A Review of UAV Vision Technologies for Intelligent Combat Scenarios

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Abstract. Unmanned aerial vehicles (UAV) are becoming more and more important in the intelligent combat scenarios of modern warfare, and at the same time, UAV intelligent vision technology plays an extremely critical role in the execution of strategic tasks such as reconnaissance, surveillance, target identification and tracking. This paper comprehensively analyzes the current status quo of UAV vision technology application in combat, systematically summarizes and concludes the recent research progress of UAV target detection, and deeply discusses the problems and challenges faced by UAV vision technology in the existing research, as well as summarizes the related problems, and further points out the future development direction of the research on UAV vision technology in intelligent combat scenarios, so as to provide an opportunity for the follow-up of the intelligent construction and the related vision technology research of the UAV to be more and more important in modern warfare. It further points out the future development direction of UAV vision technology research in intelligent combat scenarios, which provides a theoretical foundation and direction for subsequent research on UAV combat-related intelligent construction and related vision technology.

Keywords: Intelligent operation; UAV vision; Object detection.

1 Introduction

Unmanned Aerial Vehicles (UAVs), has a pivotal role in modern and future warfare. In the recent Russian-Ukrainian conflict, the UAVs used by the Russian and Ukrainian armies played a key role in reconnaissance, surveillance, target localization, communication relay, material supply, and even direct strikes on the frontal battlefield. The use of UAVs on the one hand reduces the risk to combatants and improves combat efficiency, and on the other hand is used by a large number of equipments in various countries due to its high flexibility, good concealment, and few restrictions on its use. Vision technology is the core component of UAS, which relies on high-resolution cameras, infrared imaging, night-vision equipment and other technologies to realize real-time monitoring and identification of ground targets. These technologies enable UAVs to carry out precise target identification and tracking in complex battlefield environments, provide important information for operational decision-making, and then accurately

Z. A. Zukarnain et al. (eds.), *Proceedings of the 2024 International Conference on Artificial Intelligence and Digital Management (ICAIDM 2024)*, Advances in Intelligent Systems Research 187,
https://doi.org/10.2991/978-94-6463-578-2_14

implement combat missions[1]. In addition, the cooperative operation capability of UAV swarms is also increasing, and they can collaborate with each other, share visual information, and work together to improve combat effectiveness. Vision technology plays a crucial role in the field of UAVs, which not only relates to the navigation and localization ability of UAVs, but also directly affects the efficiency and accuracy of their mission execution. With the advancement of technology, the vision system of UAVs has evolved from a simple camera to a complex system that integrates multiple sensors. With the development of artificial intelligence and machine learning technology, the visual processing capability of UAVs has been significantly improved. The application of machine learning and deep learning technologies has enabled UAVs to recognize and classify targets more intelligently, and even achieve autonomous decision-making in some cases, thus increasing the degree of automation in mission execution[2]. However, UAVs' reliance on vision technologies also poses some challenges. For example, complex background noise, dynamically changing environments, adverse weather conditions, enemy electronic jamming and stealth technology may affect the UAV's vision system. In addition, the data processing and transmission of the vision system requires a large amount of computational resources and bandwidth, which puts higher demands on the hardware and communication system of UAVs. Therefore, future UAV systems need to combine with other sensors and artificial intelligence technologies on the basis of vision technology to further develop multimodal sensing capabilities in order to improve combat capabilities in complex environments.

2 Application of Vision Technology in UAV Operations

The vision system of UAVs is becoming more and more prominent in modern warfare, and vision technology provides UAVs with a powerful ability to perceive targets in UAV combat enabling UAVs to perform some tasks in various complex environments that cannot be accomplished by combatants.

2.1 Identification and tracking of Hostile Targets in the Battlefield

Using machine learning and deep learning algorithms, the vision system of the UAV can automatically identify and track specific targets. Using deep learning algorithms trained on a large amount of labeled data, the UAV can analyze the collected images and automatically identify enemy military equipment, such as tanks, battleships, warplanes, missile launchers, etc., and can achieve a very high recognition accuracy. Once the target is identified, the UAV can track the target in real time using target tracking algorithms such as Kalman filter or Mean-Shift algorithms, which are able to deal with dynamic changes in the image sequence, and maintain stable tracking even in the case of a fast-moving target or a target that is partially obscured[3][4] . At the same time, with high-resolution imagery and advanced image processing techniques, UAVs can pinpoint targets and guide weapon systems to strike them. In complex battlefield environments, there may be multiple targets that need to be tracked at the same time. The

UAV's vision technology can handle multiple targets simultaneously, allocating resources and attention through algorithmic optimization to ensure continuous surveillance of all important targets.

In addition to identifying and tracking targets, the UAV's vision system can analyze the target's behavioral patterns. Through machine learning algorithms, drones can predict a target's next move, supporting tactical decision-making.

2.2 Battlefield Terrain Mapping and Navigation

Three-dimensional models of terrain can be rapidly generated by mounting laser radar (LiDAR) and high-resolution cameras on drones. LiDAR technology is able to accurately measure distances between the ground or objects by transmitting laser beams and receiving the reflected beams back to generate high-precision topographic maps. This technology is particularly suited to complex terrain, such as mountainous, forested or urban environments, where traditional mapping methods can be time-consuming, dangerous and unmatched in terms of precision and accuracy. In emergency situations, such as during battlefield engagements, UAVs can be rapidly deployed to conduct rapid terrain mapping of the engagement area or enemy-held territory, providing critical geographic information for rescue and subsequent support. This information can help assess the battlefield situation, deploy lines of attack, and provide more appropriate operational decisions[5].

Meanwhile a drone's vision technology can aid its navigation system, especially in areas where Global Positioning System (GPS) signals are weak or unavailable. By visually recognizing landmarks and terrain features, drones can perform more precise positioning and path planning[6].

2.3 Real-time Battlefield Intelligence Collection and Analysis

Drones can provide real-time aerial reconnaissance, capturing dynamic changes in critical areas. They can be rapidly deployed over target areas, transmitting images and video in real time through on-board high-definition cameras and sensors, providing decision makers with first-hand intelligence information. At the same time, the intelligence data collected by the UAVs can be quickly processed by the data analysis system on board or on the ground. Using deep learning and artificial intelligence technologies, the UAVs are able to automatically identify and classify targets, and even predict their behavioral patterns and trajectories of action, providing more in-depth intelligence analysis[7].As shown in Figure 1, the armed police investigators operate the UAV for reconnaissance missions.

In the course of combat, when communications infrastructure is often damaged or underdeveloped, drones can carry small communications equipment as communications relay stations, transmitting intelligence data collected through visual technology to command centers. At the same time, drones can also be combined with satellites, ground sensors and other reconnaissance platforms to form a multi-source intelligence system that provides more comprehensive, reliable and accurate intelligence information through data fusion technology, which plays a crucial role in the direction of the battlefield.

Fig. 1. UAV reconnaissance missions.

3 Research Progress in UAV Vision Technology

In the field of automatic UAV ground target identification, traditional target detection methods mainly rely on manual feature extraction, followed by identification and classification using classifiers. With the development of computer vision technology, Girshick et al. proposed a deep learning-based R-CNN target detection method in 2014, and machine learning-based methods have gradually become mainstream[8~10].

3.1 Traditional Artificial Feature-based Target Detection Methods

2010 Sokalski et al.[11]detect salient objects in UAV images by creating saliency maps. They combined mean deviation images, contrast saliency maps and multi-channel color feature maps to enhance the saliency of targets. This method was found to be effective in clean environments but not salient enough in complex environments. Later Gaszczak et al.[12] proposed a multivariate Gaussian shape matching and cascade classification method for vehicle detection. The method operates on a heat map, which is fast in detection, but again the performance in complex environments is degraded. Aiming at the effect of lighting variations on UAV aerial images, Cao et al.[13]proposed an enhanced histogram gradient feature method combined with a linear support vector machine classifier (SVM) to detect vehicles. This method improves the detection under different lighting conditions, but the detection speed is slow. Moraanduzzo et al.[14]used a keypoint-based method by extracting Scale Invariant Feature Transform (SIFT) keypoints of the image and classifying them using an SVM (as shown in Figure 2) in order to achieve automatic detection of vehicles on the ground. In the literature[15], Moraanduzzo they further explored the sliding window search and Histogram of Orientation Gradient Features (HOG) feature approach combined with dictionary comparison technique to determine the class of ground targets. Later, in the literature[16], they proposed a target detection method based on high-order gradient and Gaussian process regression, which provides a new perspective on target recognition in UAV images.Su et al.[17]developed an online cascade boosting framework that utilizes HOG to detect vehicles in UAV images. The method first calculates the HOG features of a sliding window to determine the gradient direction of the vehicle, then adjusts the window according to the estimated vehicle direction and optimizes the feature computation by integrating the histogram. By improving the weak classifier and post-processing techniques, the method can effectively improve the extraction rate of positive samples, although there is still a possibility of false detection when facing building elements with similar features to vehicles.Xu et al.[18]proposed a hybrid vehicle detection method combining HOG + SVM and Viola-Jones, which significantly improves the detection efficiency and effectiveness by adjusting the road direction and switching strategy. This method is particularly applicable to video streams captured on mobile UAV platforms without the need for image alignment or dependence on specific road databases, which is of high practical value.

Although traditional manual feature-based target detection techniques have achieved some success in UAV ground target recognition, they often require extensive prior knowledge and personal experience of the designers. In addition, they have limitations in automatic feature extraction and adaptability, especially in urban environments with changing light and weather conditions, where these methods are difficult to dig deeper into the deep semantic information in the images and have weak environmental adaptability. Therefore, vision technologies mounted on UAVs capable of adapting to battlefield environments under the prevailing technological conditions are still facing great challenges.

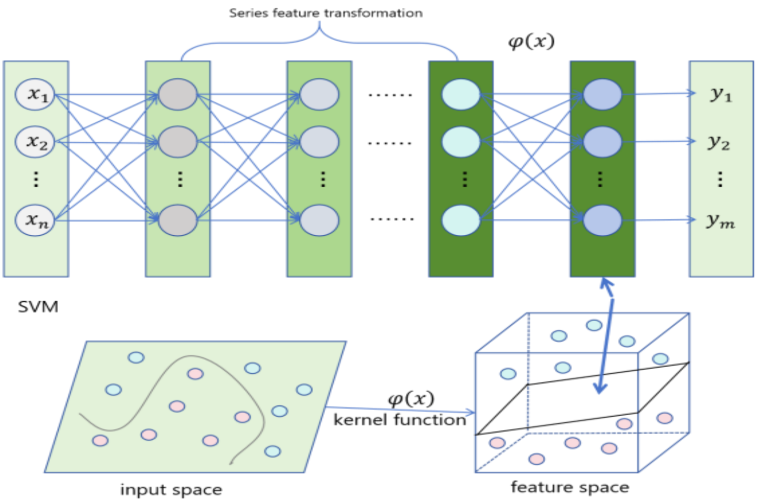

Fig. 2. Linear Support Vector Machine(SVM).

On the contrary, deep learning-based target detection technology shows significant advantages in UAV image analysis, which is particularly suitable for the intelligent combat mission requirements of UAVs. Deep learning models are able to automatically learn and extract features from data, reducing the reliance on a priori knowledge and human intervention. This provides higher accuracy and wider application prospects for combatants to use UAVs for target detection in variable and complex battlefield environments, improving the efficiency and reliability of target detection.

3.2 Deep Learning Based Object Detection Methods

Chen et al.[19]noted that traditional methods struggle to achieve a balance between target recognizability and robustness of the detection system. They also observed that deep convolutional neural networks (DCNNs) can only extract single-scale features, which limits their ability to deal with large variations in target size. To address this issue, they proposed a hybrid deep neural network (HDNN) that achieves multi-scale feature extraction by introducing a mapping of variable sensory field sizes in the highest convolutional layer and the largest pooling layer, which achieves significant performance gains in vehicle detection tasks. In the literature[20], in order to cope with the challenges posed by the high resolution and complex background of UAV images, the researchers proposed a new method that abandons the traditional sliding-window search strategy and employs a mean-shift algorithm (Mean Shift) to drastically reduce the search space. In addition, they combined an SVM classifier and a pre-trained DCNN to extract high-level semantic features, taking advantage of deep learning to enhance the performance of target detection. Bazi et al.[21]developed a Convolutional Support Vector Machine (CSVM), which is a model that performs feature extraction by alternating between a convolutional layer and a downsampling layer, and relying on a set of linear SVMs. The design of the CSVM allows for a limited number of training samples to be achieve highly accurate detection of targets in UAV images[22].Bejiga et al.[23]used a pre-trained CNN model to extract features from UAV acquired images and subsequently classified these features using linear SVMs, this approach was applied to the task of searching and rescuing people after a natural disaster. Berat et al.[24]proposed to improve the detection of targets in UAV images by combining a multi-stage detector, ResNet101[25], with a single-stage SyNet network by combining a multi-stage detector, ResNet101, and a single-stage detector, DLA-34, and combining the individual predictions of each algorithm in the fusion stage, which led to a high improvement in detection accuracy at that time.Zhao et al.[26]proposed JanusNet, an efficient CNN model that can deduct the background in-line to enable resource-constrained onboard computational hardware of UAVs to robustly detect moving targets, and is suitable for a wide range of scenarios. The performance of the algorithm is not affected even when the UAV is traveling at high speed. Although these methods have shown better results in specific application scenarios, they usually involve only feature extraction using CNNs followed by classification via SVMs and do not build a complete deep learning network. This approach may not be able to meet the detection needs of UAVs in complex field scenarios in terms of detection speed and accuracy, and thus requires further research and improvement to achieve better performance.

Nowadays, end-to-end target detection methods achieve impressive results. Such methods handle image feature extraction,target classification and localization simultaneously through a single network, effectively improving detection efficiency and reducing computational burden.Wang et al.[27]tested the mainstream detection networks SSD, Faster R-CNN, and RetinaNet[28] on the Stanford UAV dataset, and the results show that these end-to-end models exhibit highly significant advantages in UAV vision tasks. advantages.Vaddi et al.[29]utilized MobileNet and Resnet50 as the backbone network for RetinaNet, and although good results were obtained on UAV images, they still suffered from an excessive number of anchor frames and poor detection of occluded targets. In order to enable UAVs to accomplish tasks in GPS-free environments, Daniel et al.[30]propose a MobileNet-SSD CNN-based network. The network uses lightweight convolutional neural networks for obstacle detectors and classifiers as well as adding a collision avoidance algorithm with a proportional controller. It allows the UAV to monitor and avoid obstacles in real time in real scenarios with multiple obstacles in outdoor GPS-free environments.Budiharto et al.[31]Combining SSD and MobileNet[32] algorithms, the network achieves a frame rate of 14.5 FPS in the UAV image target detection task.Liu et al [33]optimized the network structure based on YOLOv3 in order to achieve target tracking and proposed YOLOv3-Tiny, which enables real-time analysis of captured images for target tracking, which improves the detection speed of the target, but the computational complexity and detection accuracy are affected.Zhao et al.[34]add a probe head to YOLOv7 to detect small target objects, and the YOLOv7-sea algorithm is proposed, which significantly improves the accuracy of target detection in UAV imagery, but it is not as accurate as other lightweight models, there is still room for improvement in inference speed.Cao et al.[35]to deploy target detection algorithms on UAV edge devices, a lightweight convolutional neural network module is designed and a multi-scale detection network is constructed, which ensures the detection accuracy as well as reduces the model size and computational cost, and achieves an inference speed of 100 FPS on the Jetson Xavier NX embedded device However, due to the limitations of experimental scenarios and data, the algorithm's detection performance for ground targets under diverse lighting and weather conditions needs further testing and validation.Li et al.[36]proposed a lightweight combinatorial neural network ComNet as the core of the target detection method considering the limited platform arithmetic of UAVs. This method is mainly based on deep learning for UAV thermal imaging target detection, compared to visible images, thermal imaging has lower requirements for light brightness, but the edges are more blurred with lower contrast. A boundary-aware salient target detection network is utilized to extract the saliency map of the thermal image to improve the image distinguishability, and the thermal image is enhanced by pipeline replacement and pixel-level weighted fusion methods, which significantly improves the average detection accuracy and detection speed, and reduces the model size by half.Wang et al.[37]propose the Cross-modal Remote Sensing Imagery Target Detection Network for Aerial Remote Sensing (CRSIOD), which can effectively learn the different sensor image features to capture target features in different scenes.CRSIOD utilizes the features of both visible light and thermal images to capture target features accurately and stably in different lighting environments and complex scenes, and detects strong occlusion targets for labeling by fully learning strong occlusion target features.

The above deep learning-based target detection method for UAV images has achieved tremendous improvement in detection speed and detection accuracy compared to previous methods. UAVs equipped with deep learning-based target detection systems can effectively adapt to various battlefield environmental challenges. Whether in low light, harsh climate or complex battlefield environments, deep learning models can automatically recognize complex patterns in images and provide the most detailed target identification and localization information possible. It enhances our combat power and early warning capability of risks, and improves the mission execution rate and effectiveness[38].Overall, the integration of deep learning technology plays a key role in enabling UAVs to successfully complete their missions during combat. However, current deep learning target detection systems still face a number of challenges, including insufficient accuracy, slow processing speed, and limited generalization capability. These issues limit the system's ability to meet the high standards of stability and reliability required for UAV missions. The following table 1 shows a comparison of mainstream algorithms for deep learning.

Table 1. Comparison of deep learning based object detection mainstream algorithms.

arithmetic	Conference and time of presentation	Main features	Major improvement
R-CNN	CVPR2014	Selective search to quickly find possible target candidates based on color, edge, texture, etc.	47s more than 30% increase in per mAP
Fast R-CNN	ICCV2015	SPPNet was added, end-to-end training, and regression was used	3s 70% per mAP
Faster R-CNN	NIPS2015	Using the network to directly generate Proposals with high recall; RPNet	5FPS mAP 73.2%
YOLO	CVPR2016	Changing to a regression problem	45FPS mAP 57.9%
SSD	ECCV2016	YOLO+Proposal+Multi-scale	58FPS mAP 73.9%

Note: 1) mAP is mean average precision.

4 Problems and Challenges of UAV Vision Technology

Through analyzing and studying the current situation of UAV intelligent combat and vision technology at home and abroad, the intelligent visual detection method of UAV in intelligent combat scenarios is still in the stage of preliminary exploration, and the current research mainly focuses on exploring how to adapt the existing deep learning target detection algorithms to the detection task of UAV images. As UAV intelligent combat is characterized by targets with diverse angles, variable sizes, and complex backgrounds, traditional target detection methods are not fully applicable. Intelligent visual detection methods still have the following difficulties or challenges that cannot be solved better:

4.1 Contextual Complexity in the Battlefield Environment

The UAV detection process is characterized by complex background factors such as insufficient light, interference from similarly shaped objects, and target occlusion. Extreme environments, such as large smoke, drastic light changes, and thunderstorms, often occur in the course of combat between two sides, which can cause a series of image degradation phenomena making it difficult for deep neural networks to extract useful information from them, thus affecting the detection system's accuracy in recognizing targets on the ground and leading to the failure of UAV combat missions. Therefore, realizing highly robust and adaptive target detection of UAVs in complex environments under intelligent combat scenarios is crucial for enhancing the effectiveness of UAVs in practical applications[39][40].

4.2 Lack of Large Datasets of Real Battlefield Scenarios

Deep learning-based UAV target detection requires a large amount of sample data to train the network, and the diversity and richness of the sample dataset directly affects the model's ability to generalize to real data. However, the current datasets of aerial images of real battlefield scenarios that can be used for training are very limited, and most of the datasets are dominated by the flat-view perspective, which largely limits the potential of the model to achieve optimal performance and indirectly contributes to the problem of low recognition accuracy of UAVs.

4.3 Arbitrariness of Target Orientation of UAV Images

In UAV image target detection, traditional methods usually use horizontal bounding boxes to recognize targets, which has certain limitations: first, the horizontal bounding box cannot accurately represent the true shape and proportion of rotating targets; second, there are difficulties in distinguishing targets from complex backgrounds; third, it is difficult to distinguish the horizontal bounding box for dense and overlapping targets. The UAV target detection process mostly adopts a top-down view, which greatly limits the possibility of extracting features from different angles. Coupled with the fact that UAVs operate at high altitude, which makes ground targets appear to have smaller features in the image, these factors increase the risk of omission or misidentification during the detection process, which in turn affects the accuracy of UAV target recognition.

4.4 The Limited Arithmetic of Drone Hardware

The performance of deep learning models requires powerful computational resources to support them, and UAV vision systems need to process large amounts of data in real time and respond quickly to adapt to the dynamically changing battlefield environment. However, the on-board computational capability of UAVs is relatively limited, which restricts the application of high-performance algorithms on UAVs. In order to solve this contradiction, a two-pronged approach is needed to optimize the algorithms and enhance the computational efficiency of the embedded platform, both to streamline the algorithms to reduce the resource consumption and to enhance the computational hardware of the UAV to achieve effective on-board target detection.

4.5 Low Robustness of Algorithms for UAV Vision Systems

The robustness of the algorithms of UAV vision systems in performing tasks is one of the key factors to ensure the success of the tasks. However, current UAV vision system algorithms have some deficiencies in robustness that may affect the performance of UAVs in various environments. For one thing, UAVs encounter complex and changing environments during actual flight, such as drastic climate changes, complex lighting conditions, and variable geographic environments. All of these factors interfere with the UAV's vision system and affect the quality of image acquisition and processing. Second, the UAV vision system will face challenges in processing dynamic targets. Tracking and recognition become more difficult due to the relative motion between the UAV and the target, and the target itself may also be moving. The rapid movement of dynamic targets may result in blurred images, affecting the recognition rate of the algorithm. Third, the robustness of the UAV vision system will likewise be tested when faced with complex background and occlusion problems. Fourth, complex elements in the background may be similar to the target and interfere with the normal operation of the algorithm. Most of the existing target detection algorithms rely on high-quality image data, but ensuring that these algorithms can maintain good detection performance even with poor image quality is an important aspect that must be considered when realizing the algorithms for application in the real battlefield.

5 Future Development and Research Direction of UAV Vision Technology

5.1 Potential Developments in Vision Technology

In the future, computer vision technology is developing in the direction of multimodal fusion to achieve a more comprehensive environment perception capability by combining multiple sensor data such as image, sound, and temperature. With the advancement of 3D sensor technology, 3D vision will become the mainstream of computer vision, allowing UAVs to more accurately understand the spatial structure and the three-dimensional form of objects[41]. In addition, devices such as drones and surveillance cameras can operate efficiently around the clock by targeting improved vision algorithms for low-light and nighttime environments. The integration of vision processing capabilities in edge devices not only reduces data transmission latency and improves response time, but also enhances privacy protection for information transmission on the battlefield and reduces the likelihood of enemy interception of secrets. The parameters are automatically adjusted according to environmental changes and user needs in order to improve the adaptive learning ability of the algorithm and optimize the performance on the actual battlefield. Meanwhile, with the development of technology, the security of the vision system will receive more attention to ensure the absolute security of data in the battlefield[42].

5.2 Requirements for UAV Vision Technology in Intelligent Combat Scenarios

UAV vision technology is becoming increasingly important in smart combat environments, especially playing a key role in improving operational efficiency and keeping soldiers safe. In order to accurately identify targets in a volatile battlefield, high-resolution imaging technology is indispensable, which ensures that clear images can be obtained even when the target is small in size or far away. Additionally, target recognition and tracking capabilities are critical; the vision system must be able to quickly recognize moving targets and maintain stable tracking when the target is moving quickly or is partially obscured. The UAV vision system must also have strong environmental adaptability and be able to work stably under different lighting conditions, weather conditions and terrain features. Real-time data processing capabilities are critical for operational environments, which require rapid tactical decision-making and response. At the same time, UAV vision systems need to be highly resistant to jamming in order to withstand electronic warfare and possible enemy deception. Concealment is also an important factor to be considered in the design of vision systems to reduce the risk of detection and attack by the enemy. In addition, UAV vision technology can be integrated into a variety of combat platforms, such as ground vehicles and satellites, enabling full linkage and coverage of battlefield equipment. In order to improve combat efficiency, the vision technology should also support the synergy between different combat units, and enhance the overall combat effectiveness through information sharing and mission coordination. Finally, in order to ensure the stable operation of the system when performing critical tasks, the reliability and redundancy design of vision technology plays an important role. By meeting these key requirements, UAV vision technology will play a more important role in the intelligent combat environment [43].

5.3 Future Research Directions for UAV Vision Technology

The future of UAV vision technology is standing at a new starting point, full of opportunities and challenges. Algorithmic innovation is the key to driving this field forward, and with the surge in the amount of available data and the significant increase in computational power, researchers are faced with the challenge of developing more efficient algorithms, which at the same time provides a stage for them to demonstrate their innovative capabilities. With big data and deep learning as the cornerstones of this field, how to effectively utilize these technologies to improve the accuracy and robustness of UAV vision systems has become an important research direction. Achieving high-performance vision processing on resource-constrained devices, such as mobile devices and embedded systems, is a technical challenge, and model compression and acceleration become the key to solving this problem, which is crucial to promoting the application of vision technology on UAVs and even various devices. In addition, small-sample learning, as an important direction for future research, enables effective learning in the presence of data scarcity, which is particularly important for vision systems that need to process large amounts of data [44].

6 Conclusion

In the intelligent combat scenario of UAVs, the study of vision technology not only represents the forefront of scientific and technological innovation, but is also the key to the development of military intelligence. With the continuous progress of technology, we have witnessed the wide application of UAVs in many fields such as reconnaissance, surveillance, target identification and tracking. However, to fully utilize the role of UAVs on the modern battlefield, we still need to conduct in-depth research and continuous innovation in the field of vision technology. This paper summarizes and analyzes the vision technology of UAVs in intelligent combat scenarios, combs through the development status of traditional target detection technology and target detection technology based on deep learning, as well as the advantages and disadvantages of the existing methods, summarizes the problems and challenges of the existing UAV vision technology, and puts forward some future research directions of UAV vision technology to provide a theoretical basis and indicate the research direction of UAV vision technology for the subsequent use in intelligent combat scenarios and UAV vision technology. It provides a theoretical foundation and points out the direction for the subsequent research on intelligent combat scenarios and UAV vision technology.

In summary, the research of vision technology in UAV intelligent combat scenarios is a field full of opportunities and challenges. Through continuous technological innovation, interdisciplinary integration and international cooperation, the future UAV vision technology will be more intelligent, efficient and safe, providing a strong technical support for modern warfare, as well as bringing far-reaching impacts to other fields of society.

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