International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Artificial Intelligence (AI) Enabled Image Upscaler for Retinal Anomaly Detection with Dense Neural Computation

V. J. Chakravarthy [1], Sri Raman Kothuri[2], K. Rajesh[3], R.Halima[4] , Mahendra T. Jagtap[5], CH. M. H. Saibaba[6]

Submitted: 16/07/2023 **Revised**: 09/09/2023 **Accepted**: 26/09/2023

Abstract: Retinal abnormality is a kind of chronic impact developed due to continuous accumulation of fluid in the retinal space. Untreated retinal infection leads to permanent damage to the organ. The segmentation of retinal cyst from the optical coherence tomography (OCT) images crucial to identify the disease in the early stages. The quality of OCT image is crucial to determine the infected area accurately. Most of the data collected from screening labs contains unstructured OCT images with and without labels. The processing time taken for handling the clogged image pixels are high. It degrade the performance of prediction system. Dropping out of low quality image is important instead of utilizing the raw data for prediction process. The segmentation of infected area is utilized to classify the type of retinal disease such as Choroidal vascularization, muscular Edema, Drusen and normal images. The proposed system is framed in such a way to create enhanced screening images through artificial intelligence (AI) enabled image upscale (AIU) using Zyro tool. The up scaled images are further utilized for feature extraction process towards deep identification of unique impacts in the OCT images. The classification is explored with deep dense neural computing (DDNC) through deep neural network (DNN). The proposed AI upscale deep dense network (AIU-DDNC) classify the feature vectors with respect to disease types of trained vectors within the same network. The RETOUCH dataset is utilized here for creating a standard model and further the presented system achieved 98.89% accuracy on retinal disease classification is compared with existing state of art approaches..

Keywords: *Retinal diseases, Artificial intelligence, Deep learning, Neural computing, Image segmentation.*

1. Introduction

Detection of diagnostically feasible regions from the retinal images are important in treatment of retinal abnormality. These detectors are helpful to analyse the anomaly present in the retinal regions towards breaking the limitations of manual evaluation through computer vision technology. Enforcing the benefit of reaching the low resolution markers in the images are feasible with image processing techniques. In contrast to natural images, medical images are composed of grey scaled images. The relevant categories of image pixels will be available in the range of average of 125 as pixel value. Optical coherent tomography (OCT) generates various levels of cross sectional images of retina helpful to collect the ocular tissues and its abnormalities in a accurate way. In order to determine the abnormal regions in the retinal area the complete evaluation of retinal fluids are important. The untreated retinal fluid infections leads to permanent damage to eyes. As the retinal OCT imaging technique contains a beam of correlated reference passed into the retinal area, the amount of reflected values are collected. The sequence of longitudinal signals, variations and cross sectional impacts are recorded for further morphological analysis. These Images provides unique perspective for analysis of retinal conditions without any fault. Using computer vision technology images are processed effectively. The utilization of artificial intelligence(AI) tools in the image processing steps enhance the process further.

The segmentation of retinal fluids from the retinal images is a important ask in medical image processing and field of of ophthalmology. It depends upon the identification and regional extraction of retinal anomalies for various types of disease classification. Early detection of retinal fluid is related to various diseases such as diabetic retinopathy, macular degeneration, edema, Drusen, retinal vein occlusion, retinal cyst even more. The timely diagnosis of these fluids segmented from the retinal area is essential to treat the diseases accurately. An untreated retinal fluid infection leads to permanent damaged to the eyes.

[1]Department of Computer Applications, Dr.MGR Educational and Research Institute, Maduravoyal, Chennai - 600 095. Email: chakravarthy.mca@drmgrdu.ac.in
[2]Department of Computer Science and Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D institute of Science and Technology, Avadi, Chennai-600 062, Tamil Nadu, India, Email:sriramankothuri@veltech.edu.in
[3]Department of Electronics and Communication Engineering, SSM Institute of Engineering and Technology, Kuttathupatti, Dindigul 624002,Email: rajeshece@ssmiet.ac.in
[4]Department of Biotechnology , Sir M Visvesvaraya Institute of Technology, Hunasamaranahalli, Bangalore 562157, Email Id: halima_biotech@sirmvit.edu
[5]Department of Computer Engineering ,PVG's College of Engineering & SSDIOM Nashik (SPPU Pune), Email : mtjagtap05@gmail.com
[6]Department of Computer science and Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India. Email: saibaba.ch77@gmail.com

On the other hand, continuous monitoring of retinal infection region is important to understand the progress of disease, follow up with the impact created by the segmented region accurately.

The continuous analysis of retinal impacts are important to treat the disease in a proper way and allow the ophthalmologist to identify the exact problem present in the retinal area.

For the research and clinical analysis of eye infections and retinal diseases these fluid segmentation is important. Automation of retinal fluid infection using artificial intelligence enabled segmentation technology is improves the existing version of analysis methods. Various image up-scaling techniques are available as a tool in artificial intelligence industry. Tele-medicine and remote medical care centers provides automatic detection of retinal fluid segmentation for further analysis of retinal diseases. The segmentation of retinal fluid from the retina is opted for treating various diseases and planning the disease diagnosis plan. Exploring the evaluation method improves the quality of prediction.

The major problem persist with the untreated retinal infection is the loss of vision. The early diagnosis is highly recommended. It leads to permanent damage to the eyes and the retina henec continous intervention is required.

Retinal fluid segmentation is applied for evaluation of diabetic retinopathy, a chronic symptom impacted the maximum peoples with diabetics.

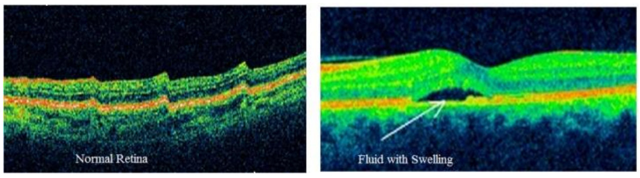

Fig 1. Pseudo colour map of retinal OCT image *(Trichonas et al.)*

Fig 1. Shows the pseudocolor map of retinal OCT image with fluid filled in the infected area covered with small swelling. Comparing with normal retina in the image the fluid filled region is highlighted. Retinal fluid cause irritation, Macular edema that leads to retinal breaks. Early detection of retinal infection is focused here with consideration of existing problems of unlabelled data, high processing time due to clogged image pixels etc.

- The proposed study is focused on developing a robust architecture that considers the constraints of early detection using automated methods.
- The large processing delay of unstructured data available from real time screening centres produce more false negatives.
- The presented system considers RETOUCH datasets. The primary goal of the system is to provide accurate segmentation and classification of retinal fluids and diseases associated with it providing less processing time.

The rest of the paper is formulated with detailed literature study in Section II. Followed by exploration of drawbacks in existing system with relevant solutions in proposed system, the tool selection etc. in Section III. The design architecture and steps involved in development of proposed model is explored in Section IV. The executed results and relevant discussions are shown in Section V.

2.Related Works

C. Zhang et al., (2020) optical coherence tomography (OCT) is highly in demand for retinal anomaly analysis. The author presented a generalized adversial network (GAN) based memory augmentation technique for analysis of OCT images. GAN architecture are optimum for analysing the OCT images to reorganize the pixels, on the other hand the complex configuration of GAN structure need the data to be completely aligned or labelled to make efficient classification. It need the accurate reference image for making the generator to meet the completed image quality.***T. Hassan et al. (2018)*** the author presented a deep abnormality detection system using deep learning based automated analysis system. The presented approach extract the abnormal retinal regions through continuous evaluations. Deep learning is highly supportive for OCT image classification however the utilization of Graphical processing unit (GPU) is more towards massive image data.

Rastiet al. (2023) presented a neural network architecture in which retinal fluid net is developed for multiple classification of retinal fluid segmentation. The benefit is based on hierarchical connections of various texture and contextual features extracted from the retinal images. The age future technical City here with the self-adaptive dual attention model. The connections are compared with the novel combinations of relevant pixels and further the super resolution pixels are extracted with the different levels. The deep fluidnet compress the multi-class the presentation of pixel regions with train images and further classify the process. The optimised technique classify the retinal images with respect to the diseases. The customized fluidNet is suitable only for the selected dataset since the layers of the network is tuned according to the trained features. Global data is not adopted to the fluidnet. Hence lightweight layer configuration eed to be developed.

Fu et al. (2017) the author explored the edge detectors and its benefits towards the segmentation of retinal abnormality. OCT images are helpful to explore the retinal abnormality in the early stages. Here an engineered solution is derived from the suitable AI toolsets. The configuration of AI toolsets for the specified software platform is complex. However the results of AI tools impact the decision making, the unique configuration is suitable for trained data. ***X. He et al. (2023)*** the author presented a cross domain optical coherent technology enabled retinal fluid segmentation where the data set is collected from standard benchmark websites. Using cross attention network a structure guided method is utilized here to extract the retinal regions in terms of identifying the fluid present in it. The multi task analysis classify the retinal structure and predict the structure into various kinds of retinal abnormality. The scale of features vary for each images under test. Dimentionality reduction need to be adopted for multi-class features else the uneven length takes random selection of pixels.

Gao et al. (2018) the author presented a multi-view gaze exploration model with convolution neural network (CNN) architecture. The presence of retinal abnormality is detected by classification of normal images and abnormal images from the publicly available database. However CNN is utilized for accurate classification, the problem of over fitting impact the results in spite of unbalanced image data.

Wang et al (2021) presented a novel semi supervisor learning technique for speckled noise removal in optical coherent technology enabled images. Images are processed to provide capsule generative adversible network(CGAN) with constructive learning approach. Further the classification of model is evaluated after the removal of spherical noise. Even after the noise removal process, fewer images are getting occluded by the image pixels. These images need to be removed from analysis to reduce the processing time.

Cecilia S Lee et al. (2017) the author explored the benefits of deep convolutional neural network (DCNN) on classification of OCT images. The retinal abnormality is explored through various infections that felt chronic within the human body. These chronic impacts need to be treated in the early stages. Continuous infection in the retinal area leads to diabetic retinopathy. The presented system considers the chronic impacts, hence more health anomaly features need to be considered for analysis to improve the accuracy of prediction.***Wang et al.,(2023)*** The author proposed a novel self-guided automation technique in which joint automation of supervised mechanism is taken. The retinal OCT images are provided here to make a connection completely with the relevant data using you shaped segmentation architecture. Consider various levels of train images available from the publicly available websites. Further to improve the segmentation accuracy semi supervised decoder is utilized here with convolution neural network architecture. The classification rely on segmentation accuracy and quality of image under test. Degradation of image pixels available in public database need to be reduced.

Wang et al.(2022) The author presented a deep learning mechanism with semi supervised version of pseudo labelled data augmentation strategy for retinal fluids segmentation. The proposed technique achieve better accuracy, comparing with various state of art approaches in terms of labelling process and the experiment undergo various levels of classification of retinal anomaly. However the distribution of public data collected from different sources, then random selection of test image using DCNN during training process impact the final classification accuracy.

Kang et al. (2018) the multi-tasking convolutional neural network enabled diabetic retinopathy is explored here. The presence of retinopathy is evaluated through various methods. The emerging growth of machine learning is highly impact the game changing performance of image processing.

As per the detailed exploration of existing reviews, the major problem persist with the OCT image based retinal fluid classification are listed below.

- Large GPU utilization when handling the massive image database in CNN architectures.
- Unbalanced image data collected from publicly available websites impact the result accuracy
- Customized images with less training images having the limited features.
- Clogged images included in the deep learning training process create over fitting and impact the accuracy of prediction.

The proposed system is further considers the drawbacks in the existing methods, and created with a solution of light weight architecture to reduce the complexity and focused on improving the result.

3.System Design

Artificial intelligence enabled image of scaling techniques are derived from the super resolution in analysis of image pixels to improve the quality of existing image. Traditional of scaling techniques includes by cubic interpolation can defect the image quality by bluing the pixels. Artificial intelligence enable the technology leverage the image pixels without disturbing the quality of the pixel. The end result provides the improved version of super pixel images for the low resolution images are converted into high resolution images with the help of scaling techniques. The purpose of artificial intelligence enabled up scaling technology derived from the base algorithm using convolution neural networks. The artificial intelligence enabled tool such as Zyro best of scaling technique is initially utilized here to improve the quality of low resolution retinal images. For that these images are opted for future extraction technique using robust feature extraction technique(RFE) and further classification is made. Single image super solution technique is utilized in various neural network algorithms to improve the low quality images into high quality images without disturbing the pixel values. Progressive super resolution technique is the continuous process of improving the image quality by slowly upscaling the image pixels with the smaller factor of corrections. It will provide better results but still the computation cost is expensive.

AI enabled upscaling techniques are replaced in various applications such as image enhancement in photography video video improvement marking of image regions quality of pixel

4. Design Methodology

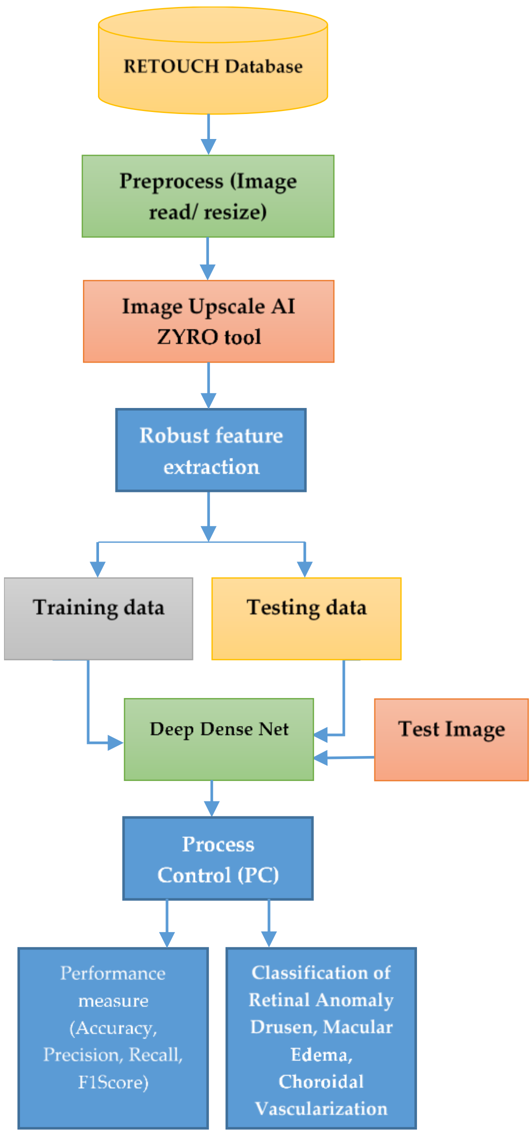

Fig 2. System architecture of proposed AIU-DDNC model

Fig 2. shows the system architecture of proposed AI up scaling enabled deep dense neural computing (AIU-DDNC) for retinal anomaly detection. The input images are collected from RETOUCH dataset. These images are publicly available labelled dataset. The quality of images are initially unstable. Here AI enhanced tool named Zyro Online platform is utilized to negotiate the deep pixel noise present in the images. The images before the noise removal process and after the noise removal process are illustrated in Fig 5.

Noise Removal using AI-Zyro

- The AI-Zyro noise removal steps includes reading the input noisy image through the web application. The browser read the OCT images and apply the AI slider. The slider remove the blur pixels in the OCT image and negotiate the pixel values to nearest integer.
- The quality of image may not get degraded by the AI slider. These pixel data is stable with the dimension hence the scale of the image remains same.
- Further these processed images are saved as .JPG or .PNG for preparation of feature extraction process.

Deep dense neural computing (DDNC)

The dense block is the combination of components present in the neural network completely availability together to create a dense network. The densely connected neural networks contains information about the feature vector of the retinal area. These features are helpful to analyses the regional impacts of the disease and further these blocks are connected in a promoted promotional day to vanish the gradient.

The deep dense neural network consists of layers contains input layer, transition layer, batch normalization, and convolution layer etc. The overall's net architecture is formed by evaluating multiple levels of dense transmission of pixel values for the classifications made using the convolution network architecture the key advantages present in the deep dense neural computing process consists of improved reuse of deeper architecture and its features repeatedly with respect to the complete evaluation of output adopted in deep learning technology.

The advantage of the Deep dense neural computing offers efficient usage of feature parameters vanishing the problem of false positive occurrence due to unstructured dataset. Here the image features are keenly processed with levels of transition layers.

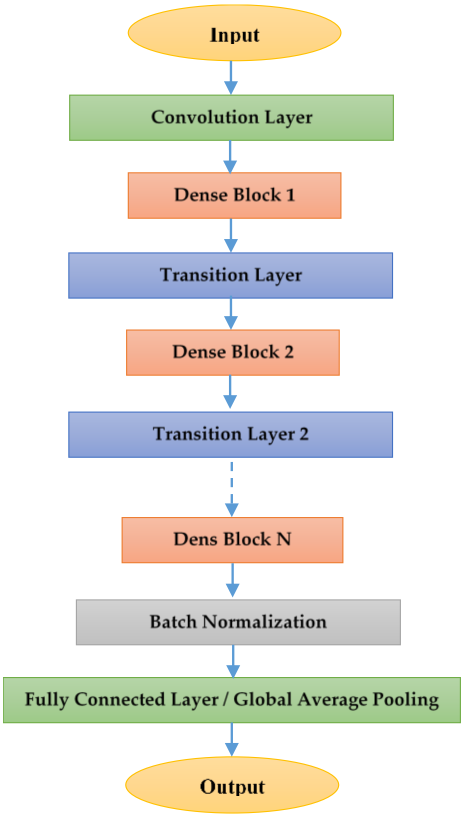

Fig 3. Deep Dense neural computing (DDNC) block

Fig 3. Shows the layers associated within the proposed Deep Dense network. The input features are fetched inside the input layer. The deep dense net composed of sequence of densely connected feature layer, with transition state layer. The initial features are convoluted in the first convolution layer. 10x10 filter stride window is utilized here for convolution. The Dense layer have the channel size of 4x4, 6x6, 8x8 windows. Each dense layer convolute the features and send it to the transition layer. The residual features are further processed again in the transition layer. The operations are consequently repeated for N=16 blocks. The final feature correlated after the fully connected layer are utilized for final classification.

5. Results and Discussions

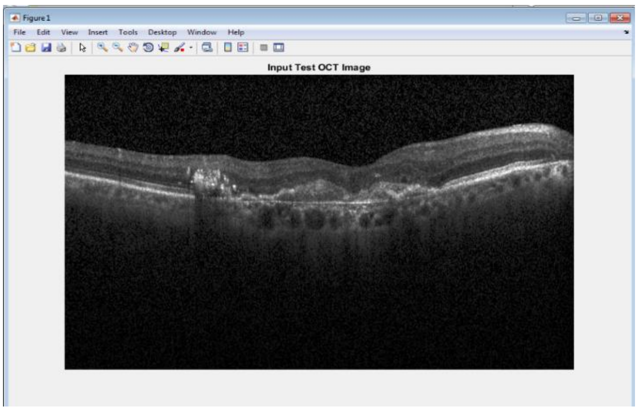

Fig 4. Input Test image

Fig 4. Shows the input test image sample collected from RETOUCH dataset. The images are various size available in the global content. Initial process includes the resizing of database converts the multiple image size into fixed image size.

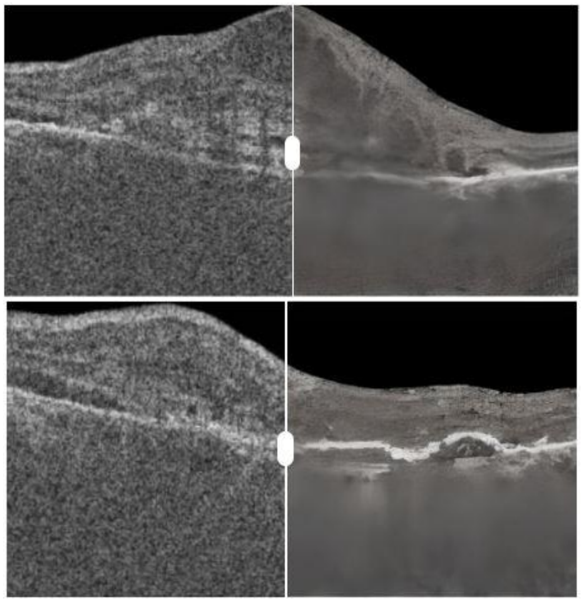

Fig 5. Application of AI-Zyro on OCT image

Fig 5. Shows the application of Zyro tool on OCT images and its end result on the same.

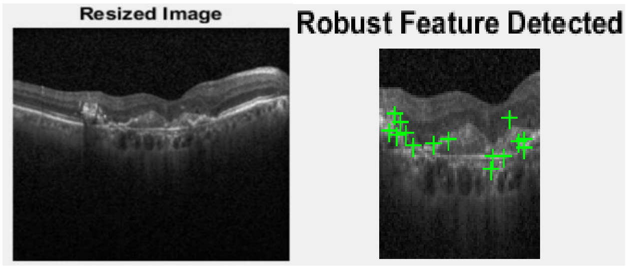

Fig 6. Resized image **Fig 7.** Robust feature extraction

Fig 6. Shows the resized image under test. The common scaling process compress the image pixels without disturbing its quality. Fig 7. Shows the Robust feature extraction (RFE) process extracts the unique pixels in the OCT test image using Harris feature extraction technique.

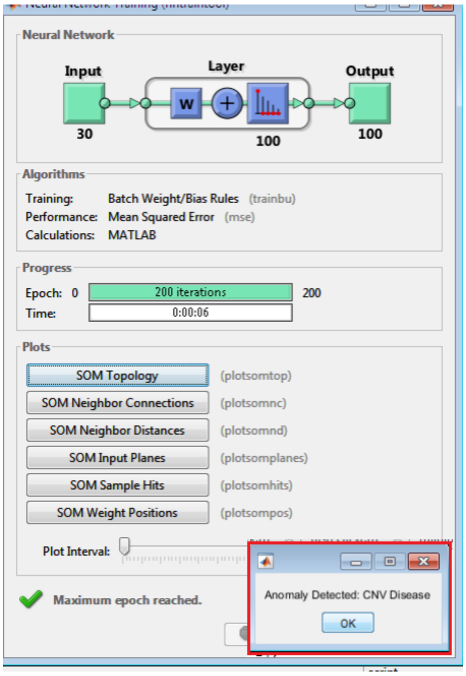

Fig 8. Deep Dense Neural Computing Machine

Fig 8. shows the configured Deep dense neural computing machine for classifiying the feature vectors extracted after the AIU process and RFE process. The classification result shows the retinal anomaly names such as Choriadal vascularization or CNV, Drusen, Edema and normal.

Table 1. Performance measure of proposed AIU-DDNC model

References	Data	Method adopted	Accuracy	Precision	Recall	Sensitivity
J. Kim et al. (2021)	OCT images	VGG-net	98.70	98.70	98.70	98.70
M. Subramanian et al. (2022)	OCT images	VGG-16	91.00	90.00	91.00	91.00
R. Bhadra et al. (2020)	OCT images	DCNN	96.50	95.20	96.50	96.50
Proposed Model	OCT images	AIU-DDNC	98.89	98.89	98.56	98.33

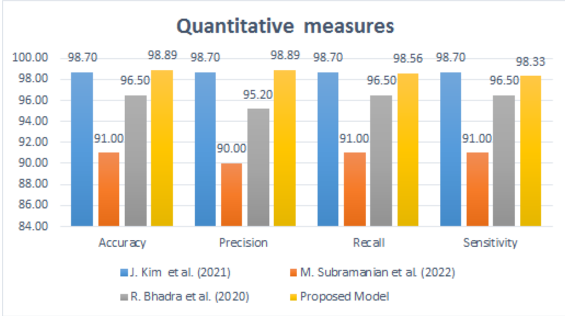

Fig 9. Performance measure of existing and proposed model

Fig 9. Shows the performance measure of proposed AIU-DDNC model with existing systems **(Table 1.)** such as [17] with VGG-Net architecture achieved 98.7% accuracy, 98.7% Precision, 98.7% Recall and 98.7% sensitivity etc. Similar architecture with VGG 16 network [18] the OCT image segmentation and classification achieved 91% accuracy, 90% precision, 91% Recall and 91% sensitivity etc. With Deep CNN architecture [19-23] accuracy of 96.5% is achieved, with 95.2% precision, 96.5%Reacll and 96.5% sensitivity etc. The proposed AIU-DDNC model achieved 98.89% accuracy, 98.89% precision, 98.56% Recall and 98.33% Sensitivity etc.

Table 2. Comparison of MCC and Processing time

Method adopted	MCC score	Processing time(sec)
VGGnet[17]	0.97	152
VGG-16[18]	0.96	145
DCNN[19]	0.95	165
AIU-DDNC	0.99	120

Table 2. Shows the comparison of existing mathews's correlation constant(MCC) score of existing design with proposed MCC value of AIU-DNNC method. The correlation is higher in the proposed approach comparatively. The processing time with dimensionality reduced image database achieved 120 seconds. The Deep Dense Net processing duration further increases if the size of the images database expanded.

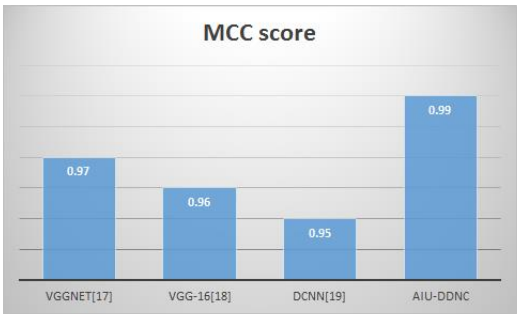

Fig 10. Comparative MCC Score

Fig 10 Shows the comparative MCC score achieved with existing and proposed model.

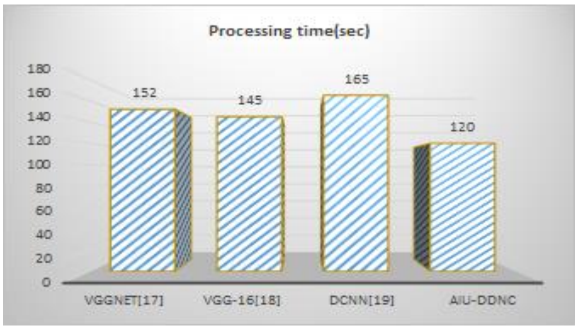

Fig 11. Processing time

Fig 11 Shows the comparative processing delay of analysis model achieved with existing and proposed systems.The major challenges faced here with the proposed approach development is handing the dense features extracted from robust feature extraction. The RFE extracts only the unique pixels from the OCT image, however dimensionality scaling is done, and these features are repeated in the dense layer processing within the 16 blocks. The goal of extracting the reduced features achieved here, further the system can be explored with multiple levels of dense layer and soft-max layers for better results.

6. Conclusion

Retinal irregularity is a sort of ongoing effect created because of constant gathering of liquid in the retinal space. Untreated retinal contamination prompts long-lasting harm to the organ. The division of retinal blister from the optical cognizance tomography (OCT) pictures significant to distinguish the illness in the beginning phases. The division of tainted region is used to characterize the sort of retinal sickness like Choroidal vascularization, strong Edema, Drusen and ordinary pictures. The proposed framework is outlined in such a manner to make upgraded screening pictures through fake intelligence(AI) empowered picture upscaler(AIU) utilizing Zyro device. The up scaled pictures are additionally used for highlight extraction process towards profound ID of exceptional effects in the OCT pictures. The arrangement is investigated with profound thick brain computing (DDNC) through profound brain network (DNN). The proposed computer based intelligence upscale profound thick network (AIU-DDNC)classify the component vectors regarding sickness types prepared inside a similar organization. The Repair dataset is used here for making a standard model and further the introduced framework accomplished 98.89% accuracy on retinal sickness order is contrasted and existing condition of workmanship draws near. The precision of proposed system is 98.89%, 98.56% Recall and 98.33% Sensitivity is achieved. Optimizing the features, removal of noise s completely focused here which parallel improved the performance of the prediction. Further the proposed approach need to be enhanced with multiple learning dataset with ensemble approach of feature parametric are suggested.

References

[1] M. S. Sarabi et al., "3D Retinal Vessel Density Mapping With OCT-Angiography," in IEEE Journal of Biomedical and Health Informatics, vol. 24, no. 12, pp. 3466-3479, Dec. 2020, doi: 10.1109/JBHI.2020.3023308.

[2] Y. Sun et al., "Adaptive-Guided-Coupling-Probability Level Set for Retinal Layer Segmentation," in IEEE Journal of Biomedical and Health Informatics, vol. 24, no. 11, pp. 3236-3247, Nov. 2020, doi: 10.1109/JBHI.2020.2981562.

[3] N. Paluru, H. Ravishankar, S. Hegde and P. K. Yalavarthy, "Self Distillation for Improving the Generalizability of Retinal Disease Diagnosis Using Optical Coherence Tomography Images," in IEEE Journal of Selected Topics in Quantum Electronics, vol. 29, no. 4: Biophotonics, pp. 1-12, July-Aug. 2023, Art no. 7200812, doi: 10.1109/JSTQE.2023.3240729.

[4] A. Cazañas-Gordón and L. A. da Silva Cruz, "Multiscale Attention Gated Network (MAGNet) for Retinal Layer and Macular Cystoid Edema Segmentation," in IEEE Access, vol. 10, pp. 85905-85917, 2022, doi: 10.1109/ACCESS.2022.3198657.

[5] M. Rahil, B. N. Anoop, G. N. Girish, A. R. Kothari, S. G. Koolagudi and J. Rajan, "A Deep Ensemble Learning-Based CNN Architecture for Multiclass Retinal Fluid Segmentation in OCT Images," in IEEE Access, vol. 11, pp. 17241-17251, 2023, doi: 10.1109/ACCESS.2023.3244922.

[6] C. Zhang et al., "Memory-Augmented Anomaly Generative Adversarial Network for Retinal OCT Images Screening," 2020 IEEE 17th International Symposium on Biomedical Imaging (ISBI), Iowa City, IA, USA, 2020, pp. 1971-1974, doi: 10.1109/ISBI45749.2020.9098717.

[7] T. Hassan, A. Usman, M. U. Akram, M. Furqan Masood and U. Yasin, "Deep Learning Based Automated Extraction of Intra-Retinal Layers for Analyzing Retinal Abnormalities," 2018 IEEE 20th International Conference on e-Health Networking, Applications and Services (Healthcom), Ostrava, 2018, pp. 1-5, doi: 10.1109/HealthCom.2018.8531198.

[8] Rasti, A. Biglari, M. Rezapourian, Z. Yang and S. Farsiu, "RetiFluidNet: A Self-Adaptive and Multi-Attention Deep Convolutional Network for Retinal

OCT Fluid Segmentation," in IEEE Transactions on Medical Imaging, vol. 42, no. 5, pp. 1413-1423, May 2023, doi: 10.1109/TMI.2022.3228285.

[9] The Edge Detectors Suitable for Retinal OCT Image Segmentation,2017 , 10.1155/2017/3978410JF - Journal of Healthcare EngineeringPB - Hindawi, A2 - Fu, ShujunAU - Luo, SuAU - Yang, Jing

[10] X. He, Z. Zhong, L. Fang, M. He and N. Sebe, "Structure-Guided Cross-Attention Network for Cross-Domain OCT Fluid Segmentation," in IEEE Transactions on Image Processing, vol. 32, pp. 309-320, 2023, doi: 10.1109/TIP.2022.3228163.

[11] Gao, QianAU - Zhou, ShengAU - Zhan, Chang'an A Dongze Lian, Lina Hu, et al., "Multiview multitask gaze estimation with deep convolutional neural networks," IEEE transactions on neural networks and learning systems,2018.

[12] Wang et al., "Semi-Supervised Capsule cGAN for Speckle Noise Reduction in Retinal OCT Images," in IEEE Transactions on Medical Imaging, vol. 40, no. 4, pp. 1168-1183, April 2021, doi: 10.1109/TMI.2020.3048975.

[12] Cecilia S Lee, Doug M Baughman, et al., "Deep learning is effective for classifying normal versus agerelated macular degeneration oct images," Ophthalmology Retina, vol. 1, no. 4, pp. 322–327, 2017.

[13] M. Wang et al., "Self-Guided Optimization Semi-Supervised Method for Joint Segmentation of Macular Hole and Cystoid Macular Edema in Retinal OCT Images," in IEEE Transactions on Biomedical Engineering, vol. 70, no. 7, pp. 2013-2024, July 2023, doi: 10.1109/TBME.2023.3234031.

[14] Wang et al., "MsTGANet: Automatic Drusen Segmentation From Retinal OCT Images," in IEEE Transactions on Medical Imaging, vol. 41, no. 2, pp. 394-406, Feb. 2022, doi: 10.1109/TMI.2021.3112716.

[15] Kang Zhou, Zaiwang Gu, et al., "Multi-cell multi-task convolutional neural networks for diabetic retinopathy grading," in 2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE, 2018, pp. 2724–2727.

[16] Trichonas, George, and Peter K. Kaiser. "Optical coherence tomography imaging of macular oedema." British Journal of Ophthalmology 98, no. Suppl 2 (2014): ii24-ii29.

[17] J. Kim and L. Tran, "Retinal Disease Classification from OCT Images Using Deep Learning Algorithms," 2021 IEEE Conference on Computational Intelligence in Bioinformatics and Computational Biology (CIBCB), Melbourne, Australia, 2021, pp. 1-6, doi: 10.1109/CIBCB49929.2021.9562919.

[18] M. Subramanian, K. Shanmugavadivel, O. S. Naren, K. Premkumar and K. Rankish, "Classification of Retinal OCT Images Using Deep Learning," 2022 International Conference on Computer Communication and Informatics (ICCCI), Coimbatore, India, 2022, pp. 1-7, doi: 10.1109/ICCCI54379.2022.9740985.

[19] R. Bhadra and S. Kar, "Retinal Disease Classification from Optical Coherence Tomographical Scans using Multilayered Convolution Neural Network," 2020 IEEE Applied Signal Processing Conference (ASPCON), Kolkata, India, 2020, pp. 212-216, doi: 10.1109/ASPCON49795.2020.9276708.

[20] Yaseen, M., Hayder Sabah Salih, Mohammad Aljanabi, Ahmed Hussein Ali, & Saad Abas Abed. (2023). Improving Process Efficiency in Iraqi universities: a proposed management information system. Iraqi Journal For Computer Science and Mathematics, 4(1), 211–219. https://doi.org/10.52866/ijcsm.2023.01.01.0020

[21] Aljanabi, M. ., & Sahar Yousif Mohammed. (2023). Metaverse: open possibilities. Iraqi Journal For Computer Science and Mathematics, 4(3), 79–86. https://doi.org/10.52866/ijcsm.2023.02.03.007

[22] Atheel Sabih Shaker, Omar F. Youssif, Mohammad Aljanabi, ABBOOD, Z., & Mahdi S. Mahdi. (2023). SEEK Mobility Adaptive Protocol Destination Seeker Media Access Control Protocol for Mobile WSNs. Iraqi Journal For Computer Science and Mathematics, 4(1), 130–145. https://doi.org/10.52866/ijcsm.2023.01.01.0011

[23] Hayder Sabah Salih, Mohanad Ghazi, & Aljanabi, M. . (2023). Implementing an Automated Inventory Management System for Small and Medium-sized Enterprises. Iraqi Journal For Computer Science and Mathematics, 4(2), 238–244. https://doi.org/10.52866/ijcsm.2023.02.02.021

[24] Rana, P. ., Sharma, V. ., & Kumar Gupta, P. . (2023). Lung Disease Classification using Dense Alex Net Framework with Contrast Normalisation and Five-Fold Geometric Transformation. International Journal on Recent and Innovation Trends in Computing and Communication, 11(2), 94–105. https://doi.org/10.17762/ijritcc.v11i2.6133

[25] Sofia Martinez, Machine Learning-based Fraud Detection in Financial Transactions , Machine Learning Applications Conference Proceedings, Vol 1 2021.