DESIGN AND ARCHITECTURE OF PERIMETER DEFENCE INTRUSION DETECTION SYSTEMS BASED ON UGV

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Abstract. Defense Intrusion Detection Systems (DIDS) are specialized subsets of intrusion detection systems tailored specifically for military and national security purposes. The proposed research is focused on the design and architecture of mobile Perimeter Defense Intrusion Detection Systems (PDIDS) based on unmanned ground vehicles (UGV). Those perimeter defense systems offer a dynamic and adaptable solution for securing critical infrastructures, military bases, and other sensitive areas. This paper outlines an innovative approach to the design and architecture of such systems, emphasizing the integration of UGVs to enhance surveillance, detection, and response capabilities.

Keywords: UGV, defense intrusion detection

1. INTRODUCTION

Protecting critical infrastructure, military bases, and other sensitive areas in today's security landscape requires advanced and reliable solutions. Traditional perimeter defense methods, while effective, often demand significant human resources and are limited by the capability of static surveillance equipment. Perimeter Defense Intrusion Detection Systems (PDIDS) based on Unmanned Ground Vehicles (UGVs) have emerged as a transformative approach to address these limitations.

UGVs, autonomous or remotely operated vehicles, bring a dynamic and adaptable element to perimeter security. They are equipped with sophisticated sensors, cameras, and communication systems, enabling them to monitor large areas, detect potential intrusions, and respond quickly to threats. This mobility allows UGVs to cover extensive and varied terrains, providing continuous surveillance and real-time data collection, significantly enhancing the detection and deterrence of unauthorized access.

The integration of UGVs into PDIDS offers several key advantages over traditional methods. These include the ability to operate in hazardous or difficult-to-reach

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areas without risking human lives, the potential for 24/7 monitoring without fatigue, and the capacity to respond rapidly and flexibly to evolving threats. Additionally, UGVs can be equipped with non-lethal deterrent devices and integrated with existing security infrastructure, creating a comprehensive and robust defense system.

2. RELATED WORKS

There are a few implementations of different types of perimeter defense intrusion detection systems. In [1], a proposed new design of UGV specialized for perimeter security tasks is presented. In [2], it presents a detailed review of unmanned ground vehicles' design and dynamics control. In [3] and [4], different types of specialized unmanned ground vehicles (UGV) for surveillance and bomb detection are presented. The researches described in [5] and [6] propose different approaches to UGV-UAV surveillance and intrusion detection.

3. DESIGN OF PDIDS BASED ON UGV

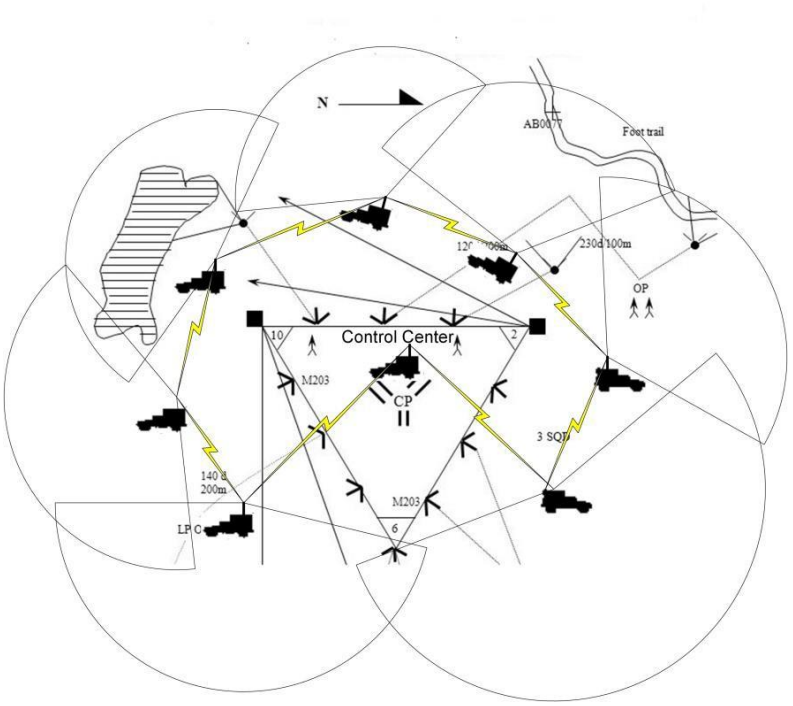

Fig. 1. Design of mobile PDIDS

The design of UGV-based PDIDS is founded on several key principles:

Comprehensive Coverage: Ensuring complete monitoring of all perimeter zones, regardless of terrain or environmental conditions. Real-time Monitoring: Providing continuous, real-time surveillance and rapid threat detection.

Scalability: Accommodating various perimeter sizes and complexities.

Resource Efficiency: Optimizing power consumption and operational efficiency for prolonged deployment.

Interoperability: Integrating seamlessly with existing security systems and technologies.

User Privacy: Protecting user data while maintaining robust security measures.

4. FUNCTIONAL COMPONENTS

The functional components related to PDIDS may be divided into the following groups of components:

Surveillance and Monitoring - continuous perimeter monitoring using high-definition cameras and sensors. Real-time detection of unauthorized activities or potential threats. Patrol and Inspection - regular patrolling of the perimeter to ensure no breaches or vulnerabilities. Ability to inspect specific areas upon detection of anomalies.

Intrusion Detection systems - real-time detection using motion detectors, thermal cameras, and other sensors. Accurate identification and classification of threats.

Threat Assessment modules - analysis of detected anomalies to assess threat levels. Determination of appropriate responses based on threat assessment.

Response and Interdiction - UGVs are equipped with deterrents like sirens, lights, or non-lethal weapons. Management of intrusions until human security personnel arrive.

Data Collection and Analysis - a collection of data on perimeter breaches, environmental conditions, and security incidents. Data will be used for further analysis and improvement of security protocols.

5. ARCHITECTURE OF PDIDS BASED ON UGV

The architecture of perimeter defense intrusion detection systems must integrate various technologies and components to provide comprehensive surveillance, detection, and response capabilities. UGVs play a critical role in enhancing these systems by offering dynamic patrolling, real-time monitoring, and rapid response to potential threats. UGV-based perimeter defense systems can protect critical infrastructures and sensitive areas from unauthorized access and potential intrusions by leveraging advanced sensors, communication infrastructure, and autonomous navigation. These systems will become even more sophisticated as technology evolves, providing robust and scalable security solutions.

The proposed architecture of UGV-based PDIDS shown in Fig. 2 involves several interrelated components working together to provide comprehensive security coverage.

Mobility Platform based on Unmanned Ground Vehicles (UGVs) - different designs (wheeled, tracked, or legged) to navigate diverse terrains. The platform includes various sensors, including cameras (visible spectrum, infrared, thermal), LiDAR, ultrasonic sensors, and radar for comprehensive environmental monitoring. Part of the platform is a set of power systems powered by batteries, solar panels, or hybrid solutions to ensure continuous operation. It is also part of the mobility platform.

Another part of PDIDS is the sensor suite mounted on the mobility platform, which includes high-definition, infrared, and thermal cameras to provide visual surveillance in various conditions, LiDAR and Radar systems for precise detection and environmental mapping, and Motion Detectors to detect movements and potential intrusions.

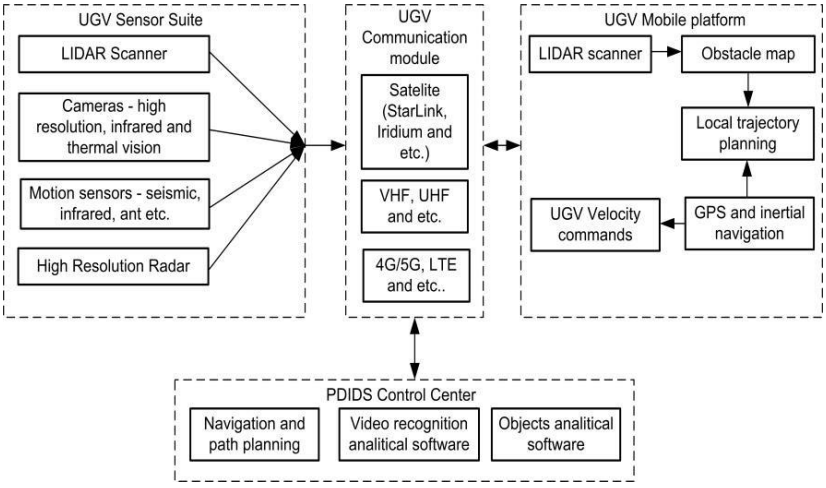

Fig. 2. Architecture of PDIDS

The UGV communication infrastructure consists of satellite communication modules for remote and inaccessible locations, secured channels for reliable and interference-free communication, low trajectory satellite systems (StarLink, Iridium, etc.), 4G/5G, and other wireless technologies. The Control Center is a key part of PDIDS. It includes data analytics tools for real-time data analysis, pattern recognition and decision-making, alert systems for real-time notifications, and alerts for detected threats.

The control center is also responsible for every UGV's navigation and path planning, which are based on GPS and Inertial Navigation to ensure accurate positioning and movement tracking. The included path planning algorithms use a machine learning-based approach for autonomous navigation and obstacle avoidance.

6. CONCLUSION

This paper outlines an innovative design and architecture of PDIDS based on UGVs, emphasizing their operational benefits, technical components, and the challenges involved in their implementation. By exploring the innovative use of UGVs in perimeter security, we aim to highlight their significant potential in enhancing the protection of critical assets and infrastructure in an increasingly complex threat environment.

The proposed new design outline comprehensively examines the principles, architecture, functionalities, and challenges involved in creating a UGV-based Perimeter Defense Intrusion Detection System. By addressing these aspects, this paper aims to contribute to the ongoing efforts to enhance the security of critical infrastructures and sensitive areas using advanced robotic technologies.

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