A Review on Augmented Reality and YOLO

Dr. M. Uma[1]
Department of computational intelligence,
SRM institute of science and technology,
Kattankulathur, India
Umam@srmist.edu.in

S. Abirami[2]
Assistant professor/CSE,
Sri Shanmugha college of engineering and technology,
Sankari, India
abirami.s@shanmugha.edu.in

M. Ambika[3]
Assistant Professor/CSE
J.J College of Engineering and Technology,
Trichy, India
muki.ambika@gmail.com

Dr. M. Kavitha[4]
Assistant Professor/CSE
Sri Krishna Collage of Engineering and Technology,
Coimbatore, India
kavitham@skcet.ac.in

S Sureshkumar[5]
Assistant Professor/CSE
J.J College of Engineering and Technology,
Trichy, India
sureshkumarcse2022@gmail.com

Kaviyaraj R[6,*]
Department of computational intelligence,
SRM institute of science and technology,
Kattankulathur, India
Kaviyaraj.r@gmail.com

2023 4th International Conference on Smart Electronics and Communication (ICOSEC) | 979-8-3503-0088-8/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICOSEC58147.2023.10275842

***Abstract*—This study comprehensively examines two emerging technologies, Augmented Reality(AR) and You Only Look Once (YOLO): these two technologies revolutionized object detection and computer vision. YOLO instantly identifies objects in images and videos, whereas AR superimposes virtual objects in the real world. This review integrates AR and YOLO and covers the aspects of each, its applications, drawbacks, and future directions. Also, this article explores the fundamentals of augmented reality and several types of AR systems, including marker-based, marker-less, and projection-based systems. The review explains how YOLO works with single network architecture and real-time detection from YOLOv1 through YOLOv8. Finally, this study summarizes the key takeaways from YOLO's development and offers insights into its future, outlining potential research directions to enhance real-time object detection systems further. Furthermore, the study highlights the potential of integrating YOLO and AR to improve user interactions. It also addresses the challenges associated with integrating AR and YOLO, providing a comprehensive overview of the obstacles that must be overcome.**

Keywords— Augmented Reality, Deep Learning, You Only Look Once, Augmented Reality and YOLO.

I. INTRODUCTION

In recent years, object identification and computer vision fields have been transformed by the development of two groundbreaking technologies: YOLO[1] and AR[2]. YOLO is a real-time object detection system that instantly identifies objects in images and videos. At the same time, AR superimposes virtual objects in the real world, enhancing the user's perception of their environment. The integration of these two technologies has the potential to significantly improve user interactions in various applications.

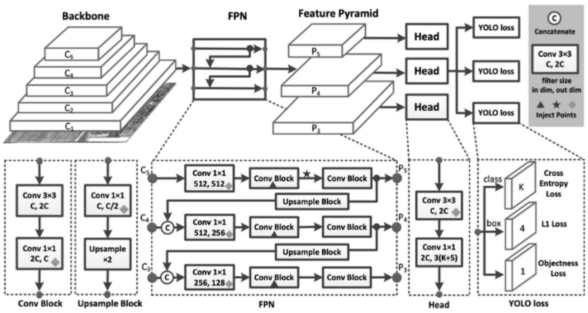

Fig 1: YOLO Architecture

This review paper provides an overview of AR and its applications and an introduction to the YOLO algorithm and its unique characteristics. YOLO is a real-time object detection system that instantly identifies objects in images and videos. The [3] paper explores the benefits and challenges of integrating AR and YOLO and provides insights into potential use cases and future research directions. The integration of AR and YOLO has the potential to improve user interactions in a variety of applications significantly. By combining the ability to superimpose digital information onto the real world with the ability to identify objects quickly and accurately in real time, these technologies can provide users with a more immersive and interactive experience. [4]However, there are also challenges associated with integrating these technologies, such as ensuring compatibility between different systems and addressing issues related to data privacy and security.

A. Overview of Augmented Reality

With the help of augmented reality[5], which seamlessly combines virtual and real-world content, users may better perceive their surroundings. It[6] adds more information, context, and immersive experiences by superimposing digital data onto the physical environment. Camera-equipped devices with AR software, such as smartphones, tablets, or smart glasses, make AR possible. The inbuilt computer vision technology scans the video stream when users aim their smartphones at things to identify them. In order to overcome the constraints of conventional 2D screens, the programme then gets pertinent information about the objects from the cloud. It presents a fascinating 3D "experience[7]" directly superimposed on the objects. Hardware, software, and tracking technologies have made tremendous improvements in AR, allowing users to easily interact with virtual objects, visuals, and information in their real-world environment. AR improves human perception and interaction by fusing the digital and real worlds, creating new opportunities across numerous industries. AR has revolutionized various industries, from gaming and entertainment to education, healthcare, architecture, and marketing[8]. AR keeps pushing the limits of innovation with its ongoing evolution. Real-time and accurate object recognition in augmented worlds is made possible by integrating cutting-edge object detection techniques like YOLO into AR. The potential for AR-based gaming, commercial applications, medical imaging, retail experiences, and other uses is expanded by this integration. The combination of AR and YOLO provides the way for improvements in computer vision, object identification, and real-world interactions, further enhancing the capabilities of augmented reality by addressing problems and examining prospects for future study.

B. Introduction to YOLO

The object identification technique YOLO has completely changed computer vision. Setting a new benchmark in the industry(Fig 1), it is intended to perform real-time object detection in photos and videos. YOLO has a unified architecture that simultaneously predicts bounding boxes and class probabilities, unlike conventional techniques that rely on multiple stages. YOLO can achieve impressive detection speed while retaining high accuracy because of its distinctive technique. YOLO has gained popularity and widespread adoption because of its effectiveness, simplicity, and capacity for handling real-time circumstances.

With the help of its deep learning algorithms, YOLO has established a reputation for having remarkable accuracy and quick processing times. Self-driving cars[9], security systems, and robotics are just a few industries where it has found use. Thanks to YOLO's adaptability in object detection in real-time circumstances, advanced computer vision systems can now be implemented in various ways[10]. An overview of YOLO, its importance in object detection, and its useful applications are intended to be provided at the beginning of this review paper. Researchers and professionals can investigate the possibilities of YOLO in resolving problems in the real world and enhancing computer vision technologies by comprehending its advantages and capabilities.

C. Objectives of the Paper

This comprehensive review study addresses AR[11] and YOLO object detection technology integration. This study examines AR and YOLO's ideas, algorithms, and applications to show how they improve user interactions and overcome difficulties. AR's concepts, principles, and varied applications are covered in the review, along with its challenges and limitations. It also introduces object detection and YOLO, exploring its inner workings and evolution through time. The study then examines the benefits, drawbacks, and potential applications of integrating AR with YOLO. Real-time object identification in AR contexts and AR-YOLO integration application cases are discussed. It also handles AR and YOLO integration issues like precise virtual-to-real-world coordinate alignment and real-time object detection calculation.

The review report also suggests AR-YOLO integration research. It emphasizes the necessity for continued research and development to enhance performance, increase capabilities, and explore new AR and YOLO integration applications. This review paper seeks to promote the field of study and inspire additional breakthroughs in augmented reality and object identification with YOLO by offering a complete analysis and proposing prospective research possibilities.

II. AUGMENTED REALITY

AR is a technology that promises to improve users' perceptions of their surroundings by seamlessly merging digital information into the real world with its types(Fig 2) . This integration can be performed in a variety of ways, each with its own set of benefits and drawbacks[12].

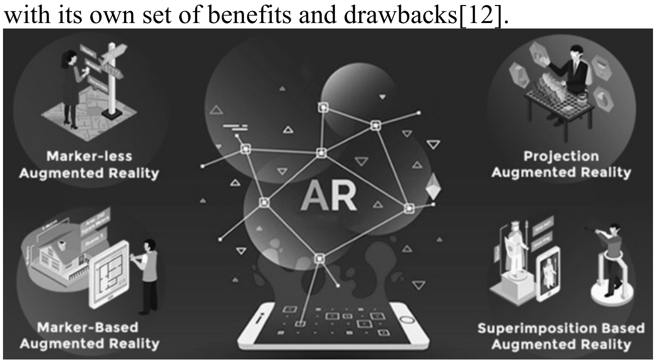

Fig 2: Types of Augmented Reality

A. Projection based AR

Projection-based AR is a popular approach in which virtual images or graphics are projected onto physical objects such as walls or floors. This method allows viewers to interact with virtual content as if it were real, producing an immersive experience.

B. Marker-based AR

Marker-based AR is another solution that uses visual markers or codes to anchor virtual items in real-world surroundings. These markers serve as reference points for the AR system, allowing it to appropriately place and align virtual information. This technology is frequently employed in applications requiring precise virtual object alignment and tracking, such as industrial training simulations or architectural visualization.

C. Marker-less AR

In contrast, marker-less AR uses computer vision algorithms to track the user's motions and arrange virtual items accordingly. This technique eliminates the requirement for physical identifiers, allowing for more natural interactions in real-world environments. Markerless AR systems can reliably track the user's position, recognize objects and surfaces, and overlay virtual content in real time by utilizing advanced computer vision techniques such as simultaneous localization and mapping (SLAM).

III. APPLICATIONS OF AUGMENTED REALITY

AR has several uses in various industries shown in Fig 3, and it is revolutionizing how we interact with the world.

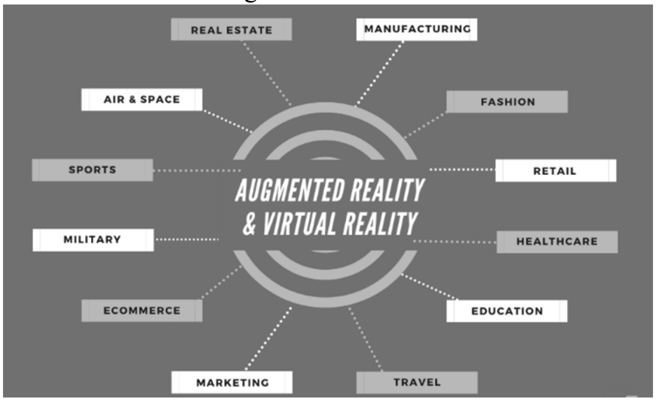

Fig 3. Applications of AR

A. Gaming

AR provides a more immersive experience in gaming by allowing players to interact with virtual items seamlessly incorporated into their physical environment[13], [14]. This adds a new level of engagement and excitement since users can see and interact with virtual characters and objects as if they were real. Another area where AR is having a considerable impact is education. AR helps the learning process by giving students interactive 3D models and simulations, making abstract concepts more tangible and understandable. Through virtual experiments, visualizations, and interactive exercises, students can better grasp and retain content.

B. Healthcare

The healthcare industry has also adopted AR technology, utilizing its potential for surgical operations, medical training, and patient education. Surgeons can benefit from real-time augmented reality overlays that reveal critical patient anatomy information during surgery, allowing for more precise navigation and better surgical outcomes. AR-based medical training allows healthcare workers to practice treatments in a secure and controlled virtual environment, honing their abilities and increasing their confidence before conducting them on actual patients[15]. Furthermore, AR allows healthcare providers to educate patients by visualizing medical diagnoses and treatments, simplifying complex material, and boosting patient comprehension.

C. Retail

AR is revolutionizing the purchasing experience in the retail sector by bridging the gap between online and physical businesses. Customers can digitally try on clothing or accessories, making informed purchasing selections without trying on every item physically[16]. AR visualization helps customers to see how furniture or home design goods might look in their living environments, delivering a realistic preview and aiding in decision-making. AR delivers an interactive and personalized purchasing experience by fusing the virtual and physical worlds, increasing customer engagement and happiness.

D. Training and Simulation

AR has emerged as a revolutionary technology in the military, providing creative solutions that improve training, situational awareness, and mission execution. One significant application of augmented reality in the military is tactical training. AR-based simulations that simulate real-world combat events can benefit soldiers by allowing them to practice in a safe and controlled setting. AR headsets, for example, can superimpose virtual threats, obstacles, and objectives for missions onto the soldier's physical surroundings, creating a very realistic and immersive training environment. Soldiers can practice important decision-making, coordination, and teamwork skills[17], preparing them for the problems they may confront in actual combat circumstances.

AR is also important for improving situational awareness on the battlefield. AR systems can give soldiers essential information such as live video feeds, geographic data, and mission-critical updates, all shown in their field of view by exploiting real-time data and sensor inputs[18]. In quickly changing scenarios, this real-time overlay of pertinent information enables soldiers to maintain a thorough awareness of the battlefield, recognize potential dangers, and make informed decisions. AR, for example, may show the location of friendly and enemy forces, identify sites of interest, and provide real-time intelligence updates, allowing soldiers to travel, communicate, and execute operations more effectively.

Furthermore, AR can improve military logistics and maintenance operations. Technicians can use AR-enabled devices to view digital manuals, step-by-step instructions, and interactive guidance that overlay physical equipment. This allows for faster and more accurate repairs, maintenance, and equipment inspections, resulting in less downtime and increased operating efficiency.

E. Challenges and Limitations of Augmented Reality

Despite its potential benefits, AR technology faces several challenges and limitations that must be overcome before it can be widely adopted. The hardware requirements are a substantial challenge[19]. AR applications require significant computing power and long battery life, and breakthroughs in display technologies are required to enable immersive and high-quality visual experiences. Overcoming these hardware constraints is critical for providing a seamless and optimal user experience.

Aside from hardware constraints, user experience problems are essential for the success of AR applications. Intuitive user interface design, reliable motion tracking, and robust occlusion handling are all areas that need to be improved. Interactions with virtual items in the real world must be seamless and natural for AR to be immersive and valuable. Furthermore, collecting and using personal data in AR applications raises privacy and ethical considerations. Protecting user privacy and maintaining ethical data usage practices are critical for developing trust and the long-term success of AR technology.

Another issue is guaranteeing compatibility and interoperability among various AR systems and devices. As augmented reality continues to evolve and new platforms and devices emerge, it is critical to develop standards and frameworks that allow for smooth communication and

TABLE I

EVOLUTION OF YOLO OBJECT DETECTION VERSIONS

YOLO Version	Year Introduced	Description
YOLOv1	2015	The first version of YOLO used a single neural network for object detection, providing fast but less accurate results than other systems.
YOLOv2	2016	Addressed limitations of YOLOv1 by incorporating a deeper neural network, batch normalization, and anchor boxes for improved accuracy.
YOLOv3	2018	Improved accuracy further by introducing a more complex neural network architecture, feature pyramid networks, and multi-scale predictions.
YOLOv4	2020	The latest version of YOLO introduced a more complex architecture, along with techniques like weighted feature fusion, spatial attention, and cross-stage partial connections for improved accuracy and speed.
YOLOv5	2020	An unofficial version developed by Ultralytics, not endorsed by the original creators, with differences in architecture and implementation compared to YOLOv4.
YOLOv6	2021	Another unofficial version based on YOLOv5, developed by researchers at the University of Massachusetts, introduces new techniques like cross-stage partial connections and hard negative example mining.
YOLOv7	2022	It was introduced by Chien-Yao Wang, Alexey Bochkovskiy, and Hong-Yuan Mark Liao and claimed to be the fastest and most accurate real-time object detector.
YOLOv8	2023	Published by Ultralytics, considered the best YOLO model to date, incorporating new features and improvements for enhanced performance and flexibility. Suitable for various object detection, tracking, instance segmentation, image classification, and pose estimation tasks.

integration across various AR ecosystems. This would ensure that users could access and enjoy AR content on various devices and platforms, supporting more adoption and collaboration in the AR ecosystem. [20] Addressing these problems and restrictions will allow the AR sector to realize its full potential and enable the development of novel and disruptive applications across multiple domains. Overcoming hardware constraints, providing user-friendly experiences, addressing privacy concerns, fostering compatibility, and upgrading tracking technologies will drive augmented reality's future growth and adoption.

IV. OBJECT DETECTION AND YOLO

Object detection is a fundamental task in computer vision that involves recognising and localising objects within an image or video. Traditional approaches depended on complicated pipelines with numerous phases, such as region proposal and categorization.

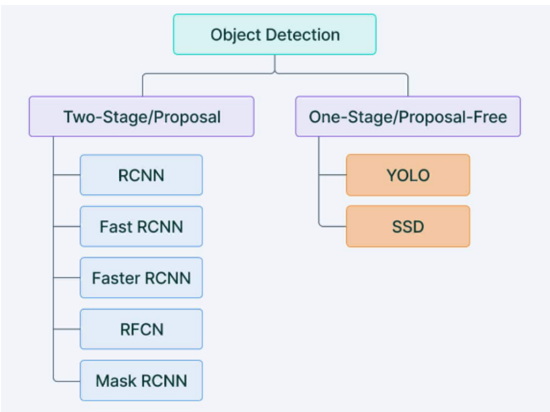

Fig 4: Object Detection Types

A. Introduction To Object Detection

There are numerous object detection methods shown in Fig 4, which can be broadly divided into two types: single-shot detectors and two-stage detectors.

Single-shot detectors, such as YOLO and SSD (Single Shot MultiBox Detector), try to detect objects in a single network pass. Two-stage detectors, such as R-CNN (Regions with CNN features) and its derivatives, generate a collection of region suggestions before classifying each proposal as one of the object classes or background[21].

Object detection algorithms have evolved, creating new techniques and approaches to increase their accuracy and speed. The most common object detection algorithms are YOLO, SSD[22], R-CNN, Fast R-CNN, Faster R-CNN, and Mask R-CNN. Each method has distinct properties and is best suited to different object detection jobs. However, with the introduction of deep learning-based techniques, such as YOLO, object detection has undergone a paradigm shift. These deep learning methods enable end-to-end detection with a single neural network, greatly simplifying the detection process. These object detection methods use machine learning techniques, principally convolutional neural networks (CNNs), to identify patterns and features in picture data associated with different object classifications. The models are trained on large-scale annotated datasets to recognize objects of interest accurately. Object detection approaches have achieved exceptional achievements by utilizing deep learning algorithms, propelling breakthroughs in a variety of industries and paving the way for creative applications.

B. Unterstanding YOLO

YOLO is a real-time object identification system known for its speed and simplicity. Splitting the input image into a grid predicts bounding boxes and class probabilities in each grid cell. YOLO's single-shot method allows for fast and accurate identification[23]. Using a deep convolutional neural network trained on large datasets, YOLO develops discriminative features for accurate object recognition. Using a single CNN, YOLO can analyse full images. YOLO uses a grid-based technique where the CNN divides the image into cells and predicts bounding boxes and class probabilities for each cell instead of complex multi-stage architectures. A final set of bounding boxes captures all detected items in the image from these predictions. This simplified method speeds object detection by eliminating region proposal and classification processes. Table 1 represents the evolution of YOLO[24] versions.

YOLO is a renowned object detection method due to its revolutionary approach and use of a unified CNN for image processing. YOLO's speed and precision have made it useful in real-time applications, including autonomous driving, surveillance systems, robots, and more.

YOLO-NAS stands for "You Only Look Once – Neural Architecture Search" a game-changer in object detection. This new model provides superior real-time object detection capabilities and production-ready performance1. YOLO-NAS is a new real-time state-of-the-art object detection model that outperforms both YOLOv6 & YOLOv8 models in terms of mAP (mean average precision) and inference latency. YOLO-NAS is a new foundational model for object detection from Deci.ai. The team has incorporated recent advancements in deep learning to seek out and improve some key limiting factors of current YOLO models, such as inadequate quantization support and insufficient accuracy-latency tradeoffs. In doing so, the team has successfully pushed the boundaries of real-time object detection capabilities.

The YOLO algorithm is widely considered as a top-tier choice for object detection in augmented reality due to its exceptional characteristics. YOLO stands out for its real-time performance, allowing for rapid object detection on resource-limited devices, which is crucial for delivering responsive and interactive AR experiences. Its simplicity and simultaneous detection capabilities eliminate the need for multi-stage processing, resulting in faster execution. YOLO's competitive accuracy across various object categories and adaptability to different contexts make it suitable for a wide range of AR applications. Moreover, the algorithm's flexibility allows developers to fine-tune and optimize models specific to their AR requirements. The robust open-source community support surrounding YOLO ensures continuous development, providing access to pre-trained models, libraries, and resources, further cementing its position as a best-in-class choice for object detection in AR.

C. Intergration of YOLO and AR

YOLO and AR can improve user interactions in many applications by integrating real-time object recognition with AR experiences. In gaming applications, YOLO[25] can instantly recognise objects in the player's environment, while AR can superimpose virtual game pieces onto those objects for a more immersive experience. In medical applications, YOLO can swiftly identify anatomical components in medical photos, while AR can superimpose virtual annotations or 3D models to help clinicians diagnose or plan surgeries. Autonomous vehicles must detect lanes, objects, and pedestrians to improve road safety. Therefore, this integration of AR and YOLO works better than the traditional approach. The YOLO model is essential for this application due to its real-time performance, simultaneous detection capabilities, competitive accuracy across object categories, and strong community support. Its ability to deliver rapid object detection, streamline architecture, and handle diverse object recognition tasks make it a valuable choice for ensuring a seamless and responsive augmented reality experience.

D. Benefits and Potential Applications

Integrating YOLO with augmented reality offers numerous benefits and potential applications. Real-time object detection within AR environments enables interactive experiences and enhances user interactions. It opens doors to AR-based gaming, where virtual objects can interact with the real world and users seamlessly. Industrial applications can benefit from AR and YOLO integration for tasks such as object recognition in augmented maintenance or quality control processes[26]. Medical imaging can leverage the combined technologies for enhanced real-time diagnostics and surgical assistance. Retail experiences can be augmented with YOLO-based object detection, allowing customers to interact with virtual product information and try virtual objects in their physical surroundings.

E. Challenges in AR and YOLO Integration

Integrating AR with YOLO has enormous offers, but it is accompanied by specific problems that must be overcome before they can be fully realised. One significant problem is assuring interoperability across different AR and YOLO devices and other technologies like cloud computing and data storage. For efficient and effective collaboration, it is critical to achieve seamless integration and interoperability between various platforms. Furthermore, the gathering and use of sensitive user data, such as location information and camera feeds, raise substantial privacy and security concerns, necessitating comprehensive procedures to protect user information[27]. Integrating AR with YOLO adds new problems that must be overcome for optimal performance. Accurate alignment of virtual and real-world coordinates is critical for ensuring that virtual items are correctly overlaid onto physical objects. [28] This necessitates the calibration and synchronisation of devices such as cameras and screens. Maintaining spatial consistency improves user experiences and allows for more seamless interaction. Furthermore, real-time object identification in the context of augmented reality necessitates significant processing resources and energy efficiency from the hardware. It is vital to address these computing needs to enable seamless and rapid object recognition in the AR environment. Overcoming these integration problems is critical to realising the full potential of these technologies, providing appealing user experiences, fast object detection, and user privacy protection.

V. FUTURE DIRECTIONS AND RESEARCH OPPORTUNITIES

The integration of AR and YOLO presents exciting research opportunities and future directions. Advancements in hardware technologies, such as improved sensors and processing units, can lead to more efficient and compact AR and YOLO devices. Algorithmic improvements in YOLO, such as better object recognition and tracking capabilities, can further enhance the integration. Research efforts can focus on developing advanced interaction techniques and user interfaces for intuitive and natural AR and YOLO experiences. Additionally, exploring novel applications and interdisciplinary collaborations can expand the potential of AR and YOLO integration in various domains.

VI. CONCLUSION

In conclusion, this study gives an in-depth examination of two new technologies: AR and YOLO. It opens with a lengthy description of augmented reality, emphasising its ability to improve user experiences by superimposing digital information onto the physical world. The paper examines the YOLO algorithm and its importance in achieving real-time and accurate object recognition, focusing on deep learning models. Throughout the review, several augmented reality and object detection applications are covered, demonstrating the wide range of sectors that can profit from these technologies. Examples include gaming, education, healthcare, retail, the military, and other industries. Furthermore, the article highlights the obstacles and constraints connected with augmented reality and object identification, such as hardware requirements, user interface design, privacy concerns, and exact spatial alignment.

Furthermore, the article dives into integrating augmented reality with YOLO, showing the possible benefits and opportunities that result from merging these technologies. It emphasises the necessity of system compatibility and handles data privacy and security issues. Combining AR with YOLO brings new opportunities for improved object detection in augmented reality situations. Overall, this article provides excellent insights into the improvements and uses of augmented reality and YOLO, providing an in-depth understanding of both technologies. This review study adds to existing knowledge by investigating their integration and lays the groundwork for future research and developments in this sector.

REFERENCES

[1] P. Jiang, D. Ergu, F. Liu, Y. Cai, and B. Ma, "A Review of Yolo Algorithm Developments," *Procedia Comput Sci*, vol. 199, pp. 1066–1073, Jan. 2022, doi: 10.1016/J.PROCS.2022.01.135.

[2] R. Kaviyaraj and M. Uma, "A Survey on Future of Augmented Reality with AI in Education," *Proceedings - International Conference on Artificial Intelligence and Smart Systems, ICAIS 2021*, pp. 47–52, Mar. 2021, doi: 10.1109/ICAIS50930.2021.9395838.

[3] Z. Liu, Y. Gao, Q. Du, M. Chen, and W. Lv, "YOLO-Extract: Improved YOLOv5 for Aircraft Object Detection in Remote Sensing Images," *IEEE Access*, vol. 11, pp. 1742–1751, 2023, doi: 10.1109/ACCESS.2023.3233964.

[4] Z. Liu and S. Wang, "Broken Corn Detection Based on an Adjusted YOLO with Focal Loss," *IEEE Access*, vol. 7, pp. 68281–68289, 2019, doi: 10.1109/ACCESS.2019.2916842.

[5] S. Sureshkumar, C. P. Agash, S. Ramya, R. Kaviyaraj, and S. Elanchezhiyan, "Augmented Reality with Internet of Things," *Proceedings - International Conference on Artificial Intelligence and Smart Systems, ICAIS 2021*, pp. 1426–1430, Mar. 2021, doi: 10.1109/ICAIS50930.2021.9395941.

[6] R. K. Sungkur, A. Panchoo, and N. K. Bhoyroo, "Augmented reality, the future of contextual mobile learning," *Interactive Technology and Smart Education*, vol. 13, no. 2, pp. 123–146, 2016, doi: 10.1108/ITSE-07-2015-0017/FULL/HTML.

[7] R. Kaviyaraj and M. Uma, "Augmented Reality Application in Classroom: An Immersive Taxonomy," *Proceedings - 4th International Conference on Smart Systems and Inventive Technology, ICSSIT 2022*, pp. 1221–1226, 2022, doi: 10.1109/ICSSIT53264.2022.9716325.

[8] M. C. F. MacEdo and A. L. Apolinario, "Occlusion Handling in Augmented Reality: Past, Present and Future," *IEEE Trans Vis Comput Graph*, vol. 29, no. 2, pp. 1590–1609, Feb. 2023, doi: 10.1109/TVCG.2021.3117866.

[9] G. Jocher *et al.*, "ultralytics/yolov5: v7.0 - YOLOv5 SOTA Realtime Instance Segmentation," *zndo*, Nov. 2022, doi: 10.5281/ZENODO.7347926.

[10] P. Nandhini, S. Hariprabha, S. Abirami, R. Jaseenash, and R. Kaviyaraj, "Design and Development of an Augmented Reality E-Commerce 3D models," *3rd International Conference on Smart Electronics and Communication, ICOSEC 2022 - Proceedings*, pp. 127–132, 2022, doi: 10.1109/ICOSEC54921.2022.9952109.

[11] U. M. Kaviyaraj R, "How Augmented Reality Helps us in Modern Education?," *Journal of Positive School Psychology* , pp. 8426–8435, Jul. 2022, Accessed: Jul. 16, 2023. [Online]. Available: https://www.journalppw.com/index.php/jpsp/article/view/9362

[12] P. Parekh, S. Patel, N. Patel, and M. Shah, "Systematic review and meta-analysis of augmented reality in medicine, retail, and games," *Visual Computing for Industry, Biomedicine, and Art*, vol. 3, no. 1. Springer Science and Business Media B.V., Dec. 01, 2020. doi: 10.1186/s42492-020-00057-7.

[13] L. A. Jeni Narayanan, C. Lakshmi Narayanan, M. S. Karthika, S. Ramya, and R. Kaviyaraj, "Railway Track Crack and Key Detection Robot using IoT," *International Conference on Edge Computing and Applications, ICECAA 2022 - Proceedings*, pp. 623–628, 2022, doi: 10.1109/ICECAA55415.2022.9936435.

[14] "Extending head-up displays." https://edoc.ub.uni-muenchen.de/22766/ (accessed May 31, 2022).

[15] S. Ren, K. He, R. Girshick, and J. Sun, "Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks," *Adv Neural Inf Process Syst*, vol. 28, 2015, Accessed: Jun. 24, 2023. [Online]. Available: https://github.com/

[16] W. Liu *et al.*, "SSD: Single shot multibox detector," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 9905 LNCS, pp. 21–37, 2016, doi: 10.1007/978-3-319-46448-0_2/FIGURES/5.

[17] Z. Wang, R. Wu, Y. Xu, Y. Liu, R. Chai, and H. Ma, "A two-stage CNN method for MRI image segmentation of prostate with lesion," *Biomed Signal Process Control*, vol. 82, p. 104610, Apr. 2023, doi: 10.1016/J.BSPC.2023.104610.

[18] J. R. Terven and D. M. Cordova-Esparaza, "A Comprehensive Review of YOLO: From YOLOv1 and Beyond," Apr. 2023, Accessed: Jun. 24, 2023. [Online]. Available: https://arxiv.org/abs/2304.00501v3

[19] L. F. de Souza Cardoso, F. C. M. Q. Mariano, and E. R. Zorzal, "A survey of industrial augmented reality," *Comput Ind Eng*, vol. 139, p. 106159, Jan. 2020, doi: 10.1016/J.CIE.2019.106159.

[20] D. Amin, S. G.-I. J. on Computational, and undefined 2015, "Comparative study of augmented reality SDKs," *researchgate.net*, doi: 10.5121/ijcsa.2015.5102.

[21] J. Radianti, T. A. Majchrzak, J. Fromm, and I. Wohlgenannt, "A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda," *Comput Educ*, vol. 147, Apr. 2020, doi: 10.1016/j.compedu.2019.103778.

[22] "INTRODUCTION TO AUGMENTED REALITY HARDWARE - Google Books." https://www.google.co.in/books/edition/INTRODUCTION_TO_AUGMENTED_REALITY_HARDWA/LdaREAAAQBAJ?hl=en (accessed Jul. 16, 2023).