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TARGET IDENTIFICATION AND TRACKING IN COMPLEX ENVIRONMENT

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This study focuses on developing advanced methods for the identification and classification of objects in complex environments. Over the past two years, there has been an increase in the use of advanced technologies in various challenging scenarios. This research is centered on accurately identifying targets and tracking them. The study addresses challenges related to object detection in multi-dimensional and intricate settings, taking into account natural conditions like rain and fog, as well as technical limitations such as camera capabilities. Special emphasis is placed on data collection for training the identification model, followed by extensive data preprocessing, including cleaning, labeling, and augmentation. The research employs YOLO and Deep Sort machine learning algorithms, focusing on improving the accuracy and reliability of target recognition and increasing data processing speed to minimize misidentification risks. The integration of YOLO, known for its quick real-time object detection, with Deep Sort, which excels in detailed feature extraction and classification, forms the basis of our methodology. This fusion is a complex combination of both models' strengths, with YOLO quickly identifying relevant objects and Deep Sort performing an in-depth analysis. The experimental phase involves extensive testing of the models in varied weather conditions and settings to evaluate performance under challenging circumstances. This work aims to enhance object identification techniques in complex environments, a critical aspect for the effectiveness of various advanced operations. The findings are expected to significantly contribute to the field by enabling quicker and more accurate target identification.

Keywords: target identification, tracking, object detection, drone reconnaissance.

КҮРДЕЛІ ОРТАДА НЫСАНАНЫ АНЫҚТАУ ЖӘНЕ БАҚЫЛАУ

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Бұл зерттеу күрделі ортадағы объектілерді анықтау мен жіктеудің озық әдістерін жасауға бағытталған. Соңғы екі жылда әртүрлі күрделі сценарийлерде озық технологияларды қолданысы артып жатыр. Бұл зерттеу нысаналарды дәл анықтауға және оларды бақылауға бағытталған. Зерттеу жаңбыр мен тұман сияқты табиғи жағдайларды, сондай-ақ камера мүмкіндіктері шектеулері сияқты техникалық ерекшеліктерді ескере отырып, көп өлшемді және күрделі жағдайларда объектілерді анықтауға қатысты мәселелерді шешеді. Объекті анықтау моделін дайындау үшін деректерді жинауға ерекше көңіл бөлінеді, содан кейін деректерді алдын-ала өңдеу, соның ішінде тазарту, таңбалау және үлкейту жұмыстары жүргізіледі. Зерттеу нысананы танудың дәлдігі мен сенімділігін арттыруға және қате сәйкестендіру қаупін азайту үшін деректерді өңдеу жылдамдығын арттыруға бағытталған, YOLO және Deep Sort машиналық оқыту алгоритмдерін пайдаланады. Нақты уақыт режимінде объектілерді жылдам анықтаумен танымал YOLO-ны Deep Sort-пен интеграциялау, оның ерекшеліктерін егжей-тегжейлі анықтау және бақылау бойынша біздің әдістемеміздің негізі болып табылады. Бұл синтез екі модельдің де күшті жақтарының күрделі үйлесімі болып табылады. YOLO тиісті нысандарды жылдам анықтайды, Ал Deep Sort терең бақылау жасайды. Эксперименттік кезеңде күрделі жағдайларда өнімділікті бағалау үшін әртүрлі ауа-райы жағдайлары мен параметрлерінде модельдерді мұқият сынауды қамтиды. Бұл жұмыс күрделі ортада объектілерді анықтау әдістерін жетілдіруге бағытталған, бұл әр түрлі жетілдірілген операциялардың тиімділігінің маңызды аспектісі болып табылады. Нәтижелер мақсатты тезірек және дәлірек анықтауға мүмкіндік бере отырып, осы саланың дамуына айтарлықтай үлес қосады деп күтілуде.

Түйін сөздер: мақсатты сәйкестендіру, бақылау, объектілерді анықтау, дрондармен барлау.

ИДЕНТИФИКАЦИЯ И ОТСЛЕЖИВАНИЕ ЦЕЛЕЙ В СЛОЖНЫХ УСЛОВИЯХ

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Это исследование направлено на разработку передовых методов идентификации и классификации объектов в сложных условиях. За последние два года наблюдается рост использования передовых технологий в различных сложных средах. Это исследование сосредоточено на точном выявлении целей и их отслеживании. В исследовании рассматриваются проблемы, связанные с обнаружением объектов в многомерных и сложных условиях, с учетом природных условий, таких как дождь и туман, а также технических ограничений, таких как возможности камеры. Особое внимание уделяется сбору данных для обучения модели идентификации, за которым следует тщательная предварительная обработка данных, включая очистку, маркировку и дополнение. В исследовании используются алгоритмы машинного обучения YOLO и Deep Sort, направленные на повышение точности и надежности распознавания целей и увеличение скорости обработки данных для минимизации рисков ошибочной идентификации. Основой нашей методологии является интеграция YOLO, известной своим быстрым обнаружением объектов в режиме реального времени, с Deep Sort, которая отличается детальным выделением признаков и классификацией. Это слияние представляет собой сложную комбинацию сильных сторон обеих моделей: YOLO быстро определяет нужные объекты, а Deep Sort проводит углубленный анализ. Экспериментальная фаза включает в себя всестороннее тестирование моделей в различных погодных условиях и настройках для оценки производительности в сложных условиях. Эта работа направлена на совершенствование методов идентификации объектов в сложных условиях, что является критически важным аспектом для эффективности различных сложных операций. Ожидается, что полученные результаты внесут значительный вклад в работу на местах, поскольку позволят быстрее и точнее определять цели.

Ключевые слова: идентификация цели, отслеживание, обнаружение объектов, разведка

Introduction. The evolution of warfare and military strategy has been profoundly shaped by technological advancements throughout history. From the invention of gunpowder to the development of nuclear weapons, each major technological leap has brought about a radical shift in the nature of conflicts and how they are fought. In this context, the rise of drones represents one of the most significant technological developments in modern military strategy. Over the past two decades, drones, also known as unmanned aerial vehicles machine, have transitioned from being mere surveillance tools to becoming pivotal assets in military operations. This transformation is a reflection of the broader changes in military tactics and technology that define contemporary conflicts. Our work delves into the critical role that drones have come to play in modern military strategies, emphasizing their importance in a rapidly evolving battlefield. This study is dedicated to advancing the methods for identifying and classifying objects in various environments, an essential aspect of military operations in this era of technological warfare. The recent surge in drone usage over the past two years highlights a paradigm shift in how conflicts are approached and managed. Drones have revolutionized several facets of military operations, including reconnaissance, targeting, and ensuring the safety of personnel [1]. Their effectiveness in these areas has made their strategic application a necessity rather than a choice. In the age of asymmetric warfare and counterterrorism operations, drones offer a unique advantage in terms of intelligence gathering and precision strikes. They enable militaries to engage in operations with a reduced footprint, lowering the risk to personnel and potentially minimizing collateral damage. This advantage is particularly significant in complex urban environments or rugged terrains, where traditional forms of surveillance and engagement are often challenging. The significance of target identification and tracking in reconnaissance in various environment.

cannot be overstated, especially in the context of modern warfare, where precision and accuracy are paramount. This aspect of military operations has gained even greater importance with the advent of drones. In contemporary combat scenarios, the ability to accurately identify and track targets is crucial for several reasons. It enhances operational efficiency by enabling precise and timely decision-making [2]. Armed with accurate information on the location and nature of a target, military strategists can devise more effective tactics, allocate resources more judiciously, and achieve objectives with greater precision. This is particularly vital in asymmetric warfare and counterterrorism operations, where identifying the correct targets while avoiding civilian casualties is both a moral imperative and a strategic necessity. Advanced target identification and tracking systems integrated into drone technology greatly improve situational awareness. Drones equipped with cutting-edge sensors and cameras can relay real-time information, providing commanders with a comprehensive view of the battlefield. This capability is invaluable in complex environments, where visibility is limited, and threats can emerge from any direction. By maintaining constant surveillance and tracking movements, drones contribute to a more informed and responsive command structure.

a) b)

Figure 1- Drone in battlefield. a) Drone take off for reconnaissance b) Information received during reconnaissance

Literature Review. The realm of military operations has significantly advanced with the integration of various technological methods for target identification and tracking. One of the methods related with hyperspectral imagery.

Key among these are approaches utilizing hyperspectral imagery, advanced neural networks, and high-resolution imaging techniques. A notable advancement is the use of Hyperspectral Imagery for the detection of military vehicles. This technology offers detailed spectral characteristics of targets, which, when processed through techniques like Principal Component Analysis and k-means clustering, results in the generation of superpixels. These superpixels enhance the ability to identify specific military objectives, providing a significant edge in vehicle detection [3]. Object detection faces unique challenges, including dealing with camouflage, blur, inter-class similarity, intra-class variance, and complex environmental conditions. Addressing these issues, the MOD benchmark proposes the use of LGA-RCNN. This model employs loss-guided attention to improve detection performance in these challenging scenarios [4]. Another innovative approach involves the deployment of Convolutional Neural Networks on embedded platforms like the TMS320C6678. This method showcases a fine balance between performance and resource constraints, contributing significantly to the accuracy and efficiency of military operations [5]. Alternative method of object tracking it's use YOLO5 architecture marks a leap in identifying and detecting small, camouflaged military objects. This model greatly improves the clarity and detail of images, thus aiding in more accurate object detection, a critical factor in modern military operations [6]. After thorough analysis of available literature, we have opted to employ the YOLO and Deepsort algorithms for our tracking and target identification endeavor. These algorithms demonstrate promising capabilities in accurately detecting and tracking objects in real-time scenarios. With their robust features and proven performance, we believe they are well-suited for fulfilling the requirements of our task efficiently and effectively.

Main Provision. The primary goal of this research is to develop a highly efficient, accurate, and robust system for target identification and tracking in complex environments, leveraging the integration of YOLO and Deep Sort. This study is anchored in the hypothesis that the combination of YOLO rapid detection capabilities with Deep Sort detailed feature analysis will significantly enhance object recognition accuracy and operational efficiency, particularly in challenging conditions.

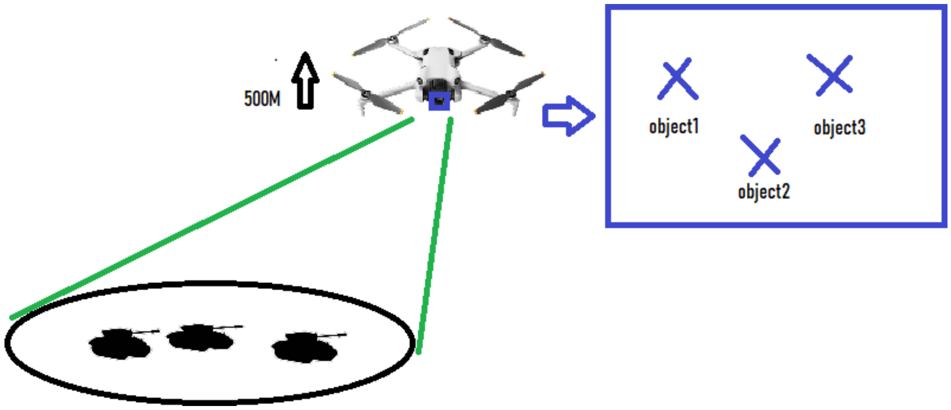

Figure 2- Schematic diagram of drone operation

The drone is shown flying at an altitude of 500 meters above the ground. The drone is equipped with a sensor or camera (indicated by the blue square on the drone), which is used to observe objects on the ground. The green lines from the drone to the ground suggest that the drone's sensors are focused on a specific area on the ground. This could be the drone's camera field of view. On the ground, there are three black shapes that appear to be the objects of interest—perhaps these are the targets the drone is meant to observe or monitor. The arrow pointing from the drone to the right implies that the drone is transmitting data. The box on the right side of the image shows the process of identifying and classifying the objects observed by the drone. This could be a visual representation of the data on a screen for an operator, or it could represent the process of the onboard computer classifying the objects in real-time. The objects are labeled as ”object1”, ”object2”, and ”object3” [7].

Figure 3 - Data annotation process

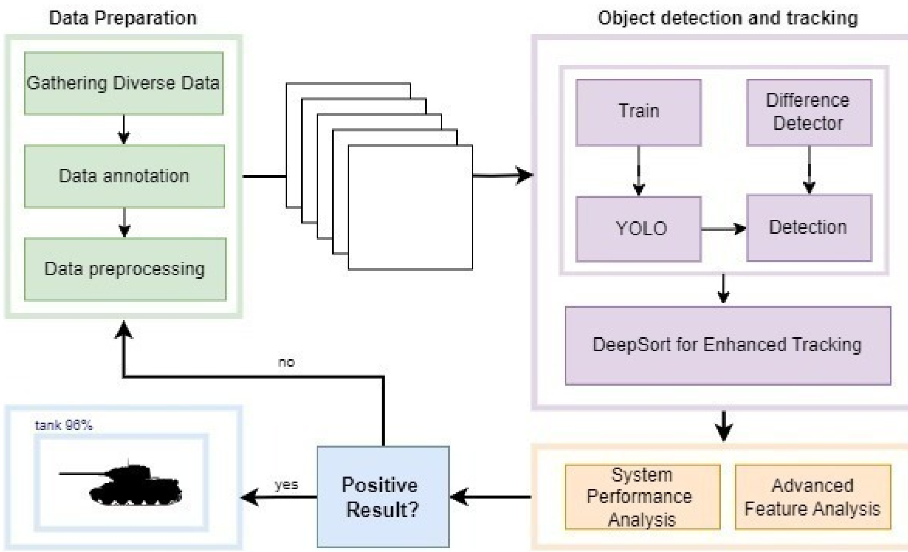

Figure 4 - Flowchart of Machine Learning Process for Object Detection and Tracking

Methods and Materials. This section delves into the technical details of how data annotated, how these algorithms are employed and fused to achieve superior target recognition accuracy and reliability in challenging battlefield scenarios. Our approach centered around the sophisticated integration of two powerful machine learning algorithms: YOLO and Deep Sort.

In the data collection and preprocessing phase, the process extends beyond simple acquisition of datasets. We focus on amassing data that represent a broad spectrum of conditions: differing light settings, varying weather conditions like rain, fog, and extreme brightness, and a multitude of angles and distances. This variety ensures that the model is not only exposed to a wide range of scenarios [8] but is also robust enough to handle real-world complexities. Once the data is collected, the preprocessing phase begins. It is critical to ensure the data's integrity and relevance. Cleaning involves removing any irrelevant or misleading information, which could skew the model's learning process [9]. We employ sophisticated techniques to filter out noise and irrelevant data, ensuring that only pertinent and high-quality data feeds into the training process. Labeling, a crucial step, involves annotating the datasets with accurate and detailed tags. This process is meticulously carried out by experts who identify and mark objects within each image or video frame, ensuring that the model learns from accurate information. This step is particularly challenging in complex environments, where objects might be partially obscured or camouflaged.

YOLO is a state-of-the-art, real-time object detection system that differs significantly from traditional methods. Traditional object detection systems repurpose classifiers to perform detection. They apply the classifier to various locations and scales in an image [10]. YOLO, however, applies a single neural network to the full image [11]. This network divides the image into regions and predicts bounding boxes and probabilities for each region. These bounding boxes are weighted by the predicted probabilities [12].

Deep Sort is employed for its superior capabilities in detailed feature extraction and classification. This algorithm takes the initially identified objects from YOLO and performs a comprehensive analysis to classify them accurately. Deep Sort utilizes a convolutional neural network to extract high-level features from the input images [13]. These features are then passed through advanced classification layers designed to identify subtle and complex features specific to the target objects. To enhance the model's ability to generalize, data augmentation techniques are employed. This includes rotating, scaling, and flipping images to simulate various viewing conditions. Deep Sort is trained on a vast dataset of labeled images, which include various objects in different environmental conditions, ensuring comprehensive learning [14].

```
Algorithm YOLO_Object_Detection
Input: Input_Image, YOLO_Model, Thresholds (Confidence_Threshold, NMS_Threshold)
Output: List of Detected_Objects
Begin
  // Preprocess the image
  Processed_Image = Resize_and_Normalize(Input_Image)
  // Forward pass through the YOLO model
  Predictions = YOLO_Model.Forward_Pass(Processed_Image)
  // Post-processing the predictions
  Final_Detections = []
  For each cell in the SxS grid of Predictions:
    For each bounding box prediction in this cell:
      confidence = Predictions[cell][box].confidence
      // Filter out low confidence detections
      if confidence < Confidence_Threshold:
        continue
      class_probabilities = Predictions[cell][box].class_probabilities
      box_coordinates = Calculate_Box_Coordinates(Predictions[cell][box])
      // Compute class-specific confidence scores
      for each class_probability in class_probabilities:
        class_confidence = confidence * class_probability
        if class_confidence > Confidence_Threshold:
          detection = {box_coordinates, class_confidence, class_id}
          Final_Detections.append(detection)
  // Apply Non-Max Suppression to filter overlapping boxes
  Filtered_Detections = Non_Max_Suppression(Final_Detections, NMS_Threshold)
  Return Filtered_Detections
End
```

The integration of YOLO and Deep Sort is the linchpin of our methodology. The process is not just about running one algorithm after the other but about creating a seamless, efficient pipeline where the output of one feeds into the input of the other, optimizing both speed and accuracy. YOLO rapidly processes the input image to identify potential targets and their locations. The identified regions by YOLO, along with their bounding box coordinates, are passed to Deep Sort. Sort conducts an in-depth analysis of these targeted regions, using its advanced feature extraction and classification mechanisms. The final output is a synthesis of both algorithms, where YOLO provides the speed and initial detection, and Deep Sort offers the depth of analysis and accuracy in classification [15].

Results and Discussion. The integrated YOLO-Deep Sort model demonstrated exceptional performance in target identification and tracking. The YOLO algorithm, with its swift real-time object detection capabilities, successfully identified potential targets within various complex environments. This initial detection was crucial for setting the stage for more detailed analysis. Deep Sort's role in providing detailed feature extraction and classification was evident in the improved accuracy of target identification. In scenarios with limited visibility or in the presence of camouflaged objects, Deep Sort was able to discern and classify the objects with high precision. Our tests showed that the integration of YOLO and Deep Sort led to a significant reduction in false positives and negatives compared to when each algorithm was used independently. In terms of processing speed, the integrated system maintained a high level of performance, making it viable for real-time applications in dynamic battlefield environments.

Figure 5 - Object identification

Figure 6 - Multiple object identification

The model was subjected to rigorous testing in diverse weather conditions including rain, fog, and extreme brightness. The results were promising, demonstrating the model's robustness and reliability under challenging natural conditions. In urban environments and rugged terrains, the system maintained a high level of accuracy, reinforcing its potential for various military applications. The significance of this work lies in its potential to revolutionize target identification in complex environments.

Figure 7 - Complex environment object detection

Figure 8 - Object Tracking

The integrated YOLO-Deep Sort model represents a significant advancement in the field of military reconnaissance and intelligence gathering. Its ability to rapidly and accurately identify and track targets in complex environments provides a substantial strategic advantage. This technology can enhance situational awareness, enabling more informed decision-making and effective mission planning. While the model has shown great promise, there are areas for improvement. One limitation is the model's dependency on the quality of input data. Future work could focus on enhancing the model's performance with lower-quality inputs or in scenarios with extreme environmental conditions. Additionally, further research into reducing the model's computational requirements could broaden its applicability, especially in resource-constrained environments. The technology has potential applications beyond military operations, such as in disaster management, where rapid and accurate identification of objects can aid in effective rescue operations. It can also be adapted for wildlife monitoring and management, where identifying and tracking animals in complex environments is crucial. As with any advanced technology, especially in military applications, ethical considerations must be addressed. The potential for misuse and the implications of autonomous target identification systems raise important questions that need to be carefully considered and regulated.

Таблица 1 - Table 1 – Object Detection Accuracy Table by Environment Field

Environment Field	Objects Detected	Correct Identifications	Detection Accuracy (%)
Steppe	1571	1509	96.1
Forested Terrains	250	239	95.6
Desert	145	134	92.4
Mountainous Regions	104	91	87.5

Table presents data on the performance of target identification in various complex environments. This table effectively conveys how the complexity of different environments impacts the effectiveness of target identification technology, with varying degrees of detection accuracy observed across different terrains.

Conclusion. In conclusion, this research represents a significant advancement in the field of target identification and tracking in complex environments using the integration of advanced machine learning algorithms, YOLO and Deep Sort. This research addresses the critical challenge of efficient and accurate target detection in modern military operations, where the use of drones and sophisticated surveillance techniques is paramount. An integrated approach involving extensive data collection in a variety of environments and rigorous preprocessing ensures the adaptability and robustness of the model. The effectiveness of the integrated system is demonstrated by its ability to reduce false and negative alarms, maintain high data processing speeds, and demonstrate resilience to adverse weather conditions and challenging terrain. Such capabilities are important not only for military intelligence and intelligence gathering, but also for applications in disaster management, wildlife monitoring, and other areas where fast and accurate object identification is important. The study also identifies areas for future improvement, such as improving model performance when using lower-quality raw data and reducing computational requirements for broader applications.

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