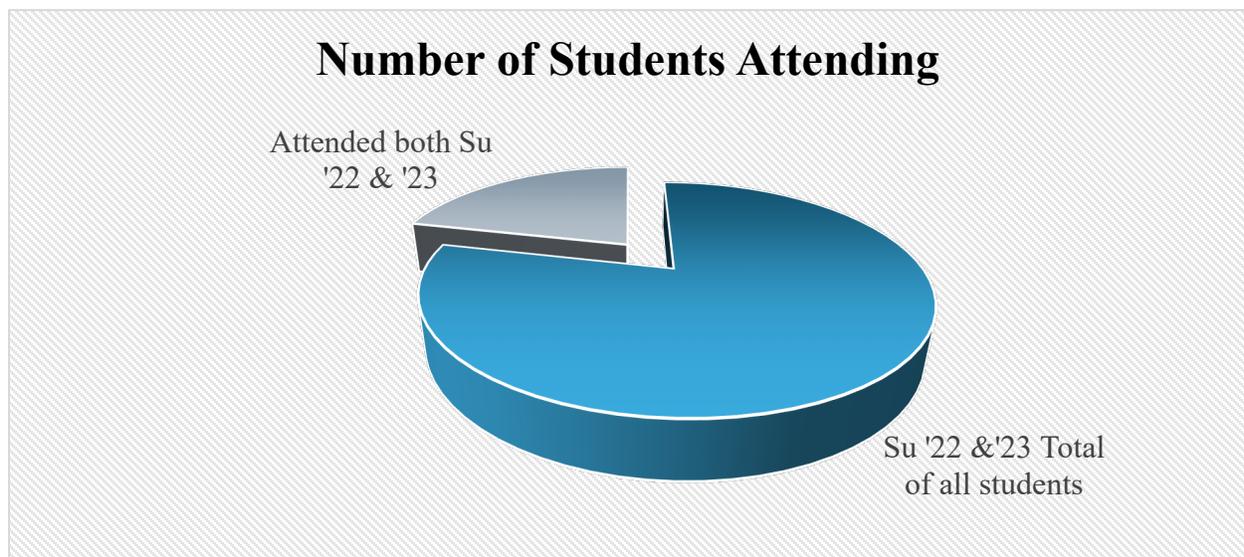


Figure 6, Number of Students Attending GEMS High School Programs for the Summers of 2022 and 2023

Students returning to conduct research having attended the previous year came back with a focus on their research typically wanting to either continue the work from the previous year or to alter the research towards a new direction. They came back ready to work and excited to see the outcomes of their research.

Obstacles that prevented students from returning were due to the students being involved in band/orchestra, sports, ROTC/ROTC leadership, and/or attending summer classes. GEMS leadership typically noticed that the students who attended GEMS also participated in multiple organizations and had a drive to learn and explore.

Conclusion

The Coding Academy looks to empower students with the fundamental programming knowledge and skills necessary for their academic and professional lives. With the core principles of the megaGEMS program in mind, students are instructed in ways that foster a collaborative and critical thinking environment. This collaboration and critical thinking are at the center of the Coding Academy curriculum wherein students are encouraged to take part in team-based projects, and reviews based on active recall. These lessons are built on top of their research project which they present at the end of camp.

The programming skills that students obtain from Coding Academy serve as a basis for STEM exposure. The majority of the megaGEMS students attribute the methods in which Coding Academy was instructed as encouraging them to consider learning and/or pursuing programming seriously. This can be explained through the number of projects that incorporate Python programming with the student's particular research interest, and the metrics from surveying presented above.

Overall, Coding Academy's implementation of engaging curriculum, and team collaboration proved to have a level of impact on each of its students. With this, it was successful in demonstrating the feasibility of developing analytical skills, and team collaboration through daily 1-hour coding lessons.

Future Work

Evolving Curriculum

The curriculum of Coding Academy features effective learning techniques but seeks to continuously improve upon itself. One such measure that it seeks to improve is adding new games and activities to invoke critical thinking and team building. Adding a new curriculum is critical to adjust the students attending year after year as well as remaining innovative.

Furthermore, adding activities, there are plans to translate lessons from Coding Academy into Saturday workshops. These short courses would help refresh students on material and/or build upon previous lessons from the summer curriculum. By supplying students with these extra lessons Coding Academy cultivates the learner and offers accessibility for students for whom summer classes, and or weekday lessons are not possible.

One question asked in the Coding Academy survey was if the students planned on learning other coding languages. Thirty-two percent of students said yes to learning another coding language and 55% said maybe. GEMS leadership is looking to create Coding Academy lessons that incorporate other languages, allowing the students to understand more high-level coding concepts and functionality. Another area Coding Academy seeks to improve upon is branching into more advanced topics and in-depth projects. The Python programming language has benefits in its clear readability, but it is a high-level language. This means the code created through it

offers a bit less control. Instruction of concepts like memory allocation, and exception handling are impeded because the language handles and allocates memory for the user. The lack of functionality places a barrier between students and important concepts.

In addition, it would be great to connect students for more in-depth projects for longer summer programs in the future for those who have a passion for coding. Considering the focus on fundamental programming skills, students progressed and in surveying confirmed the importance of projects. Coding Academy would succeed in enforcing the lessons learned through more in-depth projects that encompass multiple class sessions. During the last Coding Academy students worked on simpler in-class projects which they would finish in one session and review in another. Giving students more time to interact in their teams and work on larger projects would further ensure their capabilities to oversee larger coding tasks. In turn, better prepares them for the camp's research poster presentations. Incorporating the student's research projects into class sessions would also achieve this and allow for students to receive guidance if needed on their projects.

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