Autonomous Obstacle Avoidance for Unmanned Aerial Vehicles (UAVs)

(Technical Project)

The Ethics of Autonomous Weapon Systems

(STS Project)

A Thesis Prospectus

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By

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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

With autonomous vehicles and systems becoming more prevalent in the world, regulations set forth when militaries develop autonomous weaponry become intertwined with various laws of armed conflict. With the laws of armed conflict and rules of engagement in place for traditional weapon use, the lack of incorporation of ethics in design becomes evident. In designing such systems, the question arises regarding both the safety of civilians and soldiers. **How can autonomous weapon systems be designed to provide service that is both efficient but does not threaten the ethical nature behind the laws of armed conflict?** This question coincides with the framework of duty ethics, as the actions committed by the autonomous weapon systems must apply dignity and respect to all that would be involved (soldiers, civilians, administrators). Applying the idea that those enacting these jobs would act ethically in all circumstances, even if there is a bad result (Bonde et al., 2013).

With prior developments of autonomous weapon systems, their usage challenges the laws of armed conflict as they are efficient in carrying out missions without putting soldiers in harm's way, but also can put civilians in danger when not fully dependent on human control. Such systems promote efficiency in the reduction of friendly casualties with the ability to conduct surveillance and carry out missions for longer times and deeper beyond enemy lines than human soldiers would. These systems are also able to judge the potential for collateral damage in certain areas before engaging a target. In contrast, concerns arise in the limitations between these systems and the Laws of Armed Conflict (LOAC). These limitations are rooted in the autonomous systems taking away the mechanism of individual responsibility in LOAC, as the system would be responsible for the action that may be a violation for a human but cannot be punished or held accountable for the actions (Chameau et al., 2014). This point explains the

entanglement of LOAC and the use of these systems in war, as the responsibility for unethical actions become unclear when a system is autonomous.

More concerns that arise are the risk of using the systems behind enemy lines and them being captured or breaking down. This puts national security at risk (enemies can obtain important information from the drone), as well as the lives of soldiers as they may have to conduct additional missions to retrieve the drone if it contains information worth saving from the enemy (Sparrow, 2008, p. 173). In relation to putting these soldiers in harm's way more often, and possibly compromising national security, the cost effectiveness that comes with using drones and other autonomous systems may inspire the involvement in more conflicts than necessary. This could lead to government decision makers and military personnel to feel pressured to enter situations of war since the cost and accountability are so low. They are then engaging in the societal fields of both economic concerns and support of warfare from civilians (Walsh, 2015). This point leads to many different concerns for not only the wellbeing of soldiers and civilians, but disruptions between United States civilians and the efforts of the government and armed forces, as it may ignite larger unneeded conflicts in the future.

With the increased use of autonomous weapon systems within the last decade, the need for regulation within the laws of armed conflict brings about the concern of ethics in their use. The framework of duty ethics depicts how the distribution of responsibility and the consideration of people involved should be considered when operating autonomous weapon systems.

Technical Topic

Autonomous mobile robots, and in particular aerial vehicles, are entering our society and finding many applications like aerial photography, infrastructure inspection, surveillance, hobby application, and even search and rescue operations. This has led to a common debate among

experts regarding if fully autonomous aerial vehicles provide greater benefits than human controlled aerial vehicles. Drone crashes, safety challenges, security issues and privacy concerns have led many to believe that fully autonomous unmanned aerial vehicles are not worth the risk or cost (Gupta et al., 2021).

This project was chosen to address the common types of issues with fully autonomous UAVs. Robotics is an area that interests all members of the team, and previous project and internship work with autonomous technologies paved the way for creating a potential solution to current issues with fully autonomous aerial vehicles. Our team's goal is to investigate and enable a form of shared autonomy that incorporates both capabilities – human-controlled input and onboard autonomy (Hourican, P. et al, 2022). This compromise allows for desired human input (e.g., fly a drone to an area of interest), while keeping the system safe (or performing other tasks) through onboard autonomy and obstacle avoidance. This will allow for a much safer and efficient drone that is less likely to crash due to operator error, which our team believes is a necessary development in the advancement of autonomous UAVs.

Similar projects pertaining to shared autonomy have been completed in the past. A commercial-off-the-shelf (COTS) aerial vehicle was enhanced to include mathematical models of the quadcopter dynamics for real-time improved flight stability. The American Automobile Association did an experiment on semi-autonomous driving technology that utilized systems that assist drivers in driving and parking functions and found that collisions with cyclists occur 33% of the time at four-way crossings (Reid, 2022).

This project is different from past work by others because of the simultaneous use of both human controlled inputs and onboard autonomy, instead of switching between one or the other. For example, if the human is manually flying the drone forward, the robot can override the

manual input and stop the UAVs movement (or change the movement) in order to avoid an obstacle. Previous projects with shared autonomy usually have two operating modes, either manual (human) or autonomous. This method, however, analyzes both manual inputs from a human operator and onboard sensors/autonomy to avoid obstacles while completing the desired flight plan or performance tasks. Such actions are displayed here (see Figure 1):

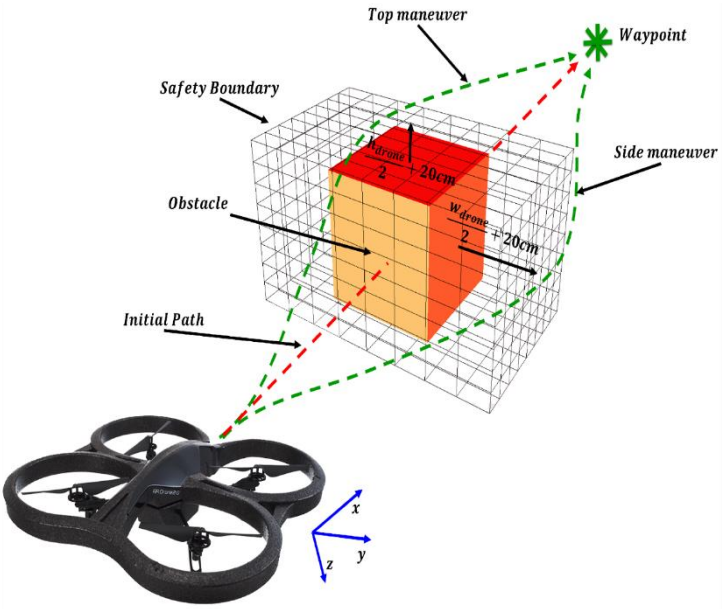

Figure 1. *Note*: This displays the obstacle detection and avoidance of a drone through waypoint tracking. From Obstacle Detection and Avoidance System Based on Monocular Camera and Size Expansion Algorithm for UAVs, by F. Toro and A. Tsourdos, 2017, MDPI.

Within this detection system, we will be using a Jetson AGX Orin Microcontroller, pictured here in Figure 2:

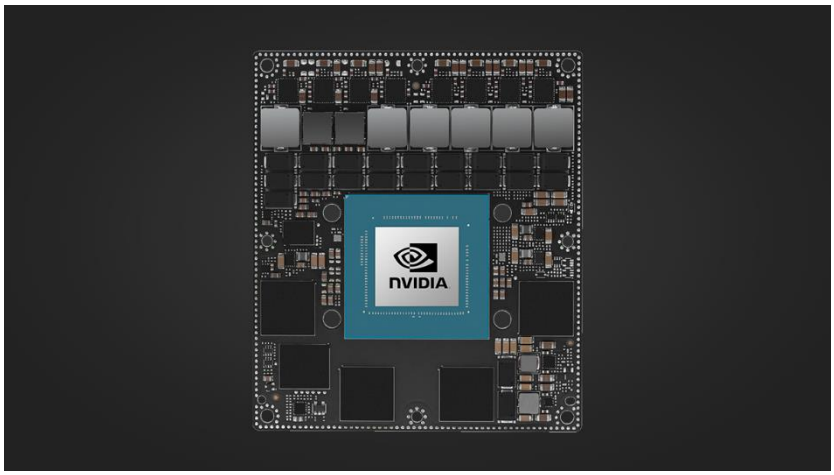

Figure 2. *Note*: The Jetson AGX Orin is a powerful microcontroller that is commonly used for high powered autonomous machines, high-speed interface support for multiple sensors. From Edge Computing: Introducing Jetson Orin Nano, n.d., Nvidia.

This microcontroller is being used to connect the actions programmed in python and implemented for communication using Robot Operating System (ROS) packages. This Jetson microcontroller will communicate with the main computer, operated by a human, and the real-time Lidar data and motor data (position, speed, etc.) will be published on a serial terminal on the main computer using the ROS system.

This technology relates to the STS problem as it addresses the interaction of commercial drones in society. The implementation of obstacle avoidance on a drone for commercial use brings about the ethical concern of unruly domestic surveillance of civilians by authorities. The concerns of residents in a surveyed area explained that drone usage by law enforcement would forgo the purpose of a warrant in some situations, as the government may use information gathered by drones that are set in place for other reasons (Martin and Steuter 2017). This concern connects to the possible need for legislation to regulate surveillance of drone use, like how the use of autonomous weapon systems employ the need for more legislation on the topic. Another connection would be the use of these drones before the implementation of obstacle avoidance, putting people in danger if a drone were to crash and injure them in an accident.

STS Topic

In the design and use of these autonomous weapon systems, it has become more evident that it may not ever be ethically possible to have them operate fully autonomously. However, the question remains of how the operations of these systems can stay within the LOAC. The operation of these systems, even when not fully autonomous, pose challenges in pinpointing

individual criminal responsibility due to the unclear legislation on placing blame in situations concerning LOAC violations with human operated drones. While the drones will be more efficient and successful on paper for some situations, there will still be concerns about the rapid communication and the follow-through of the planning stage of the mission, as aspects can change and lead to civilian casualties and war crimes to occur. Thus, this source engages in the field of ethics within warfare, studying how the use of drones under Article 57 of IHL (Precautions in Attack, 1977) may always require human supervision over the final determination of whether a target is lawful (Nucci, 2016). This idea connects the use of autonomous weapon systems into the framework of duty ethics, as it must incorporate the moral actions of all involved in a situation. The framework of duty ethics, also known as deontology, incorporates the idea of perfect duties, in which you must fully obey an objective. An example of such objectives would be “Do not kill innocent people ", in which you must obey to the fullest, there is no middle ground (Bero et al., 2016; see Figure 3).

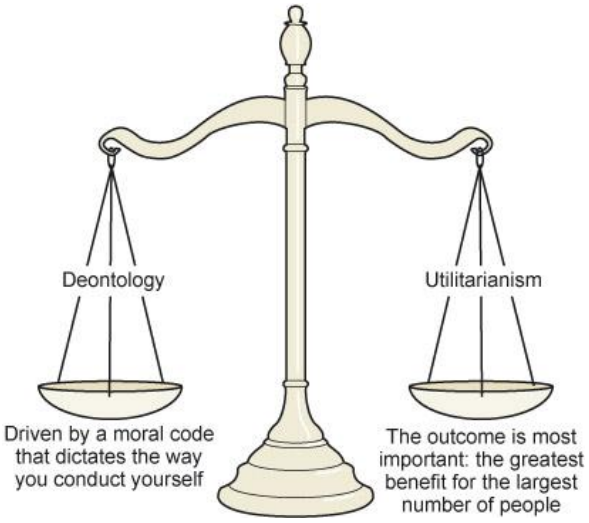

Figure 3. *Note*: This displays the difference between Deontology and Utilitarianism, as Deontology argues for the most moral decision, and does not argue for the most beneficial outcome. From Supply Chain Sustainability: Ethics in the Supply Chain, n.d., OpenLearn.

In working with autonomous weapon systems, another perspective is the idea that ethical decisions are more prevalent in the use of these systems. This is driven by the fact that the time to understand and survey difficult moral situations is not as accessible in traditional warfare. The complexity of war through autonomous weapon tactics has allowed for more philosophical thinking for soldiers (Kaag, 2013). Another perspective is also presented in the ethical field, as the psychological side of killing someone is changed through autonomous systems. These remote operations of weapon systems and the subsequent killing of other humans becomes seemingly "risk-free" and just as simple as playing a video game. This perspective drives the idea that killing another person, albeit enemies, should never be simple and easy and the continuation of this process will change the psychological state of soldiers and their take on warfare (Pehlps, 2021).

Another STS framework that is prevalent in autonomous weapon systems is Actor Network Theory (ANT) (see Figure 4):

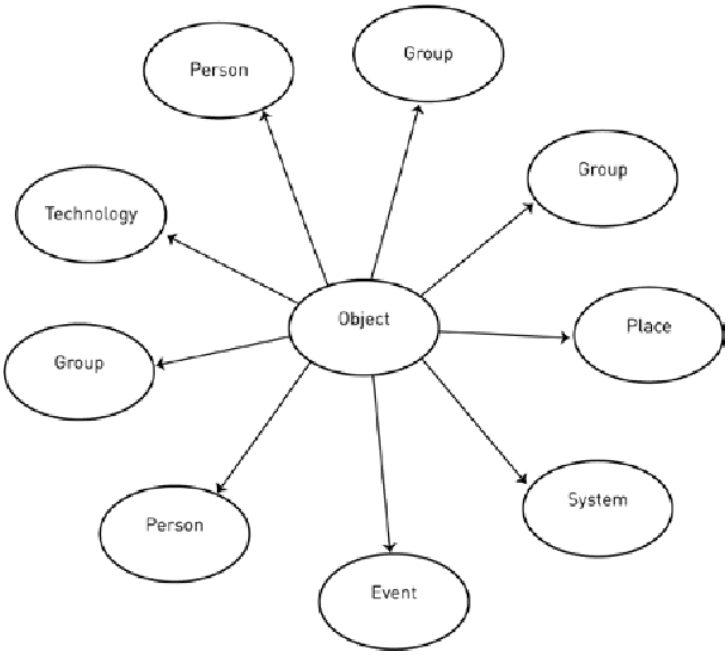

Figure 4. *Note*: The Actor Network Theory diagram depicts the key idea that everything in the social and natural worlds exist in constantly shifting networks of relationships. From

Diagramming with Actor Network Theory: A method for modeling holistic experience, by Plotts, 2008, Semantic Scholar.

ANT addresses the separation among nature, culture and technology by introducing the relationship between the three as a shifting network of relationships (Latour, 2007). With this topic, the delegation of fault and responsibility plays a great role in the arguments surrounding it. With the "network" being the connection between the technology and the human controlling the drone, while the drone can be analyzed as the "actant" as they can carry out the practices set forth by the network. As stated in Tognocchi's thesis, "Therefore, drones can be analyzed as "actants" or mediators in the spatial "network" where pilots and the people on the ground are inscribed together. Drones are capable of circulating practices from long distances and across diverse scales, intimately connecting operators to the people on the ground in real time." (Tognocchi, n.d., p. 37) This displays the idea of the network in ANT for this circumstance, and how the individual responsibility can be diverted from humans in this instance.

Research Question and Methods

The research question being addressed is: **How can autonomous weapon systems be designed to provide service that is both efficient but does not threaten the ethical nature behind the laws of armed conflict?** This question is important because it provides insight into the thought process behind the development of autonomous weapon systems. As these systems are very prevalent in the past decade of military interaction, the use of such systems poses many ethical concerns intertwined with the Laws of Armed Conflict. This connection to the LOAC concerns the division and assignment of responsibility that occurs when a human is operating a drone rather than killing in what may be a criminal matter if there was no system in the middle.

Through cross researching both autonomous weaponry development and the policies that map out the rules of engagements, I will research when policy publication took place and where they intertwine. With many different treaties and documents addressing the laws of armed conflict being produced in the last decade, I will find the rules that relate to the use of fully autonomous versus "controlled" systems. I look to find documentation that builds off of or relates to the Department of Defense Directive 3000.09 (DoDD, 2017), which was set in response to this international humanitarian debate over the ethics and morality of autonomous weapon systems, addressing the use of these weapon systems and how they must be semiautonomous in the way that they cannot determine the targets to fire upon without approval through human user intervention, known as "human supervisory control" (Galliot, 2021).

In terms of autonomous weaponry, I look to research the development of such weapons within the United States. I also look to find some documentation on autonomous weapon development within countries that do not follow the same set of rules and regulations. This information would be used to compare the production of weapons and how the differing policies/compliance of policies has affected development.

Conclusion

In the development of autonomous weapon systems, there arises many issues in addressing the ethics of the actions being committed with them. The use of such systems poses a threat to ethics in the division of responsibility, unnecessary involvement in war, and putting both civilians and soldiers in harm's way. The solution of this concept would allow for efficient warfare tactics while also preserving the lives of innocent people. This would also lead to small conflicts being settled prior to it becoming a larger issue, as well as the idea that soldiers would not be thrown into conflict that was not necessary.

I expect this research paper to find ways in which autonomous weapon systems can be designed and incorporated into warfare without violating the laws of armed conflict and staying within the guidelines of ethical frameworks. The research from this project will find the important documents that address the issues with the LOAC and the ways in which autonomous weapon design can be altered to fit them strictly without overlooking ethical guidelines.

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