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ARTIFICIAL INTELLIGENCE APPLICATIONS BASED ON REMOTE SENSING TECHNIQUES IN THE FIELDS OF DEFENSE AND SECURITY STUDIES[1]

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ABSTRACT The concept of command, control, communication and coordination in defense and security operations depends largely on the availability and analysis of accurate spatial and temporal information to reach quick decisions for executive orders. Since defense and security agencies around the world obtain huge amounts of visual surveillance data on daily basis from various sources of sensor technology, such as fixed sensors or those connected to moving objects such as drones, vehicles, and satellites, the challenge has become not in collecting the data itself, but in processing and analyzing it. Hence, machine learning and artificial intelligence can be used. It is an application of artificial intelligence that uses computational methods to simulate the human eye. Similar to how people interpret visual information, computer vision programs based on remote sensing can "see" and "respond" to visual contact, extract valuable information, and make judgments based on what is "seen". Therefore, in the current digital era, artificial intelligence applications based on remote sensing technologies have become an excellent tool for military and security commanders before, during and after any operation. The use of these applications has revolutionized the ways in which these devices operate to obtain the required strategic information. For example, machine learning enables the creation of artificial intelligence computer vision that can classify and identify huge amounts of surveillance footage captured by surveillance equipment both at low altitudes such as drones and from high altitudes such as satellites. The development of algorithms can enable us to determine the contents of these huge amounts of data, detail any abnormal cases or diagnoses, and identify relevant targets that have been programmed to be reported. The system can then alert a human operator and highlight which targets are flagged while determining the accuracy of the diagnosis. This study investigates the concept, mechanism, and applications of artificial intelligence based on remote sensing and presents practical models of these applications in the field of defense and security studies.

Keywords: Remote Sensing; Artificial Intelligence; Machine Learning; Defense; Security.

تطبيقات الذكاء الاصطناعي المعتمدة على تقنيات الاستشعار عن بُعد في مجالات الدراسات الدفاعية والأمنية

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المستخلص يعتمد مفهوم القيادة والسيطرة والاتصال والتنسيق في العمليات الدفاعية والأمنية إلى حد كبير على توافر وتحليل المعلومات المكانية والزمانية الدقيقة للوصول إلى قرارات سريعة للأوامر التنفيذية. وبما أن وكالات الدفاع والأمن في جميع أنحاء العالم تحصل على كميات هائلة من بيانات المراقبة البصرية على أساس يومي من مصادر مختلفة لتكنولوجيا الاستشعار، مثل أجهزة الاستشعار الثابتة أو تلك المتصلة بأجسام متحركة مثل الطائرات بدون طيار والمركبات والأقمار الصناعية، فقد أصبح التحدي ليس في جمع البيانات نفسها، ولكن في معالجتها وتحليلها. ومن هنا، يمكن استخدام التعلم الآلي. إنه تطبيق للذكاء الاصطناعي يستخدم الأساليب الحسابية لمحاكاة العين البشرية. وعلى غرار الطريقة التي يفسر بها الناس المعلومات البصرية، يمكن لبرامج الرؤية الحاسوبية القائمة على الاستشعار عن بعد أن "ترى" و"تستجيب" للاتصال البصري، واستخراج المعلومات القيمة، وإصدار الأحكام بناءً على ما "يُرى". لذلك، أصبحت تطبيقات الذكاء الاصطناعي القائمة على تقنيات الاستشعار عن بعد أداة ممتازة للقادة العسكريين والأمنيين قبل وأثناء وبعد أي عملية. وقد أحدث استخدام هذه التطبيقات ثورة في الطرق التي تعمل بها هذه الأجهزة للحصول على المعلومات الاستراتيجية المطلوبة. إن تطوير هذه الخوارزميات يمكن أن يمكننا من تحديد محتويات هذه الكميات الضخمة من البيانات، وتفصيل أي حالات أو تشخيصات غير طبيعية، وتحديد الأهداف ذات الصلة التي تم برمجتها للإبلاغ عنها. تبحث هذه الدراسة في مفهوم وآلية وتطبيقات الذكاء الاصطناعي القائم على الاستشعار عن بعد، وتقدم نماذج عملية لهذه التطبيقات في مجال الدفاع والأمن.

الكلمات المفتاحية الاستشعار عن بعد؛ الذكاء الاصطناعي؛ التعلم الآلي؛ الدفاع؛ الأمن.

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1.INTRODUCTION

During the Cold War, the application of the first United States Force satellite program (CORONA) collected 860,000 images (resolution of 12 meters) of many regions in the world (Dashora et al., 2007). Application of machine learning on Remote sensing data can help in situation awareness after a natural disaster, human rights violations, or refugee settlement monitoring. Quinn et al. (2018) explored the use of remote sensing data in conjunction with the Mask-RCNN model to monitor and count refugee shelters in the Middle East and Africa. They used multiple imagery platforms of Airbus and DigitalGlobe based on available data for the region. The average precision for the model was recorded at 0.78 on all the locations, justifying the use of the machine learning tool on satellite imagery. One of the biggest disadvantages of high-resolution satellite imagery analysis is the privacy implications and accidental results sharing. Most similar research sites are partially exposed, and the use of high-resolution satellite images should be

done within an agreed-upon framework that adheres to ethical and responsible principles. Figure 1 depicts an overview of multiple uses of Artificial Intelligence (AI) in the field of security, including remote sensing techniques and GIS platforms.

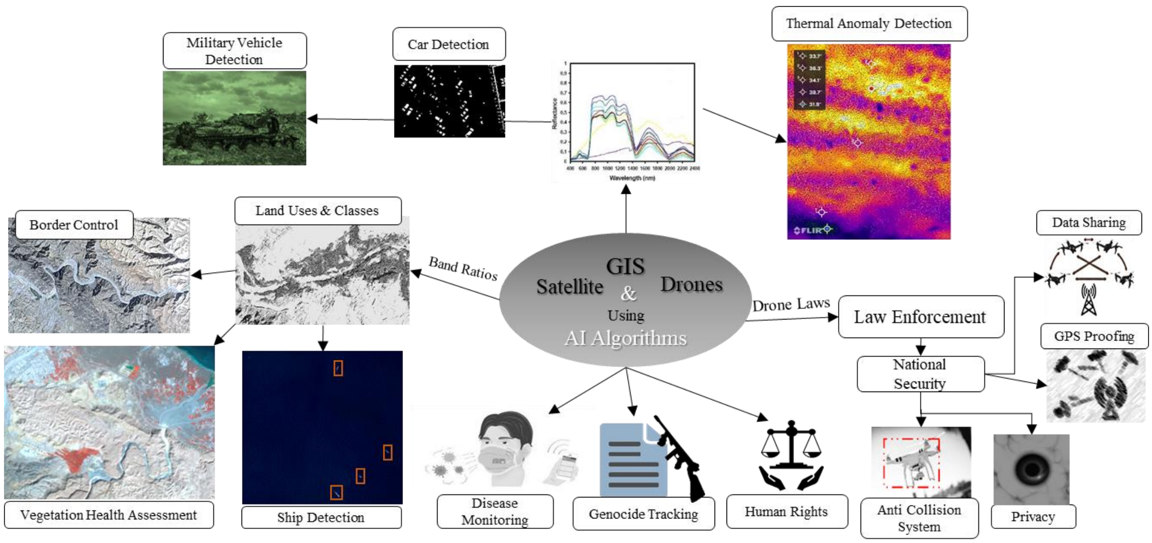

Figure 1. Overall applications of Artificial Intelligence (AI) in the field of security by incorporating aerial imagery (using satellites and drones) and GIS platforms.

This paper investigates the concept, mechanism, and applications of artificial intelligence based on remote sensing and presents practical models of these applications in the field of defense and security studies. The remainder of the paper is structured as follows: Section II contains the applications of arial imagery from drones and satellite in the field of security. Section III presents the roles of computer vision, sensors, and internet of things in the field of Security. Section IV discusses how the defense field can benefit from the applications of computer vision, sensors and IoT. Section V presents the latest knowledge on utilizing arial imagery from satellites and UAVs in the field Defense, while Section VI contains the conclusions.

2.APPLICATIONS OF ARIAL IMAGERY FROM DRONES AND SATELLITE IN THE FIELD OF SECURITY

Since August 2017, around 0.5 million Rohingya refugees fled to Bangladesh and joined others in overcrowded settlements camps (Hassan et al., 2018). In this context, spontaneous accommodation of the large number of refugees led to deforestation in the area which was examined in this study. Authors reported that the rapid expansion of the camp raised alarm against social, environmental, and forest security. So, the study utilized Sentinel (2A & 2B) satellite imagery (10 meters) using the random forest machine learning algorithm to quantify the expansion of the settlements and their effect on surroundings. Their study used the Sentinel 2 imagery acquired before and after the influx of refugees. Moreover, they also used QuickBird imagery (0.6 m, pan-sharpened) to locate the locations of the previous camps. The results show that the highest expansion of 835% in settlements was observed in the Kutupalong–Balukhali camp. Their study reported a high overall accuracy of 95% and Kappa statistics of 0.94. Their analysis showed that many refuge shelters were temporarily located inside the hosted community which reported the concerns among the local people. They observed that such expansion has already raised several issues, including the loss of life caused by elephant trampling owing to conflict with wildlife corridors. They suggested that the adoption of satellite imagery can assist government agencies in developing better security strategies for human and animal habitats surrounding the settlements.

There are mainly three types of communication platforms working at the same time in the UAV system. First, the platform is radio frequency which is used to transmit the Imagery, video, and communication with the ground control stations. Second is the cooperation with the GPS satellite for the location assessments and third is interaction between other UAVs in the area. The compromise of any of these platforms can be a huge security threat.

Adnan & Khamis (2022) reviewed the fields that use Drones in military and civilian applications and identified the reasons for the usefulness of their application in the relevant field. The authors stated that drones were used for a variety of objectives, including research, business, recreation, emergency response, search and rescue, and sports for environmental monitoring. This study reported that the use of drones by civilians for information collection raises concerns about national security. Without strict enforcement and regulations, misuse of drone technology could risk national security. Drones are easier and safer than sending human images to record visual images in risk areas. Misuse of drone technology could lead to misuse and potential misuse of national security by operating in restricted areas, like airports, posing risks to public safety and illegal data collection for security purposes.

Abiodun (2020) focused on using effective aerial surveillance, mapping technologies, and intelligence collection to tackle insecurity in Nigeria. This study provided many types and field applications of Droves and UAVs that are used in securing the community. This study recommended issuing licenses for drone applications to the security offices to identify the hideouts of criminals and their hideouts, regulating the no-fly zone near the airports, flying permits before each operation and periodically disclose information on the usage of equipment.

Deep neural networks are widely used for object detection as they collect large numbers of image data for tracking and detecting objects with high accuracy but the advancement of cyber-attacks on aerial imagery has increased in recent times. Du et al. (2022) used a threat model to target adverse attacks by altering the digital numbers of an object and performing physical-world attacks by printing patches and placing them in the attack scene (cars with different body paints in the parking). The results of the study reported that the attack level was more counted for blue color cars in the parking. They concluded the induced patches on the car are more effective as adverse attacks on the car detector model and subjected to climatic parameters such as sunlight and weather.

Satellite-based imagery provides detail on difficult terrains and surfaces and supports aid in complex situations that are not humanly possible, especially in conflicted zones (Avtar et al., 2021). This study provides insights into the application the satellite imagery for international peace and security. Shafique et al. (2021) provided an overall investigation of the UAVs and their vulnerability to security breaches.

A study by Liu et al. (2022) explored standard RGB bands from the Sentinel-2 satellite imagery with an automatic identification system (AIS) using a data fusion technique to track the movement and direction of the unidentified and unresponsive vessels. Their study utilized the deep learning model named YOLOv5 and R-CNN to strengthen the ability of small target detection. The outputs from these models were used as input parameters, including AIS data for the surveillance model (MSOA) to determine whether the vessel is AIS-associated. The results reported an overall precision of 92.3 % in detecting moving ships and ship wakes but false detection was observed in the land area background. Fisser et al. (2022) presented a remote sensing technique that employed Sentinel-2 satellite data and a random forest classifier (RFM) model to recognize vehicles traveling on roadways worldwide. The created model combined a rule set based on known motion effect factors with a recursive neighborhood search. The training data of the model was collected globally and validated with the ground data in Germany. Each band in the satellite imagery was examined individually to track the movement of the object due to time offset and sentinel 2 data was masked by using the data of roads (only larger roads) from the Open Street Maps. The RFM model was initiated and the object was extracted after running the trained model and results were compared with the next position of the vehicle to estimate the direction of movement. The overall accuracy of 84% was reported by the model validation, and the car station data and sentinel 2 truck counts had a r-value of 0.63. According to the authors, their model may be used for early warning system conservation, illegal mining detection, and truck anomaly detection.

Gadamsetty et al. (2022) used a deep learning approach to detect ships by examining the satellite imagery. The study used supervised classification and object detection using YOLOV3 to extract the objects from the study area. Subsequently, the objects were identified using segmentation procedures that adhered to the Hashing (SHA-256) in terms of ship numbers and geographical location in satellite imagery. The training dataset (231,722 images) was used with 70% and 30 percent for the training and validation process, respectively. The study asserted that it was not exclusive to YOLOV3, since accuracy was also assessed for R-CNN plus K means. YOLOV3 performed better on the same datasets, with 96.4% accuracy as compared with its competitors. The authors suggested that the model performed better than existing models in blurry conditions, small, land masking, and cloud masking, and it is more efficient in unfavorable weather situations.

Wang (2019) used the land cover data computed using satellite imagery in the Southwest US-Maxico border area (30-mile buffer zone) to address the effect of the legal and illegal crossing on the cropland and vegetation land. 70% of the study area was covered by scrubland and the other 30 5 was dominated by grassland, barren, and forests. The results from the study were correlated with the illegal crossing data and petrol enforcement data from border petrol stations. Their results reported that one standard deviation increase in illegal crossing would result in a 4.1% decrease in the vegetation cover index and one standard deviation increase in petrol agent would lead to a 19 % decrease in the vegetation cover index. This study shed light on the effectiveness of satellite imagery to link the border security policy and natural management techniques for natural resources with the lifestyle of the local communities near the border area.

Ahmed (2021) highlighted the use of microwave full-body scanning at the airport security scanners. The study included a thorough analysis of passive and active sensing systems and asserted that because passive systems do not experience signal loss at long ranges employing higher frequencies, they were desirable for standoff detection. On the other hand, the active systems are used in security scanning checkpoints as they do not need a source of energy to operate. This system can also operate at a few millimeters distance from the object under observation proving beneficial in cloth penetrations.

In order to monitor the integrity of borders, Laouira et al. (2021) recommended a multilayer surveillance system that uses sensors, radar, and unmanned aerial vehicles (UAVs). The main objective of this study was to detect and monitor any unidentified entities intruding on the borders using minimum human resources. The system works by sending the information/data collected by the Scalar sensors and radar to the control center and then the call for UAVs and patrol was given to monitor the possible border breach area. They also suggested using fine resolution techniques and monitor cameras to be on standby and used by the control room operators only when the scalar sensor alarmed from a nearby installed location.

The use of remote sensing technologies is under spotlight for the space-borne intelligence, surveillance, and reconnaissance to tackle security and address the defense of a country. Shimoni et al. (2019) reviewed the importance of hyperspectral imagery in security and defense applications. Their study divided the use of Hyperspectral imagery into two major applications, Strategic and tactical. The strategic part covered the application in the collection of information on the battlefield that used Visible and Near-Infrared (VNIR), Shortwave Infrared (SWIR), and Longwave Infrared (LWIR) bands for situation awareness, reconnaissance, and surveillance. The tactical part of this study covered the application in discrimination between targets and decoys, defeating camouflage, early warning for long-range missiles, and detection of landmines. The tactical part used the field, airborne, and space-borne platforms that used VNIR, SWIR, Mid-Wave Infrared (MWIR), and LWIR bands.

3.COMPUTER VISION, SENSORS, AND INTERNET OF THINGS IN THE FIELD OF SECURITY

The development and implementation of an advanced system for UAVs to perform real-time remote sensing tasks using onboard AI and edge computing was investigated by Koubaa, et al. (2023). They reported that applications of UAVs traditionally rely on human responses for monitoring or offline processing. Other technical methods rely on cloud computing, where reasoning is dependent on the video stream, which might present significant challenges related to limited connectivity and high latency. Their proposed approach, AERO, was a cloud–edge hybrid system where a cloud server is responsible for data storage and edge computing is responsible for processing AI tasks. It combines object detection and tracking models over multiple consecutive frames to increase the detection accuracy. This approach helps in many applications. Consider security, it provides real-time monitoring of risks and disasters, exploring extended or rough terrain areas to search for lost people, executing specialized person detection models on board, and automatically report their location in real-time.

Nie et al. (2020) discussed the deep learning methods used to detect ships in purpose of maritime surveillance and traffic supervision. They proposed enhanced ships detection and segmentation at the pixel level based on improved Mask C-RNN model. Automated ship detection can help to obtain ship distribution information. Furthermore, it can be used to control illegal fishing and cargo transportation. Traditional methos including statistical methods identifies controlled region and then delete object, which are not identified as ships. However, this method performed well in the sea regions of satellite images from panchromatic and one band within multispectral bands. But it did not perform well in the harbor area. However, by adding learning techniques to the model, it performed well in the harbor area and sea.

A view on using geospatial intelligence and AI to detect the primary infrastructure for coca paste production which has reached a record level in the recent years was explored (Pinto and Silva (2023). This study aimed to strengthen strategies against drug trafficking by using advanced AI models and remote sensing. Around 16,778 training samples have been trained and used in advanced deep learning model with 90 % as the Average Precision (AP) Score of the model.

A comprehensive framework named FogSurv was designed for real-time urban surveillance leveraging fog computing, artificial intelligence (AI), and data fusion (Munir et al. (2021). This framework aimed to enhance situational awareness (SA) and ensure timely responses to emergencies by integrating Internet of Things (IoT) devices, unmanned aerial vehicles (UAVs), fog nodes, and cloud servers. Several use cases were outlined to the framework can have a significant impact on security issues including proactive threat detection and emergency response.

Traditional imaging from satellites or high-altitude aircraft often fails to cover certain parts of the monitoring area and typically produces low-resolution images, leading to challenges in accurately identifying objects. In contrast, UAVs can operate multiple times a day without the need for extensive infrastructure for takeoff and landing, offering more flexibility and efficiency. Avola et al. (2021) applied low-altitude UAVs for detecting anomalies in small-scale areas. This study employed a One-Class Support Vector Machine (OC-SVM) anomaly detector based on customized Haralick textural features for aerial video surveillance at low altitudes. The use of textural features enabled a vision-based system to detect both micro and macro structures of the analyzed surface with high precision. From a military perspective, this approach can be utilized for mine detection, combat efficiency assessment, and battlefield mapping.

An automatic target tracking using a real time video produced by SAR was investigated by Li et al. (2024). A moving target tracking system was proposed. It was designed to be low complexity and fast for implementation through edge nodes in a mini-satellite or drone network, enabling machine intelligence in large-scale vision systems, particularly for marine transportation systems. The system employed a group of image-processing tools for video preprocessing and Kalman filtering for the main tracking task.

For testing system performance, two measures—accuracy and false alarm probability—were computed using real vision data. The analysis included scenes with a single target and more complex scenes with multiple targets. The proposed system has demonstrated high performance in these tests.

YOLO v3 deep learning approach was investigated by Zhao and Ren (2019). They compared it with fast R-CNN and SSD in order to figure out the efficiency in accuracy and speed to detect small objects using high latitude remote sensing platforms, specifically the Aircraft. This application introduced the enhanced detecting objects method, by using the same arguments for training and testing experiments. The study showed that Yolo v3 object detector has better performed R-CNN and SSD with average precision of 0.925.

Kemper and Kemper (2020) addressed a set of sensors used in the field of remote sensing and geographic information systems for various applications related to disaster management. It mentioned that annually, many people suffer injuries or death due to disasters, including natural disasters such as earthquakes and volcanoes, in addition to biological disasters as epidemics or pandemic diseases in which humans are involved in one way or another. By using modern sensors technologies for prediction, preparation, and response, disaster management has become more effective. In the case of floods, classifying areas depends on the level of hazard and finding the more safe areas. This study went on combining new sensors in new platforms with better applications. Looking at the response phase, fast data availability is crucial to successful operation on the ground. It is necessary to guide rescue teams through the situation. It is also necessary for mitigating risk analysis, preventive identification of emergency areas and responsive emergency location, and quick responsive mapping. One of these sensors is a thermal camera. It captures and measures the longwave infrared, therefore thermal images help in detecting thermal anomalies, changes in temperature or even searching for people.

Considering the security field, different IoT based sensors bring the physical objects very close the digital world which can be implemented by leveraging fog computing (Sehrawat & Gill, 2019). Positioning sensors detect the presence of things, including humans in a particular area by sensing their motion. It can increase home security by tracking any movement in doors and windows from anywhere.

There are also sensors to detect any motions or physical movements of any objects within conducted areas moreover, whenever motion is detected where photos or videos can be uploaded on the server. Temperature sensors are helpful in identifying the physical changes in objects by measuring heat energy.

Additionally, there are infrared sensors, which emit or detect the infrared wavelength to sense specific features of certain objects. Specific criteria around some restricted areas can be addressed with smart Perimeter Access Control (PAC) to alarm any entry of non-authorized people. To reduce the possibility of accidents in risky workplaces Smart Explosive Detection (SED) sensors can produce a warning alarm of any detection of harmful gases, radiation levels, and leakage exist.

These applications showcase the potential of IoT sensors to create safe and secure places. Table 1 summary all mentioned above articles which are related to the applications of computer vision, sensors and IoT in the field security.

Table 2. Summary of articles related Applications of computer vision, sensors and IoT in the field security

No.	Year	Title	Task. Applications	Platform	AI Approach	Reference
1	2023	AERO: AI-Enabled Remote Sensing Observation with Onboard Edge Computing in UAVs.	object detection and tracking models	Sensors, IOT, Computer vision)	cloud–edge hybrid system	Koubaa et al. (2023)
2	2020	Attention Mask R-CNN for Ship Detection and Segmentation From Remote Sensing Images	object detection	Computer vision	Improve Deep learning model (Mask R-CNN)	Nie et al. (2020)
3	2023	Geospatial Intelligence and Artificial Intelligence for Detecting Potential Coca Paste Production Infrastructure in the Border Region of Venezuela and Colombia	Object Detection (Identify Criteria)	Computer vision	Deep learning	Pinto and Silva (2023)
4	2021	FogSurv: A Fog-Assisted Architecture for Urban Surveillance Using Artificial Intelligence and Data Fusion	Object Detection and Tracking	AI)/machine learning (ML), information fusion, and dynamic data-driven methods/framework for real-time urban surveillance	FogSurv. fog computing. AI/ML processing, and AI- and data-driven information fusion	Munir et al. (2021)

5	2021	Low-Altitude Aerial Video Surveillance via One-Class SVM Anomaly Detection from Textural Features in UAV Images	Anomaly detection; small-scale unmanned aerial vehicles; low-altitude flights; texture analysis; feature extraction; real-time applications	Computer vision. OC-SVM anomaly detection	One-Class SVM (R-CNN)	Avola, et al. (2021)
6	2024	Target tracking using video surveillance for enabling machine vision services at the edge of marine transportation systems based on microwave remote sensing	Detect and track objects (marine field)	Computer vision. (IoT)		Li et al. (2024)
7	2019	Smart Sensors: Analysis of Different Types of IoT Sensors	Various applications for detecting objects	Sensors, IoT		Sehrawat and Gill (2019)
8	2019	Small Aircraft Detection in Remote Sensing Images Based on YOLOv3	Object detection. image classification		YOLOv3, Faster R-CNN and SSD	Zhao, and Ren (2019)
9	2020	SENSOR FUSION, GIS AND AI TECHNOLOGIES FOR DISASTER MANAGEMENT	Object detection.	Sensors,		Kemper and Kemper (2020)

4. AI APPLICATIONS BASED ON RS TECHNIQUE IN THE FIELD OF DEFENSE USING SATELLITES & DRONES

Artificial intelligence (AI) is becoming increasingly prevalent in military operations (Figure 2), mirroring its growing importance in industries and businesses (Rashid et al., 2023). AI-driven military systems process large volumes of data more efficiently than conventional systems and enhance fighting systems' self-control, self-regulation, and self-actuation. Practically every military application now involves AI, and the growing support for advanced AI technologies is expected to boost demand for AI-driven systems in the military.

Figure 2. Military application of AI.

Hyper-personalization's decision-making component greatly improves military capabilities, especially for unmanned aerial vehicles (UAVs). Drones can be outfitted with an array of sensors and cameras to gather copious amounts of environmental and target data. The decision-making part of hyper-personalization evaluates this data in real-time and provides military commanders with actionable information so they can make better decisions. Neural network analysis of UAV data is a recent invention in hyper-personalization for military decision-making. It can identify possible targets, with extreme precision, and provide commanders with recommendations in real time. The goal of modern technology is to safeguard soldiers' lives and health on the battlefield. One strategy commonly discussed is "bringing machines onto the battlefield," with bioinspired robots proposed as alternatives to conventional weapons. These robots can withstand harsh conditions and provide soldiers with better safety in combat scenarios.

Soldi et al. (2021) reported that massive datasets generated by the increasing number of space-based sensors requires advanced data processing techniques including big data analysis, machine learning, artificial intelligence (AI), and data fusion. Complex algorithms are needed to recognize and classify ships, scan satellite images, and integrate fragmented data in maritime surveillance (MS) systems with several sensors. These algorithms organize and filter massive amounts of data, producing actionable information that end users (such as law enforcement, coast guards, and other government and military authorities) can utilize to spot anomalies, neutralize threats, and prevent incidents. To properly utilize the enormous quantities of satellite images, the spread of space-based sensor technologies requires sophisticated data processing techniques including big data analysis, machine learning, artificial intelligence, and data fusion. In particular, specific algorithms are needed to interpret raw satellite images, identify and categorize ships, and combine data from many sensors in order to construct MS systems that integrate multiple sensors Ficure 3. Through the management of the growing amount of heterogeneous data, these techniques enable MS. End-users like police, coast guards, and military authorities can identify irregularities and risks like oil spills, piracy, and human trafficking with the use of the extracted data and insights, which allows for prompt intervention to stop mishaps and illegal activities.

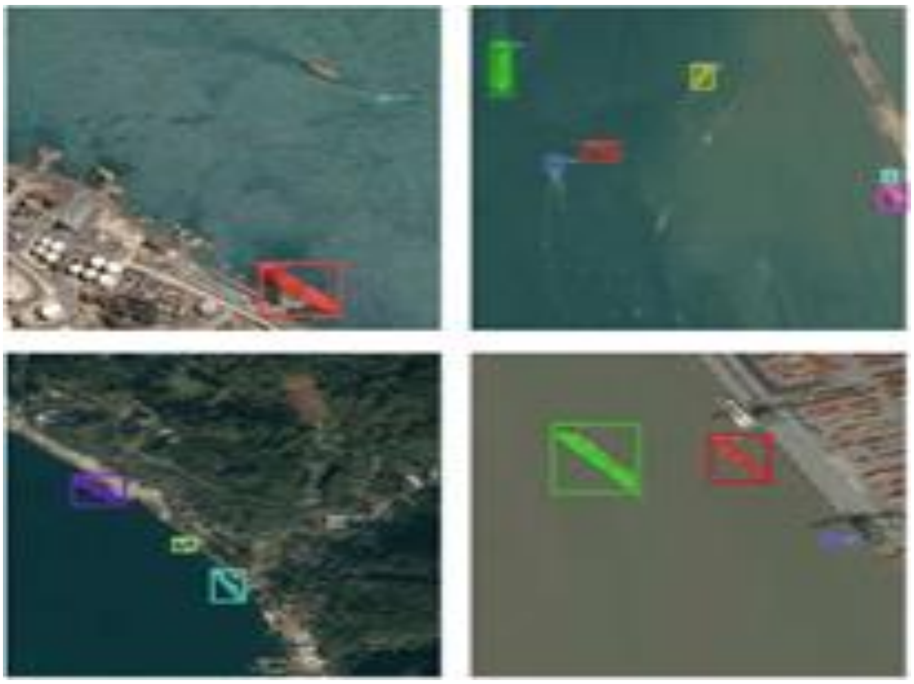

Figure 3. Detection of illegal versus legal ships on and offshores.

Real-time reconnaissance, surveillance, target acquisition (RSTA), ISR, and novel fire capabilities are all made possible by UAVs for the military. They can be used in front lines, flanks, or behind enemy lines in conventional warfare, including counterinsurgency operations. Drones are also essential in unconventional warfare, including counterinsurgency operations. Anil et al. (2023) examined the unmanned aerial vehicle of military for land mine detection and illegal migration surveillance support.

Because of their enhanced durability, stability, and efficiency, unmanned aerial vehicles (UAVs) are becoming more and more important in both military and civilian uses. UAVs with next-generation cameras can offer war and rescue missions with exact topographical data. They can carry heavier cargoes, including anti-tank guided missiles, which helps with the development of war strategies. They can also interact with soldiers on a frequent basis, providing intelligence on enemy movements. Drones are used by military forces in a variety of sizes and weights. In general, armed drones are bigger and heavier than unarmed ones. While nano and micro drones are mostly used for data collecting, small drones can be modified for intelligence, surveillance, and reconnaissance (ISR) or weapon delivery applications. Large drones, like medium- and high-altitude long-endurance (MALE and HALE drones), are used for military information gathering, search and rescue operations, tactical ISR, and battlefield support. They frequently operate beyond the operator's line of sight.

Thusnavis et al. (2022) explored drones applications in defense aspects. Drones are designed to take the place of humans in commercial and industrial settings, saving them time and effort. Bomb detection (Figure 4) is one of the most difficult and dangerous jobs. It takes a long time for humans to find the bomb. Therefore, early bomb detection is essential to preserving human life. Drones are now utilized in the military to find bombs in a variety of locations. These drones save many lives in extremely sophisticated locations because they are smaller and feature high-quality wireless cameras.

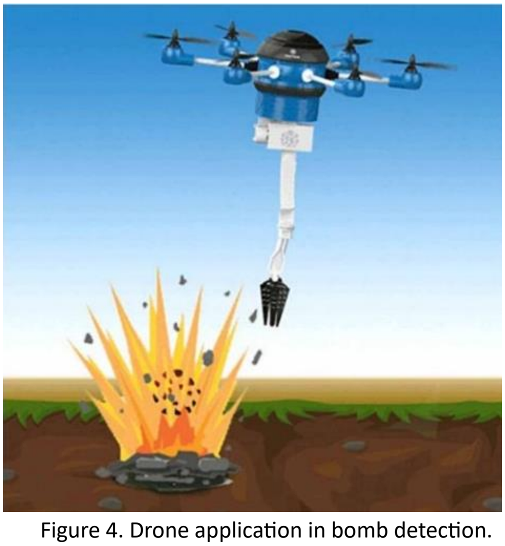

Figure 4. Drone application in bomb detection.

A comprehensive assessment on remote sensing techniques for subterranean structures was conducted by Melillos et al. (2016). Such an approach can be employed as a means of supplying the Ministry of Defense and the National Guard with pertinent data, mostly for security-related uses. They found that integrated technologies like Unmanned Aerial Vehicles (UAVs), field spectroscopy, and satellite imaging might be utilized to administer and assist a national research effort for finding "buried" military underground installations with remote sensing and GIS.

Angela et al. (2023) explained six reasons for using AI systems in the military, which are:

1) Threat detection: In real-time, AI algorithms examine a variety of data sources, including social media and satellite photos, to identify potential dangers and unearth hidden patterns.
2) Remote operations: AI manages unmanned vehicles, including as ground robots and drones, for activities like logistics, targeted strikes, surveillance, and reconnaissance.
3) Training and simulations: AI creates lifelike virtual environments that allow soldiers to safely practice in various combat situations.
4) Smart weapons: AI improves the aiming and accuracy of weapons.
5) Autonomous ground vehicles (AGVs): Similar to unmanned vehicles, these vehicles perform transportation, logistics, and search and rescue duties.
6) Predictive analytics: AI-driven systems examine huge databases to spot trends and forecast future occurrences.

On the other hand, Mori (2018) listed the ways in which the artificial intelligence has significantly improved military operations, including:

- Better situational awareness: AI makes it possible to analyze data thoroughly, which improves comprehension of the operational environment.
- Quicker decision-making: AI systems have a high rate of information processing, which enables them to react swiftly to changing circumstances.
- Enhanced cyber resilience: By more accurately identifying and thwarting attacks, AI helps strengthen defenses against cyber threats.
- Lower maintenance costs: Predictive maintenance powered by AI reduces downtime and maximizes resource use.
- Improved unit integrity: AI helps military units coordinate and communicate more effectively, resulting in more unified operations.
- Increasing complexity of joint force maneuvers: AI makes it possible for many military branches to conduct more intricate and coordinated operations.
- Improved communication connection security: AI raises the bar for encryption and secure

communication protocols, lowering the possibility of interception.

- Well-informed tactical and operational judgments: Commanders are assisted in making well-informed decisions by AI-generated insights.
- Increased operational continuity in circumstances with impaired networks: Artificial intelligence (AI) modifies operations to continue being effective even in difficult communication situations.
- Greater endurance for physically demanding missions: AI-powered autonomous systems are capable of taking on challenging assignments, reducing the hazards to human people.
- Enhanced endurance and persistence: AI-driven unmanned systems can run continuously for lengthy periods without the need for human intervention.

Petrovski et al. (2022) proposed a YOLOv5 method to detect objects of critical military importance. Path aggregation network (PANet) was used by YOLOv5 to improve information flow. Through an improved bottom-up approach, PANet enhanced the transmission of low-level features and used adaptive feature pooling to directly transfer valuable information to succeeding networks. This mechanism improved the precision of an object's location. The model was able to confirm whether there is a Military Target on the image quite correctly (Figure 5).

Figure 5. Ability of detecting military target using YOLOv5 enchanted with PANet.

5.ARTIFICIAL INTELLIGENCE APPLICATIONS BASED ON REMOTE SENSING TECHNIQUE IN THE FIELD OF DEFENSE AND SECURITY

Internet of of Things (IoT) applications in defense and security systems significantly enhance surveillance, military intelligence, border monitoring, and asset management. However, challenges such as data security, system interoperability, battery life, and big data management need to be addressed for effective implementation (Rahmah et al., 2023):

1. Advantages and benefits of IoT in defense and security systems
   - Early Threat Detection: IoT networks enable early detection of threats through border monitoring, area surveillance, and intrusion detection.
   - Accurate Threat Analysis: The data collected by IoT systems provide precise information about suspicious activities, facilitating more effective prevention and response measures.

- The integration of IoT in defense and security systems significantly enhances operational effectiveness, responsiveness, cost efficiency, and security. The real-time data provided by IoT networks empower decision-makers to act swiftly and accurately, ensuring improved oversight and protection against threats.

2. Challenges and issues of IoT in defense and security systems
   - Data security and privacy: The transmission of sensitive information across IoT networks exposes vulnerabilities to cyberattacks and hacking, mandating an unwavering focus on safeguarding data integrity.
   - Scalability and complexity of IoT networks: It demands meticulous management to mitigate operational disruptions and ensure optimal performance.
   - Critical reliance on network connectivity: It poses significant hurdles during emergencies or network outages.

Degadwala et al. (2021) developed an automated security system for defense operations capable of identifying, tracking, and eliminating targets. The system operates in two modes: automatic tracking using Arduino programming (sensors) and manual operation where an authority selects and potentially shoots the target. Python-based image processing methods are implemented via Anaconda Spyder. This system integrates image processing and automation to enhance security in defense operations. The included OpenCV was set up for detecting person movements after configuring the security stream. The development results indicate successful assembly of the hardware components and configuration of the Arduino to control stepper motors (Figure 6).

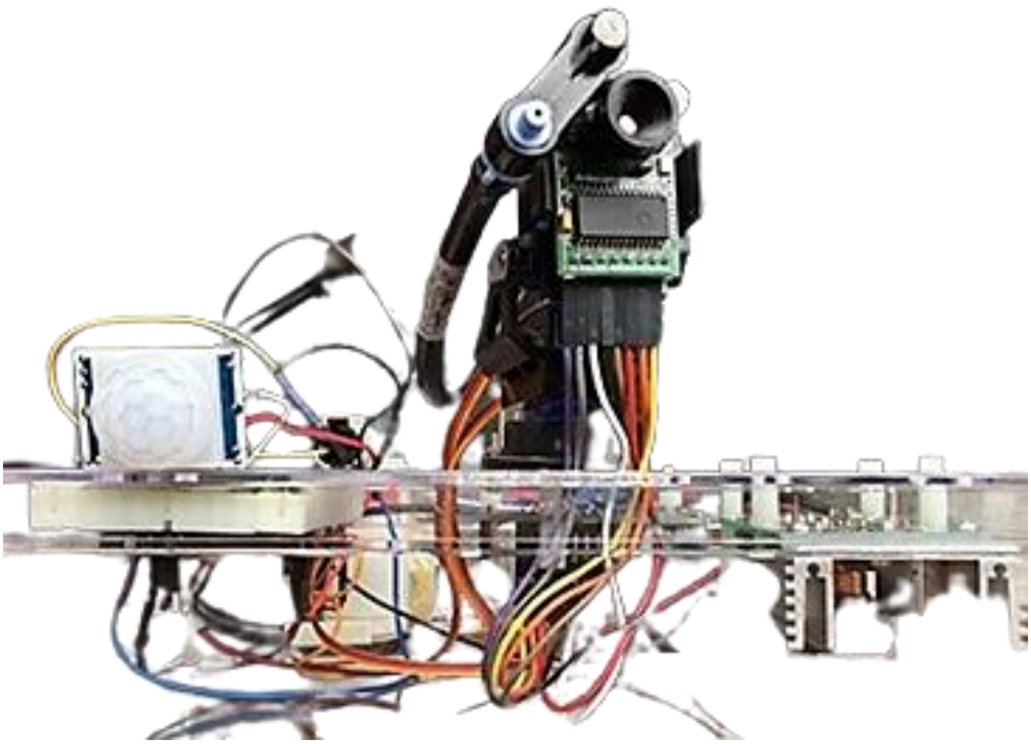

Figure 6. Hardware Module

Artificial Intelligence's rapid advancements in speech recognition, object identification, image analysis, and machine learning are enhancing defense systems and have broad applications across commercial, societal, and defense domains (Akilan et al., 2024). Globally, AI is revolutionizing defense systems, especially in cyberspace planning. Its ability to learn quickly and operate independently in diverse environments has garnered interest from military experts, international competitors, and political leaders. Hence, AI enhances the efficiency and autonomy of defense systems, particularly in automated weapons targeting and cybersecurity, reducing reliance on human intervention and increasing response speed and accuracy.

Viktor (2023) examined the difficulties and chances of the defensive use of artificial intelligence and computer vision-based technologies and applications in the defense sector. He found that these technologies can provide:

1. Detecting spoof attacks in human video frames, providing a practical tool for identifying fake video footage that can deceive smart digital systems.
2. Detection using deep learning-based methods for real-time detection of violent behavior, with the potential to enhance public safety and security.
3. Investigation of distributed ledger technology (DLT) for decentralized processing of large datasets and high computational tasks, offering insights to improve the scalability and efficiency of AI and deep learning algorithms in military contexts.
4. Advancement of violence detection techniques using deep learning architectures, particularly in the context of automated video surveillance applications, showcasing improved performance and robustness under challenging conditions such as compression artifacts.

Janakiramaiah et al. (2023) reported about the detection of military objects in defense using multi-level capsule. They found that military operations require automated systems to identify targets. A well-explored task in AI involving various classification techniques including Support Vector Machines (SVM) to classify objects, Early network (LeNet) for object detection with good performance, and smaller convolutional kernels (such as VGGNet) to enhance detection and reduce complexity. These techniques can be equipped with recent advances including:

a. LADAR Image Processing: Techniques like median filtering and segmentation were tested for vehicle detection.
b. Optimal Gabor Filtering: Combined with feature pyramid networks for detecting military objects, particularly small ones.
c. Visual Surveillance: Intelligent systems for tracking suspicious activities using adaptive methods.
d. Image Fused Object Detector (IFOD): Combines multiple image types using CNNs for military object detection.
e. Feature Clustering: Used for detecting and classifying objects by clustering surface features.
f. Deep Transfer Learning: Embedding knowledge from large datasets and retraining specific layers for military object detection.

Fontana et al. (2022) Focused on long-range threats exceeding 3000 km in range. They discussed the different categories of long-range threats, including ballistic missiles, cruise missiles, and hypersonic glide vehicles, pointing out the challenges they pose to defense systems and the importance of sensor technologies in addressing these threats and the need for independent research in this critical area. They emphasized that advancements in sensor technology and defense systems are crucial for enhancing the effectiveness of missile defense against intercontinental threats.

6.CONCLUSION

This paper investigates the concept, mechanism, and applications of artificial intelligence (AI) based on remote sensing and presents practical models of these applications in the field of defense and security studies as well as humanitarian sectors. Military AI applications are advancing quickly thanks to developments in image recognition, computer reasoning, and precision-guided munitions. Technological innovations that are becoming more widely available include robotic combat vehicles in all domains, autonomous weaponry, sophisticated decision support systems, big data processing for intelligence, surveillance, and reconnaissance and robotic vehicles. Military operators greatly value these advancements because they have the potential to greatly increase combat power, expedite the completion of missions, and lessen vulnerability to deadly attacks. By improving situational awareness and threat detection skills, artificial intelligence (AI) plays a critical role in defense and security, eventually striving to bolster national security. Even though AI has many potential advantages, it is important to weigh those advantages against the hazards. To properly reduce the hazards associated with AI, oversight and openness are essential. In general, artificial intelligence (AI) has the potential to increase military, defense and security performance in both peacetime and wartime situations by speeding up decision-making, increasing operational complexity, and improving cost competitiveness.

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