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DRONE BASED INTELLIGENT METALLIC ANOMALY DETECTION SYSTEM

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Abstract: This survey paper systematically investigates a drone-assisted intelligent system capable of detecting metallic abnormalities. Our solution utilizes multiple types of high-precision sensors along with machine learning-based algorithms to operate autonomously and examine metallic items or any possible metallic anomalies in the environment. The utilization of those technologies on a drone platform is more flexible, simple and efficient solution for industries like infrastructure monitoring, environment, and security. The system assists in improving the rate of detection while eliminating the need for human inspections. As our drone will be using a HD camera for live videography that will be transmitted to the mobile screen with the help of an app. This improvement will be a great step towards ensuring that both safety and workflow are perfect. Through a series of experiments that illustrate this method, we show the ability of this strategy to change the approach to detect and manage the metallic anomalies.

I. INTRODUCTION

Unmanned aerial vehicles, or drones, are becoming more and more prevalent in our daily lives. Drones are a great option for risky search and rescue missions as well as for delivering emergency supplies to hard-to-reach areas and disaster situations because they can travel places that people cannot. Since it relates to the struggles we face on a daily basis, the topic of safety and surveillance has been discussed for decades.

In addition, there have been explosions in the past. Keeping up with technological advancements might aid in eliminating concerns related to security and monitoring. Many nations throughout the world confront significant challenges with metal detection, and the traditional methods used to address these issues have numerous drawbacks, including greater costs and frequent inefficiencies.

Metallic anomaly detection using drones has emerged as a cutting-edge technology in various industries, offering unprecedented efficiency and accuracy in identifying hidden metallic objects beneath the earth's surface. This report aims to provide an overview of the present, past, and previous years' developments in drone-based intelligent metallic anomaly detection systems. Historically, metallic anomaly detection relied heavily on ground-penetrating radar (GPR) and other traditional methods, which were labour-intensive, time-consuming, and often lacked precision. These methods posed significant limitations in terms of coverage area and depth penetration.

In recent years, advancements in drone technology, particularly in terms of payload capacity, flight endurance, and sensor integration, have revolutionized the field of metallic anomaly detection. Early adopters began experimenting with integrating electromagnetic sensors onto drones to detect and map metallic anomalies more efficiently and accurately.

The deployment of drone-based intelligent metallic anomaly detection systems represents a paradigm shift in the way metallic anomalies are identified and managed across diverse applications. By overcoming traditional limitations and leveraging advancements in sensor technology and data analytics, these systems have the potential to revolutionize asset inspection, environmental monitoring, and archaeological exploration, driving efficiency, safety, and sustainability in various industries.

The evolution of drone technology epitomizes the convergence of innovation, ingenuity, and interdisciplinary collaboration. From humble beginnings as military assets to ubiquitous tools in the civilian domain, drones have transcended boundaries, revolutionizing the way we perceive and interact with the world around us. As we navigate the dynamic landscape of technological advancement, the transformative potential of drones continues to unfold, shaping the future of industries, economies, and societies worldwide.

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II. LITERATURE SURVEY

The literature surveyed represents the latest developments in drone-based intelligent metallic anomaly detection systems that are only possible with the growth in technology. First, the surveys have emphasized fundamental zones, granularity of analysis, and different indifs but significantly they have expanded to cover areas such as infrastructure inspection, military applications, and agriculture and they have gone as far as catering for applications like monitoring pipelines and inspection of bridges. Research carried on about anomaly detection on no matter what surroundings the networks can be built on either by the classification of the frameworks or the use of advanced machine learning models. Application-oriented surveys, in terms of the extraction features, varied from early strategies and methods as Deep learning in the company world developed changing glade manifested itself to the exhaustive assessments of drone-based detection gadgets, fuzzy logic algorithms, transformer models, and sequential transfer learning strategies.

1. Wankhade Roy F. Wiegert, Panama City; Brian L. Price “MAGNETIC ANOMALY SENSING SYSTEM AND METHODS FOR MANEUVERABLE SENSING PLATFORMS” -Technico lisboa 2018 [1]

The methodology of this survey involves sensing the presence of metal and its detection using CFD, on the wing aerodynamics when the VTOL system is installed. The optimum solution allowed a decrease of 30% on the magnetic noise and a fuel consumption of 8.71 kg of fuel for an 8-hour search operation. [1]

2. Joo, M., Yoon, J., Junejo, A.R. et al. “Optimization: Drone-Operated Metal Detection Based on Machine Learning and PID Controller” Int. J. Precis. Eng. Manuf. 23, 503–515 (2022) -International Journal of Precision Engineering and Manufacturing- 21/03/2022 [2]

This survey involves the metal anomaly detection where metal is detected and programmed by Machine Learning (ML) models. It emphasis the potential to revolutionize various industries and its role in a technologically advanced future. [2]

3. Reshma Gunturua,Kolusu Navya Durgaa,Taraks Sri Harshaa, Shaik Fayaz Ahamedb “Development of Drone based Delivery System using Pixhawk Flight Controller”-Second International Conference on IoT, Social, Mobile, Analytics & Cloud in Computational Vision & Bio-Engineering (ISMAC-CVB 2020) [3]

The methodology proposed for the flight controller calibration. A server is used which can handle multiple drone at the same time with other equipments. According to the experimental results, the present study secured the flight stability of the unmanned metal detection drones and the high detection success rate. [3]

4. Anna Konert a, \Tomasz Balcerzak b “Military autonomous drones (UAVs) - from fantasy to reality. Legal and Ethical implications” –Transportation Research Procedia -2021 [4]

The methodology of this study adopts the Military and Defense usages. Different flight controllers are used as alternative responses to the various challenges they may encounter in carrying out their missions. According to the experimental results these drone can be helped out through different military mission along with reducing casualties, enhancing accuracy, border security, research and development. [4]

5. Ana Arboleya, Yuri Alvarez, Borja Gonjalej “Synthetic Aperture Radar Imaging System for Landmine Detection Using a Ground Penetrating Radar on Board a Unmanned Aerial Vehicle” –August 2018 [5]

This survey focused on difficult-to-access areas without being in direct contact with the soil. And the technique used was composed by a radar module mounted on board an Unmanned Aerial Vehicle (UAV), which allows the safe inspection of difficult-to-access areas without being in direct contact with the soil. Therefore, it can be used to detect dangerous buried objects, such as landmines. [5]

6. Kihoon Lim, Jaehyun Yoon, Sang in Park “Multi-objective Optimization of Aerodynamic Blade Shapes for Quadcopter System to Enhance Hovering Thrust and Power Consumption Efficiency” –May 2023[6]

The methodology was focused on maximizing hovering thrust and minimizing the power consumption of a quad-copter system at the same time by conducting multi-dimensional optimization of aerodynamic blade shapes. And technique used was based on both L&D forces obtained from CFD, surrogate models are generated using the response surface method (RSM). [6]

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III. METHODOLOGIES IMPLEMENTED

The techniques described in this subsection are focused on the various methods by which drones detect metallic anomalies in the current research. These span through diverse fields from mass surveys to specialized versions like real-time identification of metal structure errors. Methods are composed of deep learning & neural networks helping to detect tiny flaws and predict the maintenance in advance. Each method works at different angles to weather multiple challenges like defining all necessary datasets and their management, as well as making smart decisions between speed and accuracy of screens from the real world.

1. Choosing the right parts:

This approach involves an in-depth analysis for the tools that will be useful for constructing the drone model. It must be made sure that the components of the quadcopter are not only reliable but also cost-effective. Each component, from the flight controller to the propellers plays an important role in the quadcopter's performance and longevity.

2. Getting ready:

The study employs a deep learning methodology by embarking a new journey for making a metal detector drone. For the Quadcopter, this means meticulously selecting the appropriate sensors that will enable it to navigate through the skies and detect the metallic anomalies on the ground.

3. Fine tuning the sensors:

This research paper proposes a real-time sentiment analysis for the calibration of the metallic sensor that will be helpful in metal detection. The calibration is likely to change the intensity of the sensor for metal detection. It involves carefully adjusting the metal detector sensor to eliminate any inaccuracies or discrepancies in its readings. The flight controller is also calibrated with the help of Mission Planner that is an open source software. The calibration ensures the quadcopter's metal detection capabilities are finely tuned for optimal performance.

4. Keeping an eye out:

The paper introduces a safety measures that should be taken while flying the drone. It is essential to keep a vigilant eye on the ground below during the flight. Similar to how a pilot scans the horizon for landmarks, the quadcopter's onboard camera allows for real-time monitoring of the area being surveyed. If anything metallic catches our eye, it's immediately noted for further investigation and the drone can be sent to that location for the further metal detection processes.

5. Sorting through the clues:

This method at the base of the drone, helps to analyze the data collected during the flight time. This involves carefully reviewing the footage from the onboard camera and examining the readings from the metal detector sensor. The main goal here is to identify any metallic anomalies that are present on the earth surface. This helps us to determine their significance within the surveyed area.

IV. PROJECT FRAMEWORK OVERVIEW: BLOCK DIAGRAM, WORKING MODEL

1. Block Diagram:

In a drone system equipped with a Pixhawk flight controller, the coordination among its components is essential for effective metal detection operations. The flight controller acts as the central processor, analyzing data from onboard sensors like accelerometers and gyroscopes to maintain stable flight dynamics. Electronic Speed Controllers regulate motor speeds under the flight controller's commands, ensuring precise control over the drone's movements for stable flight and maneuverability. For metal detection, a specialized Metal Detector Module enhances the drone's capabilities by identifying metallic objects on the ground. This module utilizes advanced detection technologies such as electromagnetic induction or ground-penetrating radar to detect metal beneath the drone's flight path. When metallic objects are detected, the Metal Detector Module communicates with the Pixhawk flight controller, prompting actions to alert the operator and potentially adjust the drone's flight path. This integration expands the drone's versatility, enabling applications in archaeology, construction, and security.

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Complementing metal detection efforts is an HD camera mounted on the drone, capturing live video footage during flight. The camera provides visual assistance to the pilot and corroborates metal detection results. The video feed is wirelessly transmitted for real-time analysis, enhancing operator awareness and decision-making based on visual and sensor data. Auditory feedback through a buzzer mounted on the drone frame further enhances operator awareness. GPS ensures accurate positioning for reliable metal detection operations, while manual drone control via an FSI6 transmitter and receiver pair offers flexibility when autonomous operation is not feasible. Integration with Mission Planner software streamlines mission planning and monitoring, maximizing the system's potential for various applications, including metal detection and reconnaissance. This comprehensive integration of components creates a robust platform for efficient metal detection and reconnaissance, showcasing technological synergy for enhanced operational effectiveness.

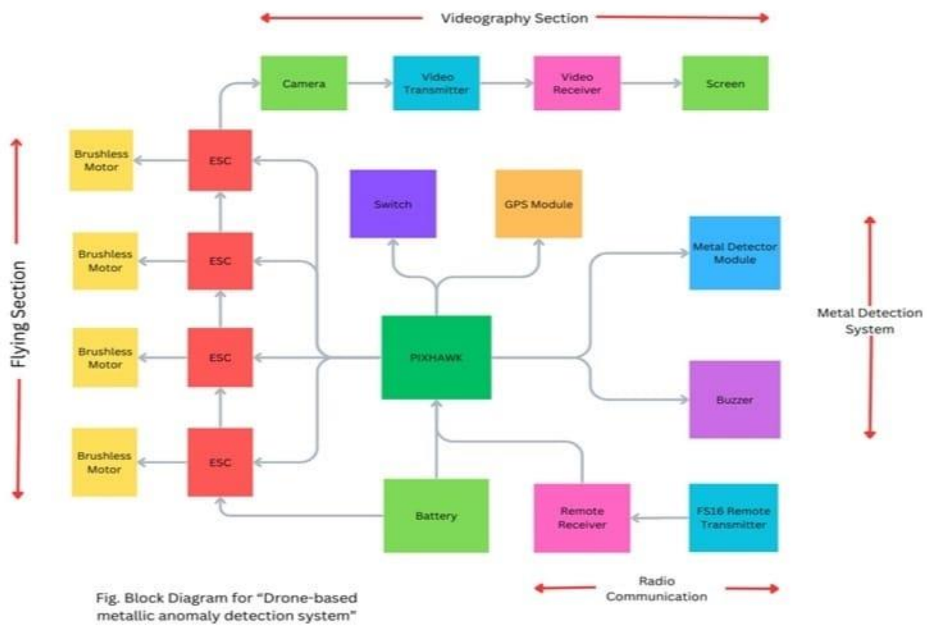

Fig 5.1 – Block Diagram

Fig 5.2 – Working Model

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V. APPLICATIONS

Combining drone technology with metal detection systems has significantly transformed numerous industries by providing innovative and efficient solutions for detecting and analyzing metallic anomalies. These applications extend across defense, mining, infrastructure inspection, environmental monitoring, archaeological exploration, search and rescue missions, law enforcement, and construction. With advanced sensors, drones offer quick, accurate, and non-invasive methods to locate hidden metallic objects, enhancing safety and reducing operational costs. This versatile technology is crucial for proactive maintenance, optimizing resource use, protecting the environment, and preserving historical sites. It highlights the substantial impact of drone-based metal detection across diverse fields and its promising potential for future advancements.

1. Defense and Security:

Drones enhance safety by identifying hidden weapons, explosives, and other metallic threats in critical areas like airports and military bases. They are also used to detect landmines and unexploded ordnance in conflict zones, providing safer conditions for both military personnel and civilians.

2. Mining and Exploration:

In mining, drones are valuable for discovering and mapping mineral deposits such as gold and copper in remote areas. They offer essential data for assessing ore quality and optimizing extraction methods, reducing the need for extensive ground surveys and improving operational efficiency.

3. Infrastructure Inspection:

Drones inspect important infrastructure, including bridges and pipelines, for signs of metal fatigue, corrosion, and structural damage. They help identify issues early, preventing failures and lowering maintenance costs. Additionally, drones can locate buried utilities to avoid damage during construction.

4. Environmental Monitoring:

Drones survey polluted sites to detect metal contaminants in soil, water, and air. They help monitor industrial facilities for hazardous waste and assess the impact of metal pollution on the environment, aiding in remediation efforts and protecting ecosystems and public health.

5. Archaeological Surveys:

Drones conduct non-invasive surveys of archaeological sites, detecting buried artifacts and ancient structures. This technology allows archaeologists to explore large areas efficiently, preserving the integrity of historical sites and assisting in the documentation and protection of cultural heritage.

6. Search and Rescue Operations:

In search and rescue missions, drones locate metallic objects like vehicles or debris in remote or disaster-hit areas. They improve the efficiency of rescue operations by providing real-time data and precise locations, helping to prioritize search efforts and save lives.

7. Law Enforcement and Forensics:

Drones assist law enforcement by finding metallic evidence such as firearms or shell casings at crime scenes. They also help monitor illegal mining and metal theft, offering critical information for forensic analysis and supporting the enforcement of legal regulations.

8. Construction and Demolition:

Drones survey construction sites to identify metal hazards such as buried pipes or cables, preventing accidental damage during excavation. They also assess the structural integrity of buildings and infrastructure, ensuring safe demolition and renovation activities while reducing risks..

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VI. RESULTS

The Pixhawk is a popular open-source autopilot system which we have used in drones for autonomous flight control. It provides the necessary hardware and software for stable flight, waypoint navigation, and integration with other sensors. Where this module is equipped with sensors capable of detecting metallic objects or anomalies.

These sensors can vary depending on the specific requirements of the application but may include electromagnetic induction sensors, magnetometers, or metal detectors. These are equipped with cameras to capture aerial footage, which is then transmitted in real-time to a ground station or monitoring station via a video transmitter. The video receiver receives this footage, allowing operators to view the live feed and analyses it for metallic anomalies.

The captured video footage is processed using intelligent algorithms that analyses the imagery to identify potential metallic anomalies. These algorithms may use computer vision techniques, machine learning, or pattern recognition to distinguish metallic objects from the background and other non-metallic objects.

The effectiveness of the system depends on factors such as the quality of the sensors, the accuracy of the algorithms, and the stability of the drone platform. Continuous refinement and optimization of both hardware and software components are essential for improving the performance and reliability of the system.

This the calibrating of the radio transmitter and the receiver with the mission planner where we are able to control the throttle movement in the transmitter This is the final look of our drone which is equipped with all the hardware components and can be flied up to 100 meters height and 1killometer distance

VII. DISCUSSIONS

In this section, we are discussing about a drone-based intelligent metallic anomaly detection system that offers an innovative solution for the monitoring and inspection of extensive infrastructures such as pipelines, bridges, and industrial facilities. This system utilizes advanced algorithms to autonomously detect and classify metallic anomalies. With high-resolution cameras and sensors, drones can collect and analyze data in real-time, hence reducing the time and cost of traditional inspection methods. The drone's mobility allows it to access hard-to-reach areas, ensuring proper coverage and enhancing safety by minimizing the need for human presence in hazardous environments. By processing the collected data, the system improves the accuracy of anomaly detection, enables predictive maintenance, and also extends the lifespan of critical infrastructure. This state-of-the-art approach to anomaly detection marks a significant advancement in the field of metal detection along with increasing the working area for a drone. The efficiency and adaptability of drone technology are combined with the robustness of sophisticated data analysis.

To be more precise, the speed and precision of the autonomous inspections carried out by this system outperform those of traditional approaches. The sophisticated sensors and high-resolution imaging capabilities allow for in-depth, real-time assessments of the state of the infrastructure. Lowering the need for significant human work and specialized equipment quickens the discovery of any problems and offers a more affordable solution. Moreover, the drones' capacity to maneuver and examine difficult-to-reach regions guarantees that no portion of the infrastructure is missed, which is sometimes a drawback of traditional inspection methods.

The method improves the inspection process's overall efficacy. Maintenance teams can take proactive measures to fix issues by having the system analyze collected data to find patterns and predict possible failures before they become critical. The capacity to perform predictive maintenance is essential for prolonging the life of infrastructure because it enables prompt interventions that stop little issues from becoming larger ones. In conclusion, combining drone technology with cutting-edge data analysis presents a revolutionary method for inspecting and maintaining infrastructure. In addition to offering a safer, more economical, and proactive maintenance plan, this combination increases the effectiveness and completeness of inspections. This sophisticated technology establishes a new benchmark for large-scale infrastructure monitoring and maintenance, marking a substantial advancement in anomaly identification.

VIII. CONCLUSION

In conclusion, Drone-based intelligent metallic anomaly detection represents a significant advancement in the field of aerial inspection and monitoring. Through the integration of drones with advanced sensing technologies and intelligent algorithms, this approach offers rapid, non-invasive, and cost-effective solutions for detecting and characterizing metallic anomalies in various environments.

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The significance of this technology is underscored by its potential applications across multiple sectors, including infrastructure inspection, environmental monitoring, and archaeological surveys. By providing real-time data on the location, size, and nature of metallic anomalies, drone-based systems enable timely decision-making, proactive maintenance, and resource optimization, thereby improving safety, efficiency, and sustainability in diverse industries.

The successful implementation of drone-based metallic anomaly detection systems relies on addressing several challenges, including sensor integration, data processing, navigation, and regulatory compliance. Continued research and development efforts are needed to enhance sensor capabilities, optimize algorithms, and improve the overall reliability and usability of these systems in real-world scenarios.

The future of drone-based intelligent metallic anomaly detection holds great promise for revolutionizing asset inspection, environmental monitoring, and archaeological exploration. By leveraging advancements in technology and fostering collaboration across disciplines, researchers and practitioners can unlock new opportunities to enhance safety, efficiency, and sustainability in various industries through the proactive detection and management of metallic anomalies.

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