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# Real-time operating system for autonomous drone control

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## 1. Introduction

Drones have become a transformative force across industries in the quickly changing world of autonomous technologies. Their applications are expanding, from precision agriculture to emergency response, thanks to developments in real-time operating systems. A key development is a "Real-time operating system for autonomous drone control" that reshapes the potential of unmanned aerial vehicles through the convergence of high-speed data processing, low-latency responsiveness, and complex control algorithms.

Autonomous drones once imagined only in science fiction, are now a real possibility and are revolutionizing a wide range of industries. The integration of autonomous drones has created new opportunities for efficiency, safety, and scalability in a variety of fields, from agriculture and logistics to disaster relief and surveillance. The ability of a real-time operating system to process information with microsecond-level responsiveness is essential to the success of these initiatives because it enables drones to navigate dynamic environments, adapt to unexpected changes, and make quick decisions.

The idea of a real-time operating system for autonomous drone control is fundamentally dependent on the coordination of hardware and software. Drones are now able to process sensor data, run intricate algorithms, and communicate precisely all in a matter of microseconds thanks to this synergy. With the help of this amazing capability, drones can carry out complex tasks like obstacle avoidance, real-time mapping, and cooperative swarming, which results in a seamless integration of automation and human intervention.

Autonomous drones can now fly autonomously, making split-second decisions while navigating challenging environments. They are no longer restricted to remote control flight. Real-time operating systems (RTOS), a key component that powers the precise and seamless control of autonomous drones, are at the core of this transformation. This study explores real-time operating systems for autonomous drone control, highlighting their importance, key elements, difficulties, applications, and potential future directions.

Drones utilize a variety of operating systems tailored to their specific needs. Embedded operating systems, a common choice, include FreeRTOS and NuttX, designed for resource-constrained environments with real-time requirements. Linux-based operating systems such as Dronecode's PX4 and ArduPilot's APM are prevalent due to their open-source nature, offering flexibility and community support. These systems provide comprehensive functionalities, from flight control to high-level mission planning. Additionally, specialized real-time operating systems like QNX and VxWorks are employed for their deterministic task scheduling and reliability, making them suitable for critical applications such as drone swarms and industrial drones. Mobile operating systems like Android are used for consumer drones, leveraging their user-friendly interfaces and app ecosystems. As drones continue to evolve across various industries, the choice of operating system depends on factors like real-time requirements, hardware constraints, and the complexity of tasks the drone is expected to perform.

Existing research has made strides in developing real-time operating systems for general purposes, but there remains a dearth of comprehensive approaches that specifically cater to the intricacies of autonomous drone control. As drones become increasingly complex and pervasive in various applications, there is a lack of

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in-depth investigation into aspects such as adaptive scheduling algorithms that consider dynamic environmental conditions, effective resource management across heterogeneous hardware components, and robust fault tolerance mechanisms. Additionally, the integration of emerging technologies like AI, machine learning, and secure communication within the context of a real-time operating system for drones requires further exploration. Bridging this research gap is essential for enabling safer, more reliable and efficient autonomous drone operations across a wide range of sectors. Therefore, the current study aimed to identify research gaps that help researchers and practitioners identify new avenues for innovation and advancement.

## 2. Objectives

- To clarify the function and importance of real-time operating systems in facilitating autonomous drone control.
- To examine the main elements and mechanisms that real-time drone operating systems rely on to function.
- To examine the difficulties encountered in creating such systems and offer potential solutions.
- To demonstrate the various ways in which real-time operating systems enable the use of autonomous drones in a variety of industries.

## 3. Market Trends and Significance

The market for autonomous drones is expanding at a never-before-seen rate. Big companies like Boeing, Google, Amazon, and Airbus are making significant investments in the research and development of autonomous drone technology. Numerous commercial, scientific, recreational, and other public service applications are using it more frequently. Based on the aforementioned variables, it is anticipated that autonomous drone revenue will increase at a CAGR of 19.3% to reach US$ 15,634.7 million in 2023.

- Short Term (2023 Q1 to 2026): Growing end-use industries will support the expansion of the autonomous drone market.
- Medium Term (2026- 2029): Due to the growing threat from terrorism, demand for autonomous drones is expected to be relatively high in North America and Europe in the medium term (2026–2029).
- Long Term (2029-2033): Market participants for autonomous drones may find new opportunities as a result of adopting cutting-edge technology.
- The autonomous drone market experienced a 15.3% CAGR from 2018 to 2022. According to a provider of market research and competitive intelligence, the market will grow at a CAGR of 19.3% between 2023 and 2033.

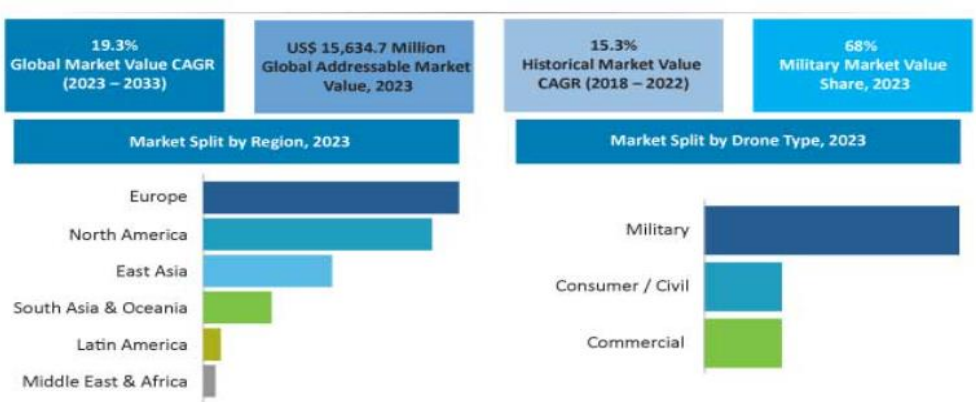

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Figure: Global Autonomous Drone Market Forecast (2023-2033) Source: https://www.factmr.com/report/autonomous-drone-market

The image above shows a market share analysis of autonomous drones based on drone type and region. With a 68% market share in 2023, the military sub-segment dominates the drone-type segment.

**4. Key Components of Real-Time Operating Systems for Autonomous Drones**

Real-time operating systems (RTOS) must be carefully designed for autonomous drones to function effectively. Drones can precisely navigate dynamic environments and carry out mission-critical tasks because of these specialized software platforms, which are made to handle the demanding requirements of real-time data processing, task execution, and responsiveness. The following capabilities of autonomous drones were listed as the main elements that make up an efficient real-time operating system for them.

**4.1. Task Scheduling and Management:**

Task scheduling assumes utmost significance in the context of autonomous drone control. An RTOS guarantees prompt task completion, prevents conflicts, and maintains the drone's responsiveness to outside stimuli. This means providing different tasks access to resources like processing power and memory according to their priority.


Figure: The 3DR Solo test bed (Source: https://arxiv.org/pdf/1907.03305.pdf)

**4.2. Sensor Fusion and Data Processing**

Information essential for drone navigation is provided by sensors like GPS, cameras, LiDAR, and IMUs. Real-time operating systems make it possible to combine the data from these sensors, giving the drone a thorough understanding of its surroundings. To make informed decisions while flying, this data must be processed effectively in real time.

**4.3. Communication Protocols**

Communication between autonomous drones, ground stations, and other devices is frequently necessary. Implementing communication protocols that allow for seamless data exchange, real-time operating systems support coordinated actions and secure operations.

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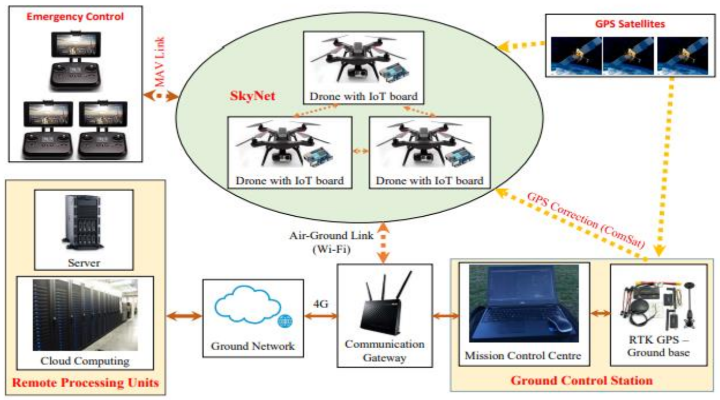


Figure: Data communication structure Source: https://arxiv.org/pdf/1907.03305.pdf

**4.4. Safety and Redundancy Mechanisms**

The primary concern is ensuring the security of autonomous drones and the surrounding area. To reduce risks related to hardware failures or unforeseen circumstances, RTOS incorporates redundancy mechanisms, fail-safes, and error handling.

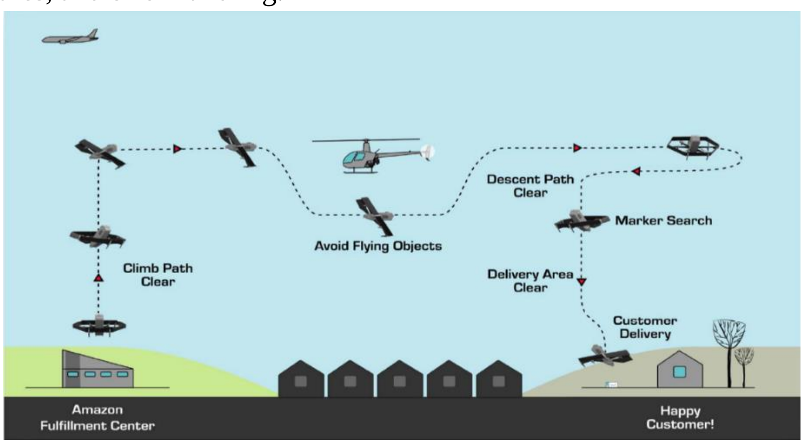


Figure: Amazon Prime Air's general concept of operations, according to its FAA filing. (Amazon) Source: https://www.aviationtoday.com/2019/08/09/following-wing-ups-amazon-seeks-approval-prime-air-drone-delivery/

**5. Challenges and Solutions**

Real-time operating system (RTOS) development and implementation for autonomous drone control present several formidable challenges. These difficulties, which range from hardware constraints to algorithmic complexity, highlight how difficult it is to implement smooth, safe, and responsive drone operations. However, these difficulties can be overcome with creative approaches and advancements, ensuring the successful application of RTOS in the field of autonomous drones.

**5.1 Hardware Limitations**

**Challenge**: Autonomous drones frequently have limited hardware resources in terms of processing speed, memory, and energy storage. These restrictions make it difficult to implement real-time operating systems that can effectively handle numerous tasks while preserving the required responsiveness.

**Solution**: Overcoming hardware constraints requires effective resource allocation and optimization techniques. Task prioritization, dynamic resource allocation, and workload partitioning are some of the

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strategies that can be used to guarantee that crucial tasks get the resources they need, avoiding resource contention and maintaining real-time performance.

### 5.2 Latency and Responsiveness

**Challenge**: For autonomous drones to navigate safely, low latency and high responsiveness are essential. To avoid accidents, real-time operations must be carried out in a matter of microseconds, particularly those involving obstacle detection and collision avoidance.

**Solution**: Task scheduling must be optimized, and effective algorithms must be used. Additionally, utilizing hardware accelerators and parallel processing strategies can speed up data processing and decision-making, decreasing the time between the acquisition of sensor data and the execution of an action.

### 5.3 Algorithmic Complexity

**Challenge**: When it comes to activities like path planning, environment mapping, and sensor data fusion, the algorithms governing autonomous drone behavior can be complicated and computationally demanding.

**Solution**: Algorithm optimization and hardware acceleration can be used in combination to address algorithmic complexity. The speed and accuracy of decision-making processes can be increased while simplifying complex calculations by utilizing machine learning algorithms and edge computing techniques.

### 5.4 Real-time Communication

**Challenge**: Real-time communication between autonomous drones, operators, and ground stations is frequently necessary. For coordinated action and situational awareness, it is essential to maintain low-latency communication channels.

**Solution**: It is essential to implement communication protocols designed for real-time data exchange. Communication between drones and between drones and operators can be made seamless by using protocols that put a high priority on reliability, low latency, and efficient data transmission.

### 5.5 Safety and Redundancy

**Challenge**: It's critical to ensure the security of drone operations. Software or hardware malfunctions can result in potentially dangerous circumstances.

**Solution**: RTOS should include safety features like redundancy, fail-safes, and error handling for autonomous drones. These mechanisms allow the drone to keep operating safely even in the face of errors or unforeseen circumstances.

### 5.6 Integration of New Technologies

**Challenge**: The difficulty is that technology is advancing quickly, resulting in the introduction of new sensors, algorithms, and communication protocols that must be seamlessly integrated into the current RTOS framework.

**Solution**: To make it simple to integrate new technologies, RTOS should be designed with modularity in mind. By using standard interfaces and APIs, new sensors and algorithms can be incorporated without causing a system-wide disruption.

### 5.7 Real-world Variability

**Challenge**: Real-world circumstances present a challenge because they are inherently unpredictable and variable. Drones have to adjust to shifting weather patterns, shifting lighting, and unforeseen obstacles.

**Solution**: RTOS should have adaptive algorithms that can modify drone behavior in real time in response to shifting environmental conditions. The drone's ability to navigate and react to changing circumstances can be improved by incorporating sensor feedback and machine learning techniques.

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## 6. Applications across different industries

Real-time operating systems (RTOS) have revolutionized a variety of industries by being integrated into autonomous drones, opening up previously unimaginable possibilities. Autonomous drones with RTOS have found a wide range of applications that go beyond conventional limitations thanks to their capacity to process data in microseconds, carry out split-second decisions, and navigate complex environments with accuracy.

### 6.1 Agriculture: Precision Farming Takes Flight

The use of autonomous drones equipped with RTOS has caused a notable transformation in the agricultural industry. These drones have developed into potent instruments for precision farming and are no longer just for taking aerial photos. Autonomous drones can evaluate crop health, identify diseases, and track irrigation patterns because they are equipped with high-resolution cameras, multispectral sensors, and thermal imaging capabilities. These drones can process data in real-time thanks to the integration of RTOS, giving farmers precise information about the condition of their crops. Rapidly identifying problem areas enables targeted interventions, maximizing the use of materials like fertilizers and pesticides. Crop yields are increased, resource waste is decreased, and agricultural sustainability is improved as a result.

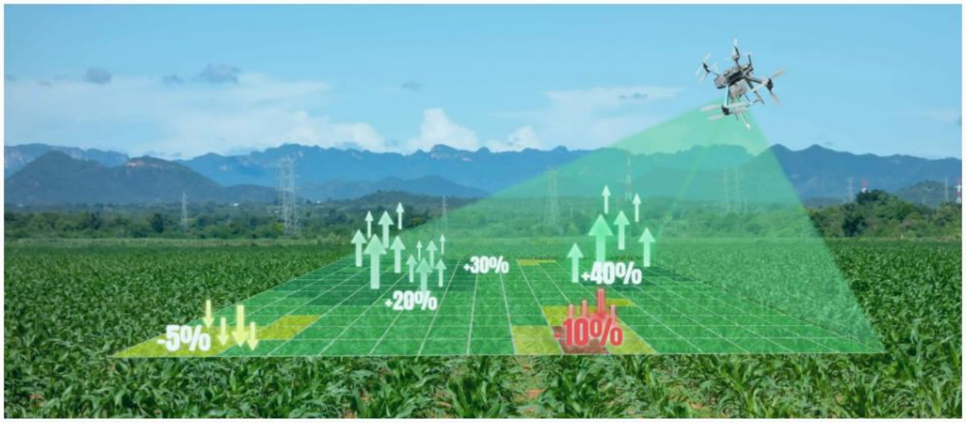


Figure: Crop damage assessment (Source: https://equinoxsdrones.com/blog/importance-of-drone-technology-in-indian-agriculture-farming)

### 6.2 Logistics and Delivery: Revolutionizing Last-Mile Transportation

A new era in logistics and delivery has been unlocked by real-time operating systems, particularly for last-mile delivery. Autonomous delivery drones with RTOS integration can efficiently deliver packages while navigating urban environments and dodging obstacles. Real-time data processing is used by these drones to determine the best flight paths, dodge obstacles, and modify courses as needed. Companies like Amazon and UPS have already started experimenting with drone delivery, promising quicker and more dependable services that can reach remote or crowded areas. The future of e-commerce and logistics is transformed by RTOS, which equips these drones to guarantee timely and secure deliveries.

### 6.3 Search and Rescue: Quick Action in Serious Circumstances

The incorporation of RTOS in autonomous drones during search and rescue missions may mean the difference between life and death. These drones can quickly cover large areas and transmit vital information to rescue teams on the ground because they are outfitted with high-definition cameras, thermal sensors, and real-time communication capabilities.

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Rapid analysis of the environment is made possible by real-time data processing, allowing operators to spot survivors, dangers, and safe landing areas. Autonomous drones with RTOS can significantly improve the effectiveness and efficiency of search and rescue missions, saving valuable time and lives, whether in natural disasters, accidents, or remote locations.

**6.4 Infrastructure Inspection: Enhancing Safety and Efficiency**

It has historically taken a lot of time and been risky to inspect vital infrastructure, like bridges, power lines, and pipelines. This process has been revolutionized by autonomous drones with RTOS because they offer a productive, economical, and secure substitute. With their high-resolution cameras and sensors, these drones can autonomously fly through complicated structures while gathering accurate data and images. Engineers and inspectors can quickly analyze the gathered data using real-time data processing to spot flaws, anomalies, and potential dangers. By taking a proactive approach to infrastructure inspection, risks related to manual inspections are reduced, downtime is decreased, and safety is increased.

**6.5 Environmental Monitoring: Aerial Insights for Conservation**

The capabilities of autonomous drones fitted with RTOS have also benefited environmental monitoring and conservation efforts. These drones can take high-resolution pictures, examine how the land cover is changing, and keep an eye on the number of animals. Using real-time data processing, environmental data can be analyzed as it happens, allowing researchers to spot trends and patterns that might point to ecosystem threats or healthy ecosystems. Drones with RTOS make environmental monitoring more accurate and efficient by having access to remote and difficult terrains, supporting conservation efforts and scientific research.

**6.6 Film and Entertainment: Capturing Cinematic Aerial Shots**

Drones with RTOS have found use in the media and entertainment sector in addition to practical uses. Stunning aerial shots that were previously expensive and logistically difficult to obtain can now be obtained by filmmakers thanks to autonomous drones that are outfitted with high-definition cameras and stabilization systems. Real-time data processing guarantees stable and slick video, improving the viewing experience and fostering imaginative storytelling.

**7. Future Directions and Innovations**

As technology advances at an unprecedented rate, the field of RTOS for autonomous drone control is poised for a trajectory of innovation that promises to reshape industries, redefine capabilities, and unlock unexplored potentials. This field is expected to advance, paving the way for remarkable developments in the field of autonomous drones, thanks to the integration of cutting-edge algorithms, machine learning, edge computing, and human-machine collaboration.

**7.1 Advancements in AI and Machine Learning**

Algorithms for artificial intelligence and machine learning hold enormous promise for improving the capability of autonomous drones to make decisions. Drones may be able to adapt and learn from their experiences by using machine learning models trained on massive datasets to make informed decisions based on both historical and real-time data. The efficiency, safety, and accuracy of autonomous drone operations can all be improved by using these algorithms, which can also optimize flight paths, anticipate environmental changes, and adapt to dynamic situations.

**7.2 Edge Computing for Onboard Intelligence**

The capabilities of autonomous drones are about to undergo a revolution due to edge computing, a paradigm that processes data closer to the source rather than relying on distant servers. Edge computing lowers latency

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and improves responsiveness by processing data in real-time onboard. Drones with edge computing capabilities can process sensor data quickly, carry out complicated calculations, and make split-second decisions, allowing them to function well even in areas with poor connectivity.

**7.3 Human-Machine Collaboration**

Incorporating real-time operating systems' capabilities with human operators' advantages will be key to the success of autonomous drone control in the future. While RTOS-enabled drones handle the complex aspects of flight, data processing, and obstacle avoidance autonomously, remote operators can offer high-level commands and strategic insights. In addition to ensuring the safety of operations, this cooperative approach enables human expertise to enhance the accuracy and agility of autonomous systems.

**7.4 Swarm Intelligence and Coordination**

Drone swarms are an emerging idea in which many drones work together to accomplish a single objective. Swarm intelligence can be enabled by RTOS, which enables real-time communication, synchronization, and coordination among drones. These swarms can be used for tasks like surveillance, disaster relief, and environmental monitoring, and they provide collective knowledge and abilities that go beyond those of individual drones.

**7.5 Energy Efficiency and Autonomy**

Extending the operational endurance of autonomous drones requires improvements in battery technology, energy harvesting, and energy-efficient hardware design. Drone autonomy and range can be increased through the use of RTOS, which can also dynamically allocate resources and implement power-saving modes. For applications like remote surveillance, tracking wildlife, and environmental monitoring, this is especially important.

**7.6 Advanced Sensor Integration**

The integration of various sensors, such as LiDAR, hyperspectral imaging, and sophisticated navigation systems, is expected to enhance the capabilities of autonomous drones. Drones will be able to collect and process multi-modal data in real-time thanks to the crucial role that RTOS will play in seamlessly integrating these sensors. This all-encompassing perception will improve obstacle detection, increase environmental awareness, and allow for more difficult tasks.

**7.7 Regulatory and Ethical Considerations**

Regulatory frameworks and ethical considerations will be more crucial as autonomous drone technology develops. Incorporating RTOS should follow ethical standards for privacy, data security, and environmental impact in addition to safety regulations. Innovations in this field will include not only technical improvements but also ethical and responsible applications.

**7.8 Collaborative Urban Air Mobility**

The integration of autonomous drones into urban airspace is becoming a reality with the emergence of urban air mobility (UAM) concepts. To ensure effective and safe operation in intricate urban environments, RTOS will be essential. Advanced real-time coordination and communication mechanisms facilitated by RTOS will be necessary for collaborative UAM scenarios involving autonomous drones, autonomous vehicles, and ground infrastructure.

## 8. Conclusion

Real-Time Operating Systems (RTOS) have sparked a revolutionary change in the world of autonomous drones that has surpassed both industry and imagination limitations. A future where accuracy, responsiveness, and innovation converge to reshape our world has been made possible by the synergy

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between RTOS and autonomous drones, which has paved the way for continued rapid technological advancement.

Drones with RTOS have shown their ability to change industries, from the productive agricultural fields to the busy logistics corridors. By performing tasks with millisecond-level precision, navigating challenging environments with ease, and making decisions that bridge the gap between human intent and machine action, these systems allow drones to go beyond their traditional capabilities. These developments in real-time data processing and task execution are not just technical breakthroughs; they mark a paradigm shift in sectors whose growth was previously constrained by human capacity and logistical difficulties.

The promise of AI-driven decision-making, the real-time prowess of edge computing, and the harmonious dance of human and machine collaboration illuminate the way ahead as we look toward the horizon of tomorrow. Future RTOS-enabled autonomous drones have the potential to completely reimagine urban landscapes, revolutionize disaster response through quick search and rescue operations, and even protect the environment through precise environmental monitoring.

This journey into the future is not without challenges, though. Continuous innovation is necessary to overcome hardware constraints, ensure safety in dynamic environments, and balance algorithmic complexity with real-time execution. Cross-disciplinary cooperation, ethical considerations, and a steadfast dedication to responsible technological advancement will be necessary for the continued development of RTOS.

The current study is one of transformation, where science fiction becomes reality and the fusion of innovation and technology leads to advancement. The integration of RTOS into the framework of autonomous drone operations has a profound impact on fields such as precision agriculture, autonomous logistics, search and rescue, infrastructure inspection, and beyond. One thing is certain: the journey has only just begun, and the limitless potential of RTOS-equipped autonomous drones is poised to redefine the very notion of what is possible as industries continue to be shaped by these technologies.

**9. Bibliography**

1. Brandenburg, Björn. "The case for an opinionated, theory-oriented real-time operating system." *1st International Workshop on Next-Generation Operating Systems for Cyber-Physical Systems*. 2019.
2. Czerniejewski, Adam, Karthik Dantu, and Lukasz Ziarek. "juav: A real-time java uav autopilot." *2018 Second IEEE International Conference on Robotic Computing (IRC)*. IEEE, 2018.
3. Hissa, L., J. E. Martins Mothé, and R. De Carvalho. "Development of an autonomous UAV." *X Congresso Nacional de Engenharia Mecânica. https://doi. org/10.26678/abcm. conem2018. con18-1600*. 2018.
4. Kangunde, Vemema, Rodrigo S. Jamisola, and Emmanuel K. Theophilus. "A review on drones controlled in real-time." *International journal of dynamics and control* (2021): 1-15.
5. Ravi, Niranjan, and Mohamed El-Sharkawy. "Integration of UAVs with real time operating systems using UAVCAN." *2019 IEEE 10th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*. IEEE, 2019.
6. Saramud, Mikhail V., et al. "APPLICATION OF FreeRTOS FOR IMPLEMENTATION OF THE EXECUTION ENVIRONMENT OF REAL-TIME MULTI-VERSION SOFTWARE." *International Journal on Information Technologies & Security* 10.3 (2018).

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7. Saramud, Mikhail V., et al. "SOFTWARE INTERFACES AND DECISION BLOCK FOR THE EXECUTION ENVIRONMENT OF MULTIVERSION SOFTWARE IN REAL-TIME OPERATING SYSTEMS." *International Journal on Information Technologies & Security* 10.1 (2018).
8. Tang, Yi-Rui, and Yangmin Li. "The software architecture of a reconfigurable real-time onboard control system for a small UAV helicopter." *2011 8th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI)*. IEEE, 2011.