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Deep Learning for Overlapping Objects Detection with Noise: A Bibliometric Analysis

Pembelajaran Mendalam untuk Pengesanan Objek Bertindih dengan Kebisingan: Analisis Bibliometrik

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ABSTRACT

This study conducts a bibliometric analysis to investigate the utilization of deep learning for detecting overlapping objects in noisy environments. Despite the advancements in deep learning, accurately detecting overlapping objects amidst noise remains a significant challenge. Relevant publications were identified using the Scopus database, and Scopus and VOSviewer were utilized for analysis. The results reveal a notable increase in research interest in this area within these past few years, highlighting the significance of the topic. Key themes identified include novel network architectures, data augmentation techniques, and evaluation metrics. However, challenges such as robustness to noise and real-time performance persist. Collaborations among researchers and institutions are observed, emphasizing the interdisciplinary nature of the research field. The results of this study provide important insights for future research areas and solutions in recognizing overlapping objects with noise. Addressing the problems discussed above necessitates continued multidisciplinary research and the creation of more robust and productive deep learning systems. By leveraging the insights from this study, researchers can contribute to advancements in overlapping objects detection, leading to improved performance and applicability in various domains, including medical imaging, surveillance systems, and autonomous driving.

Keywords**:** deep learning, object, overlapping, noise, detection, bibliometric analysis

ABSTRAK

Kajian ini menjalankan analisis bibliometrik untuk menyiasat penggunaan pembelajaran mendalam untuk mengesan objek bertindih dalam persekitaran yang bising. Walaupun terdapat kemajuan dalam pembelajaran mendalam, pengesanan objek bertindih dengan tepat dalam keadaan bising kekal sebagai cabaran yang ketara. Penerbitan yang berkaitan telah dikenal

pasti menggunakan pangkalan data Scopus. Scopus dan VOSviewer digunakan untuk analisis data tersebut. Keputusan mendedahkan peningkatan ketara terhadap minat penyelidikan dalam bidang ini sejak beberapa tahun yang lepas hingga sekarang, menunjukkan kepentingan topik tersebut. Tema utama yang dikenal pasti termasuk seni bina rangkaian baru, teknik pembesaran data dan metrik penilaian. Walau bagaimanapun, cabaran seperti kekuatan terhadap kebisingan dalam gambar dan prestasi masa nyata yang berterusan. Kerjasama antara penyelidik dan institusi diperhatikan, menekankan sifat antara disiplin bidang penyelidikan. Hasil kajian ini memberikan pandangan penting untuk bidang penyelidikan masa depan dan penyelesaian dalam mengenali objek yang bertindih dengan bunyi bising. Menangani masalah yang dibincangkan di atas memerlukan penyelidikan pelbagai disiplin yang berterusan dan penciptaan sistem pembelajaran mendalam yang lebih mantap dan produktif. Dengan memanfaatkan cerapan daripada kajian ini, penyelidik boleh menyumbang kepada kemajuan dalam pengesanan objek yang bertindih, yang membawa kepada prestasi dan kebolehgunaan yang lebih baik dalam pelbagai domain, termasuk pengimejan perubatan, sistem pengawasan dan pemanduan autonomi.

Kata kunci**:** pembelajaran mendalam, objek, bertindih, kebisingan, pengesanan, analisis bibliometrik

INTRODUCTION

Research on detecting and distinguishing overlapping objects in images has evolved significantly, particularly with the advent of deep learning techniques. This field addresses challenges in various applications, including medical imaging, surveillance, autonomous driving, and industrial inspection, where traditional image processing methods often fall short. Early advancements leveraged neural networks for improved object recognitions and segmentations, specifically convolutional neural networks (CNNs). However, the complexities introduced by overlapping objects and the presence of noise continue to present significant hurdles (Miró-Nicolau et al. 2023; Upschulte et al. 2022; Abeyrathna et al. 2022; Lo, Chiu, and Yang 2022). Despite recent strides, the field continues to grapple with issues like the computational demands of high-resolution prediction heads, the effectiveness of noise-aware training objectives, and the quality and size limitations of training datasets. Deep learning has shown promise in recent years in addressing these challenges, yet a comprehensive understanding of the research landscape, including trends, key contributors, and collaborative efforts, remains limited. Thus, this study intends to fill this void by undertaking a bibliometric analysis of deep learning research in overlapping recognition of objects amidst noise.

This research aims at investigating deep learning approaches geared towards addressing overlapping item recognition problems in noisy environments. Delving into the state-of-the-art methodologies, this discussion covers both foundational principles and recent advancements that have significantly advanced the field. The integration of innovative architectural designs, training methodologies, and data augmentation approaches targeted at improving the resilience and accuracy of models for object recognition in the context of overlapping occurrences and noise (Jahangir et al. 2023; Yamaguchi et al. 2023). Furthermore, various strategies are

explored for mitigating the adverse effects of noise on object detection performance, including noise-aware training objectives, data augmentation techniques, and robust optimization strategies (X. Y. Kong, Liu, and Qian 2021; Qin et al. 2023). The study seeks to provide a thorough analysis of previous research on deep learning for object detection, assessing its impact and effectiveness through rigorous bibliometric methods.

Utilizing bibliometric techniques, this study explores the research field's structure, identifies prominent authors and institutions, and maps co-authorship networks. Examination of publication and citation data aims to reveal research trends, document types, and collaboration patterns. Additionally, the analysis explores prevalent terms and themes in the literature, offering insights into research focal points. Through systematic evaluation of existing literature on deep learning for overlapping object detection in noisy environments, this study generates knowledge maps and highlights the current state of research. These insights aim to guide future investigations and foster robust solutions in this challenging area of object detection.

LITERATURE REVIEW

The challenges posed by complex visual environments are addressed in the literature review. A neural network model that improves the biosensors by using a region-based convolutional neural networks for reliable red blood cell recognition, achieving a 99% in training accuracy and 91. 21% of testing accuracy. However, it is constrained by the complexity of the radial gradient index filtering technique for noise reduction (Khan et al. 2024). An improved YOLOv5 algorithm with a C3N module and soft non-maximum suppression (soft-NMS) enhanced fish image detection (Xing et al. 2024), surpasses original YOLOv5 and YOLOv3 in precision and recall, but still contends with sonar image noise and feature information loss. An enhanced YOLO system with a Swin Transformer prediction head gained 45 frames per second in the real-time detection (Bai et al. 2024). Due to high-resolution prediction heads, it suffers from parameter increases. The efficiency of a weakly supervised correction method that was used for the X-ray supervision is dependent on the quality of the weakly supervised head and adaptive label corrector modules. The method increased average precision by 3. 3% and 4. 5%, and improved label reliability and detection performance in ambiguous scenarios (W. Wang et al. 2024). For hidden object recognition in MIMO-SAR pictures, a high-resolution of feature recursive alignment fusion network (HR-FRAFnet) showed improved segmentation accuracy and fewer missed detections. Nevertheless, it has difficulties controlling foreground-background imbalances and computational complexity (B. Su and Yuan 2023).

Despite the inherent difficulties of speckle noise and complex backgrounds, one study proposed a multitask learning framework (MLDet) to detect ship using SAR images. This framework included tasks like target segmentation and speckle suppression, and it demonstrated superior performance on SAR ship detection datasets (Zhao, Zhang, and Kaup 2023). Another strategy, called PVT-SAR, used a pyramid vision transformer to represent multiscale features in SAR pictures. This method outperformed CNN-based techniques by capturing global dependencies and managing targets that were densely organised (Zhou et al. 2023). Using deep learning models and specialised algorithms to manage overlapping noise,

an object detection approach was created for ship safety planning that automates the extraction of item positions and information, obtaining an average recall of 0.85 (M.-C. Kong et al. 2022). In the realm of marine debris detection, a Faster-RCNN with ResNet-50 architecture and transfer learning was utilized to classify debris types in sonar images, achieving a recall of 96%, though it faced challenges related to data scarcity (Aleem et al. 2022). A previous study also proposed a novel Bi-Threshold Constrained Adaptive Scale (BTCAS) detector was introduced for medical imaging to detect small blobs, outperforming existing methods in precision and recall on various 3D datasets by addressing issues of low resolution and overlap (Xu et al. 2021).

In the study of automated herbarium leaf extraction, a pipeline using DeepLabv3+, connected component analysis, and a binary image classifier achieved high F1-scores of 96% and 93% on in-house and public datasets, respectively, demonstrating superior performance over Faster R-CNN and YOLOv5, although the approach's complexity might limit its broader application (Hussein et al. 2021). The CRNet model, trained on a new Bone Marrow Aspirate Smear Image Dataset, showed detection precision greater than 83% and cell classification precision greater than 95% for haematological disorder diagnosis, demonstrating its robustness against noise and cell overlap. However, its limited dataset size may limit its generalizability (J. Su, Han, and Song 2021). A DNN for bird audio recognition called BirdNET displayed resilience in noisy situations and obtained 0.791 mean average precision on single-species recordings. However, its performance on complex soundscapes was lower, suggesting difficulties in a variety of real-world scenarios (Kahl et al. 2021). On the CBIS-DDSM and INBREAST datasets, a DS U-Net in conjunction with dense CRFs for mass mammography produced dice scores of 82.9% and 79%, respectively, demonstrating enhanced boundary identification, albeit false positives are still a problem (Ravitha Rajalakshmi et al. 2021). Lastly, a faster R-CNN model fine-tuned for infrared and visible sensor images from captive balloons reached accuracies of 87.1% and 86.1%, effectively detecting objects in various conditions, but manual dataset creation and the need for pretrained networks present scalability challenges (Velame, Bins, and Mura 2020).

In conclusion, the reviewed literature highlights significant progress in deep learning methodologies for detecting overlapping objects in noisy environments across various applications. These studies demonstrate that advanced neural networks, including RCNNs, YOLO variants, and transformers, effectively enhance detection accuracy and robustness against noise and occlusions. However, each approach also faces specific limitations such as the complexity of pre-processing algorithms, feature information loss, increased computational demands, reliance on label quality, and dataset size constraints. These difficulties show that, even while deep learning continues to show promise in solving challenging detection problems, more innovation and improvement are required to get beyond current obstacles and realise the full potential of these methods in a variety of real-world settings.

RESEARCH OBJECTIVES

The objectives of this study are structured to explore various facets of deep learning for overlapping objects detection with noise. Through a comprehensive bibliometric analysis, this paper aims to achieve the following objectives:

1. Investigate the research trends and documents across different publication years.
2. Identify prolific authors and subject areas contributing to this domain and determine which authors have produced the most cited articles.
3. Map the network of co-authorship relationships among researchers and analyse collaboration patterns across countries based on co-authorship.
4. Identify and analyse the most common terms associated with the study of deep learning for overlapping objects detection with noise.

The goal of this study is to do a thorough bibliometric analysis, examining patterns across publishing years in order to uncover changing interests and approaches, find new subfields, and highlight innovative times. It examines document types to illuminate the evolution of methodologies and interests, identifies prolific authors and institutions to showcase intellectual leadership and collaborative networks, maps co-authorship relationships to visually represent collaborative networks, analyses international collaboration patterns to understand global research contributions, and identifies common research terms to reveal thematic focus and terminology evolution. These analyses aim to provide a holistic understanding of current trends and future directions in deep learning for overlapping objects detection with noise, setting a foundation for future studies in this rapidly evolving field.

METHODOLOGY

The process of gathering, organizing, and evaluating bibliographic information taken from scientific publications is known as bibliometrics (Verbeek et al. 2002; Assyakur and Rosa 2022; Alves, Borges, and De Nadae 2021). Document co-citation analysis is one of the additional methods used alongside conventional descriptive data, such as publishing journals, publication year, and major author categorization (Wu and Wu 2017). A thorough literature review necessitates an iterative process that encompasses keyword discovery, literature search, and meticulous analysis to compile an extensive bibliography and obtain precise results (Fahimnia, Sarkis, and Davarzani 2015). In light of this, the study aimed to focus on high-quality papers that offer in-depth analyses of the theoretical perspectives that have influenced the growth of the research field. In order to guarantee the data trustworthiness, it is important to use Scopus database in data collect (di Stefano, Peteraf, and Veronay 2010; Khiste and Paithankar 2017; Al-Khoury et al. 2022). The Scopus database is a comprehensive database of scientific literature, which is the most widely used database in the world. Furthermore, books and lecture notes were intentionally omitted to ensure the inclusion of top-notch publications. Only articles that had undergone rigorous peer review in reputable academic journals were considered for the study (Gu et al. 2019). The researchers conducting the study were aware of

the treatment allocation. Notably, the Elsevier's Scopus was recognized for its vast coverage, aided in collecting publications from 2020 to July 2024 for further research.

1. Data Search Strategy

In conducting the bibliometric analysis on the topic of deep learning for overlapping objects detection with noise, the initial search strategy focused on capturing relevant literature using a comprehensive search string. The query encompassed a broad set of keywords aimed at covering all aspects of deep learning for overlapping objects detection with noise. However, the specificity of the topic necessitated expanding and refining the search terms to ensure comprehensive coverage of relevant literature. Incorporating multiple synonyms and related terms was essential to enhance the search and capture a broader range of documents on deep learning methodologies for detecting overlapping objects amidst noise.

The search strings included specific terms such as "Deep Learn*" and "neural network" to broadly cover deep learning methodologies, while terms like "overlap*", "intersect*", "instance segment*", and "objects recog*" targeted aspects related to the detection and recognition of overlapping objects. Additionally, keywords such as "noise*", "interference*", and "disturb*" were included to address the challenging aspects of noisy environments. The query also incorporated general terms like "object*" and specific action-related terms such as "detect*", "classif*", "recognit*", and "segment*" to ensure a comprehensive retrieval of research articles focusing on object detection, classification, recognition, and segmentation using deep learning approaches. The study began by querying the single search string from Table 1, which included all the terms, on the Scopus database, resulting in an initial retrieval of 2152 articles. The final search after the criterion selection based on Table 2, yielded 830 items that can be used for bibliometric analysis. As of July 2024, the study covered all Scopus papers on overlapping object detection with noise using deep learning.

TABLE 1. Search string

Scopus	("Deep Learn*" OR "neural network") AND (overlap* OR intersect* OR "instance segment*" OR "objects recog*") AND (noise* OR interference* OR disturb*) AND (object* OR instance*) AND (detect* OR classif* OR recognit* OR segment*)

TABLE 2. Selection criterion

Guideline	**Inclusion**	**Exclusion**
Timeline	2020-2024	<2023
Language	English	Non-English
Document Type	Article	Non-Article
Source Type	Journal and proceeding	Book, Review
Publication Stage	Final	In-press

2. Data Analysis

The VOSviewer program, developed by van Eck and Waltman of Leiden University in the Netherlands (van Eck and Waltman 2017, 2010), is a user-friendly bibliometrics application. One of the most prominent text analysis and visualisation tool for scientific literature, is used to create user-friendly network visualisations. Their strength is in grouping similar items together and creating density maps which provide to researchers a much more detailed overview on the topic they selected. While the flexibility it affords makes possible a number of network analyses, such as co-authoring or co-citation and keyword co-occurrence networks, aimed at illuminating the research environments in which researchers operate. VOSviewer is able to handle large datasets in an efficient and dynamic way through its interactive interface, which can be quickly adapted for exploration purposes thanks also to regular updates. Moreover, its capacity to compute metrics, tailor visualizations, and seamlessly integrate with diverse bibliometric data sources renders it an indispensable asset for scholars navigating intricate research domains.

By rendering intricate bibliometric data into easy-to-own maps and charts that are easily understood even by a novice, VOSviewer has created an edge for itself. With a forte in network visualization, it remains adept at clustering similar objects together, looking for clusters of keyword co-occurrence and creating density maps. An easy to use interface for both newbies and pros saves time navigating research landscapes in a timely manner! With substantial updates over time VOSviewer maintains its status among top bibliometric tools that allow calculation of metrics and are able to produce impressive visualizations. The flexibility of this tool to perform different types e.g. co-authorship, citation network constructed from bibliometric data contribute to making it an indispensable instrument in the hands of academicians who are chasing deeper comprehension and insights within their respective areas.

The publication year, title, author name, journal, citation, and plaintext keywords of records from the scopus database spanning from 2020 to July 2024 were obtained. Version 1.6.19 of the vosviewer program was utilized to analyze these datasets. The program facilitated the creation and analysis of maps by utilize the vos clustering and mapping techniques. Vosviewer specializes in organizing objects in two-dimensional spaces, unlike the multidimensional scaling (mds) method. Their connection and likeliness are guaranteed reflects by any two item's closeness accurately (van Eck and Waltman 2010). VOSViewer, akin to the MDS technique (Appio, Cesaroni, and Di Minin 2014), differs in its approach to normalising co-occurrence frequencies by employing the association strength (AS_{ij}), which is calculated as follows (Van Eck and Waltman 2007):

$$AS_{ij} = \frac{C_{ij}}{W_i W_j} \quad (1)$$

The observed and expected co-occurrences of components i and j show a strong correlation with the index used by VOSviewer to organize items on the map. This index assesses the relationship between these occurrences by considering proportionality, as it

reflects the ratio of the actual number of i and j co-occurrences to the expected number of such co-occurrences assuming that i and j occur independently. By utilizing this index, VOSviewer is capable of reducing the weighted sum of squared distances between feature pairs, resulting in a more user-friendly map.

RESULT AND FINDING

1. Total publication based 5 years of range

From 2020 to 2023, the field of deep learning for overlapping objects detection with noise has seen substantial growth in scholarly publications, indicating its rising importance and popularity among researchers. From 74 documents in 2020 to 252 documents by 2023, there was a strong compound annual growth rate (CAGR) of almost 35%. This upward trend underscores heightened interest and investment in advancing techniques for detecting overlapping objects in noisy environments. Key drivers include advances in deep learning methodologies, particularly in neural networks tailored for complex scenarios (Song, He, and Liu 2021). Moreover, the availability of large-scale datasets and improved computational resources has facilitated exploration of more sophisticated algorithms and models (T. Li, Johansen, and McCabe 2022). The broad applicability of these advancements, spanning autonomous systems, medical imaging, and environmental monitoring, further highlights the field's impact and relevance.

The publication pattern reveals distinct annual fluctuations, with peaks observed in 2023 (252 documents) and a promising start in 2024 with 185 documents (22.29% of the total), despite being only at the mid-year mark. This suggests potential to surpass the 2023 total by year-end, indicative of periods of intensified research activity and breakthroughs. These fluctuations likely correspond to advancements in deep learning techniques, increased dataset availability, and enhanced computational capabilities. The cumulative impact of these publications underscores the field's growing significance across diverse domains such as computer vision and environmental monitoring. This growth reflects the increasing relevance of deep learning in addressing complex challenges and sets the stage for ongoing innovation and practical application in real-world scenarios involving overlapping and noisy objects detection.

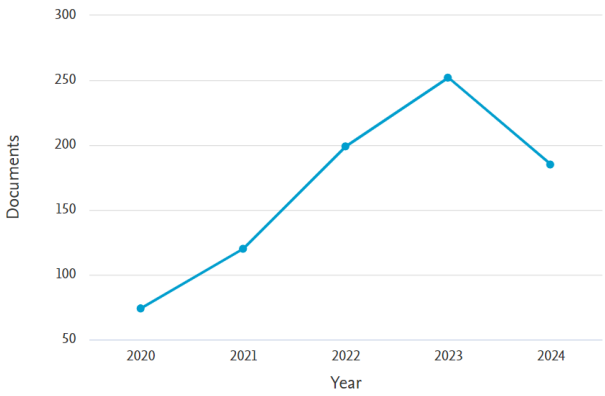

FIGURE 1. Plotting document publication by years

2. Publication made by each author based on the topic

The analysis of publications by authors reveals several notable patterns and contributions. Among the most prolific authors, Chen, T., Han, J., and Hu, X. emerge as leading contributors with 4 documents each, representing 0.48% of the total 830 documents analysed. This indicates a consistent and significant research output, underscoring their expertise and active engagement in advancing the field. Following closely, Fu, Q., Hu, A., Jiao, L., Karim, H.A., Lema, D.G., Li, Y., Ma, W., Meng, F., Miao, J., Miao, Q., Pedrayes, O.D., Usamentiaga, R., Wang, S., Xiao, J., Yang, H., Zhang, G., and Zhang, L. each contributed 3 documents, reflecting a robust research interest and diverse contributions to the domain.

This distribution indicates a diverse and engaged research community actively contributing to advancements in deep learning techniques for addressing the challenges of overlapping objects detection in noisy environments. The impact of these publications over the 5-year period is evident in the cumulative knowledge base they establish, influencing both theoretical developments and practical applications. By refining algorithms and methodologies, these authors collectively contribute to advancing the state-of-the-art in computer vision, enhancing the accuracy and reliability of detection systems in complex scenarios (T. Chen et al. 2022; L. Li et al. 2022; Kou et al. 2023; Hu et al. 2020). Their ongoing research efforts not only expand the scientific understanding of the field but also pave the way for innovations that can potentially transform various industries reliant on robust visual recognition technologies.

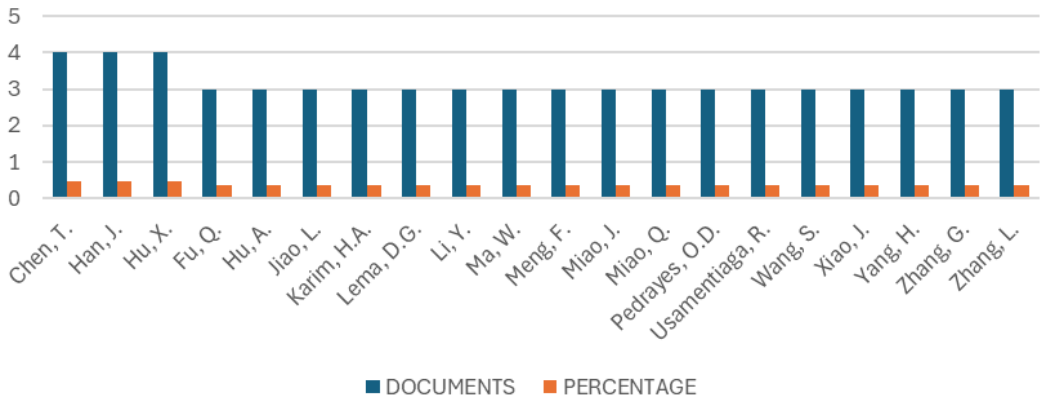

FIGURE 2. Plotting document publication by authors

3. Document published based on the subject area

In the realm of deep learning for overlapping objects detection with noise, the analysis of publications across various subject areas reveals a dominant presence in Engineering and Computer Science disciplines, comprising 27.84% and 27.49% of the total documents respectively. These fields demonstrate a robust engagement, likely driven by their foundational role in developing and applying computational methods for image processing and pattern recognition (L. Chen et al. 2022; Yeh et al. 2022). This pattern underscores their pivotal contribution to advancing techniques in handling complex visual data, particularly in scenarios

involving overlapping objects and noisy backgrounds. Additionally, disciplines such as Earth and Planetary Sciences (9.34%) and Physics and Astronomy (7.38%) also exhibit significant contributions. These domains likely explore applications of deep learning models in remote sensing, astronomical image analysis, and environmental monitoring, where precise object detection amidst complex environmental conditions is crucial (Y. Wang et al. 2022; Liang et al. 2023; Ye et al. 2023). The consistent presence in Materials Science (5.65%) and Mathematics (4.38%) further highlights interdisciplinary efforts, focusing on algorithmic developments and material characterization techniques enhanced by deep learning frameworks.

The impact of these publications extends beyond academic and industrial domains, shaping the landscape of deep learning applications in nuanced ways. By advancing object detection accuracy amidst challenging conditions like overlapping objects and noise, these studies not only enhance the capabilities of autonomous systems and medical imaging but also contribute significantly to environmental monitoring and remote sensing technologies. The interdisciplinary collaborations fostered by these publications not only enrich theoretical frameworks but also propel practical applications, ensuring that innovations in deep learning continue to drive transformative changes across scientific disciplines and technological sectors alike. As these trends evolve, the integration of robust computational methods with domain-specific knowledge promises to unlock new potentials, further solidifying deep learning's role as a cornerstone of modern scientific and technological advancement.

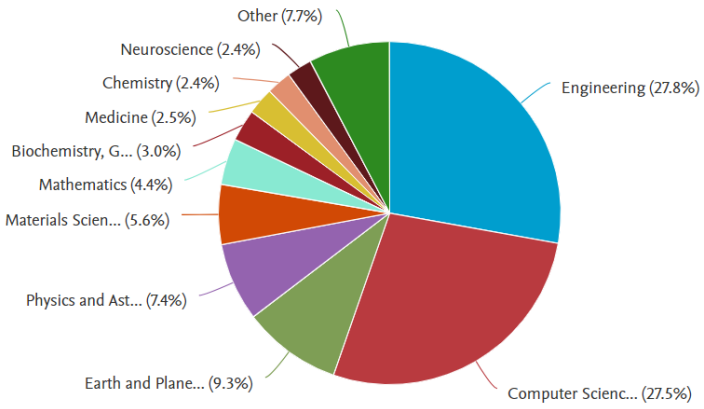

FIGURE 3. Pie chart of document publication by subject area

4. Total citation by top 10 documents

The top 10 documents in terms of citation counts demonstrate significant contributions in a variety of artificial intelligence (AI) fields. Tao et al. 2020 work on detecting power line insulator defects using CNNs, cited 441 times, illustrates significant advancements in infrastructure maintenance through AI-driven image analysis. Comparably, applications in ecological informatics and remote sensing are highlighted by Kahl et al. 2021 with their BirdNET for avian diversity monitoring (237 citations) and Cheng et al. 2022 with their Anchor-Free Oriented Proposal Generator (166 citations) for object detection. These papers

exemplify how deep learning techniques are enhancing capabilities in environmental monitoring and infrastructure management.

In addition, S. Li et al. 2021 YOLO-FIRI (129 citations) for infrared image object detection and Ma et al. 2020 improved YOLOv3 (115 citations) for post-earthquake building detection underscore the practical applications of AI in challenging environments. Furthermore, Tassis, Tozzi de Souza, and Krohling 2021 work on identifying coffee leaf diseases (105 citations) and Xia et al. 2023 automated driving systems platform (101 citations) demonstrate AI's contributions to precision agriculture and autonomous vehicle technologies. These studies collectively highlight the transformative impact of AI and deep learning across various disciplines, from healthcare and agriculture to transportation and environmental monitoring, driving innovation and efficiency in research and industry.

The diversity of applications showcased by these top-cited papers underscores the widespread adoption and impactful contributions of AI and deep learning methodologies. Their citations reflect not only their academic significance but also their practical implications in solving real-world challenges, advancing fields ranging from healthcare diagnostics to ecological conservation and infrastructure management. As these technologies continue to evolve, their integration into everyday practices promises further advancements and efficiencies across multiple domains, shaping the future landscape of AI-driven innovation and research.

TABLE 3. Top 10 documents based on total citation by research

Authors	Title	Year	Source title	Cited by
Tao X., Zhang D., Wang Z., Liu X., Zhang H., Xu D. (Tao et al. 2020)	Detection of power line insulator defects using aerial images analyzed with convolutional neural networks	2020	IEEE Transactions on Systems, Man, and Cybernetics: Systems	441
Kahl S., Wood C.M., Eibl M., Klinck H. (Kahl et al. 2021)	BirdNET: A deep learning solution for avian diversity monitoring	2021	Ecological Informatics	237
Cheng G., Wang J., Li K., Xie X., Lang C., Yao Y., Han J. (Cheng et al. 2022)	Anchor-Free Oriented Proposal Generator for Object Detection	2022	IEEE Transactions on Geoscience and Remote Sensing	166
Li S., Li Y., Li Y., Li M., Xu X. (S. Li et al. 2021)	YOLO-FIRI: Improved YOLOv5 for Infrared Image Object Detection	2021	IEEE Access	129
Ma H., Liu Y., Ren Y., Yu J.(Ma et al. 2020)	Detection of collapsed buildings in post-earthquake remote sensing images based on the improved YOLOv3	2020	Remote Sensing	115
Tassis L.M., Tozzi de Souza J.E., Krohling R.A. (Tassis, Tozzi de Souza, and Krohling 2021)	A deep learning approach combining instance and semantic segmentation to identify diseases and pests of coffee leaves from in-field images	2021	Computers and Electronics in Agriculture	105

Xia X., Meng Z., Han X., Li H., Tsukiji T., Xu R., Zheng Z., Ma J. (Xia et al. 2023)	An automated driving systems data acquisition and analytics platform	2023	Transportation Research Part C: Emerging Technologies	101
Chen X., Qi L., Yang Y., Luo Q., Postolache O., Tang J., Wu H. (X. Chen et al. 2020)	Video-Based Detection Infrastructure Enhancement for Automated Ship Recognition and Behavior Analysis	2020	Journal of Advanced Transportation	101
Lu X., Ji J., Xing Z., Miao Q. (Lu et al. 2021)	Attention and feature fusion SSD for remote sensing object detection	2021	IEEE Transactions on Instrumentation and Measurement	98
Liu Z., Yang C., Huang J., Liu S., Zhuo Y., Lu X. (Liu et al. 2021)	Deep learning framework based on integration of S-Mask R-CNN and Inception-v3 for ultrasound image-aided diagnosis of prostate cancer	2021	Future Generation Computer Systems	97

5. Authors bibliography coupling

Bibliography coupling analysis among authors provides detailed insights into collaborative dynamics and the influence of key researchers. For instance, authors like Tianyou Chen and Xiaoguang Hu demonstrate significant total link strength, indicating they frequently cite shared references across their publications. This suggests a concentrated research focus on refining deep learning methodologies specifically tailored to address challenges in object detection amidst noise. Their consistent collaboration through shared citations not only underscores their alignment in research interests but also highlights their potential influence in shaping methodologies and theoretical frameworks within the field. Similarly, Rui Zhang's high total link strength across documents suggests a robust engagement in collaborative efforts, contributing to advancements in overcoming complexities related to overlapping objects in visual data analysis.

Conversely, authors such as Junwei Han and Lei Wang exhibit high citation counts but lower total link strength. This pattern suggests that while their individual contributions are widely cited within the field, their research may influence a broader spectrum of researchers without necessarily forming tightly knit collaborative clusters. Han and Wang likely play influential roles in shaping the broader research landscape by introducing innovative approaches or theoretical perspectives that resonate across multiple research groups. This dissemination of ideas contributes to the diversification and enrichment of methodologies applied in deep learning for object detection, highlighting their impact beyond direct collaboration networks.

Moreover, the clustering of authors like Wei Wang and Jing Zhang, who exhibit moderate to high link strengths across multiple documents, illuminates robust collaborative networks within the research community. These authors likely engage in frequent knowledge exchange, sharing methodologies and insights that collectively advance the field's understanding and capabilities in addressing challenges such as noise and overlapping objects. Such collaborative

networks are essential for driving innovation, fostering interdisciplinary approaches, and accelerating progress towards more effective and reliable deep learning solutions in practical applications. By identifying and understanding these collaborative patterns, researchers can strategically leverage shared expertise and resources to tackle complex research questions and further enhance the applicability of deep learning techniques in real-world scenarios.

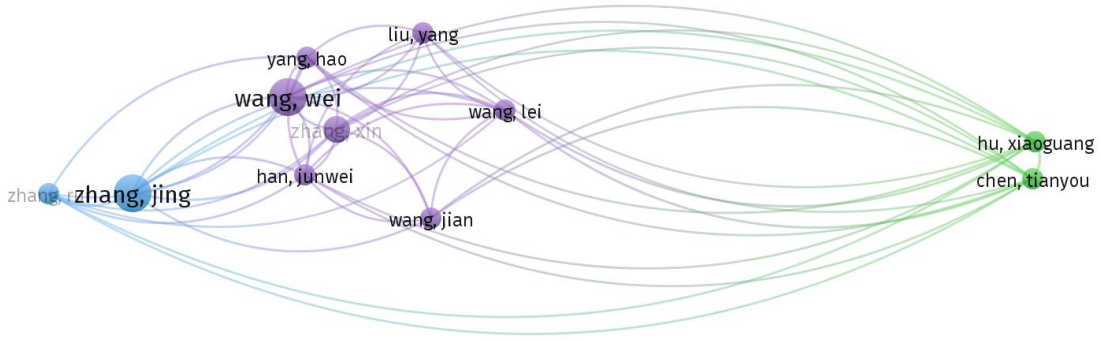

FIGURE 4. Bibliography coupling analysis based on authors

6. Popular Keywords on the topic

The analysis of keyword co-occurrence in research focused on deep learning for overlapping objects detection with noise reveals pivotal trends and impacts within the field. Central to these findings is the prevalence of "convolutional neural networks" (CNNs), which appear 371 times across the dataset. This dominance underscores CNNs' critical role in addressing the complexities of detecting overlapping objects in noisy environments, highlighting their robustness in feature extraction and classification tasks. Concurrently, keywords such as "object detection" and "object recognition," with a collective occurrence of 1133 instances, underscore the field's emphasis on enhancing accuracy and reliability in identifying objects amidst clutter and noise. This focus indicates a shift towards more sophisticated techniques capable of handling real-world challenges, such as autonomous driving and surveillance applications.

Moreover, the prominence of "deep learning" (501 occurrences) and "deep neural networks" (95 occurrences) underscores ongoing advancements in leveraging deep architectures for complex visual data analysis. This trend reflects a concerted effort to push the boundaries of detection performance through deeper and more intricate network designs. Additionally, the co-occurrence of "feature extraction" (155 instances) and "convolution" (186 instances) highlights ongoing research into optimizing these fundamental processes within convolutional frameworks. This pursuit aims to refine object localization and classification capabilities, thereby enhancing overall system performance in practical deployment scenarios.

In essence, a thorough examination of keyword co-occurrence not only notes existing research trends but also makes reference to upcoming developments targeted at enhancing the resilience and reliability of deep learning models for detecting overlapping items in noisy settings. These

insights are crucial for guiding future research directions and technological advancements in computer vision and machine learning applications.

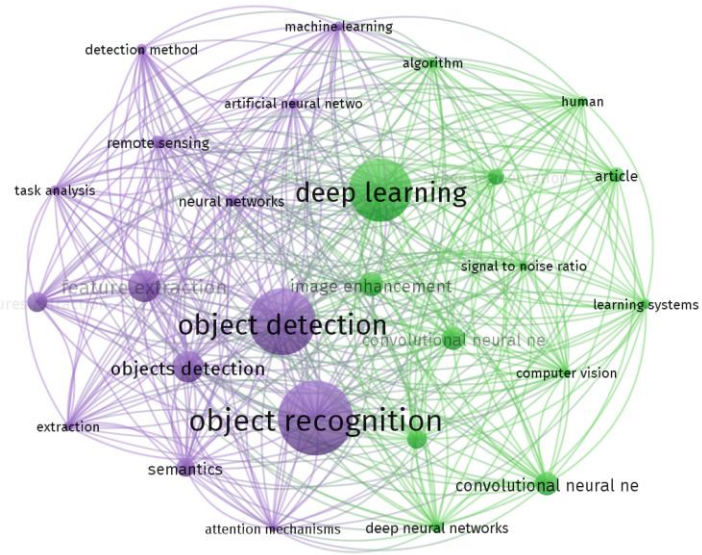

FIGURE 5. Keywords' co-occurrence based on network visualization mapping

7. Co-Authorship countries' collaboration

Co-authorship patterns among countries in research, particularly in the domain of deep learning for overlapping objects detection with noise, reveal compelling insights into global collaboration dynamics. China emerges prominently with a substantial number of 548 documents and 6127 citations, indicative of its significant research output and impact in the field. The strong collaboration networks that China maintains suggest robust partnerships with other research-intensive nations, fostering extensive knowledge exchange and collective advancements in deep learning methodologies for complex object detection scenarios. Significant contributions are also made by the United States and the United Kingdom, each of which has a noteworthy document count and citation effect. Their active engagement in international collaborations signifies their pivotal roles in shaping global research agendas and disseminating cutting-edge techniques for overcoming challenges in noisy data environments. These collaborations not only enhance the quality and scope of research outputs but also facilitate the adoption of advanced deep learning models across different application domains.

Countries like India and South Korea, while demonstrating considerable document outputs, show varying levels of collaboration strength. India's high citation impact relative to its document numbers suggests impactful research outcomes, albeit with opportunities to strengthen international partnerships further. South Korea, with a balanced citation impact, indicates active participation in global research networks, contributing to advancements in overlapping object detection techniques through collaborative efforts with other leading research nations. Overall, the analysis underscores the critical role of international collaboration in advancing research on deep learning for overlapping objects detection with noise. Stronger collaborative links among countries like China, the US, and the UK not only

amplify research impact but also facilitate the development of more robust and versatile deep learning algorithms capable of handling complex real-world scenarios effectively. As these collaborative efforts continue to evolve, they are likely to drive further innovation and application of deep learning techniques in diverse fields ranging from healthcare to autonomous systems.

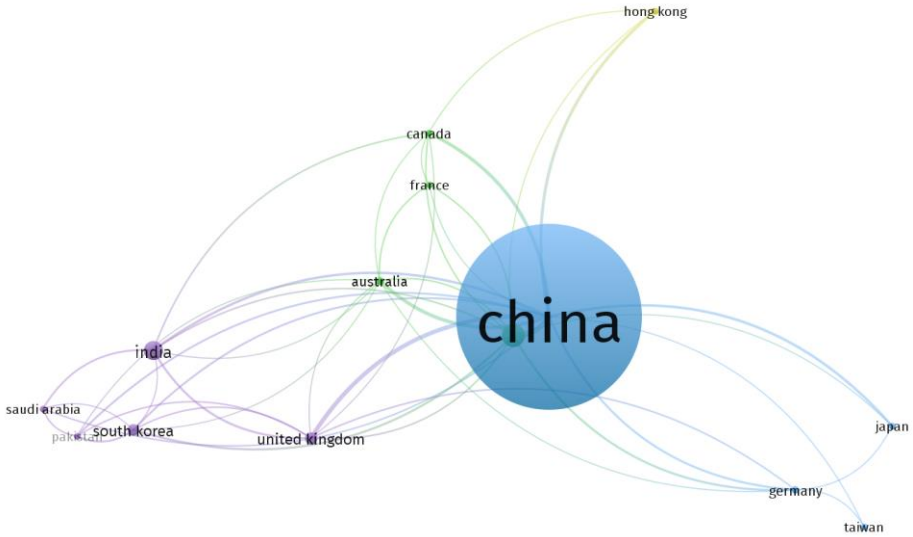

FIGURE 6. The countries whose authors collaborate on object detection using deep learning

DISCUSSION

The substantial surge in publications from 2020 to 2024 underscores a burgeoning interest in deep learning techniques for detecting overlapping objects in noisy environments. This period of heightened research activity reflects significant advancements in computational capabilities and methodologies, highlighting the field's increasing relevance across diverse applications in computer vision and beyond. CNNs, one of the key technologies in deep learning approaches, are responsible for this 35% increase in the compound annual growth rate (CAGR). CNNs are essential for handling challenging image identification problems. Key figures such as Chen, T., Han, J., and Hu, X. have emerged as pivotal contributors, advancing critical algorithms that underpin both theoretical insights and practical applications in visual recognition. Their collaborative efforts are evidenced by robust co-authorship networks and frequent citation of shared references, illustrating a concerted push towards refining noise-resistant object detection methodologies through deep learning. For example, Chen and Hu’s work collectively has a total link strength of 352, indicating significant shared influence. This collaborative spirit extends globally, enhancing research impact and fostering cross-border knowledge exchange. The interdisciplinary engagements spanning Engineering, Computer Science, Earth and Planetary Sciences, Physics, Materials Science, and Mathematics underscore the field's broad impact in advancing computational methods and improving algorithmic precision for various scientific applications.

However, the rapid increase in publications highlights several limitations that need to be addressed to ensure sustainable progress. The growth risks fragmenting research efforts and

prioritizing quantity over quality and practical applicability. Variability in experimental setups and evaluation metrics across studies complicates comparisons and hinders the establishment of standardized benchmarks for model performance. Moreover, while collaborative networks among authors and countries are evident, there are concerns about inclusivity and diversity within the research community. Dominance by certain regions or institutions may exclude valuable perspectives and hinder innovation in addressing challenges specific to noisy environments and overlapping object detection. Additionally, the field's heavy reliance on CNNs and deep learning methodologies may limit exploration of alternative approaches, such as transformer-based models or hybrid systems, which could enhance detection system robustness and adaptability across diverse applications.

This study comprehensively analyses research trends and document types across different publication years, revealing the evolving landscape of deep learning for overlapping objects detection with noise. By identifying influential authors and institutions and analysing their contributions and affiliations, this research identifies key figures driving advancements in this domain and elucidates the most impactful articles shaping current discourse. Mapping the intricate network of co-authorship relationships among researchers and institutions reveals collaborative patterns across countries, uncovering synergistic partnerships crucial for advancing deep learning methodologies in complex visual recognition scenarios. Furthermore, this research identifies key topics and technical trends influencing the creation of reliable algorithms for object recognition in noisy settings by examining frequently used phrases related to the field. Addressing the identified limitations, such as establishing standardized benchmarks and fostering inclusive research practices, will not only foster more innovative research but also ensure the continued progress and applicability of deep learning solutions in real-world settings.

CONCLUSION FUTURE WORK

In summary, the bibliometric study of publications related to deep learning for noise-affected overlapping object recognition offers important new perspectives on the dynamic character of academic research. The results highlight the necessity of ongoing assessment and adjustment within the research community to traverse changing trends and obstacles and advance deep learning successfully. A combination of teamwork and individual contributions can be seen in the authors' distribution of publications, demonstrating the wide spectrum of researchers developing deep learning techniques. This diversity not only enriches the field but also encourages interdisciplinary collaboration, essential for tackling complex problems in object detection. Moreover, the analysis reveals several key trends that are pivotal for shaping future research directions. Collaborative networks among authors and institutions demonstrate the synergistic benefits of teamwork in achieving impactful research outcomes. Future studies could further explore how different types of collaborations influence research productivity and innovation.

The identification of popular keywords reflects ongoing interests and advancements in deep learning architectures applied to object detection tasks. Future research could delve deeper into

emerging technologies and methodologies, such as hybrid models combining deep learning with other AI techniques or novel approaches to handle noisy data environments. Patterns of international collaboration highlight global contributions to deep learning research, with opportunities for enhancing cross-cultural knowledge exchange and leveraging diverse expertise. Future efforts may focus on fostering more inclusive collaborations and addressing disparities in research impact across regions. Furthermore, the analysis identifies areas for improvement, such as enhancing research quality in specific geographical regions or underrepresented disciplines within deep learning. This suggests opportunities for targeted strategies and increased collaboration to elevate the visibility and impact of research efforts in these areas. Overall, this study underscores the evolving landscape of deep learning research and emphasizes the need for ongoing monitoring and adaptation to effectively navigate fluctuations and drive advancements in object detection applications. By leveraging these insights, future research can build upon current findings to foster collaboration, innovate methodologies, and address emerging challenges in deep learning for overlapping objects detection with noise.

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