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Research Article

Segmentation of Retinal Layers in Diseased Optical Coherence Tomography Scan Images

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Abstract

Medical treatments are greatly enhanced by implementing X-rays that help in the suitable development of scanned images and, at this moment, helping in the establishment of the three-dimensional structures for increasing the doctors' performance through accurate visualization. The increase in performance is more greatly enhanced by establishing machine learning models that help develop the predictive results for increasing data outcomes in a broader approach. Moreover, the use of OCT helps in the development of scanned images for the eyes, heart, brain, and other internal organs that prove to be effective in the establishment of proper medical treatments. Human eyes are important parts of the human body. They not only provide vision to humans and provide a learning mechanism for our brain. Neurons get trained for new objects seen by eyes. Retinal Optical Coherence Tomographical imaging provides early detection of retinal diseases which may cause blindness. The ophthalmologist uses the OCT imaging technique for the diagnosis of retinal diseases in the early stages. The segmentation of retinal layers could easily identify the severity of retinal diseases.

Keywords: *Retinal oct scan images, drusen, diabetic macular edema.*

Introduction

This imaging has been established through the suitable penetration of different types of rays within the body parts or opaque bodies, thereby helping establish the suitable images in a three-dimensional pattern. The application of electromagnetic radiation helps develop suitable images of opaque bodies that are generally known to be the procedure for

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tomography. Tomography helps in the establishment of multiple projections through the implementation of the radiographs. It thereby uses the X-rays for the suitable construction of the images that help in the possibility of image processing by implementing the wave penetration for the suitable identification of the image patterns that could be used for different purposes.

The application of the computer devices that helps in the suitable representation of the images developed through the use of the X rays helps in the establishment of the CT scan or computed tomography and thereby helping in the development of vision within the internal body parts for the doctors for enhancing the medical treatments that are usually represented through the generation of the images established through scanning [1]. The implementation of the X-rays is mostly considered and being passed through the internal body organs, thereby helping in the accomplishment of the images that are being demonstrated through the images or three-dimensional patterns established in the computer screen for viewing the faults generated within the organs tissues, and bones. The differences that are mostly generated with the different organs of the human bodies are identified through the suitable flow of wave energy that helps establish the clear impingement within the targeted structures. The application for tomography facilitates the generation of the three-dimensional structures that help in the suitable detection and recognition of the faults developed within the internal body parts by analyzing the faults from different angles formed through images.

OCT or "Optical Coherence Tomography" has been considered a part of the tomographic process that, in turn, has been known to be the efficient technique applied for imaging for the suitable establishment of the images in an appropriate manner [2]. The suitable application of the techniques for the imaging makes use of the light having low coherence and thereby helping in the suitable capturing and recording of the resolution in micrometres for the appropriate establishment of the images in both three or two dimensions that are being significantly recorded from the biological tissue or the "optical scattering medium". The implementation of the procedure for OCT is mostly configured in establishing the images through the application of X-rays and thereby helping in a recording of the eyes' back portion or retina. The retina is being considered to be the screen of the eye and thereby making use of OCT for the development of the ideas regarding the diseases developed within it that results in the deformation of the retina and thereby helping in the establishment of the suitable images for developing the suitable three-dimensional structures on the computer screen in an effective manner for enhancing medical treatments [38-46].

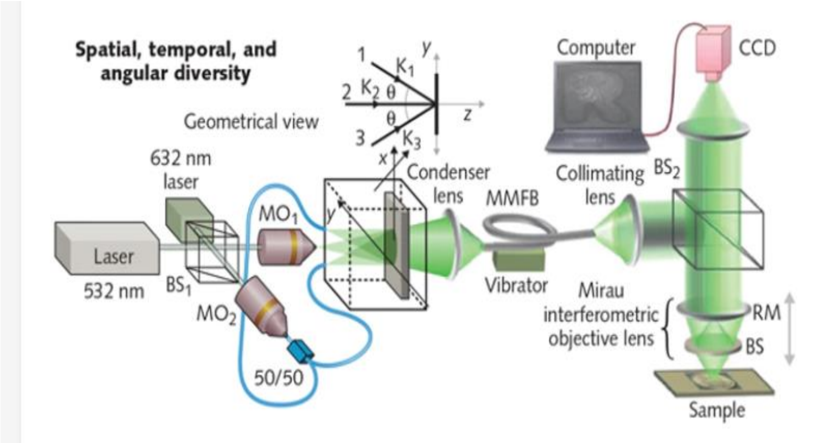

Figure 1. Optical Coherence Tomography [30]

OCT helps in the suitable engagement of the non-invasive, high resolution, and high speed for the suitable establishment of the imaging modality, thereby helping to capture the three-dimensional structures developed inside the retina. For the suitable establishment of the patient-specific data, that helps in implementing the crucial information and thereby making use of the automated response and results through the application of OCT effectively [3]. Processing the information established through the application of the real-time data proves to be effective in establishing the quantitative data through the analysis developed for the retina images [47-65].

The diseases that are mostly being developed within the retina are macular degeneration that mostly enhances through ageing and glaucoma, which in turn helps in the significant increase in the deformation of the retina, thereby leading to a significant decrease in retinal performance. OCT helps identify the faults or diseases present in the retina, thereby helping establish the analysis developed through the formation of quantitative images through high resolution and high-speed methods for imaging modality in a non-invasive pattern [66-72]. The development of the resolution established across the axis that considers two microns facilitates the suitable removal of the complexities established inside the retina by generating the computational data. The data established through computation helps in the clear representation of the three-dimensional imaging for helping the patient and the doctors by developing the three-dimensional datasets [4]. For the suitable establishment of the retinal segmentation, the application of the OCT helps in the suitable removal of the complexities developed within the retina and thereby helping in the development of suitable decisions for enhancing the clinical research effectively [73-87].

The detection of the diseases that have been encountered through the implementation of the retinal segmentation, in turn, proves to be effective in the development of the analysis for getting clear datasets for the retina. The process of segmentation that is accomplished through the consideration of the information for the nuclear membrane and blood vessels that are mostly being accomplished through the use of the algorithm for retinal segmentation and thereby helping in the suitable generation of the three-dimensional datasets for developing sustainable decisions through them the consideration of the developed images [5]. Nowadays, the consideration of machine learning approaches like ANN, Naive Bayes, and decision trees are used for the development of suitable decisions through predictions and thereby helping in the suitable detection of retinal diseases through the application of the retinal segmentation for enhancing the quality of the medical treatments through early predictions and generation of three-dimensional datasets [6].

Methods

Procedures or methods that have been selected through the application of the approach for the OCT that helps in the development of the suitable images for the retina and thereby helping in the accomplishment of segmentation for developing the datasets for the three-dimensional structures through the suitable detection of the availability of the diseases affecting the human eyes on a large scale [7]. This section of the research helps in the suitable identification of the methods that have been recommended for the collection of valuable data regarding OCT that proves to be beneficial in the generation of the suitable information regarding retinal segmentation for the suitable identification of the diseases that are being demonstrated through imaging. This section helps in the generation of useful data regarding the methods implemented in this research to enhance the feasibility of this research by collecting the data and thereby helping in the development of the analysis for the establishment of suitable results. The design and strategy implemented for the accomplishment of this research are demonstrated, thereby helping in figuring out the demerits developed within this research to understand the importance of this research.

The research has been established through the suitable consideration of the methods that helps in enhancing the performance of the research through the generation of the data sources for developing the analysis that in turn helps in the establishment of desired results for the proper detection of eye diseases affecting the retina that could visualize through the implementation of the OCT [8]. The method that has been configured for this research is the second method that helps in generating the secondary data sources for performing the analysis for this research. The research has been accomplished by developing the review on six research journals that contains useful information regarding the retinal segmentation accomplished through OCT, thereby helping in the establishment of analysis for enhancing the productivity of this research.

The approach has been developed to understand the process selected by this research to establish the valuable information through proper data collection and thereby help; ping in the development of the strategies for increasing the research [9]. The selection of the inductive approach has been accomplished for the suitable application of the existing suggestions and theories of the authors and thereby helping in the enhancement of the new knowledge through the application of the secondary methods that help in the increase in the research performed for the generation of the valuable results through analysis. Data collected through the inductive approach helps provide information regarding the scanned images for OCT that helps in the suitable detection of the diseases developed in the retina by implementing retinal segmentation.

Philosophy has been accomplished for understanding the motives that are developed for the performance of this research and thereby helping in increasing efficiency through the establishment of the analysis [9]. The establishment of the methods for performing this research is mostly based on identifying the importance developed through the application of the OCT for developing the scanned images through retinal segmentation and thereby helping in the establishment of the three-dimensional structures for enhancing medical treatments. Realism, interpretivism, positivism, and post-positivism are the most common philosophical methods used for analysis. Based on the motive acquired through the development of this research, the philosophy of positivism has been selected for enhancing the rate of positive outcomes through the development of this research.

Research design has been accomplished for understanding the structure developed for the collection of the valuable data sources that helps in enhancing the research performance. The development of the design for this research has been implemented using the qualitative methods that use the secondary resources through the review developed on six journals and thereby helping in the suitable collection of the resources for making suitable analysis of the data [10]. Based on the information developed through the previous research, the assumptions are developed to establish data analysis for understanding the application of the OCT for detecting the diseases and, at this moment, helping in the formation of the scanned images through retinal segmentation. The strategy has been established by collecting useful information, thereby helping to accomplish the archival research for implementing strategic ideas regarding the data implementation for developing the quality of the analysis effectively.

The implementation of the strategy helps identify the suitable methods that resulted in generating the innovative results and thereby helping in meeting the desired outcomes for this research. Data collection approaches that have been accomplished in this research are through applying the secondary resources that mostly comprise the data generated through the research, thereby helping to accomplish the analysis for developing results [11].

The limitation has been identified by recognizing the methods and approaches for data collection that resulted in the generation of the demerits for producing an effective analysis. The demerits that have been diagnosed through the application of this research are the generation of the obstacles by implementing the qualitative methods that use secondary resources and thereby limiting the flow of the information on a large scale [12].

The establishment of the summary of this research is accomplished through the development of the research methods that make use of the secondary methods and thereby helping in the better implementation of the inductive approach for the establishment of the new ideas that will help in the application of the positive outcomes through positivism for accomplishing the research through the use of the archival strategy. The limitations are diagnosed that could be applied in the future for enhancing the quality of this research on a large scale [13]. [Referred to Appendix 2]

Analysis & Results

Architectural Frameworks

According to the paper of [14], being a particular type of non-invasive style of imaging modality, the OCT or "Optical Coherence Tomography" technology has provided even a micrometer level of resolution in producing three-dimensional images of the retinal structures. This is exactly the reason behind its use as a diagnosis of retinal diseases such as edema. The technology is well recognized in the ophthalmological applications in providing sub-surface images of biological tissues quite effectively that may be a handful for diseases such as "age-related macular degeneration" or AMD. The high quality of visualization that this technology can provide helps visualize the entire structure of the retinal tissues. In this regard, the application of the FCN or "Fully Convolutional Neural Networks" has been able to produce an effective performance in the case of image segmentation. The study followed three particular processes: layer segmentation, fluid detection, and the classification model. The images were collected from the "MICCAL RETOUCH group", and a total of 3 training datasets were used for the purpose with 70 total volumes [15]. Data collected from three OCT devices were used with manual labelling of the dataset. The labelling was conducted for three particular fluid labels as SRF, IRF, and PED. For the layer segmentation, cross-correlation was used to correct axial motion, and then a "boundary variation 3D smoothing" was used to enhance the boundaries between layers. The layers were segmented automatically with the help of a "3D graph-cut based algorithm". The study has used an FCN model based on the following architecture:

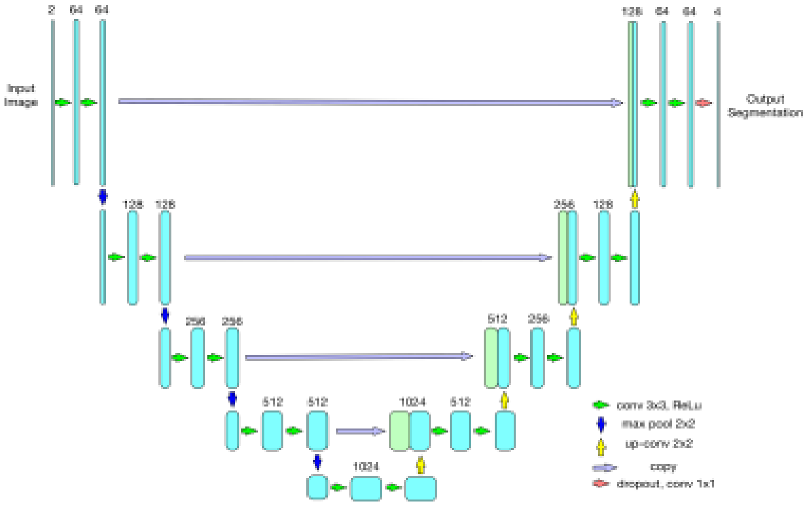

Figure 2. FCN Architecture [29]

The FCN model has used two paths: an expansive path (on the right side) and a contracting path (on the left side). The key advantage of using this particular architecture is that it can be applied over arbitrary size images without any fully connected layer. Thus, the training based on the images from the three different devices is based on this architecture. In this architecture, the "random forest classification" is used to analyze the data [16]. The paper has effectively shown how an effective novel framework can be applied to segment the layers for detecting the exact 3D structure of the retinal tissue. But the training data sample was yet considerably limited in this regard. For judging the exact accuracy of the suggested framework, it would be best to use a larger size of accumulated data.

According to Janpongsri et al. in [17], it is possible to use a pseudo-real-time segmentation method for the retinal layers with C/C++ on an OCT acquisition system. The method has focused on five particular aspects, which are image cropping, noise reduction with logarithmic scaling, weight calculation with layer-endpoint initialization, RPE and ILM layer segmentation, search region limiting. The graph-cut is the main technique that has been utilized for the application in the paper.

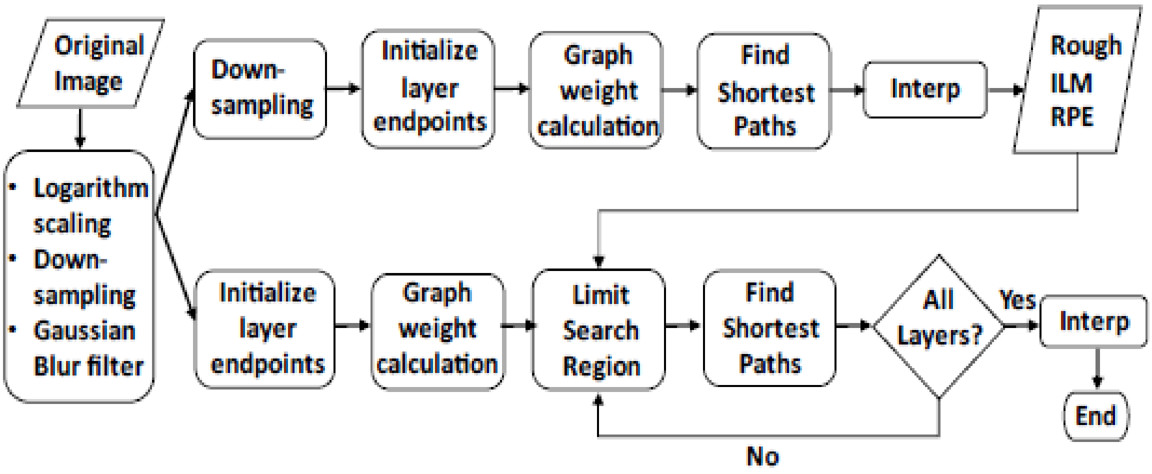

Figure 3. Flow Chart of the Process [31]

In this particular context, it is identified by the authors that the usual graph cut technique has the potential to generate an unwanted layer labelling in between two actual layers. The "Dijkstra's Algorithm" the graph cut is performed with the help of "minimum cost path". This helps in producing a single path between layers without artefacts. Thus a simple generic interface is possible to be implemented in the application of the layer segmentation technique. Also, this makes it easy to be used with the help of C/C++ with the application of just an additional header file. The technique used by the researchers was focusing on implementing a "pseudo-real-time retinal layer segmentation" that will provide "a face image generation" based on the layer structures of retinal anatomy. The study has shown how heterogeneous computing depends on the nature of the tasks to be done [18]. The GPUs used for the purpose, in particular, are aiming for performance optimization with smaller (independent) parts having low or zero communication among the parallelized tasks. It was also explained that alternate computational nodes and hardware could be implemented with this particular framework. This would help to cope with the rapid development needs of the OCT applications based on the expanding needs of the uses in the ophthalmology context. The resource (power and time) optimization is the key achievement that was possible to be gained with the help of the proposed framework. This indicates the possibility of using OCT applications with the help of mere "consumer-grade PCs" for real-time image processing to generate B-scan images.

Repeatability

As per the research work of Lee et al. [19], it is also crucial to focus on the repeatability of the measurement achieved with the help of the OCT applications such as vessel density (VD). It is a critical factor to be considered as the technique's precision depends on this particular aspect of the technology. Samples of scan images were used from patients with retinal diseases to gain a practical understanding of the particular case scenario. The suitable application of the techniques for the imaging makes use of the light having low coherence and thereby helping in the suitable capturing and recording of the resolution in micrometres for the appropriate establishment of the images in both three or two dimensions that are being significantly recorded from the biological tissue or the "optical scattering medium". The implementation of the procedure for OCT is mostly configured in establishing the images through the application of X-rays and thereby helping in a recording of the eyes' back portion or retina. Consecutive (two) measurements with OCT were applied for the analysis. The study has followed a linear regression model to analyze the test results. In total, 134 eye samples were subjected to the study, of which 20 had DME, 44 had RVO (macular edema), 50 had ERM, and 20 had wet-AMD. The mean age of the population was about 65 years.

Table 1.

Baseline Characteristics of the Sample Population [32]

Number of Subjects	134
Diabetic Macular Oedema(%)	20(14.9)
Retinal vein occlusion(%)	44(32.8)
Epiretinal membrane(%)	50(37.3)
Wet AMD(%)	20(14.9)
Age(year , mean±SD)	64.9±10.4
Male gender(%)	62(46)
Diabetic mellitus(%)	44(32.8)
Hypertension(%)	61(45.5)
Right laterality(%)	76(56.7)
Phakic eye(%)	94(70.1)
BCVA(logMAR , mean±SD)	0.24±0.23
Spherical equivalent(dioptres , mean±SD)	-0.16±1.79
IOP(mm Hg , mean±SD)	15.9±2.9
Axial length(mm , mean±SD)	23.7±1.2
Mean Signal strength(mean±SD)	8.8±1.0
Mean CMT(µm ,mean±SD)	391.6±115.5
Mean GC*IPL thickness(µm ,mean±SD)	61.4±28.6

The repeatability was measured in the study with the help of CV and ICC of the results. This helped to analyze the statistical repeatability of the output data so that comments on the repeatability aspect of the test outputs can be made. The results are as such:

Table 2. Statistical Results [33]

	First mean VD	Second mean VD	ICC	CV (%)	TRTSD
Full	17.7±3.1	17.6±2.9	0.812	6.72	0.74
Inner	18.4±3.3	18.5±3.1	0.867	5.60	0.66
Sectoral					
Central	10.9±4.4	110±4.7	0.905	14.74	0.89
Superior	18.2±4.1	18.3±3.8	0.840	8.38	0.96
Nasal	18.2±3.3	19.0±3.4	0.798	7.56	0.87
Inferior	18.1±4.0	18.1±3.8	0.884	7.70	0.81
Temporal	18.3±3.8	18.6±3.7	0.737	8.86	1.01

Also, multivariate, and univariate linear regression was conducted to judge the association between anatomical and clinical parameters along with the coefficient of variation.

Table 3. Multivariate and Univariate Linear Regression Results [34]

	Univariable		**Multivariate**	
	B(95% CI)	P values	B(95% CI)	P values
Age	0.001(-0.172 to 0.173)	0.995	-	-
Sex	-1.084(-4.667 to 2.499)	0.551	-	-
Laterality	2.025(-1.568 to 5.619)	0.267	-	-
Phakic eye	-1.978(-5.872 to 1.917)	0.317	-	-
Diabetes	-2.190(-5.980 to 1.601)	0.255	-	-
Hypertension	-1.801(-5.380 to 1.778)	0.321	-	-
SE	-.367(-0.632 to 1.366)	-.468	-	-
BCVA	8.553(0.775 to 1.322)	0.031	3.844(-4.283 to 11.972)	0.351
IOP	0.153(-0.463 to 0.768)	0.624	-	-
Axial Length	0.414(-1.922 to 1.094)	0.588	-	-
Mean signal strength	-1.967(-3.920 to -0.014)		-1.193(-3.153 to 0.767)	0.231
Mean CMT	0.019(0.004 to 0.034)	0.015	0.007(-0.010 to 0.024)	0.483
Mean GC-IPL thickness	-0.103(-0.163 to -0.043)	0.001	-0.074(-0.144 to -0.003)	0.040

The analysis has shown considerable repeatability regarding the measurements achieved with the help of the statistical analysis over the data collected [20]. Still, some possible factors were identified as the impactors on the repeatability of the outcome results. These factors are such as signal strength, BCVA, GC-IPL, and CMT. So, these aspects must be critically taken into consideration while going for OCT applications.

Applications

In the study of Ramzan et al. [21], a detailed process framework for the application of OCT for the automated detection of glaucoma has been shown. Glaucoma is a particular type of blindness disease caused by the CDR or "cup-to-disc region" increase. A novel framework for the extraction of ILM or "Inner Limiting Membrane" and the RPE or "Retinal Pigment Epithelium" has been implemented in the particular aspect of the OCT application scope. The study has been used in the scope of the "Armed Forces Institute of Ophthalmology" dataset. Based on the analysis, the model needed to classify the subjects into two classes: glaucomatous or normal. In the RPE segmentation, a particular method of "centroid-based thresholding" is implemented for removing the extended ILM region. The correlations were analyzed between the CDR-generated values and clinical annotations. New colour-based channels are used for the quality assessment where the ILM is segmented out. Both the RPE breakpoints and the ILM layer are used for the calculation of disc and cup. The "horizontal/flat cup diameter" criterion is proposed in the study for the RPE breakpoint evaluation. The three key results obtained from the study are the accuracy, specificity, and sensitivity that came out to be 79%, 72%, and 87%. Also, the system proposed is estimated to have a sensitivity value of 92.59%. It has been concluded to be a great decision-support system for young doctors in practice.

According to Lupidi et al. [22], There are different sorts of methods that need to be considered for the research area, and those methods are going to represent in the below research work. "The joint extraction of the multiple layer boundaries" is structured within the framework of "CRF-based Energy Minimization". During the period of training, the energy of CRF is parameterized linearly. Its characteristics are learned in the manner of supervised and end to end by posing as "StructSVM optimization problem". During testing, the CRF is inferred to extract the boundaries of multiple layers in a step with single optimization. Image processing is another sort of step which combines with the "flattening of the retinal curvature, extraction of the region of interest (ROI) containing the retinal tissue, reducing the speckle noise and intensity standardization of the OCT B-scans". The flattening of retinal curvature is an important step of preprocessing that decreases the variation in the specific location of the tissue of retina "A-scans in an OCT image". It aids in gaining a tighter ROI by decreasing the requirements of memory and time and gives a consistent structure of the layer for the process of segmentation [23]. The retina tissue is surrounded by a dark colour background at the bottom and top in each sort of B-scan. To estimate the ROI, the image in terms of input is smoothed by a large filter of Gaussian with alpha= nine, and that is done to reduce the impact of speckle noise in the background and neglect the dark portion in the tissues of the retina.

In the case of the study of Chakravarty & Sivaswamy [4], there are also different sorts of methods that go with the research area, such as the design of the study. The study of reliability was developed in the "Odeon Ophthalmology Center (Paris, France)". This research was done following "the Declaration of Helsinki after approval by the Paris Institutional Ethics Committee". Written consent with full confirmation was generated from different research of patients, which is done before scanning with "the prototype OCT system". "Forty-seven eyes of 47 healthy subjects underwent best-corrected visual acuity (BCVA) testing, slit-lamp biomicroscopy, intraocular pressure measurement, fundus evaluation, and OCT-A between September 2015 and December 2015". The OCT-A, as discussed previously, was developed by computing the method of decorrelation among the B-Scans, which was acquired at a similar location. The ART model consists of the lower distance among two B-scans supported in making betterment to the SNR. The eye-tracking system with active manners permits the patient to take rest in case of any sort of fatigue at the time of testing. This gives the best "high-resolution C-scan angiogram, even in case of poor fixation or blinking" [24]. [Referred to Appendix 1].

Discussion

Focusing on the results that are developed through analysis, the overview has been developed for providing a suitable explanation of the concepts developed in this research through the implementation of the right methods that helps in the establishment of the suitable knowledge regarding OCT that helps in the suitable accomplishment of the retinal segmentation for the development of the scanned images in an effective manner [25].

The research has been developed by considering the six different journals and thereby helping in collecting effective data and suggestions for the accomplishment of the analysis. It could be established through the research that the application of the architectural frameworks helps in the application of the "FCN model" that makes use of the real-time constraints for the development of the classification of the random forest and thereby helping in the development of the versatility through the suitable retinal segmentation and thereby helps in making more applicable performance in the detection of the diseases within the retina. This is because the application of this model helps in the suitable representation of the three-dimensional structures that are being detected through the application of the X rays for the retina and thereby helping in a suitable increase in the performance on a large scale through the formation of the accurate imaging [26]. The development of the procedure for the OCT that has been accomplished through the use of this model makes use of the application of the machine learning concepts that mostly engages the algorithmic structures like Dijkstra's Algorithm for developing the results through predictive calculations and thereby helping in the establishment of the accurate images through scanning.

Moreover, the application of the OCT could also be generated through the engagement of the programming language for C++ and thereby helping in the accomplishment of the scanned images of the retina through the use of computer devices for better visualization. The accomplishment of the images that are developed through the scanning could be efficiently generated through the application of the programming commands and thereby helping in the establishment of the flexible outcomes through the application of the OCT for understanding the possibility of the diseases that result in the deformation of the retina [27].

Through the application of the above two models or architectural frameworks helps in the clarification of the fact that the procedure of the OCT is much more flexible in terms of the applications as it helps in the development of the desired results through the application of both machine learning and simple computer programming compilation model and at this moment helps in the establishment of the evidence for developing the scanned images for providing suitable retinal segmentation.

The establishment of the OCT helps in the suitable reduction in the repetition of the data achieved through the scanning, thereby helping develop accurate images efficiently [28]. Based on the development of the results developed through statistics, it could be configured that there is a suitable decrease in the data repetition through OCT that helps establish the data accuracy. Focusing on the use of OCT, it could be configured that the application of this method for developing scanned images helps in the enhancement of the medical treatment through the establishment of the scanned images for glaucoma and macular degeneration

Conclusion

The accomplishment of the future work has been conducted by implementing the recommendations developed through the application of the OCT that helps in the generation of the scanned images for the retina and thereby helping in the accomplishment of the retinal segmentation effectively. The recommendations are established through the generation of research by applying the secondary resources that help in the accumulation of suitable information regarding the OCT that helps enhance the future scope in the fields of medical treatments.

Recommendations

The application of the OCT that uses both machine learning and a simple computer compilation model helps clarify the fact that there has been a considerable increase in the flexibility within the developed three-dimensional datasets that helps in enhancing the medical treatments on a large scale. Therefore, in the future, the use of OCT could be utilized for developing the quality of the results for scanned images of the retina on a large scale.

Based on the analysis developed and thereby making consideration of the results developed through statistics, it could be assumed that there will be a significant increase in the data accuracy as the OCT helps in implementing the constraints of the real-time and results in the generation of a particular value for scanned images for n number of times. Therefore, in the future, it is recommended as per the results developed through statistics, there will be a significant improvement in the quality of the medical treatments through effective fault detection and disease diagnosis for increasing the rate of satisfaction for the patients through the accomplishment of the accurate images.

Future Work

In future, the application of the approach for the machine learning helps in the establishment of the predictive outcomes through the effective detection of the disease like glaucoma and macular degeneration and thereby helping in the generation of the future condition of the retina of the patients for developing the precautions and medical safety in an innovative manner. The present condition of the retina would be analyzed through ANN, thereby helping establish future results for the suitable generation of alerts and thereby helping in the development of the precautions on a large scale. To conclude, the research is accomplished by identifying the methods that prove beneficial in the generation of valuable data sources for developing effective use of the OCT to enhance the procedure for retinal segmentation. The different architectural frameworks have been identified for performing an effective analysis and thereby helping in understanding the benefits of the OCT for increasing the procedure for retinal segmentation for establishing scanned images for the suitable identification of the images.

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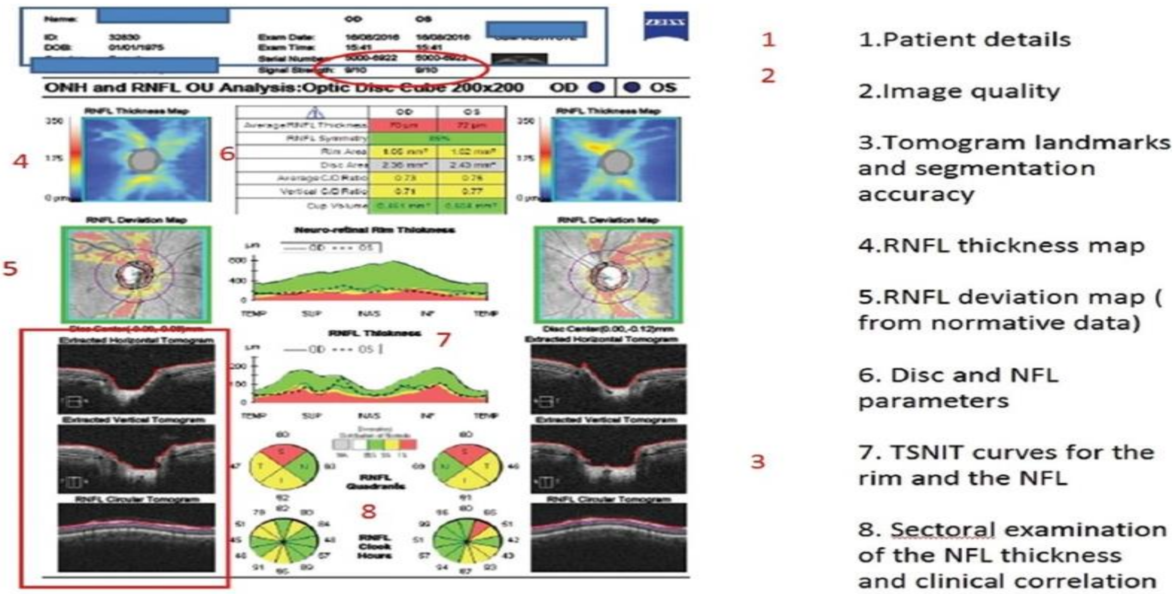
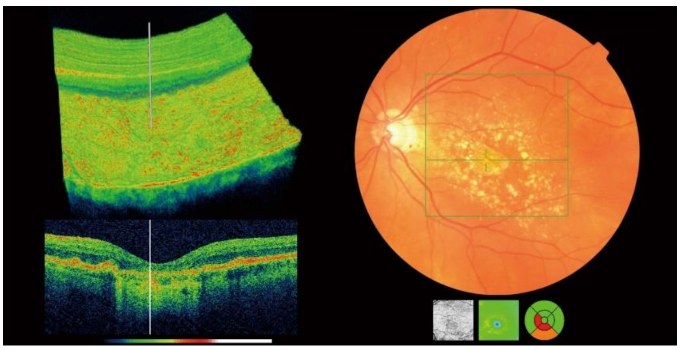
Appendices

Appendix 1. OCT Applications



Appendix 2. OCT



Source: https://www.pybusopticians.co.uk/oct-eye-scans-now-available-pybus-opticians/