The Development of an Autonomous Multirotor Drone in Conjunction with OptiTrack

Autonomous Drone Impact on the 2023 Israel-Hamas Conflict

A Thesis Prospectus
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

My technical project is entitled "The Development of an Autonomous Multirotor Drone in Conjunction with OptiTrack." My group and I developed a quadcopter drone with autonomous functions and learned more about how to use OptiTrack motion system in order to gain flight data. My STS project is entitled "Autonomous Drone Impact on the 2023 Israel-Hamas Conflict." Both of these projects focus on autonomous drones, and both of these projects touch specifically one quadcopter drones. I speak of Da Jiang Innovations (DJI) drones in my STS project, which are quadcopter drones with autonomous capabilities. The research question for my STS paper is: "How does the usage of both militarized and recreational autonomous drones impact the 2023 Israel-Hamas conflict, and how do policies and programmers influence the technology behind drones?" With technology exponentially growing, it is also becoming cheaper. This means that people can get their hands on high levels of technology without having to spend much money—such as taking DJI recreational drones and militarizing them for a fraction of the cost of military-grade drones. The dangers of this should be controlled by policies and programmers. All of this will be covered in the STS paper.

This prospectus will first have a brief section detailing what my technical project is on and the progress made on it. Then, I will detail how I will write my STS paper, as well as touch on which methods and framework I will be using for my STS paper. This prospectus will include references to some key texts that were used in my STS paper that were very important in the understanding of the topic and the underlying issues. Connections will be made between authors' points of view in order to form a complete understanding of how the STS paper will be written and its significance.

Technical Project

My technical project was to create an autonomous multi-rotor drone to be flown in the Reactor Room at the University of Virginia's (UVA) old nuclear reactor site. The Reactor Room is a circular room with a ceiling around 10 meters high. This room is the home of multiple projects, including the autonomous multirotor drone project. There is a net cage located near the entrance of the Reactor Room to account for safety when the drone is flying. A motion capture system, OptiTrack, consists of 16 cameras placed at even intervals around the top of the room and was installed in order to conduct drone research. OptiTrack provides high-precision 3D positional data, which allows for mission planning and high-level object avoidance when paired with hardware onboard drones flying in the space. The data gathered from OptiTrack, such as velocity, acceleration, rotation and orientation, marker trajectory, and more are able to be exported to software such as MatLab for further analyzation. In order for the system to pick up on drones flying in the Reactor Room, they must have at least three reflective markers placed in visible locations around the drone.

To begin this technical project, my group constructed a quadcopter drone with autonomous capabilities through Raspberry Pi and PixHawk using ArduPilot. Manual outdoor flight was successful with a few autonomous features such as stabilize, loiter, and return to home. These three simple autonomous features were programmed into the remote controller we were using and were activated by a single switch. ArduPilot autonomy was achieved outdoors with two waypoints tested. Indoor manual flight was achieved, but indoor autonomy was not attained this year. The Raspberry Pi onboard the drone has "connect and arm" as well as "take off and land" scripts ready to be tested. Once these are tested, a closed-loop connection should be established between the Raspberry Pi and OptiTrack in order to use OptiTrack for autonomy.

Autonomous Drone Impact on the 2023 Israel-Hamas Conflict

In my STS paper, I will be focusing on autonomous drone usage in the 2023 Israel-Hamas conflict. One ethical dilemma that is introduced here is the capability of autonomous drones to take the lives of innocents by means of bombing or shooting. I will be touching on the ethics of sending drones, which have questionable abilities to make good judgments, to kill thousands, as well as an alternate view, which delves into the precision and accuracy of drones as opposed to a human soldier. There have been terrible tragedies of soldiers shooting and killing unarmed civilians, which may be avoidable with the use of a drone. Drones are also extremely effective at destroying whatever they are sent to destroy and much more effective than RPGs (rocket-propelled grenades), which are daunting. I will also detail the companies supplying drones in the 2023 Israel-Hamas conflict and whether the companies truly have the freedom to turn down Israel, Hamas, or either of their allies.

To analyze the ethicality of the usage of autonomous drones in the 2023 Israel-Hamas conflict, I will delve into the brief history of Hamas and Israel, the impacts of military vs. recreational drones in warfare, and the usage of this technology by Hamas, Israel, and others who engage in the war. To further this study, laws and policies regarding drone usage and civilian safety will be researched for all involved parties. Delving into both history and public policies is necessary to conduct a fully informed study of the ethicality of drone usage in this particular conflict because the history will show more of who is involved and where; whereas, the laws and policies set in place currently will show exactly what has been done in order to set standards for drone usage in warfare. The history of the Israel and Hamas conflict will only be used as the starting point of the history of autonomous drone usage between the two and the ethicality of it. The United States is also a player in this conflict, so their part involving autonomous drones will

be explored and evaluated. Autonomous drone history and evolution is a major component of this research because of how advanced both military and non-military drones have become, and specifically how Hamas has started to use recreational drones (or cheaper drones) as armed weapons. This touches on public policy as well since Hamas is using recreational drones to do their bidding; therefore, it is hard to make laws against using them in war because doing so would also affect civilian usage of drones.

The history between not only Israel and Hamas but Israel and Palestine as a whole will be explored. Hamas is a Palestinian nationalist organization created by the continuous hardships Israel has put Palestine through. It is important to understand the history of Palestine and the Gaza Strip exchanging leaderships and governments for many decades, even centuries. Understanding Palestine's struggle against Israel in particular is important to understanding why Hamas was formed and what part Israel has in their coming demise. Although Hamas has a love for primitive attacks, such as using Qassam rockets, they have found the need to turn to more advanced technology in order to combat Israel.

The framework SCOT (social construction of technology) will be used in this paper. This framework is based on the thought that humans influence technology, not the other way around. Creation of new technology is essentially driven by human needs or wants, so it only makes sense that the creator's ideas are then essentially applied to the technology they have created or advanced. This framework essentially personifies technology in the sense that the technology is now a miniature version of the person who programmed it. Now transfer this idea to autonomous drones—especially artificial intelligence (AI) drones. These are self-flying drones that are sent on planned missions. The flight path programmed into the drone will invariably have unexpected obstacles or setbacks along the way, but the drone is equipped to make decisions on how to

continue onward and finish the mission successfully. The path the drone chooses to take to get back on track varies depending on the situation and could be unwanted by the user. Furthermore, imagine the mission of the drone is to target and kill a specific person. What if the drone cannot find the person to shoot once it arrives at the location where this person is supposed to be? These are questions people should be asking because the moral standards of the drone itself need to be 100% solid when people are not directly involved in the firing of missiles, shots, or other weapons. The programmers and companies who develop the drones used in the 2023 Israel-Hamas conflict will be evaluated based on how they program their drones and whether these companies have the ability to refuse to create this technology for their customers.

The avaibility of advanced technology is out of the roof in 2023. Hamas' lack of capital, as compared to their adversary, Israel, hinders Hamas but does not stop them. This is possible because with the accessibility of technology increasing comes the cost of said technology decreasing. These two groups are using the same technology of drone warfare and autonomy but in two completely different fashions. Israel, with the help of the United States, has a nice arsenal of advanced, expensive, military-grade drones, whereas Hamas is using repurposed recreational drones. It will be explored in this paper what this means for warfare as a whole. What does it mean for warfare to suddenly become much more lethal? How do countries combat such cheap but effective equipment? It is also important to realize that there are a lot of open-sourced networks on the internet. Hamas also has a nice team of engineers and quite a high level of planning and thought in their opporation. A future question to be considered is money going to be an object in the future relative to warfare? At this point in time, money is certainly an object in warfare. However, it would be interesting to do some statistical analysis and research about whether or not knowledge and coding skills might one day be as proficient as heavy hardware.

Delving more into the programmers and company's side of things, they will be analyzed based on their policies regarding the usage of their drones and how they implement these policies. For example, the company DJI has made a strict statement against the usage of their drones in any conflict at all. They made this statement starting when Russia repurposed DJI's recreational drones to military drones and used them against Ukraine. Ukraine picked up on Russia's idea and is now following suit. So is Hamas. The idea of repurposing DJI drones specifically is not original to Hamas, but it is still a fairly new idea and implementation of DJI drones. At the time of this paper being published, the Russians and Ukranians have been in a war for two years. How can DJI say they have a "strict policy" against their drones being militarized yet let it happen for years? Not to mention, DJI is a Chinese-company, which could be under China's thumb. DJI seems to be turning a blind eye to conflicts such as these. Therefore, more evaluation on this will be conducted in my STS Paper.

Policies will be hard to evaluate in this paper considering the 2023 Israel-Hamas conflict is an international matter. To add, international war crimes, as agreed upon by many countries, are not heavily enforced. It is especially hard to enforce punishments for these crimes from an external point of view, such as being in the United States dealing with both Israel and Hamas. Both groups have committed war crimes, but only their own jurisdiction can truly punish the prepetrators—perpetrators being their own leaders. Politics is tricky, complicated, and many times ineffective. However awful and tangly politics is, it is necessary to induce change in any capacity. This paper will delve into what policies there are already installed, as well as what solutions there could be to this conflict. These solutions cannot be technical, only social.

This paper's objective is to answer this research question: "How does the usage of both militarized and recreational autonomous drones impact the 2023 Israel-Hamas conflict, and how

do policies and programmers influence the technology behind drones?" With the methods of delving into the history of Israel, Palestine, and Hamas and looking into policies by not only countries involved but also companies involved will allow for a better understanding of the topic itself and what the conflict has to do with drones. The framework SCOT is perfect for this paper because of the connection drawn between technology and society. The connection between autonomous drones and the implications of using this technology in a warzone is profound. The growth of technology is unabounding and ever-changing. There is not much anyone can do about that, even in the defense industry. The world will continue growing into a safer place because of the overabundance of technology. By the same token, the world will also continue decaying from its heavy reliance on technology and the technology that is here to hurt, not help. It is ever important to stay vigilant of the technology on the market and how it can impact others.

Although this STS paper is on drones and their autonomy, they are only a small representation of a larger societal issue. Although the United States cannot necessarily solve Israel and Hamas' problems, they can surely solve their internal issues. Hamas and other countries repurposing DJI drones as military drones begs the question: what next? Who will be the next to turn innocent recreational drones into militarized weapons? The gun problem in America is outrageous right now. Imagine adding militarized drones to the list of internal issues in America. The United States needs to watch other countries and their low-cost tactics carefully because these tactics could very well make it into their country if weapons in America aren't more heavily regulated.

Key Texts

Balint in "Drone Evolution, Grouping, Use and Control" talks much of how drones have become extremely prevalent in today's society in more than one way. Both recreational and military drones are used on a regular basis in America. Balint urges policymakers to catch up with the times and make a few policies addressing some gray areas in how drones are allowed to fly. He goes into how this is especially important regarding recreational drone usage because there are little to no policies regarding the usage of recreational drones. Similar ideals were brought to attention in Gilli's "Drone warfare: An evolution in military affairs," but touching more on military drones than recreational. Gilli goes into how warfare is changing, for better or worse, and that countries must rise to the occasion or else they will have a harsh reality check. Gilli touches on new technologies entering the military all the time. Drones are not the firstmajor evolutionary step in war. However, he shows that all evolutionary steps in war are important for countries to keep up with in order to be able to defend themselves.

To dive more deeply into Israel and Hamas themselves, Mendelboim and Antebi in "Hamas and technology: One step forward, two steps back" detail Hamas' detailed strategic plans pertaining to drones and technology. As the title alludes, this piece also touches on the struggles Hamas has faced in building its military. Svirsky and Bignall in "Agamben and colonialism" really dive into the history between Israel, Gaza, the Palestinians, and Hamas. This piece spans from the beginning of the conflict between Israel and Gaza in the 1800s to now where Israel is using drone warfare against Hamas, and Hamas' adaptations to this new kind of combat.

Bibliography

Air Force. (2021, March). *MQ-9 reaper*. Air force. https://www.af.mil/About-Us/Fact-

Sheets/Display/Article/104470/mq-9-reaper/

AJLabs. (2024, March 15). *Israel-Gaza war in maps and charts: Live tracker*. Aljazeera.

https://www.aljazeera.com/news/longform/2023/10/9/israel-hamas-war-in-maps-and-

charts-live-tracker

Balint, M. (2022). History, types, application and control of drones. *Safety and Security Sciences

Review*, *4*(3), 1-13. https://biztonsagtudomanyi.szemle.uni-

obuda.hu/index.php/home/article/view/222

Department of the Army. (2019). The commander's handbook on the law of land warfare.

https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/ARN19354_FM%206-

27%20_C1_FINAL_WEB_v2.pdf

DJI. (2022, April 21). *DJI statement on military use of drones*. DJI.

https://www.dji.com/newsroom/news/dji-statement-on-military-use-of-

drones#:~:text=DJI%20has%20only%20ever%20made%20products%20for%20civilian,b

een%20identified%20as%20being%20used%20for%20military%20purposes.

Elbit Systems. (2018). *Hermes 450*. Elbit Systems.

https://elbitsystems.com/media/hermes_450_2018.pdf

Frantzman, S. J. (2023, October 20). *In the war against Hamas, Israeli drones are key. Here is

why*. Foundation for defense of democracies.

https://www.fdd.org/analysis/2023/10/20/in-the-war-against-hamas-israeli-drones-are-

key-here-is-why/

Gilli, A. (2022). *Drone warfare: An evolution in military affairs*. JSTOR.

    https://www.jstor.org/stable/pdf/resrep44897.pdf?refreqid=fastly-

    default%3A228693a2b03d377fa7c79b67772e1349&ab_segments=&origin=&initiator=&

    acceptTC=1

Hollister, S. (2022, April 27). *DJI is halting all shipments to Russia and Ukraine to slow*

    weaponization of drones. The verge. https://www.theverge.com/23045059/dji-halt-drone-

    shipments-russia-ukraine-war

Malinowski, D. (2023, October 20). *How to program DJI Naza*. Robots.net.

    https://robots.net/tech/how-to-program-dji-

    naza/#:~:text=Installing%20the%20DJI%20Assistant%20software%20is%20the%20first,

    Naza%20flight%20controller%2C%20ensuring%20optimal%20performance%20and%20

    functionality.

Mendelboim, A., & Antebi, L. (2019). Hamas and technology: One step forward, two steps back.

    Strategic Assessment, 22(2), 43-55. https://www.inss.org.il/wp-

    content/uploads/2022/12/fe-4219723712.pdf

McCrisken, T. (2013). Obama's drone war. *Global Politics and Strategy, 55*(2), 97-122.

    https://doi.org/10.1080/00396338.2013.784469

Reuters. (2023, November 3). *Israel-Hamas war: What are the US MQ-9 Reaper drones that*

    have been flying over Gaza? Reuters. https://www.reuters.com/world/what-are-us-mq-9-

    reaper-drones-that-have-been-flying-over-gaza-2023-11-

    03/#:~:text=Several%20U.S.%20MQ-

    9%20Reaper%20drones%20have%20been%20orbiting,are%20said%20to%20be%20fro

    m%20the%20United%20States.

Samaan, J. L. (2020). Nonstate actors and anti-access/area denial strategies: The coming

    challenge. https://www.govinfo.gov/content/pkg/GOVPUB-D101-PURL-

    gpo134118/pdf/GOVPUB-D101-PURL-gpo134118.pdf

Svirsky, M., & Bignall, S. (2012). *Agamben and colonialism*. Edinburgh University Press.

    https://books.google.com/books?hl=en&lr=&id=1YRvAAAAQBAJ&oi=fnd&pg=PA178

    &dq=how+did+Israel+get+the+Gaza+strip&ots=ve128JcDJD&sig=--

    h0IVwlbJYCHB7oFNBNSuI7t8Q#v=onepage&q=how%20did%20Israel%20get%20the

    %20Gaza%20strip&f=false

Xu, F., & Muneyoshi, H. (2017). A case study of DJI, the top drone maker in the world. *Kindai*

    Management Review, 5, 97-104. https://www.kindai.ac.jp/files/rd/research-

    center/management-innovation/kindai-management-review/vol5_6.pdf

Yousef, M., Iqbal, F., & Hussain, M. (2020). Drone forensics: A detailed analysis of emerging

    DJI models. *2020 11th International Conference on Information and Communication*

    Systems (ICICS), 66-71. 10.1109/ICICS49469.2020.239530

Zanotti, J. & Sharp, J. M. (2023, October 10). *Israel and Hamas: Major conflict after surprise*

    attacks. Congressional research service. https://crsreports.congress.gov/product/pdf/IN/I

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