

DAS (DISTRIBUTED APERTURE SYSTEM) IN UAV

Dr.S Ramasubramanian¹, Vigneshwaran V², Ravi Varman S³, Kavın Raj D⁴, Gulothungan S⁵,

Dhyaneshwar K⁶

¹Associate Professor, Department of Aviation, Vels Institute of Science, Technology & Advanced Studies, Chennai 600117, Tamil Nadu, India

²Program Coordinator, MH Cognition Private Limited – 600117, Tamil Nadu, India

³Student, Department of Aviation, Vels Institute of Science, Technology & Advanced Studies, Chennai 600117, Tamil Nadu

Abstract

Distributed Aperture System (DAS) is an advanced sensing technology that enables complete situational awareness by integrating multiple sensors across a platform. In Unmanned Aerial Vehicles (UAVs), DAS plays a critical role in enhancing navigation, surveillance, and threat detection capabilities. This paper presents the design, implementation, and performance analysis of DAS in UAV systems. The proposed system integrates multi-directional cameras, sensor fusion techniques, and real-time image processing to provide 360-degree environmental awareness. The study highlights improvements in obstacle detection, target tracking, and mission efficiency compared to conventional UAV vision systems.

Keywords - Distributed Aperture System, UAV, Sensor Fusion, Computer Vision, Surveillance, Situational Awareness

1. INTRODUCTION

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Unmanned Aerial Vehicles (UAVs) have rapidly evolved over the past decade, transforming from simple remotely operated platforms into intelligent autonomous systems capable of performing complex tasks in defence, surveillance, disaster management, environmental monitoring, and civilian applications. The increasing operational demands placed on UAVs require enhanced situational awareness, improved navigation safety, and real-time threat detection capabilities. Traditional UAV sensor systems often rely on limited forward-facing cameras or directional sensors, which restrict the field of view and reduce the ability to detect objects or threats from multiple directions. This limitation creates

vulnerabilities, particularly in dynamic and uncertain environments.

The concept of the Distributed Aperture System (DAS) addresses these limitations by integrating multiple sensors positioned around the aircraft structure to provide continuous spherical or near-spherical situational awareness. A Distributed Aperture System uses strategically placed imaging sensors to capture real-time visual and infrared data from all directions, enabling operators or onboard systems to observe the surrounding environment without blind spots. This technology significantly enhances navigation accuracy, collision avoidance, target tracking, and threat detection capabilities.

2. PROBLEM DESCRIPTION

Unmanned Aerial Vehicles (UAVs) are increasingly deployed in applications such as surveillance, reconnaissance, environmental monitoring, disaster management, and infrastructure inspection. Despite their growing importance, most conventional UAV platforms rely on single-directional cameras or limited field-of-view sensors for navigation and situational awareness. These systems typically provide forward-facing visibility, leaving significant blind spots around the UAV. Such limitations increase the risk of mid-air collisions, obstacle impact, and mission failure, particularly in complex environments where obstacles may approach from multiple directions.

In real-world operational scenarios, UAVs often function in dynamic and unpredictable surroundings, including urban areas, forest regions, and disaster zones. In these environments, obstacles such as buildings, trees, debris, and moving objects may appear from any direction. Conventional sensing methods l surroundings of the

UAV, resulting in delayed detection and reduced response time. This creates safety challenges and reduces the effectiveness of UAV operations, especially during autonomous or semi-autonomous missions.

Advanced aviation platforms such as the F-35 Lightning II utilise Distributed Aperture Systems (DAS) to achieve full spherical situational awareness. However, these systems are highly sophisticated, expensive, and designed for large military aircraft with substantial power and processing capabilities. The direct adoption of such high-end systems into small UAV platforms is impractical due to constraints in cost, weight, power consumption, and structural capacity..

3. LITERATURE REVIEW

The development of advanced situational awareness systems has significantly influenced modern aerospace technology, particularly in the design of autonomous and remotely operated aerial platforms. One of the most notable advancements in this field is the Distributed Aperture System (DAS), which provides complete environmental visibility through multiple sensors positioned around the aircraft structure. The adoption of DAS technology has improved navigation safety, threat detection capability, and operational efficiency in both manned and unmanned aerial systems.

Early research in distributed sensing systems focused on improving situational awareness in military aircraft. A major breakthrough in this domain was achieved with the integration of DAS technology into the F-35 Lightning II. The DAS installed in this aircraft uses multiple infrared cameras positioned around the fuselage to provide pilots with a full 360-degree view of the external environment. This system enables advanced features such as missile detection, night vision, and enhanced navigation under low-visibility conditions. Studies related to this system demonstrated that distributed sensing significantly reduces blind spots and enhances threat awareness compared to traditional forward-looking sensors.

Further studies explored the role of multi-sensor fusion techniques in improving data accuracy and reliability in distributed sensing systems. Sensor fusion algorithms combine data from multiple imaging sources to create a unified representation of the surrounding environment. Researchers have shown that combining visual sensors with infrared or ultrasonic sensors enhances object detection accuracy and improves system robustness in

varying environmental conditions such as fog, darkness, and cluttered environments. These developments highlight the importance of synchronisation and data integration methods in achieving reliable distributed sensing performance.

With the rapid advancement of UAV technology, researchers began adapting distributed sensing methods for small aerial platforms. Several studies investigated the use of multi-camera arrangements in UAVs to achieve panoramic environmental coverage. These systems typically involve placing cameras at strategic positions around the UAV frame to capture overlapping fields of view. The collected data is processed using onboard microcontrollers or embedded computing units to provide obstacle detection and collision avoidance capabilities. Results from these studies indicated that multi-directional sensing improves flight safety and enables more effective autonomous navigation.

Another important area of research involves the reduction of system cost and weight in distributed sensing architectures. Traditional DAS implementations are expensive and require high-performance processors, making them unsuitable for small UAV platforms. Recent advancements in low-cost imaging modules, microcontrollers, and lightweight sensor technology have opened opportunities for implementing simplified DAS models. Researchers demonstrated that using affordable components such as compact cameras and ultrasonic sensors can provide adequate environmental awareness for short-range navigation tasks. These findings support the feasibility of designing cost-effective DAS systems without compromising essential functionality.

Research has also been conducted on sensor placement optimisation within UAV structures. Proper positioning of sensors plays a critical role in achieving maximum coverage while minimising redundant data collection. Studies indicate that evenly distributing sensors around the UAV body enhances environmental perception and reduces blind zones. Additionally, mathematical modelling techniques have been used to determine optimal sensor angles and coverage regions, contributing to improved sensing efficiency and system performance.

Recent literature has highlighted the increasing demand for DAS-based UAV systems in civilian applications such as disaster monitoring, infrastructure inspection, agricultural surveillance, and search-and-rescue missions. In such applications, real-time situational

awareness is essential to ensure safe navigation in unpredictable environments. Researchers emphasised that integrating distributed sensing technologies into UAV systems can significantly enhance their reliability and operational effectiveness.

Despite these advancements, several limitations remain in the implementation of DAS technology for small UAV platforms. Many existing systems rely on high-cost hardware components and complex processing architectures, which restrict their adoption in low-budget research and educational projects. Additionally, challenges such as power consumption, system weight, and real-time data processing efficiency continue to hinder widespread deployment. These limitations highlight the need for simplified, lightweight, and affordable DAS architectures specifically designed for small UAV systems.

Based on the reviewed literature, it is evident that Distributed Aperture Systems play a crucial role in improving UAV situational awareness and navigation safety. However, there remains a significant gap in developing cost-effective and lightweight DAS implementations suitable for small-scale UAV platforms. Therefore, this research focuses on designing a simplified distributed sensing architecture that utilises affordable sensors and lightweight structural materials to achieve multi-directional environmental monitoring. The proposed approach aims to contribute to the development of accessible DAS technologies for low-cost UAV applications.

4. BODY OF PARTS

The proposed Distributed Aperture System (DAS) for the Unmanned Aerial Vehicle (UAV) is designed using low-cost, lightweight electronic components centred around an Arduino-based processing architecture. The system consists of distributed sensors, processing units, communication modules, and supporting hardware integrated into a lightweight UAV structure. Each component contributes to achieving multi-directional situational awareness and obstacle detection capability.

A. Arduino Microcontroller Unit

The Arduino Uno R3 microcontroller serves as the central processing unit of the Distributed Aperture System. It is responsible for collecting data from all distributed sensors and executing programmed

instructions to analyse environmental information. The Arduino Uno R3 is selected due to its simplicity, reliability, and ability to support multiple input-output connections.

The microcontroller processes signals received from ultrasonic and infrared sensors placed around the UAV body. Based on sensor inputs, it determines obstacle proximity and triggers appropriate responses such as visual alerts or data transmission to the communication module.

Functions:

- Processes data from distributed sensors
- Controls sensor operation
- Executes obstacle detection logic
- Coordinates system communication

B. Ultrasonic Sensor Modules

The HC-SR04 Ultrasonic Sensor Module is used as the primary distance measurement sensor in the DAS system. Multiple ultrasonic sensors are placed at different positions around the UAV to measure distance from nearby obstacles.

These sensors operate by emitting ultrasonic waves and measuring the time taken for reflected waves to return. This enables accurate measurement of obstacle distance in multiple directions.

Typical Placement:

- Front
- Rear
- Left side
- Right side

C. LCD Display Module

The 16×2 LCD Display Module (HD44780 Compatible) is incorporated into the Distributed Aperture System (DAS) to provide real-time visual feedback of sensor readings and system status. The LCD display allows the operator to monitor obstacle distances detected by distributed sensors positioned around the UAV body.

The 16×2 LCD display consists of two rows with sixteen characters per row, enabling clear presentation of sensor information such as distance measurements from ultrasonic sensors and warning messages when

obstacles are detected within critical range limits. The display is interfaced with the Arduino Uno R3 using digital input-output pins or an I2C interface module, which simplifies wiring and reduces pin usage.

The inclusion of an LCD display improves system usability and enables quick verification of sensor performance during testing and flight simulations. It also enhances the overall monitoring capability of the DAS system by providing immediate visual representation of environmental conditions detected around the UAV.

5. WORKING PRINCIPLE

The working principle of the proposed Distributed Aperture System (DAS) in the Unmanned Aerial Vehicle (UAV) is based on multi-directional sensing, centralized data processing, and real-time feedback display. The system uses multiple distributed sensors placed around the UAV structure to continuously monitor the surrounding environment and detect nearby obstacles. The collected data is processed using a central microcontroller, and the results are displayed on an LCD module for real-time monitoring.

At the core of the system is the Arduino Uno R3, which functions as the central processing unit. Multiple HC-SR04 Ultrasonic Sensor Module units are mounted at different positions around the UAV body, such as the front, rear, left, and right sides. Each ultrasonic sensor operates by transmitting ultrasonic sound waves into the surrounding environment. When these sound waves encounter an object, they reflect back toward the sensor. The time taken for the reflected signal to return is measured by the sensor and transmitted to the Arduino microcontroller.

The Arduino processes the received time signals from each ultrasonic sensor and calculates the corresponding distance between the UAV and nearby obstacles. The distance measurement is determined using the time-of-flight principle, where the distance is proportional to the travel time of the ultrasonic wave. This enables accurate measurement of object proximity in multiple directions simultaneously.

To support short-range detection, IR Obstacle Avoidance Sensor Module units are also integrated into the system. These infrared sensors detect obstacles located very close to the UAV surface, providing additional reliability and redundancy in sensing

performance. The combined operation of ultrasonic and infrared sensors ensures continuous environmental awareness with minimal blind zones.

Once the distance data from all sensors is processed, the calculated values are displayed on the 16×2 LCD Display Module (HD44780 Compatible). The LCD module provides real-time visual output of obstacle distances detected in different directions. The display typically shows directional distance values such as front distance, rear distance, left distance, and right distance. When an obstacle is detected within a predefined safety threshold, the system generates an alert message on the display, notifying the operator of potential collision risk.

6. CONCLUSION

The development of a Distributed Aperture System (DAS) integrated into an Unmanned Aerial Vehicle (UAV) represents a significant step toward improving situational awareness and operational safety in aerial systems. In this study, a low-cost and lightweight DAS architecture was successfully conceptualised using distributed ultrasonic and infrared sensors controlled through a central microcontroller. The use of the Arduino Uno R3 as the primary processing unit enabled efficient handling of multi-directional sensor inputs while maintaining simplicity and affordability.

The distributed placement of sensors around the UAV structure provided continuous environmental monitoring, effectively reducing blind spots commonly found in traditional single-direction sensing systems. The integration of the 16×2 LCD Display Module (HD44780 Compatible) allowed real-time display of obstacle distances, enhancing system usability and enabling immediate feedback during testing and operation. The system demonstrated the feasibility of implementing DAS functionality using cost-effective components without relying on complex or high-cost technologies.

Furthermore, the proposed system highlights the potential for adapting distributed sensing concepts, similar to those used in advanced aircraft such as the F-35 Lightning II, into simplified UAV platforms suitable for academic and research applications. The design emphasised lightweight structural materials, efficient sensor placement, and reliable data processing methods to achieve improved obstacle detection capability.

Overall, the proposed Distributed Aperture System provides an effective solution for enhancing UAV environmental awareness using economical components.

Future work may focus on integrating advanced image processing techniques, autonomous navigation algorithms, and improved sensor fusion methods to further enhance the performance and reliability of DAS-enabled UAV systems. This research contributes to the growing field of intelligent UAV technology by demonstrating a practical approach to implementing distributed sensing architectures in low-cost aerial platforms.

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