OBJECT DETECTION WITH DEEP LEARNING

Table of Contents

Introduction

The term “Object detection” is a real and challenging task in computer vision. The idea is to identify and localise detailed objects within digital images, posters or videos (Chidananda *et al.*, 2023). Nowadays, the remarkable advancements in “deep learning” techniques have revolutionized the field of computer vision, moving “object detection” to a level of accuracy and efficiency. “Object detection” has enhanced exponentially in today's world. The introduction of AI technologies, especially the “deep learning” technologies has been helping in many ways (Drukker *et al.*, 2020). Here in this literature review delves into the improvement created in “object detection” utilising “deep learning” approaches and exploring the key processes, algorithms, and inventions that have moved the field forward. The standard approaches to “object detection” depended heavily on handmade elements and detailed engineering, completing them difficult and computationally expensive. However, the source of “deep learning models”, particularly “convolutional neural networks (CNNs)”, has greatly simplified the process by allowing automated feature extraction directly from raw pixel data. The new technological advancement helping to reach excessive success. This shift has paved the way for the growth of highly effective and scalable “object detection” systems. The numerous important milestone in “object detection” with “deep learning” came with the introduction of the “region-based convolutional neural network (R-CNN)” architecture (Murthy *et al.*, 2020). In the year 2014, R-CNN was proposed and with the subsequent variant, it included Faster R-CNN and spread the groundwork for the two-stage detection pipeline. Object regions via selective search or region proposal networks are suggested by this method. It classifies and refines those areas using CNNs. While effective, these methods suffer from slow beginning times due to the two-stage process.

Addressing the drawbacks of two-stage detectors, single-stage detectors appeared as an alternative. One of the pioneering single-stage models was the “You Only Look Once (YOLO)” detector and this is the most relevant and effective method. This detector directly predicted bounding boxes and class probabilities in a single pass. “Deep learning” models such as “Single Shot Multibox Detector (SSD)”, “You Only Look Once (YOLO)”, “Faster R-CNN”, and others have taken centre stage in this field. These models leverage the power of “deep neural networks” to learn complicated representations directly from raw image data, and video data eradicating the need for handcrafted features (Patel, 2021). In this era of “data abundance and computational prowess”, small and large-scale labelled datasets and powerful “GPUs” have created it feasible to prepare and deploy these refined models efficiently. Moreover, the “transfer learning techniques” permit leveraging pre-trained models, and which are trained on massive datasets to enhance “object detection” tasks on smaller datasets effectively. The “Object detection” with “deep learning” pushes into the key concepts, methods, models and cutting-edge advancements in this particular field. It can be discussed that the various applications where “object detection” plays a vital role, creating computer vision systems more intelligent, efficient and versatile. While working on real-world applications, understanding the concept of “object detection” with “deep learning” will enlarge a world of possibilities and opportunities to tackle complex visual challenges, handle multiple problems and develop innovative solutions. So the “object detection” with “deep learning” has taken multiple things to explore. Techniques such as “fine-tuning” and “knowledge distillation” have allowed the transformation of models to particular “object detection” tasks with unreasonable annotated data (Kim *et al*., 2022). Here this literature review focuses on the contributions of various “deep learning-based” “object detection” techniques, analysing their positiveness, flaws, and other practical applications.

Concept of Deep learning for Object detection

In recent years the concept of “object direction” with “deep learning” has witnessed massive success in various aspects. The modern advancement, and improvement of “deep learning” methods, particularly “convolutional neural networks (CNNs)” is taking growth in the “object detection” (Mendoza *et al*., 2021). The top goal of “object detection” is to deliver objective and real-time results, allowing a wide spectrum of applications such as surveillance systems, autonomous vehicles, augmented reality, and robotics. There are many challenging and expensive ways where the only dependency is to rely on the modern technologies. However, with the advent of “deep learning”, the field experienced a paradigm shift. “Deep learning” models, especially “CNNs”, are qualified for relevant components from raw pixel data and eliminate the need for “manual feature engineering”. There are some principles which in the “object detection”. The main principle behind “object detection” with “deep learning” concerns splitting the task into two main elements such as “object localization” and “object classification”. “Localization” aims to precisely specify the coordinates of the object's bounding box, indicating its position within the image. Secondly, the classification concentrates on determining the object's class or category. The multiple fundamental architecture that laid the foundation for “object detection” is the region-based “convolutional neural network (R-CNN)” presented in recent times and “R-CNN” operated a two-stage approach, The first stage, the potential object regions via particular investigation or region proposal networks (Chaudhuri, 2021). Following feature extraction, these regions were fed into a “CNN” for classification. “R-CNN” was not without flaws, however, most notably a slow inference time brought on by the necessity of several passes through the “CNN”. Faster and more effective variations were developed to solve these shortcomings. The region proposal and classification stages were integrated into one network using Fast “R-CNN” and Faster “R-CNN”, which reduced computational overhead.

The effectiveness and speed of object detection were greatly enhanced by this development. The “You Only Look Once (YOLO)” model is an example of a single-stage detector, which is another noteworthy method for object identification with deep learning. In one pass across the network, “YOLO” first released in 2016, predicted object box boundaries and class probabilities. This significantly increased its speed and made it suited for real-time applications. Impressive results were shown by “YOLO” and its later iterations, “YOLOv2”, “YOLOv3”, and “YOLOv4”, especially in situations where speed is important (Terven and Cordova-Esparza., 2023). The predetermined anchor boxes required by conventional two-stage detectors were no longer necessary thanks to further improvements that produced anchor-free detectors. Models such as "CenterNet" and "FCOS" directly predicted the centres and sizes of objects, streamlining and boosting the accuracy of the object detection process. Large-scale datasets such as "ImageNet" have been used for transfer learning and pretraining, both of which have been crucial in improving the accuracy of object detection models (Zhu *et al*., 2021). Transfer learning helps object detectors generalize more effectively, even with little labelled data, by utilizing experience gained from similar tasks. Transfer acquisition and anchor-free techniques, together with the combination of localisation and categorization into a single network, have significantly increased accuracy and effectiveness. “Deep learning” object identification is anticipated to become more and more important as technology advances, changing numerous industries and influencing the development of computer vision applications (Li *et al*., 2021).

Literature Review

A fundamental “visual identification” challenge in computer vision, object detection has received a lot of attention in recent years. “Visual object recognition” seeks to locate objects of certain target classes inside a given picture with high localization accuracy and to label each object instance with the appropriate class. Deep learning-based object identification methods have been extensively investigated recently due to the enormous success of deep learning-based picture categorization. Wu *et al.*, 2020 provide a thorough overview of current developments in deep learning-based visual object recognition in this work. The survey is organised into three main sections: (I) "detection components," (ii) "learning algorithms", and (iii) "applications & benchmarks" after a thorough analysis of a significant body of current relevant research. Include a wide range of elements, such as “detector designs”, “feature learning”, “proposal generation”, and “sampling techniques”, in the survey that are covered in detail. Discuss a few potential future avenues to help and encourage more “deep-learning” research in visual object recognition.

The task of organising and finding things in an image or video is known as “object detection”. Its many uses have allowed it to become more well-known in recent years. This article reviews recent advances in “object detectors” powered by “deep learning”. Along with some of the well-known backbone techniques utilised in recognition tasks, a succinct review of benchmark “datasets” and “evaluation criteria” utilised in detection is also given. It also concerns modern, lightweight categorization techniques employed on “cutting-edge technology”. Lastly, Zaidi *et al.*, 2022, determined these architectures' results across various criteria.

In order to find examples of semantic objects of a particular class, “object detection” is one of the most crucial and difficult areas of computer vision. It has been widely used in people's daily lives, including security monitoring, autonomous driving, and other areas. The performance of object detectors has significantly increased as a result of the quick development of deep learning algorithms for detecting tasks. To fully and profoundly comprehend the object detection pipeline's primary state of development, in this survey, Jiao *et al.*, 2019, Describe the benchmark datasets first, then analyse the typical detection models that are currently in use. After that, and in the main, give a thorough, systematic overview of several object detection techniques, covering the one-stage and two-stage detectors. List both the conventional and novel uses as well. In addition, a few exemplary branches of object detection are examined. The architecture of using various object detection techniques to produce an effective and efficient system is then discussed. A collection of development trends is also pointed out to help you better follow cutting-edge algorithms and future research.

When compared to conventional article recognition algorithms, object identification is a more important use of deep learning technology that is praised for its component representation and element learning. The article discusses classic methods for object acknowledgment and draws comparisons and connections between them and deep learning methods for object discovery. It describes the evolution of article recognition algorithms in the context of deep learning and provides an explanation of the common practises used today for article positioning. In this paper, Patil *et al*., 2022, "Deep Learning" methods were used to construct a model to assess accuracy and improve image quality by detecting objects in pictures.

Computer vision-based deep learning-based object recognition techniques have captured everyone's interest recently. Deep learning has great promise because to the expanding UAV market trends and interest in possible uses including surveillance, visual navigation, object identification, and sensors-based obstacle avoidance planning. Moving photos taken by drones may now be processed using object detection algorithms built into deep learning frameworks. The primary objective of the paper which is made by Mittal *et al*., 2020, aims to present a thorough analysis of the most current deep learning-based object detection methods and to examine how these algorithms have recently contributed to low-altitude "UAV datasets". Low-altitude "UAV datasets" are the main focus of the research because they make up a smaller portion of the literature as compared to normal or remote-sensing-based datasets. The following methods are covered in the paper: "CornerNet", "Objects as Point", "Faster RCNN", "SSD", "RetinaNet into one stage", "Cascade RCNN", "R-FCN". under advanced stages in deep learning-based detectors. Additionally, one, two, and advanced stages of detectors are carefully examined with an emphasis on datasets from low-altitude "UAVs". The publication offers a comprehensive overview of low-altitude datasets and the related research in detection algorithms for researchers' possible usage. There are also a number of research gaps and difficulties for object recognition and classification in "UAV datasets" that need to be addressed in order to improve performance.

"Salient object detection (SOD)", a crucial issue in computer vision, has drawn more and more study interest over time. "Deep learning-based" solutions (also known as deep SOD) have mostly been driving recent advancements in "SOD". In this study, Wang *et al.,* 2021 give a thorough survey encompassing different elements, spanning from algorithm taxonomy to unresolved difficulties, to provide an in-depth knowledge of "deep SOD". Review "deep SOD methods" in particular from several angles, including as network design, supervision level, learning paradigm, and object/instance level identification. summarise and analyse the current "SOD datasets" and assessment metrics. Then, compare a substantial number of typical "SOD models", and offer in-depth assessments of the findings. For the first time in the area, more research is needed to determine how resistant "SOD models" are to adversarial assaults and random input perturbations. Examine the generalisation and challenge of the "SOD datasets" that are currently available. Finally, we through several still-open "SOD" concerns and sketch down some future research areas.

This work suggests an enhanced Faster “RCNN” to identify healthy tomato leaves and four diseases, including “powdery mildew”, “blight”, “leaf mould fungus”, and “ToMV”, in order to increase the recognition model accuracy of crop disease leaves and pinpoint infected leaves. First, Zhang *et al*., 2020 replace “VGG16” for image feature extraction with a depth residual network in order to extract deeper illness characteristics. The bounding boxes are then clustered using the “k-means clustering technique”. Adapt the anchoring as well based on the clustering findings. The enhanced anchor frame leans towards the dataset's actual bounding box. Finally, do a “k-means” experiment using three alternative feature extraction networks of different types. Compared to the original quicker “RCNN”, the enhanced approach for agricultural leaf disease detection had a quicker detection speed and an identification accuracy that was “2.71% higher”.

“Deep learning” has recently proved successful at detecting objects in camera photos. This method is becoming closer to being used in production cars due to increasing detection rates and computationally efficient network architectures. However, the camera's sensor quality is compromised by increased sensor noise in dimly illuminated spaces at night and in adverse weather situations. By combining camera data with sparse radar data and projecting it into the network layers, the method improves on “2D object identification networks” that are already in use. The suggested “CameraRadarFusionNet (CRF-Net)” automatically discovers the level at which the sensor data fusion is most advantageous for the detection outcome. Additionally, Nobis *et al*., 2019, present “BlackIn”, a learning approach that concentrates on a particular sensor type and was inspired by Dropout. Then demonstrate that, for two separate datasets, the fusion network outperforms a cutting-edge image-only network.

“Deep learning (DL)” has a significant impact on many areas of research and has solidified itself as a flexible approach for tackling new problems in the “Earth observation (EO) community”. Despite this, the entrance barriers for “EO researchers” are high since the area is crowded and evolving quickly, mostly because to developments in “computer vision (CV)”. This paper provides an overview of the development of “DL” with an emphasis on image segmentation and object recognition in “convolutional neural networks (CNN)” in order to remove the hurdles for “EO researchers”. The study runs from early “2012” through late “2019”, when “CNN” established new benchmarks for image recognition. To make it easier to evaluate contemporary “DL models”, emphasise the relationships between the most significant “CNN” architectures and the foundational elements from a “CV”. Additionally, Hoeser and Kuenzer, 2020, present an overview of the datasets in “EO” as well as a brief history of the most well-known “DL frameworks”. Reduce the gap between theoretical notions from “CV” and their practical implementation in “EO” by talking about effective “DL architectures” on these datasets and commenting on “CV” advancements and their influence on upcoming “EO research”.

Considering how closely object title relates to “video analysis” and “visual comprehension”, it has received a lot of study interest lately. In this paper, Zhao *et al*., 2019, review “object detection” frameworks based on “deep learning”. A brief history of deep learning and its illustrative tool, the “Convolutional Neural Network (CNN)”, is given at the outset of the review. Next, concentrate on standard generic “object detection” architectures, along with various changes and helpful techniques to further improve detection performance. Examine briefly a number of specific tasks, such as “salient item recognition”, “face detection”, and “pedestrian detection”, since different specialised detection tasks display different properties. Additionally, experimental studies are offered to contrast different approaches and reach some insightful results. In order to serve as suggestions for future work in both object identification and pertinent neural network-based learning systems, a number of intriguing directions and challenges are offered.

Target recognition and tracking from aerial pictures utilising drones with onboard powered sensors and gadgets have become more and more popular in recent years. A deep learning framework-based technique for this application is proposed by Hossain and Lee in 2019. Small flying robots are equipped with a state-of-the-art embedded hardware technology that enables them to do the real-time onboard computing required for object tracking. Two different kinds of embedded modules were created: one was built on an “Intel Neural Compute Stick”, while the other was based on a “Jetson TX” or “AGX Xavier”. These are appropriate for real-time onboard processing power for compact flying drones.Using the designated “GPU-based embedded computing modules”, a comparative investigation of the most advanced “deep learning-based multi-object recognition algorithms” was done to acquire precise metrics concerning compute power and frame rates. offer a successful target-tracking strategy for moving objects as well. The expansion of straightforward online and real-time monitoring serves as the foundation for the algorithm for tracking moving objects. It was created by combining simple online and real-time tracking (“Deep SORT”), which employs a hypothesis tracking technique with “Kalman filtering” and a “deep learning-based association metric”, with a “deep learning-based association metric” approach. In addition, a guiding system that employs a “GPU-based algorithm” to track the target location is shown. Finally, use real-time tests with a tiny multi-rotor drone to show the usefulness of the suggested algorithms.

Successful and accurate object identification has been a key topic in the advancement of “computer vision systems”. The purity of object detection has grown dramatically with the introduction of “deep learning algorithms”. In this paper, Arya *et al*., 2021, Using a “wireless sensor network”, and employed a wholly deep learning-based technique to handle the difficulties of object recognition from start to finish. Despite the fact that various approaches have been created, this article will address some well-known and fundamental concepts of “object detection” using “deep learning”. Finally, their generic applications and outcomes are shown here.

The article which is made by Kaur *et al*., 2022, focuses on a light introduction to “AI” and the principles of “machine learning (ML)” and “deep learning (DL)”. The fast advancements in “DL approaches” compelled us to do this research. From basic theoretical notions to implementations, the concept of “DL” is flourishing. “Deep neural networks” are presently cutting-edge “ML models” that are widely employed in academia and business in a variety of domains ranging from image identification to “natural language processing”. These breakthroughs have enormous implications for “medical imaging technologies”, “medical data processing”, “medical diagnostics”, and overall healthcare. The goal is twofold: (1) to conduct a survey of “DL methods” to “medical pictures”, and (2) to investigate “DL-based object recognition algorithms”. The essay effectively describes new breakthroughs, “advanced learning technologies”, and platforms utilised for “DL techniques”. Object detection is the most researched and difficult subject in “computer vision systems”. Researchers are paying more attention to this topic since it includes real-time applications such as the “face”, “pedestrians”, and “text”.

More “synthetic aperture radar (SAR)” photos are now available than ever before because to the introduction of “space-borne satellites”, allowing enabling “dynamic ship tracking”. “Deep learning” object detectors outperform competitors thanks to a free public dataset. Unfortunately, due to a scarcity of labelled datasets, object detectors for “SAR ship detection” have progressed slowly. A “SAR dataset” is created to aid in the development of object detectors in “SAR pictures”. “SAR professionals” labelled this dataset, which was constructed using “102 Chinese Gaofen-3 pictures” and “108 Sentinel-1 images”. It is made up of “43,819 ship chips” with “256 pixels” in range and “azimuth”. These ships are mostly distinguished by their sizes and backdrops. Furthermore, modified state-of-the-art “object detectors trained” on natural pictures can be employed as baselines. “Object detectors show greater mean average precision (mAP)” on the test dataset and have strong generalisation performance on fresh “SAR images” without “land-ocean segmentation”, proving the value of the dataset Wang *et al*, 2019, created.

Despite the fact that many contemporary “3D object identification algorithms” depend heavily on cameras and “LiDAR”, cameras and “LiDAR” are susceptible to adverse “weather” and “lighting conditions”. “Radar” on the other hand, is impervious to such situations. However, it was only lately that researchers discovered how to apply “deep neural networks” to “radar data”. Lee, 2020, provide a deep learning solution to “3D object identification” using just radar in this study. The authors are the first to show a “deep learning-based 3D object identification model” trained on a publicly available radar dataset. To address the scarcity of radar-labelled data, we suggest a unique method of using copious “LiDAR data” by translating it into a radar-like point cloud data and aggressive radar “augmentation techniques”.

“GPR” is a potential “non-destructive assessment” tool for locating buried subterranean items in metropolitan settings. In this sector, a “deep learning approach” has recently been used to automate the interpretation of “GPR data”. However, there is no appropriate approach for capturing the individuality of “metropolitan road pavements”. Kim *et al*., 2020 offer a subsurface object recognition approach appropriate for urban road pavement employing a statistically calculated threshold amplitude and a large number of “GPR B-scan picture libraries” in this work. Based on the statistical distribution of “GPR data”, a novel automatic thresholding approach has been created. The suggested technique successfully emphasises and classifies the features of subsurface objects such as hyperbola, manhole cover, layer interface, and subsoil backdrop.

The aim of this study which is made by Obaid *et al*., 2022, is to compare the performance of pre-trained models to the likelihood % of prediction in terms of execution time. The “COCO dataset” is used in this work to test both pre-trained “image recognition” and “object identification algorithms”. The findings indicated that “Tiny-YoloV3” is the optimum approach for real-time applications since it is faster. “ResNet 50”, on the other hand, is necessary for applications that demand a high likelihood percentage of prediction, such as medical picture categorization.

Table

Author	Title	Comments

Wu, Sahoo, and Hoi., 2020.	“Recent advances in deep learning for object detection. Neurocomputing.”	The researchers provide a thorough overview of current developments in deep learning-based visual object recognition in this work. The survey is organised into three main sections: (I) "detection components," (ii) "learning algorithms", and (iii) "applications & benchmarks" after a thorough analysis of a significant body of current relevant research.
Zaidi, Ansari, Aslam, Kanwal, Asghar and Lee., 2022.	“A survey of modern deep learning based object detection models. Digital Signal Processing.”	This article reviews recent advances in “object detectors” powered by “deep learning”. Along with some of the well-known backbone designs utilised in recognition tasks, a succinct review of benchmark “datasets” and “evaluation criteria” used in detection is also given.
Jiao, Zhang, Liu, Yang, Li, Feng, and Qu., 2019.	“A survey of deep learning-based object detection. IEEE access.”	The researchers describe the benchmark datasets first, then analyse the typical detection models that are currently in use. After that, and in the main, give a thorough, systematic overview of several object detection techniques, covering the one-stage and two-stage detectors.
Patil, Raut, Pande, Yeruva, and Morwani., 2022.	“An efficient approach for object detection using deep learning. Journal of Pharmaceutical Negative Results.”	The article discusses classic methods for object acknowledgement and draws comparisons and connections between them and deep learning methods for object discovery. It describes the evolution of article recognition algorithms in the context of deep learning and provides an explanation of the common practises used today for article positioning.
Mittal, Singh, and Sharma., 2020.	“Deep learning-based object detection in low-altitude UAV datasets: A survey.	The aim of this, study is to present a thorough analysis of the most current deep learning-based object detection methods and to examine how these algorithms have recently contributed to

	Image and Vision computing.”	low-altitude “UAV datasets”. Low-altitude “UAV datasets” are the main focus of the research because they make up a smaller portion
Wang, Lai, Fu, Shen, Ling, and Yang., 2021.	“Salient object detection in the deep learning era: An in-depth survey. ”	The researchers give a thorough survey encompassing different elements, spanning from algorithm taxonomy to unresolved difficulties, to provide an in-depth knowledge of “deep SOD”. Review “deep SOD methods” in particular from several angles, including as network design, supervision level, and learning paradigm.
Zhang, Song, and Zhang, 2020.	“Deep learning-based object detection improvement for tomato disease.”	This work suggests an enhanced Faster “RCNN” to identify healthy tomato leaves and four diseases, including “powdery mildew”, “blight”, “leaf mould fungus”, and “ToMV”, in order to increase the recognition model accuracy of crop disease leaves and pinpoint infected leaves.
Nobis, Geisslinger, Weber, Betz and Lienkamp., 2019.	“A deep learning-based radar and camera sensor fusion architecture for object detection.”	The researchers present “BlackIn”, a learning approach that concentrates on a particular sensor type and was inspired by Dropout. Then demonstrate that, for two separate datasets, the fusion network outperforms a cutting-edge image-only network.
Hoeser and Kuenzer, 2020.	“Object detection and image segmentation with deep learning on earth observation data: A review-part i: Evolution and recent trends. Remote Sensing.”	The researchers give an overview of the datasets in “EO” as well as a brief history of the most well-known “DL frameworks”. Reduce the gap between theoretical notions from “CV” and their practical implementation in “EO” by talking about effective “DL architectures” on these datasets and commenting on “CV” advancements

		and their influence on upcoming “EO research”.
Zhao, Zheng, Xu, and Wu., 2019.	“Object detection with deep learning: A review. IEEE transactions on neural networks and learning systems.”	In this particular research the researchers suggest different approaches and reach some insightful results. In order to serve as suggestions for future work in both object identification and pertinent neural network-based learning systems, a number of intriguing directions and challenges are offered.

References

Arya, C., Tripathi, A., Singh, P., Diwakar, M., Sharma, K. and Pandey, H., 2021, April. Object detection using deep learning: A review. In Journal of Physics: Conference Series (Vol. 1854, No. 1, p. 012012). IOP Publishing.

Chaudhuri, A., 2021. Hierarchical modified Fast R-CNN for object detection. Informatica, 45(7).

Chidananda, K., Naik, M.G., Mohan, Y., Madhavan, N., Arfan, S.A. and Kativarapu, A., 2023. An efficient novel paradigm for object detection through web camera using deep learning (YOLOv5's object detection model). In E3S Web of Conferences (Vol. 391, p. 01093). EDP Sciences.

Drukker, L., Noble, J.A. and Papageorghiou, A.T., 2020. Introduction to artificial intelligence in ultrasound imaging in obstetrics and gynecology. Ultrasound in Obstetrics & Gynecology, 56(4), pp.498-505.

Hoeser, T. and Kuenzer, C., 2020. Object detection and image segmentation with deep learning on earth observation data: A review-part i: Evolution and recent trends. Remote Sensing, 12(10), p.1667.

Hossain, S. and Lee, D.J., 2019. Deep learning-based real-time multiple-object detection and tracking from aerial imagery via a flying robot with GPU-based embedded devices. Sensors, 19(15), p.3371.

Jiao, L., Zhang, F., Liu, F., Yang, S., Li, L., Feng, Z. and Qu, R., 2019. A survey of deep learning-based object detection. IEEE access, 7, pp.128837-128868.

Kaur, A., Singh, Y., Neeru, N., Kaur, L. and Singh, A., 2022. A survey on deep learning approaches to medical images and a systematic look up into real-time object detection. Archives of Computational Methods in Engineering, pp.1-41.

Kim, J., Huh, J., Park, I., Bak, J., Kim, D. and Lee, S., 2022. Small object detection in infrared images: Learning from imbalanced cross-domain data via domain adaptation. Applied Sciences, 12(21), p.11201.

Kim, N., Kim, K., An, Y.K., Lee, H.J. and Lee, J.J., 2020. Deep learning-based underground object detection for urban road pavement. International Journal of Pavement Engineering, 21(13), pp.1638-1650.

Lee, S., 2020. Deep learning on radar centric 3D object detection. arXiv preprint arXiv:2003.00851.

Li, W., Zheng, T., Yang, Z., Li, M., Sun, C. and Yang, X., 2021. Classification and detection of insects from field images using deep learning for smart pest management: A systematic review. Ecological Informatics, 66, p.101460.

Mendoza, M., Tsvetkov, P.V. and Lewis, M., 2021. Multi-modal global surveillance methodology for predictive and on-demand characterization of localized processes using cube satellite platforms and deep learning techniques. Remote Sensing Applications: Society and Environment, 22, p.100518.

Mittal, P., Singh, R. and Sharma, A., 2020. Deep learning-based object detection in low-altitude UAV datasets: A survey. Image and Vision computing, 104, p.104046.

Murthy, C.B., Hashmi, M.F., Bokde, N.D. and Geem, Z.W., 2020. Investigations of object detection in images/videos using various deep learning techniques and embedded platforms—A comprehensive review. Applied sciences, 10(9), p.3280.

Nobis, F., Geisslinger, M., Weber, M., Betz, J. and Lienkamp, M., 2019, October. A deep learning-based radar and camera sensor fusion architecture for object detection. In 2019 Sensor Data Fusion: Trends, Solutions, Applications (SDF) (pp. 1-7). IEEE.

Obaid, O.I., Mohammed, M.A., Salman, A.O., Mostafa, S.A. and Elngar, A.A., 2022. Comparing the performance of pre-trained deep learning models in object detection and recognition. Journal of Information Technology Management, 14(4), pp.40-56.

Patel, D., 2021. Single shot detector for object detection using an ensemble of deep learning and statistical modelling for robot learning applications (Doctoral dissertation, Laurentian University of Sudbury).

Patil, S.M., Raut, C.M., Pande, A.P., Yeruva, A.R. and Morwani, H., 2022. An efficient approach for object detection using deep learning. Journal of Pharmaceutical Negative Results, pp.563-572.

Terven, J. and Cordova-Esparza, D., 2023. A comprehensive review of YOLO: From YOLOv1 to YOLOv8 and beyond. arXiv preprint arXiv:2304.00501.

Wang, W., Lai, Q., Fu, H., Shen, J., Ling, H. and Yang, R., 2021. Salient object detection in the deep learning era: An in-depth survey. IEEE Transactions on Pattern Analysis and Machine Intelligence, 44(6), pp.3239-3259.

Wang, Y., Wang, C., Zhang, H., Dong, Y. and Wei, S., 2019. A SAR dataset of ship detection for deep learning under complex backgrounds. remote sensing, 11(7), p.765.

Wu, X., Sahoo, D. and Hoi, S.C., 2020. Recent advances in deep learning for object detection. Neurocomputing, 396, pp.39-64.

Zaidi, S.S.A., Ansari, M.S., Aslam, A., Kanwal, N., Asghar, M. and Lee, B., 2022. A survey of modern deep learning based object detection models. Digital Signal Processing, 126, p.103514.

Zhang, Y., Song, C. and Zhang, D., 2020. Deep learning-based object detection improvement for tomato disease. IEEE access, 8, pp.56607-56614.

Zhao, Z.Q., Zheng, P., Xu, S.T. and Wu, X., 2019. Object detection with deep learning: A review. IEEE transactions on neural networks and learning systems, 30(11), pp.3212-3232.

Zhu, C., Chen, F., Ahmed, U., Shen, Z. and Savvides, M., 2021. Semantic relation reasoning for shot-stable few-shot object detection. In Proceedings of the IEEE/CVF conference on computer vision and pattern recognition (pp. 8782-8791).