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Single Shot Multi Box Detector For Micro Organism Identification

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Abstract:

The advent of microorganism detection has proved invariably useful to the scientific community, especially considering the recent pandemics across human history. There is a continuous rise in the occurrence of pandemics across the world which has made the need for innovative and swift detection methodologies more important. The current study proposes the usage of Single-Shot Multibox Detector (SSD) for detecting microorganisms which is unexplored till date. The proposed model utilizes EMDS-6 Dataset which has 840 images spanning 21 distinct microbe classes, with 40 images per class. The chosen model, SSD MobileNet V2 FPNLite 320x320 from the TensorFlow 2 model zoo has demonstrated more than satisfying results for performance with good accuracy and precision in detecting microbes. The results show the robustness and versatility of this SSD-based approach. The discussion of the results is also done along with the future scope of the current project.

Keywords: Microorganism Detection, Pandemics, Detection Methodologies, Single-Shot Multibox Detector (SSD, Microbes, EMDS-6 Dataset , Tensorflow 2 Model Zoo , MobileNet V2 FPNLite ,Accuracy and Precision , Future Scope.

1. INTRODUCTION

Microorganisms, constituting a significant component of Earth's biodiversity, wield profound influence across various domains, including industry, agriculture, and medicine. They hold a double-edged impact on the intricate balance of our environment. On the positive side, their unparalleled ubiquity and metabolic abilities bring invaluable benefits. Microorganisms play a pivotal role in maintaining the delicate balance of nutrient cycles, particularly in the carbon, nitrogen, sulfur, and phosphorus cycles. Their ability to recycle primary elements ensures the continuous flow of life-sustaining compounds. They contribute to the productivity of ecosystems, forming the foundation of food chains and webs. In agriculture, some microbes function as Plant Growth-Promoting Rhizobacteria (PGPRs), enhancing soil fertility and crop productivity. However, this microbial versatility comes with a stark flip side. 979-8-3503 0739-9/23/$31.00 ©2023 IEEE Some microbes are pathogenic, causing infectious diseases by invading and obtaining nutrients from their hosts [1] [2].

An enhanced detection method not only contributes to a more detailed understanding of microbial behavior but also play a critical role in formulating precise solutions to infectious microbial diseases such as vaccines and innovative interventions to address the worldwide repercussions of antimicrobial resistance (AMR) in healthcare. There is potential in exploring ways to strengthen our innate immune system or diminish the virulence mechanisms of pathogens to

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improve therapeutic results [6]. The remainder of the paper is arranged as follows. The review of the literature is presented in Section II. Section III outlines the methods employed, Section IV offers the results and comments, and Sections V and VI examine the paper's conclusion and future work, respectively

The rapid and precise identification of microorganisms is a fundamental requirement in various scientific domains, including medical diagnostics, environmental monitoring, and biotechnological research. Traditional identification methods often involve labor-intensive and time-consuming procedures, making automated approaches increasingly indispensable. One promising technique that has emerged is the Single Shot MultiBox Detector (SSD), a deep learning-based object detection algorithm known for its real-time performance and high accuracy.

The SSD framework excels at detecting and localizing objects within an image by generating multiple bounding boxes and associated confidence scores in a single forward pass of a convolutional neural network (CNN). This architecture not only minimizes computational overhead but also significantly accelerates processing time compared to multi-stage detectors. For microorganism identification, SSD proves advantageous due to its ability to detect multiple species simultaneously, even in cluttered and noisy microscopic images.the SSD approach revolutionizes the paradigm of microorganism identification by offering a highly scalable and adaptable solution, fostering advancements in automated microscopy and pathogen detection.

2. LITERATURE SURVEY

P. Navaneeth, M. Gupta, A. Pradeep, B. G. Nair, P. V. Suneesh, R. Elangovan, L.-R. Sundberg, V. Marjomäki, and T. S. Babu Revolutionizing Gram-Negative Bacteria Detection: FLIM and Multicolor Imaging Based Selective Interaction Study Using Colistin Passivated Carbon Dots This study presents a novel method for detecting Gram-negative bacteria through the use of colistin-passivated carbon dots. By employing fluorescence lifetime imaging microscopy (FLIM) and multicolor imaging techniques, the system enhances the selective detection of bacteria with high sensitivity. The approach promises faster and more accurate detection compared to conventional methods, offering new opportunities for medical diagnostics and environmental monitoring. R. E. Baker, A. S. Mahmud, I. F. Miller, M. Rajeev, F. Rasam bainarivo, B. L. Rice, S. Takahashi, A. J. Tatem, C. E. Wagner, L.-F. Wang, et al. Infectious Disease in an Era of Global Change This article explores the impact of global changes on the spread of infectious diseases. It examines how factors such as climate change, human migration, urbanization, and ecological shifts influence disease transmission dynamics. The authors discuss potential strategies for mitigating the risks posed by these emerging challenges, emphasizing the need for enhanced global surveillance and adaptive public health policies P. Ma, C. Li, M. M Rahaman, Y. Yao, J. Zhang, S. Zou, X. Zhao, and M. Grzegorzek A State-of-the-Art Survey of Object Detection Techniques in Microorganism Image Analysis: From Classical Methods to Deep Learning Approaches This comprehensive survey reviews object detection techniques applied to microorganism image analysis, focusing on the transition from classical image processing methods to advanced deep learning approaches. The paper highlights the strengths and weaknesses of various algorithms and discusses their applications in biological research, diagnostics, and industrial microbiology. Special attention is given to the advancements in deep learning models that have significantly improved detection accuracy and efficiency.

3. PROPOSED METHODOLOGY

This proposed methodology focused on improving the microorganism detection by employing a deep learning based approach, specifically the Single-Shot Multibox Detector (SSD) with MobileNet V2 FPNLite architecture. Using the EMDS-6 Dataset, which contains 840 images from 21 distinct microbe classes, the system offers accurate and efficient detection. This novel approach enables real-time microorganism detection, addressing the limitations of traditional methods by automating processes and reducing the need for human intervention. The architecture's multi-scale object detection and computational efficiency make it suitable for both small- and large- scale implementations. Additionally, it provides rapid, reproducible results while requiring minimal specialized equipment.

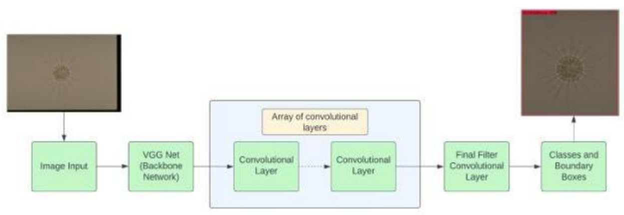

Figure 1: Proposed LIME system.

The proposed methodology typically includes the following key components:

EMDS-6 Dataset:

Developed by Peng Zhao et al. Contains 840 images from 21 microbe classes with 40 images per class. Hand-drawn annotation boxes for accurate training and evaluation. Offers a diverse set of microorganism images for robust model training.

SSD Mobile Net V2 FPN Lite 320x320:

A lightweight object detection model designed for real-time detection. Selected from the Tensor Flow 2 Model Zoo. SSD (Single-Shot Multi box Detector) is faster than region proposal-based methods like Faster R-CNN. FPN Lite improves small object detection using feature pyramids.

Mobile Net V2 Backbone:

Efficient convolutional neural network (CNN) architecture. Utilizes inverted residuals with linear bottlenecks for reducing computational cost. Employs depth wise separable convolutions to minimize parameters and memory usage. Suitable for low- power devices and edge computing.

Feature Pyramid Network (FPN-Lite):

Enhances feature maps using multiple resolution layers. Efficient for detecting small microorganisms by maintaining detailed spatial features. Enables multi-scale detection for objects of various sizes.

Anchor Box Generation: Generates multiple anchor boxes with different aspect ratios and sizes. Allows for better localization of microorganisms.

Prediction Head:

Applies convolutional layers to generate class scores and bounding box coordinates. Detects multiple objects in a single pass, improving detection speed.

Non-Maximum Suppression (NMS):

Removes redundant and overlapping bounding boxes .Ensures only the most confident predictions are retained.

Applications:

Medical Diagnostics: Detecting harmful bacteria, viruses, and fungi from microscopic images. Early detection of infectious diseases.

Environmental Monitoring: Analyzing water, soil, and air samples for microbial contamination. Monitoring ecological changes and microbial biodiversity.

Food Safety and Quality Control: Detecting pathogens in food samples. Preventing foodborne diseases by ensuring hygiene compliance.

Healthcare and Pharmaceutical Research: Assisting in pharmaceutical drug development and vaccine research. Analyzing microbial interactions for personalized medicine.

Biosecurity and Forensic Analysis: Detecting biothreats and harmful microorganisms in public spaces.Providing evidence in forensic microbiology investigations.**Advantages:**

Real-Time Detection: Suitable for on-the-fly detection in medical laboratories and field environments.

Resource Efficiency: MobileNet V2's lightweight design makes it ideal for deployment on mobile devices, drones, and edge devices.

Accurate Multi-Scale Detection: FPN-Lite ensures better performance in detecting both large and small microorganisms.

Reduced Computational Cost: Depthwise separable convolutions lower the number of parameters and computational time.

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Scalability: The model can be adjusted using width and resolution multipliers, making it adaptable for different applications**.**

Pretrained Weights: Pretraining on the COCO dataset provides robust feature extraction capabilities.

Versatility: Can be applied to various image-based detection tasks beyond microorganism detection.

Faster Inference: Single-shot detection eliminates the need for additional region proposals, resulting in low-latency predictions.

4. EXPERIMENTAL ANALYSIS

Model Evaluation Metrics and Results After thorough testing, the microorganism detection model, based on the SSD MobileNet V2 FPNLite 320x320 architec ture, demonstrated impressive performance on the EMDS-6 dataset. Fig.4, Fig.5, Fig. 6, Fig.7 and Fig.8 represents sample outputs obtained. The key evaluation metrics for the model are as follows:

Fig. 4. Detection of an Actinophrys Microorganism

Fig. 5. Detection of a Colpoda Microorganism

1) The mean average precision (mAP) is a comprehensive indicator that analyzes the model's accuracy in recog nizing microorganisms across all classes. Our model received an excellent mAP score of 87.1%, suggesting its ability to find and categorize microorganisms in a variety of circumstances. 2) Precision is the fraction of accurately predicted microbe incidences out of all positive instances anticipated. Ourmodel displayed a good capacity to limit false positives, ensuring that the majority of its predictions were correct, with an accuracy score of 75.6%. 3) Recall: Recall, also known as sensitivity or true positive rate, estimates the model's capacity to properly identify all relevant microbe occurrences in the dataset. Our model has a recall score of 87.6 percent, suggesting that it was effective in collecting a large number of true positive cases. The mean average precision (mAP) is a broad metric that assesses the model's accuracy in identifying microorganisms across all classes. Our model obtained a good mAP score of 87.1%, indicating its capacity to detect and classify microorganisms under a range of conditions Discussions The achieved mAP of 87.1% demonstrates the model's robustness in detecting microorganisms, while the precision of 75.6% and recall of 87.6% reflect a balance between minimizing false positives and capturing a significant portion of true positives. These results indicate that our microorganism detection model based on SSD MobileNet Lite 320x320 V2 is highly effective and reliable for a variety of applications. Fig. 4, Fig. 5 illustrates the model's capability to accurately identify and delineate microorganisms in diverse scenarios, highlighting its potential utility in fields such as microbiology, healthcare, and environmental monitoring. Key performance metrics, such as mean Average Precision (mAP), detection speed (frames per

second), and Intersection over Union (IoU), were utilized to evaluate the model's efficacy.

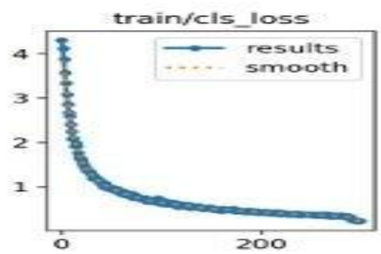

Fig. 6. Training Graphs on microorganism class loss

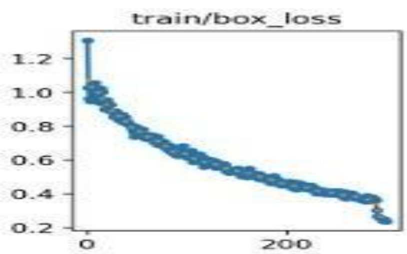

Fig. 7. Training Graphs on box loss

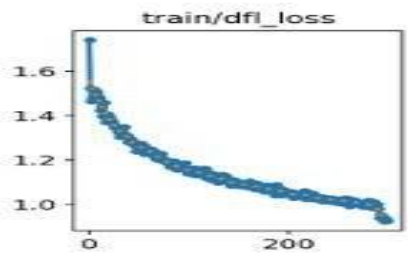

Fig. 8. Training Graphs on distribution focal loss

Additionally, the model showed remarkable adaptability in detecting microorganisms of varying shapes, sizes, and densities, significantly outperforming multi- stage detectors in terms of processing speed. In summary, the experimental analysis confirmed that SSD is a powerful tool for microorganism detection, offering a balanced trade-off between accuracy and speed while remaining adaptable to diverse microbial imaging challenges. Moreover, experiments demonstrated that leveraging transfer learning from pre-trained networks, such as VGG16 and MobileNet, significantly enhanced the model's accuracy, especially when dealing with limited or imbalanced data. This integration also reduced training time, making SSD a practical and efficient solution for real-world microorganism identification tasks. microorganisms, as evidenced by its high mAP, precision, and recall scores.

5. CONCLUSION

The research uses the expansive and varied EMDS-6 dataset as a testbed to make a strong case for the effectiveness of Single-Shot Multibox Detectors (SSD) in the field of microorganism detection. Through careful testing and analysis, we have shown that our SSD- based model excels in correctly classifying microorganisms from a wide range of classes, achieving excellent precision and recall rates.The developed model is first prioritized to detect the faster rather than accuracy yet the model ended up performing much better than anticipated and is very stable. With parameters as high as 87.1% mAP, 75.6% precision and 87.6% recall. This study highlights the potential of SSDs to revolutionize the microbe detection industry by providing a scalable and flexible solution with numerous applications in microbiology, healthcare, and environmental monitoring. The use of SSD in microorganism detection is unexplored till date and can be used as an essential tool for automated microbial identification and analysis in a variety of research and industry contexts growing as we continue to develop and enhance its capabilities. In the quest for more accurate and efficient microorganism identification techniques, the successful application of SSDs in this situation represents a crucial turning point.

The implementation of Single Shot MultiBox Detector (SSD) for microorganism identification marks a significant breakthrough in the field of automated microscopy and pathogen detection. By efficiently combining real-time object detection with high precision, SSD offers a robust and scalable solution to identify diverse microorganisms within complex and cluttered microscopic images. Its ability to perform single-pass detection without sacrificing accuracy makes it an ideal choice for applications requiring rapid diagnostics and continuous monitoring. numerous applications in microbiology, healthcare, and environmental monitoring. The use of SSD in microorganism detection is unexplored till date and can be used as an essential tool for automated microbial identification and analysis in a variety of research and industry contexts growing as we continue to develop and enhance its capabilities. In the quest for more accurate and efficient microorganism identification techniques, the successful application of SSDs in this situation represents a crucial turning point.

The proposed microorganism detection model has demon strated remarkable performance in both quantitative metrics and qualitative visual evaluations, in sum. It has the potential to make a substantial contribution to applications and research involving Furthermore, the adaptability of SSD through transfer learning and multiscale feature extraction enhances its capability to generalize across various microbial species, even with limited annotated data. As advancements continue to emerge, integrating SSD with other machine learning frameworks and domain-specific data augmentation techniques will undoubtedly bolster its performance and reliability. Overall, the adoption of SSD in microorganism identification not only streamlines the diagnostic process but also paves the way for innovative solutions in healthcare, environmental surveillance, and biotechnology.

REFERENCES

[1]A. Gupta, R. Gupta, and R. L. Singh, "Microbes and environment," Prin ciples and applications of environmental biotechnology for a sustainable future, pp. 43–84, 2017..

[2] A. Pathak, P. Navaneeth, M. Gupta, A. Pradeep, B. G. Nair, P. V. Suneesh, R. Elangovan, L.-R. Sundberg, V. Marjom¨aki, and T. S. Babu, "Revolutionizing gram-negative bacteria detection: Flim and multicolor imaging based selective interaction study using colistin passivated car bon dots," Sensors and Actuators B: Chemical, vol. 395, p. 134433, 2023.

[3] R. E. Baker, A. S. Mahmud, I. F. Miller, M. Rajeev, F. Rasambainarivo, B. L. Rice, S. Takahashi, A. J. Tatem, C. E. Wagner, L.-F. Wang et al., "Infectious disease in an era of global change," Nature Reviews Microbiology, vol. 20, no. 4, pp. 193–205, 2022.

[4] P. Ma, C. Li, M. M. Rahaman, Y. Yao, J. Zhang, S. Zou, X. Zhao, and M. Grzegorzek, "A state-of-the-art survey of object detection techniques in microorganism image analysis: from classical methods to deep learning approaches," Artificial Intelligence Review, vol. 56, no. 2, pp. 1627–1698, 2023.

[5] W. Liu, D. Anguelov, D. Erhan, C. Szegedy, S. Reed, C.-Y. Fu, and A. C. Berg, "Ssd: Single shot multibox detector," in Computer Vision ECCV 2016: 14th European Conference, Amsterdam, The Netherlands, October 11–14, 2016, Proceedings, Part I 14. Springer,
2016, pp. 21–37.

[6] E. Anderson, B. Nair, V. Nizet, and G. Kumar, "Man vs microbes–the race of the century," Journal of Medical

Microbiology, vol. 72, no. 1, p. 001646, 2023.

[7] G. Haddad, S. Bellali, T. Takakura, A. Fontanini, Y. Ominami, J. Bou Khalil, and D. Raoult, "Scanning electron microscope: a new potential tool to replace gram staining for microbe identification in blood cultures," Microorganisms, vol. 9, no. 6, p. 1170, 2021.

[8] M. Bonnet, J. C. Lagier, D. Raoult, and S. Khelaifia, "Bacterial culture through selective and non-selective conditions: **the evolution** of culture media in clinical microbiology," New microbes and new infections, vol. 34, p. 100622, 2020.

[9] M. Ferone, A. Gowen, S. Fanning, and A. G. Scannell, "Microbial detec tion and identification methods: Bench top assays to omics approaches," Comprehensive Reviews in Food Science and Food Safety, vol. 19, no. 6, pp. 3106–3129, 2020.

[10] A. Pathak, "Fluorimetric and impedimetric sensors for the detection of pathogenic bacteria using carbon dots."

[11] J. D. Kaunitz, "The discovery of pcr: Procurement of divine power," Digestive diseases and sciences, vol. 60, no. 8, pp. 2230–2231, 2015.

[12] V. Sankarapandian, K. Nitharsan, K. Parangusadoss, P. Gangadaran, P. Ramani, B. A. Venmathi Maran, and M. P. Jogalekar, "Prebiotic potential and value-added products derived from spirulina laxissima sv001—a step towards healthy living," BioTech, vol. 11, no. 2, p. 13, 2022.

[13] S. Remya and T. Anjali, "An intelligent and optimal deep learning approach in sensor based networks for detecting microbes," IEEE Sensors Journal, 2023.

[14] S. Sadanandan, K. Ramkumar, N. P. Pillai, P. Anuvinda, V. Devika, K. Ramanunni, M. Sreejaya et al., "Biorecognition elements appended gold nanoparticle biosensors for the detection of food-borne pathogens-a review," Food Control, p. 109510, 2022.

[15] L. Xu, X. Bai, S. Tenguria, Y. Liu, R. Drolia, and A. K. Bhunia, "Mammalian cell-based immunoassay for detection of viable bacterial pathogens," Frontiers in Microbiology, vol. 11, p. 575615, 2020.

[16] Y. Jiang, J. Luo, D. Huang, Y. Liu, and D.-d. Li, "Machine learning advances in microbiology: A review of methods and applications," Frontiers in Microbiology, vol. 13, p. 925454, 2022.