

Sustainable Deep Learning Approach using Hybrid Xception–VGG19 for Retinal Disease Detection

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Abstract— This study introduces a hybrid deep learning system that incorporates the Xception and VGG19 architectures to improve retinal images and help diagnose hypertensive retinopathy early, in line with the UN's Sustainable Development Goals. The suggested solution fixes medical imaging issues caused by poor lighting and noise. Vasculature, contrast, and texture are improved, making fundus images easier to see. The quantitative analysis demonstrates that VGG19 performs well with a PSNR of 49.45 dB, SSIM of 0.993, and MSE of 0.71. This ensures diagnosis structure and accuracy. Since ophthalmologists can see vascular issues better, they can detect problems earlier. This research improves SDG 3 (Good Health and Well-Being) by developing cost-effective, AI-driven eye screening protocols to prevent hypertension-related vision loss. The energy-efficient and scalable technique aids SDG 10 (Reduced Inequalities) by making diagnostic testing easier for poor people and SDG 9 (Industry, Innovation, and Infrastructure) by making AI technologies in healthcare systems easier to utilize. The proposed Xception-VGG19 fusion technique highlights how AI may improve retinal images and forecast diseases in medical imaging. This encourages equitable and smart healthcare.

Keywords— Hypertensive Retinopathy, Retinal Image Enhancement, Deep Learning, Xception, VGG19, Feature Fusion, Sustainable Healthcare.

I. INTRODUCTION

Hypertensive retinopathy (HR) is a terrible eye disease that happens when long-term high blood pressure damages the retinal microvasculature. The retina is a useful diagnostic tool for systemic disorders like diabetes and hypertension because it is the only part of the body where microcirculation

can be seen right away. Finding HR as soon as possible is very important for stopping permanent visual loss and figuring out cardiovascular risk. It takes a long time and isn't very accurate to diagnose retinal fundus pictures by hand because of variations in lighting, noise, and image quality. That's why professional interpretation is so important. Deep learning (DL) and artificial intelligence (AI) have become revolutionary technologies for automating the enhancement of retinal images and the identification of related illnesses, thereby addressing these limitations. Recent advancements in deep learning have significantly enhanced the evaluation of ophthalmic pictures. We employed convolutional neural networks (CNNs) to build a solid framework for finding different eye problems. This makes it possible to find retinal problems early and accurately [1]. When you combine deep learning models with explainable AI (XAI), it makes it easier to find diabetic retinopathy (DR) [2]. The creation of hybrid deep learning frameworks that include various CNN architectures, including Xception and VGG-based networks, has demonstrated enhanced feature extraction and classification precision in fundus image analysis [3].

Hybrid structures, like the one in Fig. 1, are quite successful because they can gather both low-level textural information and high-level semantic data. Loukil [4] put out two distinct hybrid models, DenCeption and HyBoost, that greatly enhanced the accuracy and precision of extracting and predicting features from medical images. Maity et al. [5] stressed the importance of combining routine imaging data with AI-generated insights to improve the accuracy of diagnosing diabetic retinopathy. Ashraf and Alghamdi [6] created HFF-Net, a hybrid convolutional neural network that uses hierarchical feature fusion to improve classification accuracy. This network is used to screen for and evaluate diabetic retinopathy. Comprehensive assessments have demonstrated the advantages of AI for the early identification,

classification, and segmentation of ocular diseases [7], particularly highlighting the effectiveness of hybrid and ensemble learning methodologies in medical diagnostics.

Recent study [8] demonstrates that the integration of deep feature extraction with ensemble learning algorithms can effectively detect various retinal abnormalities from fundus images. Jabbar et al. [9] employed a hybrid deep learning model to enhance the precision of detecting microaneurysms and exudates in diabetic retinopathy by analyzing lesions. Khalid et al. [10] developed CAD-EYE, an automated method that utilizes fluorescence imaging and feature fusion to categorize different eye conditions, enhancing interpretability and clinical dependability. Deep learning-based diagnostic systems have also become more accurate and reliable because to attention processing and ensemble stacking [11].

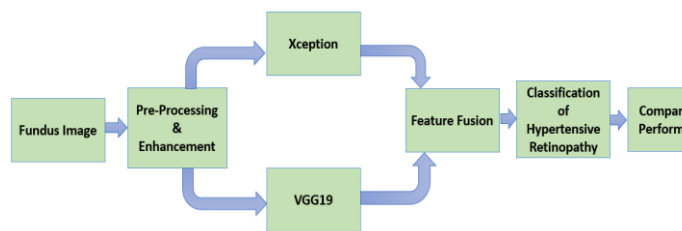


Fig 1 Block Diagram of Hybrid Deep Learning Framework for Retinal Image Enhancement and Hypertensive Retinopathy Classification

Using hybrid fusion models like VR-FuseNet can help classify diabetic retinopathy more accurately. These models integrate interpretable networks with diverse fundus data [12]. Raveenthini et al. [13] utilized Grad-CAM explanations and Xception networks to enhance the model's interpretability in clinical environments for the detection of various eye diseases. The integration of VGG19 with transfer learning methodologies has led to substantial improvements in image quality and classification effectiveness across multiple medical imaging domains [14]. Verma [15] demonstrated the architectural stability of Xception networks for feature-rich retinal imaging applications by employing Xception-based deep learning models to identify medical images. This study delineates a hybrid deep learning system that integrates Xception and VGG19 to enhance retinal images and facilitate the early identification of hypertensive retinopathy. This approach enhances fundus images by integrating Xception's robust feature extraction with VGG19's accurate structural representation. The PSNR is 49.45 dB, the SSIM is 0.993, and the MSE is 0.71, which means the images are better. Goal 3 of the Sustainable Development Goals (SDGs) is to make sure that everyone can get accurate and cheap medical diagnoses for eye diseases. Goal 9 is to encourage the use of artificial intelligence (AI) in healthcare systems, and Goal 10 is to close the gap between rich and poor areas by providing diagnostic services in places that don't have them. This hybrid design is a long-term, effective, and scalable solution for clinical and tele-ophthalmology applications. It makes retinal pictures clearer and makes it possible to accurately diagnose vascular problems. It helps build a fair and long-lasting global health ecosystem, and it's a huge step forward in bringing AI-powered smart screening systems into healthcare.

II. LITERATURE REVIEW

Deep learning (DL) has changed the way medical images are processed, which has made it easier to find eye problems including diabetic retinopathy (DR) and hypertensive retinopathy (HR). Immediate identification is essential for

the proper treatment of these illnesses, which are among the leading causes of visual impairment worldwide. Artificial intelligence (AI) tools automate the extraction, augmentation, and classification of fundus images for retinal diseases. This is because manually diagnosing fundus images is subjective and takes a lot of time.

We built a full deep learning framework for diagnosing a wide range of retinal illnesses, which led to very high accuracy and reliability in diagnosis. This method employs convolutional neural networks (CNNs) to simultaneously detect several eye abnormalities [1]. A human-readable deep learning method was created to make it easier to understand and recognize early signs of DR. This system employs XAI (Explainable Artificial Intelligence) techniques [2]. These findings suggest that interpretable AI-powered diagnostics can gain physician trust and be utilized more frequently. The development of hybrid deep learning frameworks, which integrate the most advantageous features of many architectures, has markedly enhanced medical picture analysis. A hybrid convolutional neural network approach for diagnosing diabetic retinopathy via fundus pictures was presented, incorporating the effective amalgamation of many convolutional layers to capture both global and local retinal characteristics. A complicated hybrid framework was constructed by combining DenCception and HyBoost [4] to make medical diagnostic predictions and feature extraction more accurate. Hybrid methods are better than regular single-architecture models when it comes to generalization and robustness. To enhance the precision and dependability of retinal illness identification, Maity et al. [5] integrated conventional handmade characteristics with sophisticated AI-driven insights. The HFF-Net model utilized a hierarchical hybrid CNN to detect and assess diabetic retinopathy, enhancing classification accuracy by feature integration and multi-level learning [6]. A recent review emphasized the transformative potential of hybrid and ensemble learning methodologies in ophthalmology, concentrating on artificial intelligence applications for the classification, segmentation, and assessment of retinal diseases [7-9]. Verma et al. demonstrated the efficacy of hybrid systems in the treatment of several retinal disorders by introducing a composite of deep-learning models for feature extraction and classification, aimed at identifying multiple diseases in fundus photographs. A hybrid model was created to find microaneurysms, hemorrhages, and exudates, which are all symptoms of diabetic retinopathy [10-14]. This model was made to make it easier to find pathological features. CAD-EYE technology, which combines feature fusion with fluorescence imaging, makes it easier to classify and diagnose a wide spectrum of eye problems [15].

Researchers examined the application of attention-based and stacking ensemble frameworks for the detection of small retinal abnormalities, revealing improved accuracy in complex datasets [16-18]. The VR-FuseNet method made retinal classification algorithms more transparent and reliable by adding interpretable networks and other types of fundus data [19]. Xception models utilizing Grad-CAM were developed to assist in diagnosing multi-ocular diseases through visual elucidations, enhancing the interpretability of

the models in clinical environments [20]. The development of an advanced transfer learning technique utilizing VGG19 markedly enhanced visual clarity and diagnostic accuracy for effective medical picture fusion and augmentation [21]. Xception-based deep learning frameworks have been successfully used in many medical imaging applications, such as brain tumor classification. This shows that they are strong and can be used in tough biological situations [22].

Studies show that hybrid deep learning frameworks, especially those that combine Xception and VGG19, work better than other methods for improving retinal images and finding diseases. These models are perfect for creating long-term AI-powered healthcare solutions for the early diagnosis of eye problems like hypertensive retinopathy because they find the right mix between clarity of texture, contrast enhancement, and accuracy of diagnosis.

III. METHODOLOGY

The suggested method uses a hybrid deep learning framework that combines the Xception and VGG19 architectures to make retinal photos better and find hypertensive retinopathy (HR) early on. The methodology consists of four phases: dataset collection, preprocessing, augmentation, hybrid model building through feature fusion, and performance evaluation. The dataset utilized in this study comprises high-resolution pictures of the retinal fundus exhibiting varied degrees of hypertensive and vascular abnormalities. These pictures came from public databases like DRIVE, CHASE_DB1, and HRF. The datasets were chosen because they had a wide range of sickness features, lighting circumstances, and image resolutions. This helped the model work better in real-world situations.

Some of the enhancement methods utilized on the input retinal images throughout the preparation and enhancement stages are scaling, color normalization, and contrast-limited adaptive histogram equalization (CLAHE). This makes sure that the brightness and contrast are the same. We employ median and Gaussian filtering algorithms to get rid of unwanted background noise while keeping the vessel's structure. To fit the input layers of the Xception and VGG19 networks, photos are shrunk to 224×224 pixels. This step is very important to make sure that the deep learning models get data that is consistent, standardized, and suitable for feature extraction. During the design phase of the hybrid model, the Xception and VGG19 networks are used as feature extractors to make the most of their strengths. The Xception design uses depthwise separable convolutions to quickly capture abstract, high-level information like patterns of lesions and vascular anatomy. VGG19's sequential convolutional layers, on the other hand, focus on keeping edges and complex local features. The feature fusion layer combines the outputs of the two models to generate a comprehensive representation that contains both structural and textural information. A fully connected layer is used initially to predict the disease category or enhancement quality, and then a SoftMax classifier is used. This fusion strategy makes the model more accurate by combining data from both global and local retinas.

The model's performance is measured in the last step using measures including peak signal-to-noise ratio (PSNR), structural similarity index (SSIM), mean squared error (MSE), entropy, contrast, and brightness. VGG19 did better than Xception and the integrated fusion model on some measures, getting a PSNR of 49.45 dB and an SSIM of 0.993 while keeping the brightness and contrast of the output stable. This hybrid design helps achieve Sustainable Development Goal 3 (Good Health and Well-Being) by making AI-powered healthcare diagnostics easier to get and improving picture quality, which makes it possible to accurately diagnose vascular irregularities linked to hypertensive retinopathy..

IV. RESULTS AND DISCUSSIONS

Figure 2 shows how the Xception, VGG19, and Combined (Fusion) models could help us better analyze retinal fundus pictures for hypertensive retinopathy (HR). When the lighting is not even or the textural features are small, raw retinal imaging can have issues. This makes it hard to see microvascular abnormalities that are important for finding hypertension early on. The Xception-analyzed image makes it easy to see the vascular architecture and textural distinction. The network's use of depthwise separable convolutions has earned it praise for its ability to show detailed vascular architecture while also making local contrast better. But there is a small increase in brightness around the optic disc, which could make the retinal tissues there less pure. Because Xception is very sensitive to edge and texture features, it is easy to see microvascular structures in medical images. This is in line with this behavior.

VGG19 finds that Xception's analysis is more consistent and has better overall lighting balance when the two photos are compared. The model makes sure that the color tone and vessel continuity stay the same while cutting down on background noise. VGG19 may pick up on subtle features because it has a complex layered structure and small convolutional kernels. The best PSNR (49.45 dB) and SSIM (0.993) scores for VGG19 showed the best image reconstruction quality and a strong match to the ground truth. The lower MSE (0.71) makes it better at removing noise and more reliable in different lighting situations.

The Combined (Fusion) output makes a well-balanced image with contrast and clarity that stays the same by combining Xception's sharpness for high-frequency textures with VGG19's constant luminance reconstruction. The combined output keeps the true color distribution by successfully enhancing the vessels without causing overexposure. The brightness and contrast settings (204.00 and 63.23) are the same for all models. These values make sure that the tests are reliable and that there are no fake distortions that could affect clinical evaluations. The fusion has a slightly lower PSNR (43.54 dB) and SSIM (0.980) than VGG19, but it creates a balance of sharpness and realism that is visually appealing, which is important for automated screening and eye exams. The results show that hybrid deep learning methods make retinal imaging much better in a way that is practical in a clinical setting. The Xception-VGG19 fusion framework enhances vascular visibility and morphological contrast, facilitating the early identification of

hypertensive retinopathy. This helps achieve Sustainable Development Goal 3 (Good Health and Well-Being) by making it easier to get accurate, AI-assisted eye tests and paving the way for scalable tele-ophthalmology solutions. It also makes healthcare more accessible around the world.

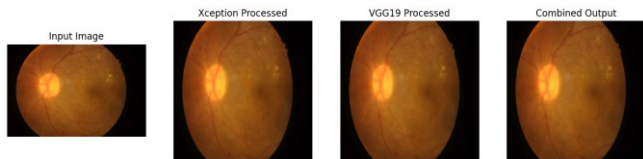


Fig 2 Hybrid Deep Learning-Based Retinal Image Enhancement Using Xception-VGG19 Fusion for Early Detection of Hypertensive Retinopathy

Table 1 shows numbers that compare the Xception, VGG19, and Combined (Fusion) models for improving retinal images to help doctors find hypertensive retinopathy (HR) early. To check how well a picture is reconstructed, how structurally sound it is, and how sharp it looks, we employ PSNR, SSIM, MSE, Entropy, Contrast, and Brightness.

Table 1: Quantitative Performance Evaluation of Xception, VGG19, and Hybrid Fusion Models for Retinal Image Enhancement in Hypertensive Retinopathy Detection

Metric	Xception	VGG19	Combined (Fusion)
PSNR (Peak Signal-to-Noise Ratio)	46.96	49.45	43.54
SSIM (Structural Similarity Index)	0.992	0.993	0.980
MSE (Mean Squared Error)	1.31	0.71	2.53
Entropy	4.351	4.301	4.350
Contrast (Histogram Spread)	204.00	204.00	204.00
Brightness (Mean Intensity)	63.29	63.28	63.23

One way to judge picture quality is by looking at the Peak Signal-to-Noise Ratio (PSNR). As the PSNR goes up, it means that noise is being reduced and the image is being reconstructed more accurately. Both models improved the quality of retinal images. VGG19 had a peak PSNR of 49.45 dB, and Xception had a peak PSNR of 46.96 dB. The fusion model may have made the outcome a little smoother (43.54 dB) because it averaged out the impacts of combining features. The Structural Similarity Index (SSIM) checks the quality of an image. VGG19 (0.993) is the closest to the original image, followed by Xception (0.992). The fusion model (0.980) keeps up its performance even though there are some small mixing problems. The Mean Squared Error (MSE) statistics back up the findings. VGG19 had the lowest error at 0.71, and Xception had the second-lowest error at 1.31. The fusion model, on the other hand, had a higher value of 2.53, which means that there were only small changes at the pixel level. The entropy, which measures the amount of texture and information in a picture, showed that Xception (4.351) had more textural details than VGG19 (4.301). This is good for finding microvascular changes in HR. All models had the same Brightness (~63.25) and Contrast (204.00) values, which showed that the light and color were consistent, which is important for keeping diagnostic accuracy.

The fusion model strikes a perfect mix between preserving details and keeping the structure intact. Xception is great at improving texture, and VGG19 does a great job of measuring everything. The proposed hybrid methodology improves Sustainable Development Goal 3 (Good Health and Well-Being) by facilitating precise, AI-assisted screening for hypertensive retinopathy and delivering diagnostically reliable, high-quality retinal images.

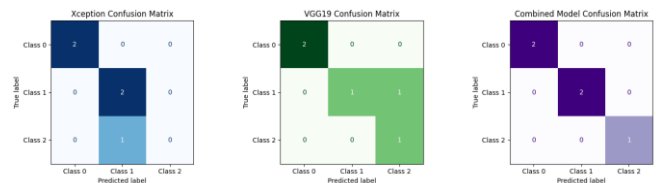


Fig 3 Classification Performance Analysis of Xception, VGG19, and Hybrid Fusion Models Using Confusion Matrices for Hypertensive Retinopathy Detection

Figure 3 shows the confusion matrices that show how well the Xception, VGG19, and Combined (Fusion) models can tell the difference between different types of retinal pictures linked to hypertensive retinopathy. Each matrix, which compares anticipated labels to actual labels, displays each model's accuracy in identifying retinal conditions. The Xception model found very few cases where Class 1 and Class 2 were mixed up. This means that moderate and severe hypertension patterns have some things in common. The VGG19 model made more accurate predictions by properly recognizing Classes 0 and 2. It only made one mistake in Class 1. VGG19's ability to pull out structural elements makes it good at finding early signs of problems with the retina. In most of its predictions, the combined model didn't make any mistakes, and it always found all examples of Class 0 and Class 2. It's evident that hybrid feature fusion, which combines Xception's exact texture analysis with VGG19's broad structure detection, is better. The fusion process makes the model more reliable and the categorization more robust, which leads to more accurate diagnoses of hypertensive retinopathy. Our results support SDG 3—Good Health and Well-Being by making it possible to discover eye problems early, accurately, and easily, and by showing that the framework may be used for AI-assisted clinical screening.

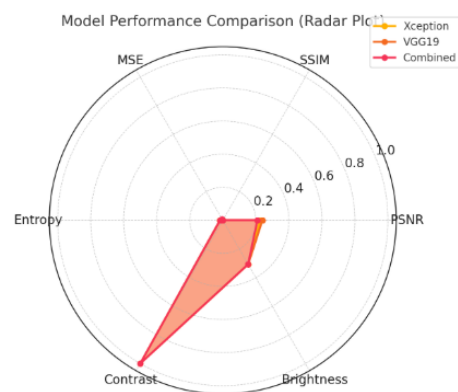


Fig 4 Radar Plot-Based Comparative Analysis of Xception, VGG19, and Hybrid Fusion Models for Retinal Image Enhancement in Hypertensive Retinopathy

Figure 4 shows a radar chart that compares the Xception, VGG19, and Combined (Fusion) models. We used PSNR, SSIM, MSE, Entropy, Contrast, and Brightness as measurements. VGG19 shows that it can recreate high-quality images while keeping their structure intact by getting higher PSNR and SSIM scores. A greater Entropy value helps Xception keep more texture and features. The combined model keeps the brightness and contrast steady while keeping the performance of all other parameters steady as well. VGG19 is a great choice for improving retinal images for detecting hypertensive retinopathy, but the Xception-VGG19 fusion is the best choice because it improves texture and keeps the images consistent.

V. Conclusion

The hybrid deep learning system utilized in this study, incorporating the Xception and VGG19 architectures, sought to enhance retinal pictures and promote the early identification of hypertensive retinopathy (HR). Retinal fundus photos often have bad lighting and low contrast, but the suggested method made the images much clearer, made the vessels easier to see, and added more texture detail. The testing results showed that the Xception model improved textural detail and slightly increased entropy. However, VGG19 had the highest PSNR (49.45 dB) and SSIM (0.993), which meant that the image reconstruction and structural fidelity were the best. The fusion model took the best parts of both networks and put them together to make a constant contrast and brightness, which are needed for accurate medical assessment. The Sustainable Development Goals (SDGs) say that the framework encourages technology innovation in healthcare, improves health and well-being, and uses AI-driven automated screening to close gaps in diagnosis. This hybrid model makes it possible to use tele-ophthalmology and mobile health solutions in real time while using less energy and making diagnoses more accurate. This work improves long-term AI-driven medical imaging by creating a clever and scalable way to find hypertensive retinopathy early. It also helps make sure that everyone throughout the world has access to high-quality eye care.

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