Sri Lanka Institute of Information Technology (SLIIT)

SOS Assignment

Real-time operating system for autonomous drone control

BSc Honors degree in IT (Sp. Cyber Security)

Secure Operating Systems - IE2032

- **Topic** - Real-time operating system for autonomous drone control.
- **Module Code** – IE2032

- Group members

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Introduction

The paper focuses on the development of a real-time operating system (RTOS) for autonomous drones, the topic elaborates the importance in the field of operating systems. Apart from the traditional operating systems, an RTOS ensures the critical tasks are executed within that particular time constraint, making it essential for autonomous systems.

These systems are employed based on the drone's requirements for example, android would be used for consumer drones , PX4 and *ArduPilot* are used for complex missions, and *FreeRTOS* and *Nuttx* are used for low-resource instances. Objectives of this research are to Understand the function and importance of RTOS in drone control, analyze the key components and mechanisms of RTOS, identify challenges and Recommend solutions and explore RTOS applications in different industries. [1]

Significance

Real-time computing plays a crucial role in IOT, automotive, robotics and industrial automation. The demand for efficient task managing and low latency processing opens a pathway for the growth of technological advancements, by addressing these challenges like energy efficiency and resource utilization. Also, the paper contributes to the boarder fields of embedded systems and intelligent automation. Understanding the future operating system supports real-time applications ensuring high reliability and faster response time. The study emphasizes how modern OS must adapt to meet the raising demand of autonomous and AI-driven technologies.

According to research, growth will be fueled by rising demand across various industries from 2023 to 2026 which denotes a short term growth. From 2026-2029,demand for the security concerns in Europe and North America will increase. All in all, cutting edge technology would create a new path way to find new opportunities in autonomous drone market from 2029 to 2033. The figure below shows data of autonomous drones, With a 68% market share in 2023, Moreover the military dominates the drone-type segment. [2]

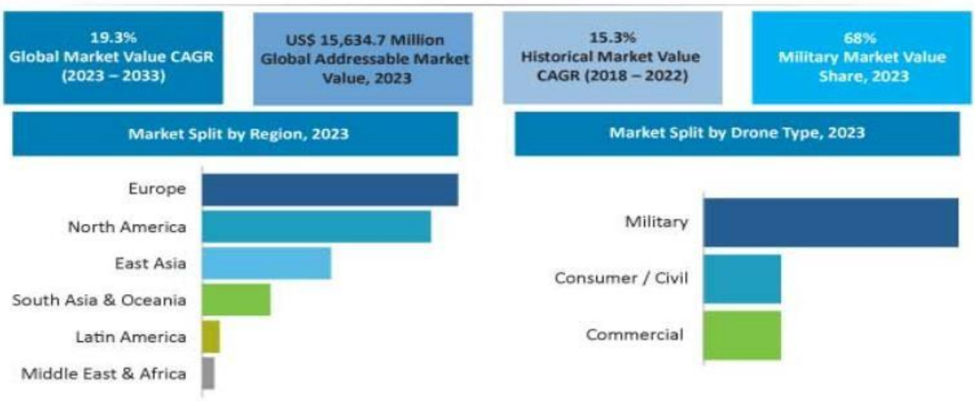

Figure 1 - Global Autonomous Drone Market Forecast (2023-2033) [2]

Complication & Resolution

Domain	Problem	Solution
Hardware Restrictions	Limitations in processing speed, memory and energy storage, difficulty in implementing real time system with multiple tasks.	To overcome requires techniques like task prioritization, dynamic resource allocation and workload partitioning.
Latency and Responsiveness	Requires low latency and high responsiveness to navigate with real time operations, mainly obstacle detection and collision avoidance occurring which could occur in micro-seconds.	By using efficient algorithms, along with hardware accelerators and parallel processing can speed up data processing and decision making by reducing the time between sensor data and action execution
Algorithmic Complexity	Tasks like planning, environment mapping, and sensor data fusion can be complex and computationally intensive.	By enhancing decision-making, speed, accuracy and algorithm optimization hardware acceleration can be achieved. Machine learning and edge computing can improve performance and simplify calculations
Real-time Communication	Needed for reliable, Low latency communication protocols.	Implement protocols that focus on high priority on reliability, low latency and efficient data transmission.
Safety and Redundancy	Importance of redundancy mechanisms and error handling protocols.	Implementing safety features like redundancy and error handling for error free execution.
Integration of New Technologies	Necessity for modular RTOS design with standard interfaces.	Use of standard interfaces and APIs, new sensors and algorithms to make the integration process simple.
Real-world Variability	Use of sensor feedback to ensure operational stability in challenging environments.	Integrate adaptive algorithms that can modify drone behavior real-time.

Data Analysis

A. Key Components of RTOS for Autonomous Drones

- Task Scheduling and Management - It ensures that timely task execution, avoids conflicts, and keeps the drone responsive to external stimuli and manage the resources effectively.

Figure 2 : The 3DR Solo test bed [3]

- Sensor Fusion and Data Processing – Use sensors like GPS, cameras and IMUs (Inertial Measurement Units) for navigation. It helps the drone to understand the surroundings and take quick decisions.

- Communication Protocols - RTOS helps by using communication protocols for smooth data exchange and coordinate actions for secure operations.

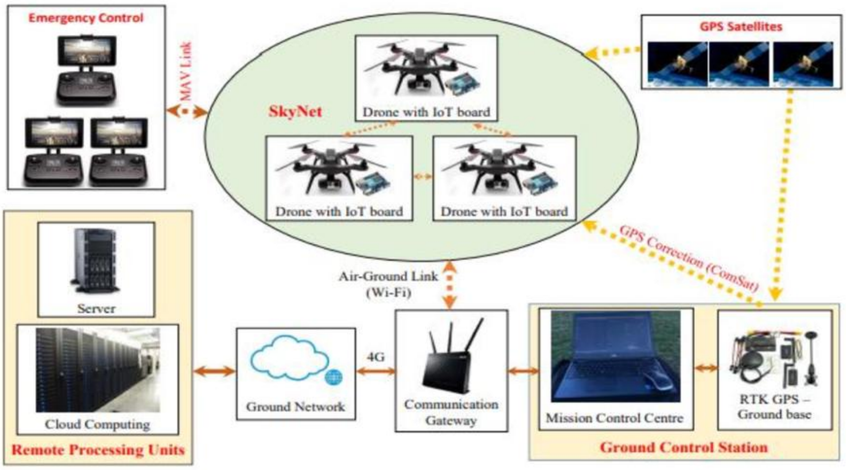

Figure 3 - Data communication structure Source [3]

- Safety and Redundancy Mechanisms – RTOS reduces the risks around by adding a backup systems for failures and error handling to prevent hardware issues.

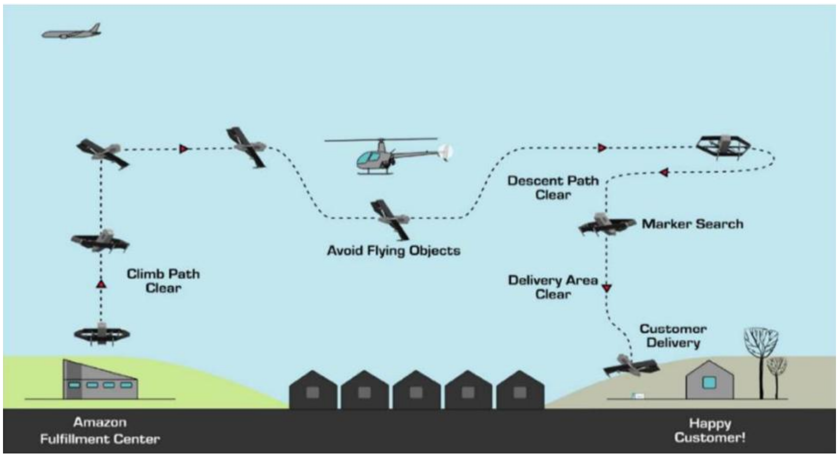

Figure 4 -Amazon Prime Air's general concept of operations, according to its FAA filing. [5]

B. Problem and its Importance

The main problem is making drones fast and more reliable by using RTOS. Traditional OS can be slow for drones which need to react to obstacles and commands real-time. It is important because drones are used in rescue missions and surveillance, where delays can cause severe damage. RTOS system helps by scheduling tasking properly to improve communication among software and hardware.

C. Strengths

Domain	Strengths
Task Scheduling and Management	• Assures prompt task completion • Avoid conflicts over resources • Continue to be receptive • Multitasking effectively
Sensor Fusion and Data Processing	• Smooth fusion of sensors • Instantaneous decision making • A better understanding of the context • Better use of available resources
Communication Protocols	• Smooth data transfer • Encouragement of unified activity • Boosts security • Dependable connection supervision
Safety and Redundancy Mechanisms	• Increased dependability and safety • On-the-spot error correction • Enhanced resilience to errors • Reduced operational hazards

D. Weaknesses

Domain	Weaknesses
Task Scheduling and Management	• Difficulty in execution • Limited resources • Concerns about task prioritization • Issues with debugging
Sensor Fusion and Data Processing	• High processing requirements • Problems with latency • The intricate creation of algorithms • Problems with synchronization
Communication Protocols	• Interference and delay in networks • Incompatibility with protocols • High bandwidth demand • Higher usage of power
Safety and Redundancy Mechanisms	• A more sophisticated system. • An increase in power usage • The possibility of overhead delays • Issues with development and upkeep

Broader Concepts

A. Contribution to Understanding Operating Systems

The study of real time operating systems for autonomous drones helps our understanding of operating systems in various ways. It prioritizes deterministic task scheduling in resource constrained contexts, where exact timing limitations are required for safety critical processes, as opposed to general purpose operating system which prioritize average performance. This study advances understanding of resource management by demonstrating how limited computing/computational resources, memory and power must be efficiently allocated across competing tasks with changing priorities.

The drone context focuses on interrupt handling and concurrency management in safety critical systems, demonstrating how several concurrent processes must be controlled without sacrificing responsiveness. Additionally, it highlights fault tolerance methods which include redundancy approaches and error handling that allows for seamless failure recovery while maintaining system integrity. When all has been said and done, the drone RTOS demonstrates how real time systems are capable are more important throughout operating system ecosystem.

B. Relevance of Concepts to Modern OS

The concepts in the paper are highly applicable to the modern operating systems, especially because modern operating systems focus on real time responsiveness, multitasking, and efficiency, which is very crucial for autonomous drones. The paper also highlights the key areas such as memory management, task scheduling, inter-process communication and all the important aspects in modern RTOS used for embedded systems, IOT devices and robotics.

Moreover, with the rise of autonomous systems in industries like healthcare, defense and transportation, requires real-time processing which is more critical than ever. Conventional OS like Linux, MacOS or windows may not strictly comply to real-time constraints, whereas RTOS executes time-sensitive tasks.

Areas like optimizing resource allocation and improving energy efficiency aligns with the modern OS trends, particularly in mobile computing. Additionally, the paper also addresses the areas like *agriculture*, *Logistics and Delivery*, *Search and Rescue*, *Environmental Monitoring* and *Film and Entertainment* to describe how RTOS are applied across different industries. The below figure describes how crop damage assessment is conducted through drones.

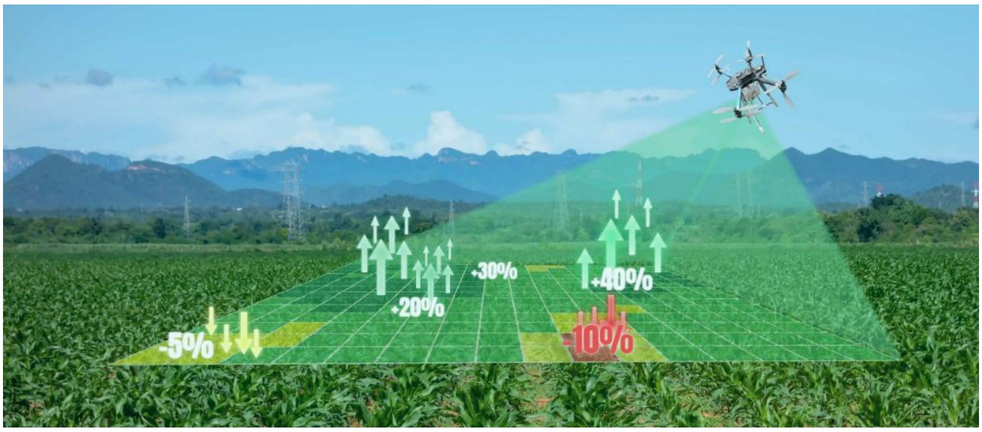

Figure 5 - Crop damage assessment [4]

C. Application of the Paper's Ideas to Future OS

The concepts in this paper could be applied to current and future operating systems by optimizing efficient energy, real-time processing and AI integration. Modern systems such as industrial robots, smart home IOT devices and self-driving cars require low latency task scheduling and efficient resource management which is supported by RTOS.

Future OS could be designed to integrate machine learning for predictive tasks. Allowing systems to prioritize critical operations. Moreover, the paper focuses on inter-process communication which could enhance distributed computing ecosystems, which enable multiple devices to coordinate simultaneously and operate real-time. The papers describe the future innovations in areas like AI, machine learning, edge computing, human-machine collaboration, swarm intelligence, advanced sensor integration and rules and regulations to be considered when implementing RTOS.

Additionally, integration of cloud and edge computing could offload computations to remote servers, improving the performance and minimizing the power consumption. Real-time threat detection could be also incorporated to protect the autonomous systems.

Results

The results of the paper emphasize that RTOS significantly improves the performance of drones by minimizing the response time, enhancing system stability and optimizing the resources efficiently. The improved task scheduling ensures reliability in critical operations, such as obstacle avoidance and flight control may occur with any delays.

These findings maps to boarder implications for areas like autonomous vehicles, robotics and internet of things (IOT) systems where real-time processing is crucial. Improvements in energy efficiency suggest that future autonomous systems could operate effectively making them more viable for real-world applications.

Furthermore, the results highlight the potential for scaling the RTOS solutions in other industries like smart cities to implement traffic control systems and healthcare to enforce real-time monitoring systems. Also, this study reinforce the need for further research in implementing AI and machine learning driven decision making systems to enhance autonomy and adaptability, enabling a new gateway for intelligent systems for next generation.

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