APPLICATION OF DRONES WITH ARTIFICIAL INTELLIGENCE FOR MILITARY PURPOSES

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2 authors:

Aleksandar Petrovski
University Goce Delcev" Stip Military academy, Skopje, North Macedonia

Marko Radovanović
Vojna akademija Beograd

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ALEKSANDAR PETROVSKI
University "Goce Delchev" - Shtip, Military academy "General Mihailo Apostolski", Skopje, aleksopetrovski@gmail.com

MARKO RADOVANOVIĆ
University of defence, Military academy, Belgrade, markoradovanovicgdb@yahoo.com

ANER BEHLIC
University "Goce Delchev" - Shtip, Military academy "General Mihailo Apostolski", Skopje, kadet.behlic.aner@gmail.com

Abstract: *One does not have to look far to see how Artificial Intelligence (AI) – the ability of machines to perform tasks that typically require human intelligence – is transforming the international security environment in which all involved security forces operates. Due to its cross-cutting nature, AI will pose a broad set of international security challenges, affecting both traditional military capabilities and the realm of hybrid threats, and will likewise provide new opportunities to respond to them. AI will have an impact on all of core tasks of every collective defense, crisis management, and cooperative security systems. With new opportunities, risks, and threats to prosperity and security at stake, the promise and peril associated with this foundational technology are too vast for any single actor to manage alone. As a result, cooperation is inherently needed to equally mitigate international security risks, as well as to capitalize on the technology's potential to transform enterprise functions, mission support, and operations.*

The aim of the paper is to present drones that learn on their own, i.e., that possess artificial intelligence, and which can be used for military purposes. The paper presents the possibility of autonomous use of drones with artificial intelligence in combat and non - combat operations of the army. Drones supported by GIS, C5IRS (command, control, computers, communications, cyber-defense (C5), intelligence, surveillance, and reconnaissance (ISR) and AI will give significantly advantage on the ground, because they can operate alone and will learn in line with the ground situation. With the fusion of human, information, and physical elements increasingly determining decisive advantage in the battlespace, interoperability becomes even more essential.

Keywords: *Drone, UAV, Artificial Intelligence, GIS, C5IRS, Security, YOLOv5.*

1. INTRODUCTION

Modern combat operations require the use of the most sophisticated combat means in order to efficiently perform the assigned tasks. The use of unmanned aerial vehicles is an indispensable segment of modern combat operations. Due to its versatile use and different capabilities, it provides a wide range of capabilities to units equipped with this type of combat equipment. By applying unmanned aerial vehicles integrated into the C5IRS system, it is possible to have a real-time image from the battlefield, which gives the decision maker the possibility of timely and efficient command of forces in the operation. Modern types of unmanned aerial vehicles are used in modern combat operations, from commercial to armed unmanned aerial vehicles. Both foreign and domestic authors have dealt with this topic. Milić et al. analyze the possibility of using drones in operations in urban environments.[1] Radovanovic et al. (2020) shows the possibility of using civilian drones in the protection and monitoring of the land security zone. [2] Adamski analyzes the effectiveness of UCAVs used in modern armed conflicts. [4] Jović analyzes the combat use of drones in a counter-terrorist operation. [5] Petrovski and Radovanović analyze the use of drones in cooperation with the C5IRS system for the needs of the army.[6] Ilić and Tomašević analyze the impact of the Nagorno-Krabah conflict on the perception of combat drones.[7] Radovanovic et al. analyzes the possibility of implementing drones in mortar units in order to increase the efficiency of fire support units by applying a fire management system in cooperation with the C4IRS system.[8] Bares performs interoperability modeling for the C4IRS system in a collective security system.[9] Petrovski et al. analyzes the application of GIS in cooperation with the C5IRS system in geography for the needs of the military.[10] Radovanovic et al. analyzes the selection of UAVs for the needs of military and police tactical units using the fuzzy AHP - VIKOR model of multicriteria decision making.[11] Žnidaršič et al. shows several types of drones and anti-drone means for implementation in the units of the Serbian Army.[12] Petrovski and Toshevski present the application of GIS in geo-reconnaissance and C5IRS for military purposes. [13]

2. DEFINITION AND CLASSIFICATION OF UNMANNED AIRCRAFT

So far, there is no generally accepted definition of unmanned aerial vehicles as well as their classification, so the European Association of Unmanned Vehicles Systems - EUROUVS has defined the classification of unmanned aerial vehicles in relation to purpose flight altitude, flight duration, speed, Maximum takeoff weight - MTOW, aircraft dimensions, signal range, etc. [14]

According to the model of control and management of unmanned aerial vehicles, they are divided into autonomous systems, self-control systems, radar or radio beam control systems, telecommand control systems and combined systems (autonomous, non-autonomous). In relation to flight altitude, take-off weight and maximum range, drones are divided into four categories. [14][15]

- Category 1 (weight up to 1 kg, flight altitude up to 50 m, AGL - Above Ground Level, range up to 150 m);
- Category 2 (mass greater than 1 kg to 5 kg, flight altitude up to 150 m AGL, range up to 500 m);
- Category 3 (mass greater than 5 kg to 20 kg, flight altitude up to 300 m AGL, range up to 2500 m);
- Category 4 (mass greater than 20 kg, flight altitude greater than 300 m AGL, range greater than 2500 m)

Petrovski and Radovanović defined the terms drone and UAV and their classification (figure 1). [6] The term UAV has a broad meaning, it means with a motor that is remotely controlled by the operator or it is a means that has a certain level of autonomy (control is done using communication software, and often uses artificial intelligence and different types of sensors), which they can be used once or repeatedly and can carry deadly or non-lethal cargo, transmit data in real time, using as a WiFi station and ect. It is a synthesis of the means and devices necessary to manage it. They differ in purpose, construction characteristics (shape, dimensions, weight, payload, maximum flight altitude, maximum range, flight time, speed, etc.) of the environment in which they are used, the energy source with which they are driven. Depending on the purpose, they can be used in different environments such as land, water, air and space, and a wide range of possibilities has created a condition for application in defense and security (for the needs of the army and police - original purpose). agriculture, construction, traffic, trade, communication, science, medicine, research, architecture, video and photography, geology, forestry, mining, oceanography, environmental management, sports, mapping, etc. The term drone is more general than the term unmanned aerial vehicle, because all unmanned aerial vehicles can be called drones, while a drone does not necessarily have to be an unmanned aerial vehicle. [6]

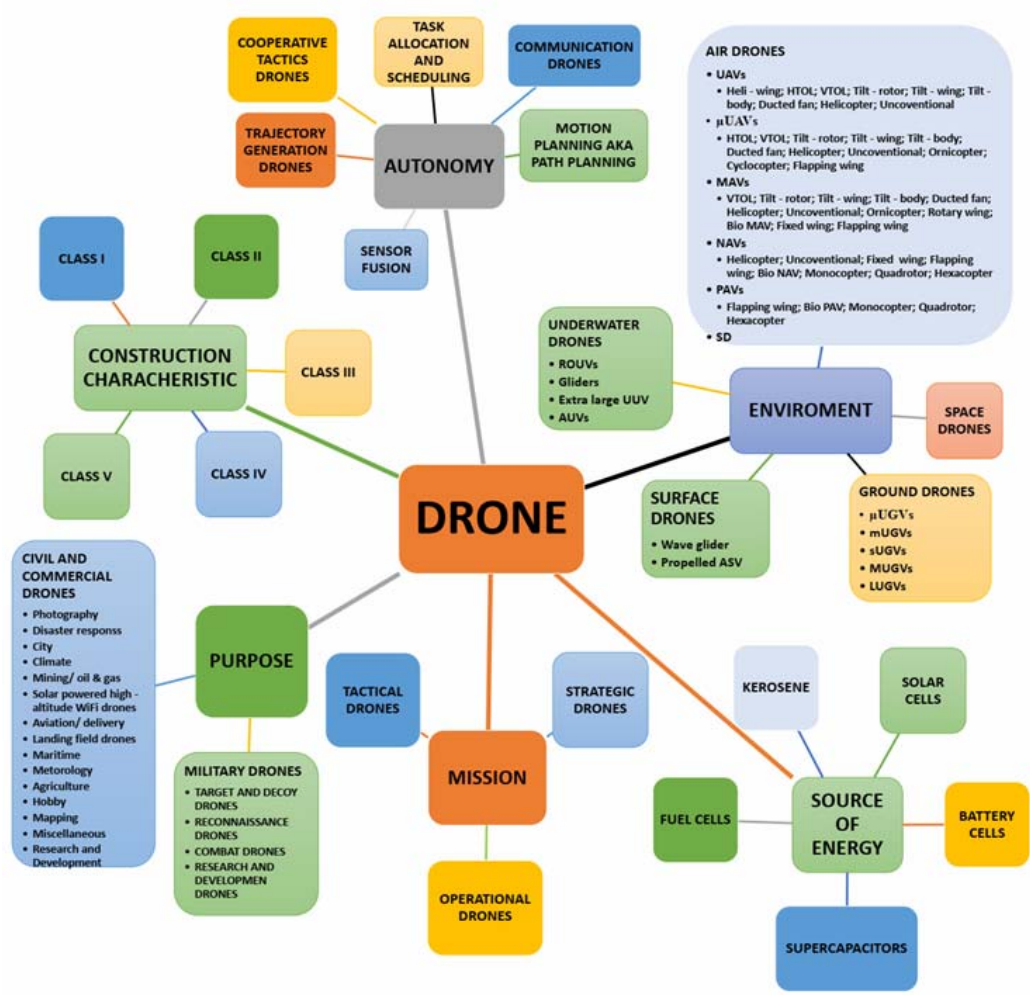

Figure 1: Classification of drones

Based on the classification of unmanned aerial vehicles, it is concluded that the characteristics of unmanned aerial vehicles usually depend on their purpose. It is necessary to analyze the tactical and technical characteristics of unmanned aerial vehicles in order to consider their possibility of use in modern combat operations.

Military use of unmanned aerial vehicles can be classified into three groups: naval, land and air use, while for civilian purposes it can be used in various areas of human activity, such as. in geodesy (photogrammetry), agriculture, industrial production, civil protection, disaster management, critical infrastructure surveillance, environmental protection, police surveillance, protection and rescue of people, intelligence and security services, journalism, commercial activities and leisure.

3. APPLICATION OF DRONES WITH ARTIFICIAL INTELLIGENCE FOR MILITARY PURPOSES

Drones have improved military capabilities around the world in many ways. It will also continue to change military warfare through the following: The Use of Military Drones: The Impact on Land Forces and Legal Implications Command and Control –Drones can relay crucial information on enemy movements, locations, and positions of strategic targets. This information allows commanders to be more efficient and make better decisions when in the field.

Drone technology itself is a relatively new area of military technology, but military engineers took to combining drones with artificial intelligence rather quickly to create a product that in some cases might be comparable to the performance of human reconnaissance teams. Shield.AI, AeroVironment, and Lockheed Martin all showcase how military defense contractors are combining current computer vision technology and image recognition with drones to solve military problems without the need of endangering human life. Shield AI’s drone can purportedly navigate unknown lands without the need for GPS tracking. Such a UAV could give military troops the capability to collect data that could allow them to move faster and check if they are being pursued during tactical reconnaissance, tracking, combat assessment, and cartographic missions. Drones could allow operators to make decisions without being concerned that they might be ambushed from the rear, for example.

Implementing artificial intelligence for drones is a combination of mechanical devices, navigational instruments, and machine vision. The AI behind the drone needs to be trained using a supervised learning process. I think that this will be much harder to achieve than you can imagine as combat drone technology is in my opinion capable of being the most lethal and effective tools ever created for intermediate & close combat scenarios.

The Army’s office for countering small drones sees artificial intelligence and machine learning as key technologies for defeating enemy systems, service officials said Oct. 15. And drone swarms could be used for simultaneous, multi-directional attacks in ways that could overwhelm human defenders. The aerospace and defence industry initially made drones for counterinsurgency and defence, which have proven helpful in these environments. Today, many Military Warfare industries develop drone technology integrated into more military programs worldwide. They provide many benefits and advantages that make them extremely useful for different roles. Military drones have come to revolutionize warfare. They are roving on land, streaking through the skies, and diving under the seas. Since their creation, more than fifty years ago, drones have constantly evolved to the present, becoming one of the main artificial intelligences (AI) weapons, integrated into military forces throughout the world. As a result, more military forces are looking to use drones to increase their combat and surveillance capacity.

Military advantages are in autonomous weapons systems act as a force multiplier. That is, fewer warfighters are needed for a given mission, and the efficacy of each warfighter is greater. Next, advocates credit autonomous weapons systems with expanding the battlefield, allowing combat to reach into areas that were previously inaccessible. Finally, autonomous weapons systems can reduce casualties by removing human warfighters from dangerous missions.

4. YOLOV5 METHOD FOR ENCHANCED MILITARY DRONE SURVEILLANCE WITH AI SOFTWARE CAPABILITIES

This article covers real-world model incorporate in either drones or the AI software behind them: In this article, we’ll look at several military drones and UAVs with AI capabilities. There are a variety of use cases for AI when it comes to drone technology. The military seems to commonly apply AI for allowing its drones to fly on their own, which requires machine vision.

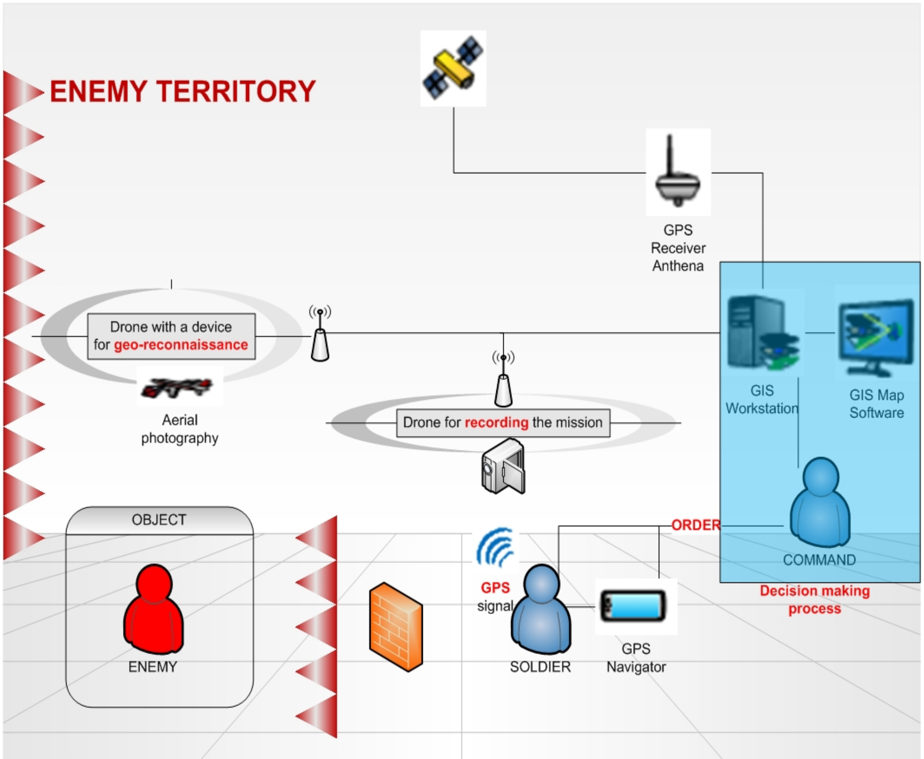

Figure 2: Model of Geo-reconnaissance and commanding (GRC) information system in UAV supported with C4IRS systems and AI (Petrovski A. and Mihajlo T. defined this model - figure 2)

4.1. YOLOv5 Method for enhanced military drone surveillance

The proposed framework aims to detect objects of critical military importance based on the images received from the video stream of military surveillance drones. The actions will be taken depending on the obtained result. Figure 3 summarizes the suggested methodology of this paper.

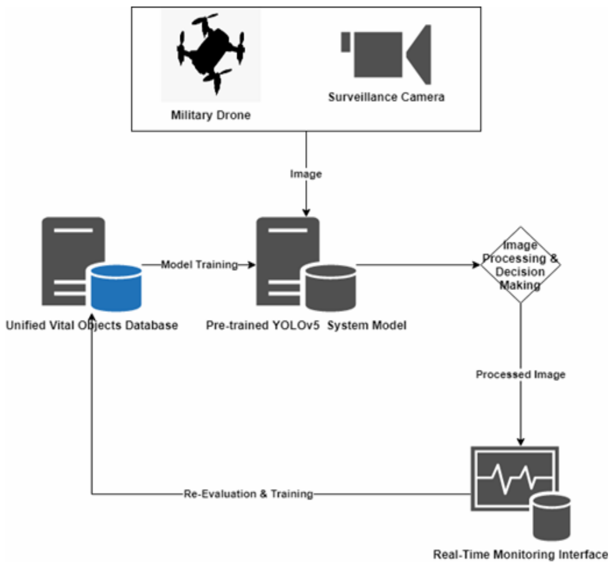

Figure 3: Overview of the Methodology

Firstly, a unified Vital Objects Database is created by using verified images of objects that are critical for military surveillance such as weapons, bunkers, military buildings, vehicles, tanks, and artillery pieces, collected from various internet and local sources. Furthermore, upon that dataset a YOLOv5 model is trained and evaluated. A Surveillance Camera is set up on a military surveillance drone, which is connected to the System Model. The camera forwards real-time video through the system model which processes the data in real time. Moreover, the processed image is projected on the Real-Time Monitoring Interface which shows the result of image processing, including alarms for detection of vital military objects. False positives and vital military objects which weren't detected by the system but self-identified by the human operator, are captured and further forwarded to the unified Vital Objects Database, where they are re-evaluated and used for further training of the system.

This paper proposes a real-time vital Military Objects detection system based on Convolution Neural Network using the YOLOv5 (You Only Look Once) framework. The main contributions of this approach include:

1) The proposed system can be implemented easily on already existing surveillance drones
2) It detects vital military objects with high accuracy from large distances.
3) The software used for development is free and open source.
4) A unified large dataset for vital military objects including weapons, vehicles, tanks, buildings, bunkers and artillery pieces, with various scenarios and conditions.
5) It aids military commanders and personnel in decision making, tracking, and identification of vital military objects.

4.2. YOLOv5 Approach for Vital Military Objects Detection

YOLO is based on Convolution Neural Network (CNN) and represents a very fast end-to-end object detection algorithm. [16] Continuous improvements have made it achieve top performances on two official object detection datasets: Pascal VOC (visual object classes) [17] and Microsoft COCO (common objects in context). [18]

The network architecture of Yolov5 is shown in Figure 4. There are three reasons why Yolov5 is chosen as the main method for training the system model. Firstly, Yolov5 incorporated cross stage partial network (CSPNet) [18] [19]into Darknet, creating CSPDarknet as its backbone. CSPNet solves the problems of repeated gradient information in large-scale backbones, and integrates the gradient changes into the feature map, thereby decreasing the parameters and FLOPS (floating-point operations per second) of model, which not only ensures the inference speed and accuracy, but also reduces the model size. In military surveillance task, detection speed and accuracy are imperative, and compact model size also determines its inference efficiency on resource-poor edge devices. Secondly, the Yolov5 applied path aggregation network (PANet) [19] as its neck to boost information flow. PANet adopts a new feature pyramid network (FPN) structure with enhanced bottom-up path, which improves the propagation of low-level features. At the same time, adaptive feature pooling, which links feature grid and all feature levels, is used to make useful information in each feature level propagate directly to following subnetwork. PANet improves the utilization of accurate localization signals in lower layers, which can obviously enhance the location accuracy of the object. Thirdly, the head of Yolov5, namely the Yolo layer, generates 3 different sizes (18 × 18, 36 × 36, 72 × 72) of feature maps to achieve multi-scale prediction [20], enabling the model to handle small, medium, and big objects.

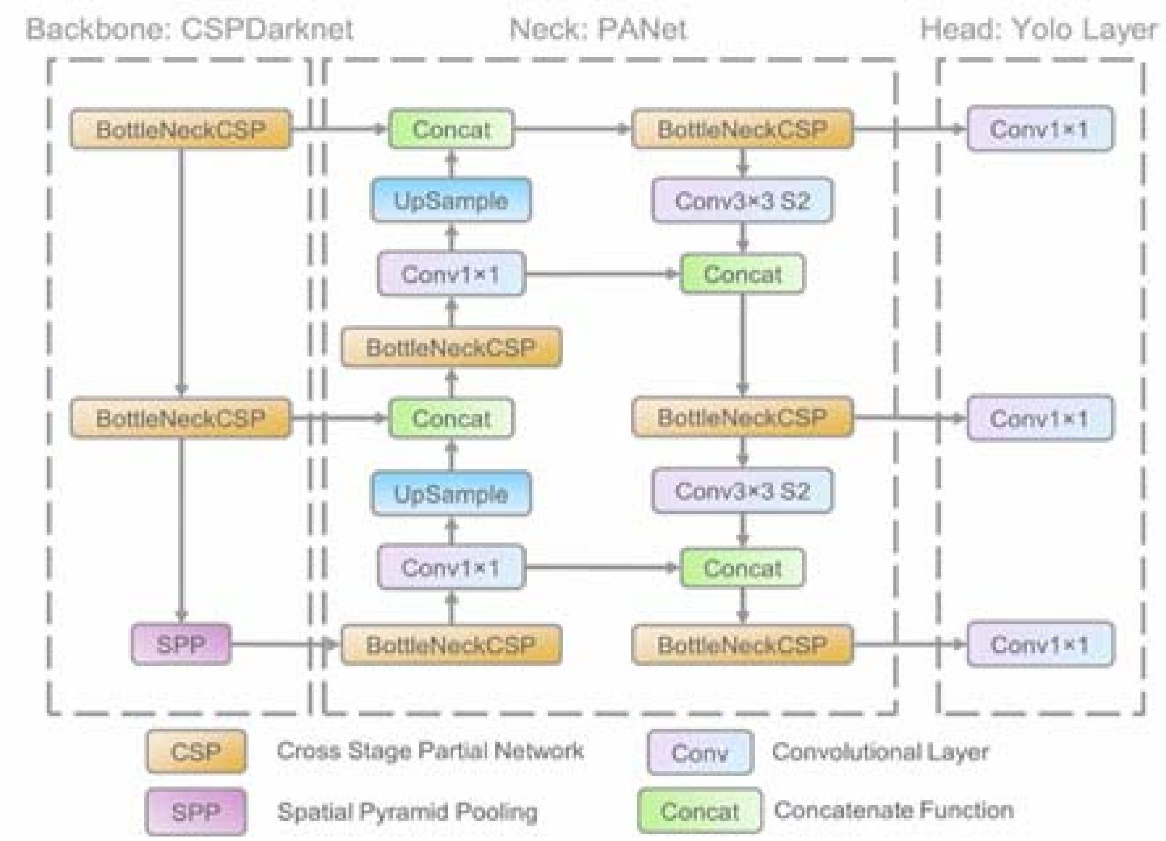

Figure 4: The network architecture of Yolov5. It consists of three parts: (1) Backbone: CSPDarknet, (2) Neck: PANet, and (3) Head: Yolo Layer. The data are first input to CSPDarknet for feature extraction, and then fed to PANet for feature fusion. Finally, Yolo Layer outputs detection results (class, score, location, size) [22]

In the YOLO method, the input images are only seen once through the neural network, and it predicts the detected object in the image. It works by dividing the input image into different grids based on predefined grid size and then predicts the probability of the desired object in each grid. It predicts all the classes and the object bounding that are in the image in one run of the Algorithm.[23]

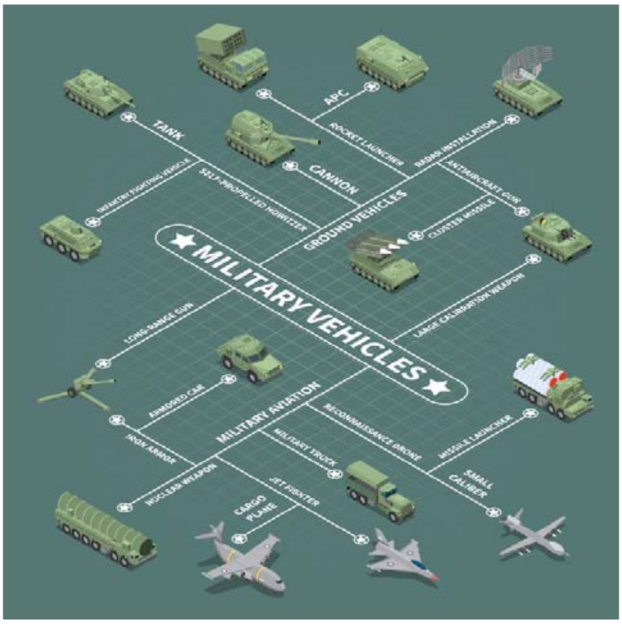

Figure 5: Overview of military vehicles that can be recognize with drone pre-input images in data bases.

The proposed YOLOv5 based (pre-trained) solution is extremely lightweight and fast to recognize the critical objects of military importance. Good accuracy and the fps are two important things to consider when working on real-time surveillance and data gathering.

4.3. Model Training Process & Dataset

To train, validate and evaluate the model a customized dataset was built. The finalized dataset contains around 10000 images of military trucks, tanks, that were collected from publicly available datasets, Google images, and local sources as presented in Table 1.

Table 1. Distribution of images in the dataset

Dataset type	Size & Type	Source
Military Trucks, Tanks, APC	6772 images	Military Vehicles – Mendeley Data[23]
Military Tanks	1078 images	Military Tanks – Kaggle[23]
Military Artillery, Tanks, MRL Systems, Trucks	1000 images	Moving and Stationary Target Acquisition and Recognition (MSTAR) Dataset[23]
Stationary Military Equipment, Artillery, Command posts & fire stations	2000 images & 20 videos	Local Sources

The images cover a verity of scenarios Military Targets in various scenarios and terrain including day and night time, forests, desert, and urban, as seen in Figure 6. However, even then the dataset is severally limited, therefore, we included several videos with different Military Targets in different conditions such as size, shape and color. In order to successfully adopt and train the dataset in YOLOv5 the dataset itself was assigned labels and the annotating bounding boxes. The value of the annotating box coordinate in each image is then normalized between 0-1. This process was carried out using Roboflow [23], which makes it possible to annotate and make data labels in the desired format. Furthermore, the dataset is carefully split into 3 different categories for training, validation and testing. Additionally, by carefully assigning the images to each category, we avoided a biased model by using data with a similar number of images for each class which forms a balanced dataset.

First and foremost, in the model training process we fine-tune the YOLOv5m model which is already pre-trained on the COCO data set. Furthermore, Transfer learning was used to train on the unified dataset. Moreover, various augmentation processes such as HSV, color spacing, mosaic, image scaling were applied. The hyperparameters that are fine-tuned are used here, such as SGD optimizer, 0.01 learning rate, 0.0005 weight decay and then finally 600 epochs on batch size 32.

The model was built using Google Collaboratory resources to process the dataset.

Figure 6: Training Process on the Unified Dataset, annotating Military Targets by class (Tanks, APC's, Artillery, MRL Systems)

5. RESULTS AND DISCUSSION

To evaluate the performance of the proposed system, the trained model was tested in different environments including forests, mountains, open fields, etc. The results are performed with a confidence threshold of 0.4, Initially, when performed on the handpicked test data from the unified dataset, we achieved on average 0.922 map@0.5. Furthermore, From the displayed confusion matrix in Figure 7 it can be seen that the models can label maximum of the data quite correctly Also from Figure 9 it can be seen that the model can confirm whether there is a Military Target on the image quite correctly.

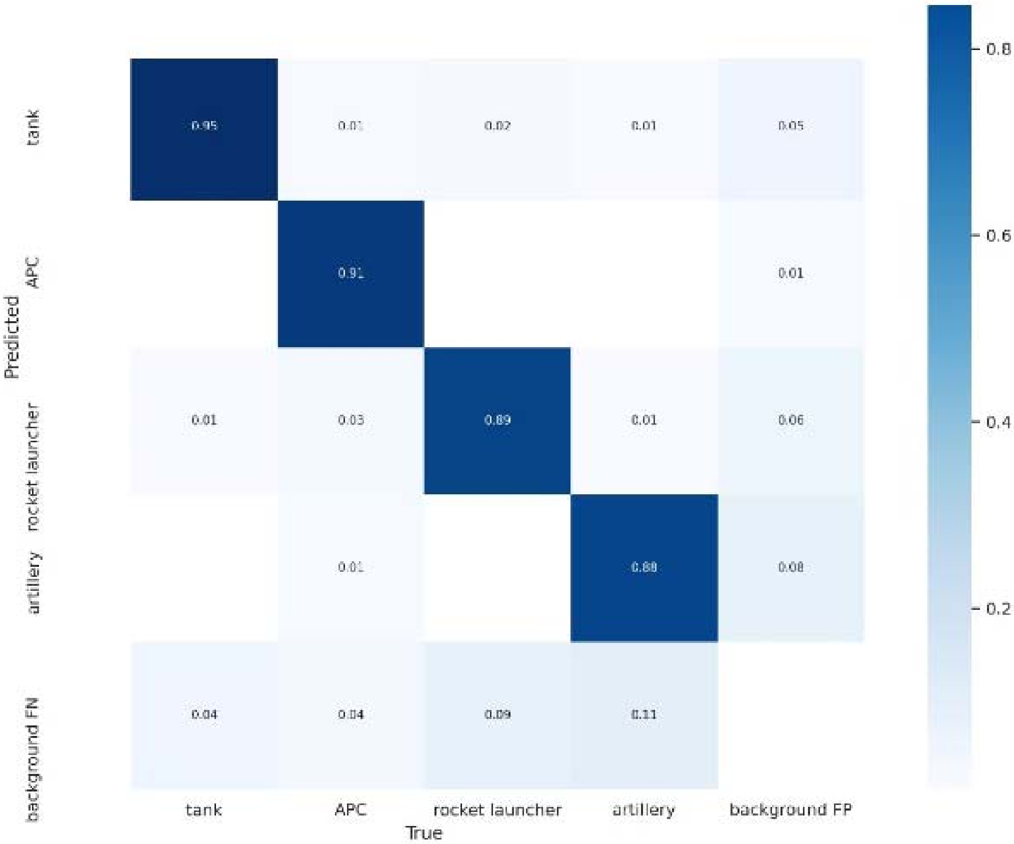

Figure 7: Confusion Matrix of the model

This obtained value and prediction results shown on performance graphs in Figure 8 prove that there is a pretty good potential to use the YOLOv5 algorithm to detect Military Targets in real-time during drone surveillence. The confidence value of the Military Targets the model recognizes is quite high also. Moreover, we can see the performance of the suggested model applied to validation data through performance graphs in Figure 8.

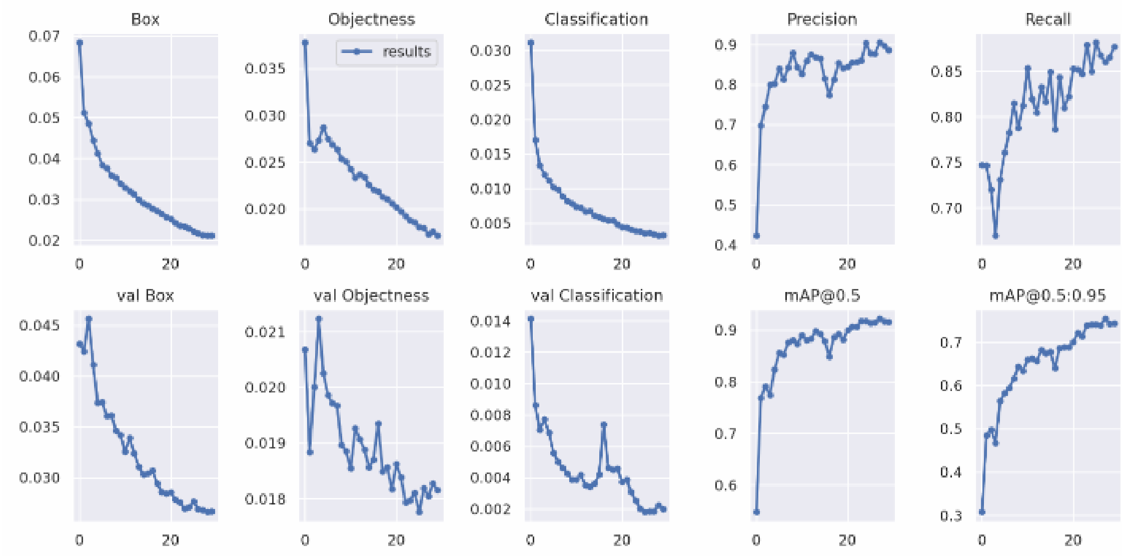

Figure 8: Result Graphs obtained from model training and validation

The model is lightweight and fast enough to deploy. It can be incorporated with in-built capturing tools, in this case, Surveillance Cameras mounted on drones, and predict recognition in almost real time with minimum delays.

Figure 9a: Examples of predicted output's

Figure 9b: Examples of predicted output's

6. CONCLUSION

The use of unmanned aerial vehicles equipped with AI and modern technical devices (high resolution cameras, infrared and thermal cameras, microphones, various types of sensors, guided and non-guided missiles and other accessories) integrated into the C5IRS system significantly increases the efficiency of units engaged in combat operations. The use of this sophisticated technology enables timely and accurate information about the event in real time, as well as the destruction of the target without risk to humanity, while transmitting the situation to the battlefield command center. Unmanned aerial vehicles can still be used to deliver medical supplies and other necessary combat and non-combat equipment to units in the area of operation.

The use of unmanned aerial vehicles in combat operations, regardless of limitations, increases the efficiency and effectiveness of the units engaged in the operation, and also increases the protection and reduces the risk to the engaged personnel. Based on the tactical and technical characteristics of unmanned aerial vehicles, it is possible to realize various tasks.

Today’s environment also requires the collective capabilities and efforts of multiple organizations. Unfortunately, traditional C4ISR systems weren’t built with interoperability in mind—in the past, they were designed to meet mission-specific requirements and to solve a particular set of problems facing an organization.

However, it is difficult to say that the proposed model does not have any shortcomings. The model may cause errors and consider, non-military vehicle, and other military like objects, as real targets. These issues mainly increase as the distance of the target increases, which the camera then captures in an unclear image, which confuses the model. However, longer training times, more concrete and larger datasets would highly likely yield a good result in this process and eliminate most of the false positives.

Further research should be focused on the integration of the modern C6ISR system (combat command) to the combat systems of the army and the advantages that the mentioned system provides to units during the execution of a modern combat operation in a different environment.

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