Autonomous Drone's in Indoor or Urban Environments

The Effect of Autonomous Drones on Cities

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Aerospace

By
Luke McNabb

November 3, 2023

Technical Team Members:

Kendall Moore, Duc-Lo Nguyen, Yuvraj Singh, Matthew Kuzjak

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.

ADVISORS

Prof. Pedro Augusto P. Francisco, Department of Engineering and Society

Prof. Tomonari Furukawa, Department of Mechanical & Aerospace Engineering

Introduction

In our capstone project, my team's focus is on enhancing the navigational capabilities of autonomous drones in both urban and indoor environments. This complex issue comprises two

main challenges. Firstly, the intricate interactions between drones and surrounding structures, like walls, ground, and other obstacles, create significant navigational complexities, especially in urban landscapes. For efficient drone delivery in densely populated areas, it's crucial to enable drones to maneuver seamlessly through these dynamic spatial constraints. Secondly, the current autonomous codes governing drone operations lack the necessary robustness for real-world applications. As drones gradually become integrated into various aspects of urban life, including delivery services, surveillance, and safety measures, the need for advanced, adaptable, and reliable autonomous drone technology becomes increasingly essential.

In my parallel Socio-Technical Study (STS) research, I am exploring the ethical, regulatory, and societal implications of integrating autonomous drones into everyday urban environments. The swift proliferation of drone technology raises critical socio-technical concerns about privacy, security, and public acceptance. Understanding the societal impact and fostering responsible technological implementation is crucial for ensuring a harmonious integration of drones into urban ecosystems.

The connections between my capstone project and the STS research lie in the intersection of technological advancement, societal adaptation, and ethical considerations. By enhancing the capabilities of autonomous drones in urban environments, we aim to address technical challenges and navigate the intricate socio-technical landscape governing their integration. Through a comprehensive understanding of the complex interplay between technology and society, we strive to develop a robust framework that promotes the responsible and ethical deployment of autonomous drone technology in urban settings.

Drone Testing in Urban Environments

Our capstone project is a response to the pressing need for more advanced drone technology capable of operating seamlessly in intricate urban and indoor environments. As drones are increasingly employed for a diverse array of tasks, ranging from parcel delivery to surveillance, the challenges associated with their navigation in complex cityscapes have become more apparent.

Consider the scenario of a drone tasked with delivering packages in a bustling urban center. Navigating through a dense network of skyscrapers, narrow alleys, and bustling streets, the drone encounters numerous obstacles that can impede its safe and efficient operation. From evading pedestrians and vehicular traffic to negotiating sudden changes in wind patterns and localized weather conditions, the drone must possess sophisticated navigation capabilities to ensure precise and timely delivery without endangering public safety.

Moreover, the implementation of drones in urban environments necessitates the development of robust and adaptive software solutions that can account for the dynamic nature of cityscapes. Advanced algorithms are required to enable drones to swiftly adapt to real-time changes in their surroundings, identify the safest and most efficient flight paths, and respond to unforeseen obstacles with agility and precision. This involves refining the drone's autonomous takeoff and landing capabilities to ensure smooth integration within busy urban landscapes while ensuring compliance with safety regulations and airspace management protocols.

Furthermore, the integration of drones into cities also demands the establishment of secure communication networks and data transmission protocols to facilitate seamless connectivity and real-time data exchange between the drones and central control systems. The development of comprehensive fail-safe mechanisms and emergency protocols is crucial to

ensure the drones' ability to handle contingencies such as system malfunctions, communication blackouts, or unforeseen technical glitches, thereby guaranteeing the safety of both the drones and the urban populace.

By addressing these complex challenges and leveraging cutting-edge technologies, our project aims to contribute to the evolution of a robust and reliable drone ecosystem that can effectively operate within the intricate fabric of modern urban environments. Through the development of advanced navigation systems and adaptive software solutions, we envision a future where drones seamlessly coexist with city life, revolutionizing key sectors such as logistics, surveillance, and emergency services, while upholding the highest standards of safety, efficiency, and ethical operation.

Social Impact of Drone Cities

As the integration of autonomous drones in urban environments becomes increasingly imminent, the potential for various social challenges and implications looms large. In anticipation of this technological advancement, it is crucial to proactively identify and address the potential social, ethical, and legal issues that may arise.

One significant area of concern pertains to the potential infringement of privacy rights, as the widespread use of drones in densely populated areas may raise apprehensions about unauthorized surveillance and data collection. Residents might express concerns about the indiscriminate gathering of personal information, leading to a breach of privacy and a sense of constant surveillance. As such, there is an urgent need to establish stringent privacy protection

protocols and data encryption standards that safeguard individuals' privacy rights while allowing for the effective operation of drones in urban landscapes.

Moreover, the rapid proliferation of autonomous drones in cities brings to the fore the critical issue of liability and accountability in the event of drone-related accidents or mishaps. Given the complexities associated with drone operations, questions may arise regarding the allocation of responsibility in cases of property damage, personal injury, or privacy breaches resulting from drone activities. Consequently, the formulation of clear and comprehensive liability frameworks, outlining the roles and responsibilities of drone operators, manufacturers, and regulatory authorities, becomes imperative to ensure fair and just resolution of any potential disputes or legal claims.

Furthermore, the integration of drones in urban environments may potentially disrupt existing airspace regulations and norms, necessitating the development of robust and adaptive policies to manage the safe coexistence of drones with other airspace users, including manned aircraft and helicopters. Establishing designated drone flight corridors, implementing real-time airspace monitoring systems, and enforcing strict no-fly zones in sensitive areas such as airports and critical infrastructure sites are some of the crucial measures that can help mitigate the risks associated with drone airspace integration and ensure the safety of both airborne and ground-based activities.

In light of these complex social and legal challenges, my research aims to conduct an in-depth analysis of the various policy frameworks and legal mechanisms required to effectively

regulate the integration of autonomous drones in urban environments. By delving into case studies and engaging with diverse stakeholders, including policymakers, legal experts, and community representatives, I seek to identify common concerns and develop comprehensive regulatory guidelines that not only address the technical aspects of drone operations but also prioritize the protection of individual privacy rights, the establishment of clear liability norms, and the promotion of harmonious coexistence between drones and urban communities. Through these efforts, I aim to contribute to the development of a robust and socially responsible regulatory framework that fosters the responsible integration of autonomous drones into urban landscapes, ensuring the protection of individual rights and the promotion of societal well-being.

Conclusion

In conclusion, our technical research endeavors to enhance the navigational capabilities of autonomous drones in complex urban and indoor environments, thereby facilitating their seamless integration into various urban operations such as delivery and surveillance. Concurrently, our STS research highlights the critical need for effective regulations and ethical frameworks to govern the integration of autonomous drones in urban settings, considering their potential impacts on privacy, safety, and societal well-being.

By developing advanced drone navigation systems and proposing comprehensive regulatory guidelines, our research aims to address the multifaceted challenges associated with the safe and responsible integration of drones into urban landscapes. The successful implementation of our technical deliverables will enable more efficient and reliable drone operations, while our proposed STS deliverables can foster public acceptance and ethical deployment of drone technology. Together, these outcomes have the potential to mitigate societal concerns, ensuring a harmonious coexistence between autonomous drones and urban

communities, thus paving the way for a more technologically advanced and socially responsible urban environment.

References

Alsamhi, S. H., Ma, O., Ansari, M. S., & Almalki, F. A. (2019). Survey on Collaborative Smart Drones and Internet of Things for Improving Smartness of Smart Cities. IEEE Access, 7, 128125–128152. https://doi.org/10.1109/access.2019.2934998

This paper presents a comprehensive survey on the utilization of collaborative drones and IoT in enhancing the efficiency and quality of various smart city applications. By focusing on aspects such as data collection, privacy and security, public safety, disaster management, and environmental sustainability, the survey aims to illustrate how these technologies contribute to the overall improvement and smartness of modern urban environments.

Cataleta, M. S. (2020). The Fragility of Human Rights Facing AI. East West Center, 2. https://www.academia.edu/43891664/The_Fragility_of_Human_Rights_Facing_AI

Affective computing facilitates machines understanding human emotions, enhancing human-computer interaction. Ethical guidelines must be computationally adaptable to address unforeseen situations, protecting human rights and ensuring moral responsibility.

Corrêa, N. K., Galvão, C., Santos, J. W., Del Pino, C., Pinto, E. P., Barbosa, C., Massmann, D., Mambrini, R., Galvão, L., Terem, E., & de Oliveira, N. (2023). Worldwide AI ethics: A review of 200 guidelines and recommendations for AI governance. Patterns (New York, N.Y.), 4(10), 100857. https://doi.org/10.1016/j.patter.2023.100857

The research paper conducts a comprehensive analysis of 200 policies and ethical guidelines for AI usage globally, identifying 17 prevalent ethical principles. It aims to establish a global consensus on the ethical standards that should govern AI applications, contributing to the formulation of future regulations. The paper emphasizes the importance of addressing ethical concerns, such as privacy breaches, algorithmic discrimination, security, reliability, and transparency issues associated with the rapid expansion of AI. By releasing its findings as an open-source database and tool, the paper promotes transparency, accountability, and responsible AI use, encouraging adherence to ethical guidelines in the development and deployment of AI technologies.

Drones for smart cities: Issues in cybersecurity, privacy, and public safety. (n.d.). Ieeexplore.ieee.org. Retrieved November 6, 2023, from https://ieeexplore.ieee.org/abstract/document/7577060/citations#citations

This survey paper aims to examine the multifaceted role of drones in future smart cities, focusing on their potential contributions to various sectors alongside the associated challenges in cybersecurity, privacy, and public safety. Additionally, it will provide insights into the impact of drone-based cyber-attacks on society.

Hibbard, B. (2014). Ethical Artificial Intelligence. In arXiv [cs.AI]. http://arxiv.org/abs/1411.1373

This article examines ethical issues in AI, proposing methods such as mathematical equations and utility-maximizing agents to prevent unintended AI behaviors and discussing the future implications of AI, including its potential role in understanding the universe and human existence.

Jensen, O. B. (2016). Drone city – power, design and aerial mobility in the age of “smart cities.” Geographica Helvetica, 71(2), 67–75. https://doi.org/10.5194/gh-71-67-2016

This paper delves into the intersection of drones and urban environments, drawing upon the concepts of the "mobilities turn" and "smart city" discourse. It aims to explore the potential implications of the integration of drones in cities, highlighting their transformative effects on surveillance, data collection, and governance.

Muehlhauser, L., Helm, L., Eden, A., Søraker, J., Moor, J. H., & Steinhart, E. (n.d.). Intelligence Explosion and Machine Ethics. Intelligence.org. Retrieved October 20, 2023, from https://intelligence.org/files/IE-ME.pdf

The paper discusses the potential dangers of a self-improving AI surpassing human control and suggests programming the AI's goals to align with human values as a preventive measure. However, it highlights the complexity of human values, drawing on evidence from moral philosophy, psychology of motivation, and neuroeconomics. It concludes by recommending the use of ideal preference theories of value as a suitable approach for developing ethical guidelines to manage the risks associated with an intelligence explosion or technological singularity.

Qin, C., & Pournaras, E. (2023). Coordination of drones at scale: Decentralized energy-aware swarm intelligence for spatio-temporal sensing. Transportation Research. Part C, Emerging Technologies, 157(104387), 104387. https://doi.org/10.1016/j.trc.2023.104387

The paper presents a new energy-efficient method for coordinating drones in Smart City applications, leading to improved performance in spatio-temporal sensing, particularly for traffic monitoring.

Yang, C.-H. (2022). How artificial intelligence technology affects productivity and employment: Firm-level evidence from Taiwan. Research Policy, 51(6), 104536. https://doi.org/10.1016/j.respol.2022.104536

This study examines the impact of AI technology on firm productivity and employee profiles in Taiwan's electronics industry from 2002 to 2018, using a keyword-matching method to analyze patent grants. The research finds that AI technology positively influences productivity and employment, leading to changes in workforce composition by decreasing the proportion of workers with college-level or lower education, with similar effects observed for non-AI patents.

Yin, M., Jiang, S., & Niu, X. (2024). Can AI really help? The double-edged sword effect of AI assistant on employees' innovation behavior. Computers in Human Behavior, 150(107987), 107987. https://doi.org/10.1016/j.chb.2023.107987

This study looks at how smart AI assistants can both help and harm employees' ability to come up with new ideas at work. It finds that when AI assistants are very smart, they can boost employees' confidence in their creativity, leading to more innovative work. However, this same smart AI can also make employees worry about their jobs being replaced by technology, which can discourage their innovation, especially when their workplace isn't well-prepared for AI. The study emphasizes the importance of how ready a company is for using AI, as this can affect how employees see and respond to AI, offering valuable insights into the relationship between AI, employees, and the organization.