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Diabetic Retinopathy Detection: Solutions Through Application of Meta-Heuristic Approaches

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ABSTRACT

In recent times, occurrences of diabetes related disorders is experiencing a steep climb with most of the symptoms being asyptomatic. One such disorder which affects the human eye is Diabetic Retinopathy (DR). DR is being diagnosed only at later stages which are quite critical. These last stages may result in eventual blindness as DR tends to cause damage to the retina behind the human eye. Hence, early detection aids in appropriate treatment resulting in prevention before its occurrence. Early detection methods involve processing with optical coherence tomography images (OCT) or the well-known fundus images which require image processing tehcniques in both cases. A case of retinal fundus image processing is investigated in this paper with more emphasis on adopting nature inspired algorithms for improved accuracy of detection. Apart from their well-known traits of fast convergence, their closeness to real time applications and events, they aid in optimal selection of features which is critical phase on the segmentation and detection process. A few well-known meta-heuristic methods have been investigated in this paper projecting their merits and limtiations to aid in future research.

Keywords: Diabetic Retinopathy, Image processing methods, Nature- Inspired algorithms, Detection, Optimal Feature selection.

Introduction

Diabetic Retinopathy (DR) is a disease that directly affects the retina of the eye and it causes blindness, if left untreated or undetected at an early stage. Diabetic Retinopathy is a disease is attributed to Diabetes Mellitus which leads to eye complication in diabetic retinopathy. In Diabetic Retinopathy, blood vessels of the retina get damaged and there is a leakage of blood. Due to damage in blood vessels of the retina and capillary of the retina, vision is affected in diabetic patients. DR will affect both eyes which will cause anincrease in blood glucose level. DR can be cured in the early stages with diabetic control and regular check-up [1].Screening of diabetic retinopathy is the first stage called Microaneurysms which is used to prevent any complications arise due to diabetes.The density of this stage is helpful for disease progression and DR. In DR, Proliferative and Non-Proliferative Diabetic Retinopathy are the two stages. In PDR, vessels of the blood which is used to grow newly are used to bleed on the retina surface. In NPDR, it is only found by the photography of the retina and it contains three stages which are NPDR- early, middle and final NPDR. The closeness of DR with diabetes condition could be well understood from the following illustration

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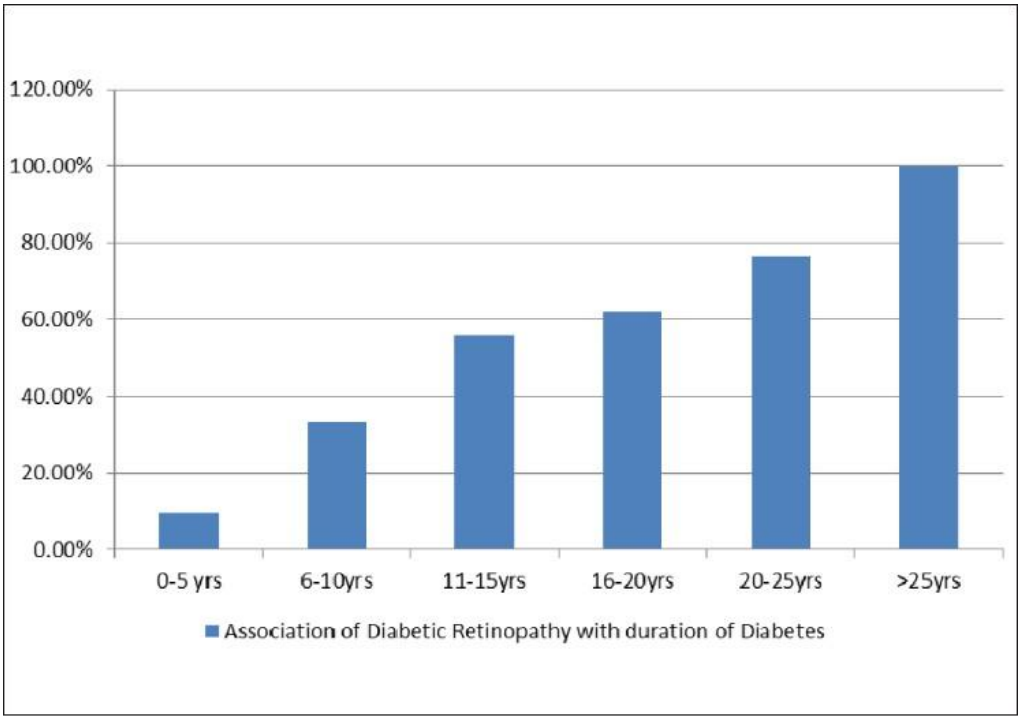

Figure 1 Correlation of Diabetes with Diabetic Retinopathy Occurrences

[Courtesy: Medical Journal of Dr. DY Patil Vidyapeeth]

In India, diabetes is rapidly increasing, and now 65 million adults are affected by this disease. It is expected to reach over 130 million by 2045. In the worldwide population, the percentage of diabetes goes on increase up to 4.4% by 2030. People whose age is above 50 are mainly affected by this type of diabetes, and it causes vision loss. DR which is recognized by a computer in digital photographs which compromises repays for screening retina by reducing the price and value. Manual processing of blood vessel segmentation of image extraction in the medical field is long [4]. Due to technology development, applications in the medical field can be determined by computer techniques. Automatic processing of the image is mainly used in more medical diagnoses. In recent times, the processing of images in the medical field helps for detecting diseases and retinal images automatically.

The approach usedin the image which is taken digitally is Optical Coherence Tomography (OCT). This provides an image of the retina which is useful for diagnosing diabetic retinopathy disease.It also finds the severe stages of the disease. Image of the OCT is a technique in which extraction of the image will be viewed cross-sectionally. In recent times, diabetes is viewed as the main cause of blindness. Detection of the early stage of the DR is more critical for preventing the vision impairment and it is also critical in treatment. DR contains symptoms named exudates.DR cannot be observed thoroughly from the first stage onwards. But, detection of the disease at an earlier stage is used for better treatment. In the stage of non-proliferative, exudates are found and is identified as soft whereas hard one is identified in the stage of proliferative[2]. Exudates are hard ones that causes harm to blood vessels which are seen in the retina and these are the main reasons for causing leakage in the blood vessel in which a fluid is leaked out of the vessel which is known as exudates.The exudatesform dots and its borders are sharp. They can be detected by various other methods namely image segmentation through the watershed, splitting of the region and the methods which are growing, the method used for threshold and splitting purely. The features of the retina are categorized as features of the land-mark and lesions of the retina. The first one is

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named fovea and the second one called the exudates [3]. These two features of the retina will similarily appear. Some of the similarity of these features of the retina are colour will be similar in a blood vessel, etc. Then the haemorrhage which is a larger one has differed geometrically and the haemorrhage which is a smaller one is similar in its colour.The Exudates contains a region that is brighter and colours are similar whereas the fovea contains a darker region and it's colour also appear similar. Diabetic retinopathy disease contains a name called silent. In diabetes patients, Diabetic Macular Edema (DME) is the reason for lack of vision in patients. In the developed world, this is the main reason for blindness and is also named diabetes complication. The final stage of diabetic retinopathy is found by lesions on the retina. Annual examination of diabetic retinopathy patients is determined by eye specialist by images of the fundus colour.

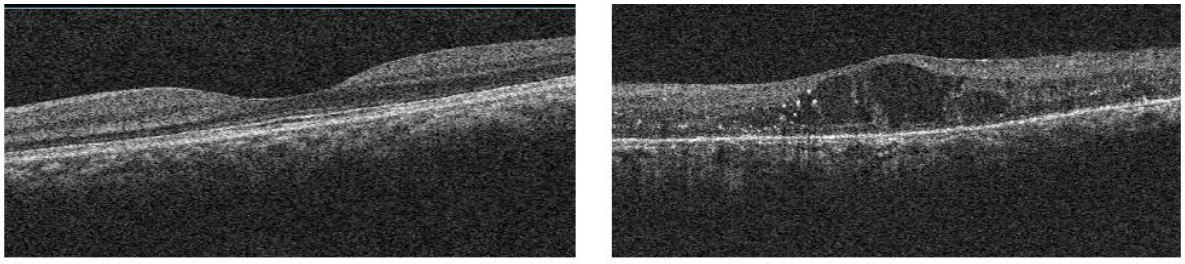

Figure 2 Illustration of normal and DR affected Retina from OCT images

[Courtesy: Park *et al.* 2016]

On the other hand, fundus images can be used for detection. A vesselthat is enlarged can be shown as a yellow andthe spot which is seen isa white colour that can be seen in images and outskirts are sharp.A typical retinal fundus image is shown in figure 1.

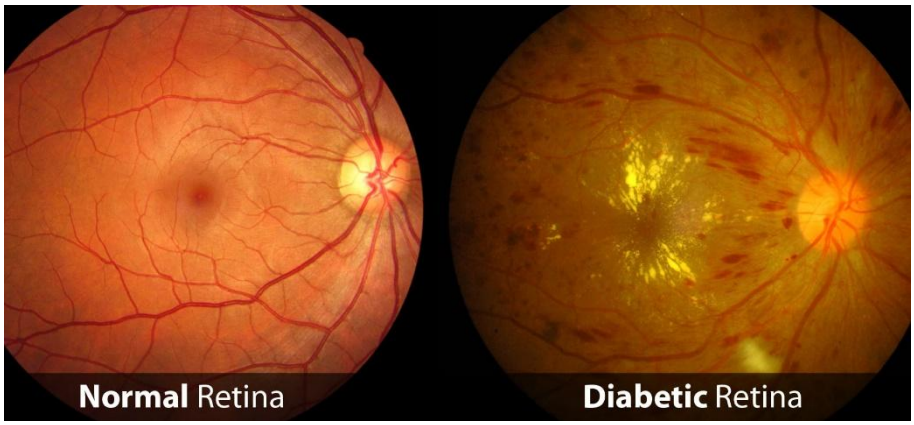

Figure 3 Illustration of normal and DR affected Retina from fundus images

[Courtesy: Eye Physicians of Northampton, 2019]

Fluorescein angiography is a method used for getting fundus images, it is necessary for fluorescein injection which is used in the flow of blood. Fundus image contains a projection of a 3-D retinal image in which intensity and representation of the light are reflected. This type of image can be used to diagnose various diseases like hypertension, etc.A typical flow process of DR detection is illustrated below in figure 4.

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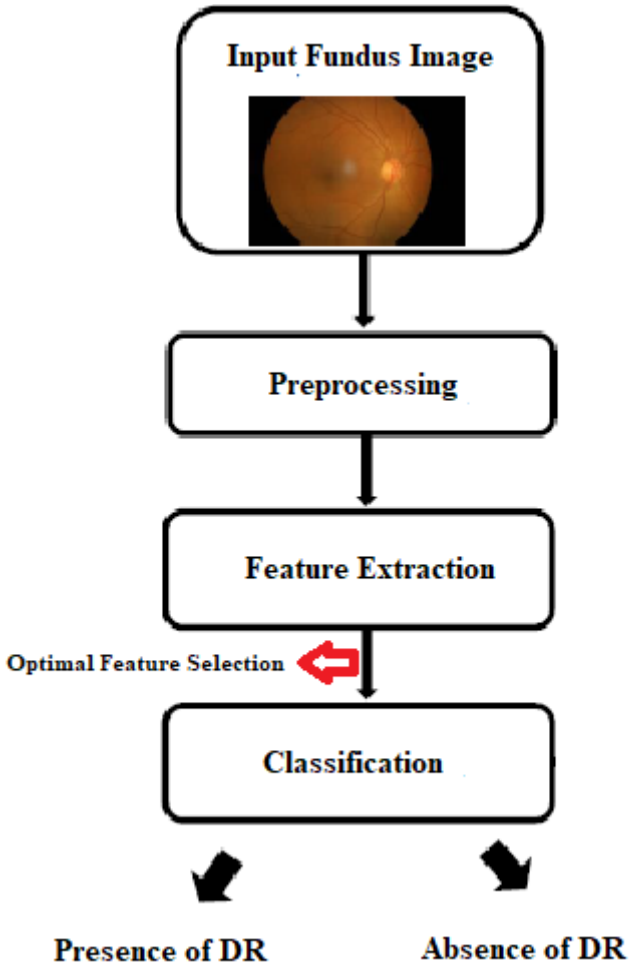

Figure 4 Block Schematic of DR detection process

As depicted in figure 4, the input fundus images are available from open source data bases like DRIVE, STARE, MESSIDOR, ORIGA etc. The input images are subject to preprocess to remove noise and thereby enhance the quality of fundus images. Following preprocessing stages, features from the images are extracted to form a feature vector. The feature vector is usually a high dimensionl vector and may even contain redundant data. Hence, careful choice of feature vector dictates the accuracy of detection in such applications. Following feature selection, the classification is achieved by learning methods or decision based modules related to presence/absence of diabetic retinopathy. In the above flow, emphasis is laid on feature selection process through meta-heuristics which forms the essence of this study.

Related works

Diabetic Retinopathy is a major diseaseand it is an impairment of vision in humans between age 20 and 80. Early detection of DR cannot be done by humans manually. In technology development, nowadays many techniques and implementation of algorithms are used for DR detection.Problems of inaccuracy arise in manual methods as well as in technological implementations. Hence, continued research has been done in the field of DR detection to improve detection efficiency through modified and enhanced approaches. A summary of some of recent works done predominantly employing nature inspired/evolutionary algorithms in literature have been presented in this section.

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A Support Vector Machine with Glowworm Swarm Optimization [8] in combination with Genetic Algorithmhave been used for diabetic retinopathy classification.In the Support Vector Machine, parameter C and gamma are used to control the classifier performance. And also, the Support Vector Machine combined with the GSO-GA with chromosomes will direct the search of the GA in space. This GSO does not contains any memory and also glow worms does not store any information in their memory. An improved accuracy of detection is reported in this method. For this, SVM fused with hybrid GSO is used for classification of DR. A hybrid GSO is used to update the location based on the population and it will provide a better solution. Hybrid GSO uses a strategy of searching in local on GA for optimal values. Thus, these shows that hybrid GSO and SVM will give better accuracy.

Diabetes seen in humanis mainly by increasing blood glucose level. Humans should maintain their insulin level at a constant range. Because the person who has diabetesis majorly affected by this type of eye infection called Diabetic Retinopathy (DR). Exudates are useful to classify the DR stages. The process of separating the retina landmarks and retina lesions for DR classification [9] has been presented through a machine learning algorithm. The machine learning algorithm is used for the evaluation of DR by using images of the retina. Image process like OD and BVs are also used and then later it is removed.

The supervised learning method is used as a proposed algorithm in segmenting blood vessel which is followed by an extraction done on images[10]. The segmentation is done by clusters and used to extract.Support vector machine is used for classification. More accuracy is achieved by the EBOS algorithm which is used for blood vessel segmenting.

Retinal vessel segmenting is done automatically by using a clustering name called fuzzy c-means. GA and fuzzy c-means used for extracting the network of the blood vessel. Accuracy is similar to the segmentation process done manually. This segmentation is used for the automatic screening of retinal disease. Results will be incorrect due to an error in the classification of the network. PSO withthe fuzzy neural network used for segmentation of the blood vessel. The OD segmentation can be improved by using a bee colony algorithm. SVM used for true and false classification and these techniques are used for effective diagnoses of retinal diseases. In this Kalman filter and Hybrid PCA is mainly used [11]. GLCM also increases the accuracy in the classification of the network. Thus this approach makes the true classification of the vessel from false one but the elimination of this will helps in improvingthe accuracy of classification to high.

For the diagnosis of ocular diseases, retinal vessel segmentation contains a tool called computer-assisted. In this, the authors proposed an approach called unsupervised retinal blood vessel segmentation which is based on an elite-guided multi-objective artificial bee colony algorithm (EMOABC)[12]. In this energy,the curve is used to find a value of criteria to select thresholds that will separate vessels and also to decrease the noise. EMOABC algorithmis simple and faster than other algorithms.

Microaneurysms are circularin retinal blood vessels in humans due to diabetes and an increase in blood pressure in the intra-retinal region. It is important in finding an early diagnosis and detecting lesions bear which is more important in diabetic retinopathy diagnoisation. In this,the main aim is to detect microaneurysms automatically which is more difficult to detect early stages in fundus images. Ant colony algorithm is used instead of the technique called conventional image processing and it is used for segmentation ofmicroaneurysms which makes it effective. These images can be manually detected but this method detects even when the image quality is lower and it is used to diagnose easily[13].

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Thus, ant colony based is used for early detection of diabetic retinopathy and its results are more useful rather than traditional methods.

Extraction of the vessel fromthe image of the retina is the first step to treatment, diagnosis and also various diseases like diabetes, etc. Due to blindness, it is a deadly disease of diabetes called diabetic retinopathy. It mainly occurs when the blood vessel in the retina gets damage due to diabetes. Early-stage cannot be detected by patients in diabetic retinopathy. In exudates segmentation, computer-aided diagnosis is used [14]. This combination of the ant colony and particle swarm optimization (HACPSO) is used to give more specificity. The dataset which is used is DRIVE and STARE which is used for segmenting vessel of the image by using the HACPSO method and then they are extracted.

In the threshold of vessel areas, the method named Ostu is used. The accuracy of the DRIVE and STARE dataset will be average. And in this work graphical user interface can be implemented. Images are taken by the retinal camera and these images are used to diagnosis [15]. This method will provide high -rate accuracy and various methods also used to filter and extract the vessel.A parallel processing algorithm is used for a better solution and it is very fast too.

In the active population, the main reason for the lack of vision is due to Diabetic retinopathy (DR).Manual detection of DR is hard and consumes more time. Computer-Aided Diagnosis is used for detecting DR images. In this, CAD is used, which will detect automaticallyand it tells whether it is normal or it is affected by the disease. In this filter, dilation is used in images and thenby using the Greedy algorithm, Optic Disk (OD) is implemented for segmentation [16]. For accurate extraction, from images of the fundus,some of the regions of OD are removedit is because ODintensity is similar to the intensity of DR. CT and SIFT are used to concatenate and provide the set. These set further given to other classifiers namely SVM, NB classifier and KNN.

This process is tedious for describing the disease at-risk level. In this detection, the image is done by pre-processing and then extracted by using an optimization method called particle swarm. For a diabetic patient, it is necessary to check for vision once a year to prevent this type of disease. In these, the KNN classifieris used as a classifier in the detection and this shows a better performance.

This type of diseases used to analyse the eye structure and the images which are available online can be taken it contains normal retina and abnormal view. Through segmentation, we can easily identify eye diseases. In this, extraction is done by using ICA which is known as Independent Component Analysisand then the selection process is done and then by using different techniques it can be optimized. Here Naïve Bayes is used for the classification process [17]. This process is done for normal retina and abnormal also. We can take images from the online dataset called DRIVE and CHASE and this dataset is tested by implementing PSO and Lion Optimization Algorithm.

The bleeding in the membrane which is in the backside of the eye in the retina is known as retinal haemorrhage. After filtration, GLCM, GLRLM and SIFT can be usedand after that ANFIS method can be used. The images of the retina undergo pre-processing method and it is done by the median filter [18] and using this we can extract filtered images and then classifications are done by ANFIS. By this, normal and abnormal images are split and then the abnormal image goes for segmentation. In segmentation, PSO is applied to the threshold and then images are segmentedand its performance is better than other methods.

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This method composes of enhanced ensemble deep neural networks (DNN) for optic disc segmentation by using the retinal images for this method an improved Particle Swarm Optimization (PSO) algorithm is used [19]. It comprises six searching mechanisms for the searching process such as a random leader-based search operation, a modified PSO operation, a refined super-ellipse operation, an accelerated super-ellipse action, an average leader-based search operation and the spherical random walk mechanism for the enhancement. It is evaluated by Messidor and Drions datasets and consists of search methods for solving the optimization functions and DME detection.

It is based on the Ant Colony Optimization method for optic cup segmentation that was carried out in retinal fundus images and the solutions were constructed based on the intensity gradient of the optic disc area and the vessels curvature. It is obtained by accurate segmentation of the cups and non-obvious or weak images [20]. It is tested with the RIM-ONE dataset with an average of 24.3% overlapping error cup segmentation and 0.7957 AUC cup to disc ratio for the assessment of glaucoma. It is one of the best methods for comparing cup segmentation using a public dataset.

PSO in which each particle is moved, and it is used for searching for the optimum value[5]. The particle is moved due to its velocity, and it remembers its position where it is reached during its journey. Particles will transfer the information about the best places they visited, and it is used for finding the best solution. It is done by communicating the fitness value of one particle to a neighbour particle.

$$p_{v+1} = p_v + a*r* (p_b - x_v) + a*r* (g_b - x_v) \quad (1)$$

In this equation, p_v represents particle velocity, p_b denotes swarm value, and g_b is used for the best value. In this PSO model, it overcomes by search method. Multiple solutions are used to guide the search method. The searching method contains super-ellipse, velocity, mean, random, and global best.

In Bee colony algorithm, bees will go to the source of the food and they collect the amount of nectar. Then bee used to collect the nectar and then position the bee which is an onlooker. The bee which is onlooker assesses the amount of nectar and it compares with the neighbour and it fixes the best value which is best. For searching more sources for food, scouts will be sent and it will remember the best one. This algorithm is mainly based on the behaviour of honey bees. Space that is searched indicates the food location and then the value of the fitness indicates the quality of the source of the food which can be linked to the source location. Thus this procedure indicates honey bee is used to search for good food which is similar to that getting solution optimally[6]. The bee shares the information with the onlooker that is going to hive, another bee which is onlooker move to a source that is founded by the bee which depends on the probability. If the value is better compared to the value which is attained now, then the bee moves to the source which is new otherwise the old is kept. Bee will continuously search a good food for certain cycles and then if value still remains in the same condition they become scout one. While converging a colony of bee, the centre one is considered as the solution of the search at the initial stage. While updating the centre of the cluster which is obtained will raise the result. Another method called HACPSO includes selecting the noise and point of the edge. For noise suppressing Gaussian filter can be used during a technique pre-processing which is used to eliminate the noise precisely. After every update, it sets a parameter that is sent to ACO in which detection of the edge is done and the value which is calculated denotes the quality of the edge is also detected. The particle goes in various directions depending upon the value and then the location is updated periodically for

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the upcoming generation [7]. PSO which uses location it obtained newly for their segmentation until they reach the time of the iteration. It will update only local for segmentation to make fewer iterations. The advantage of the PSO is to implement easily, particle uses memory in less and then speed is high for convergence. These particles will find a better position. Thus PSO and bee colony are useful in diabetic retinopathy by segmenting blood vessel image and then it will provide better results which is useful for treatment.

Findings from the survey

The findings of the exhaustive survey related to nature inspired algorithms for detection of DR is summarized below.

- Clinical methods of diabetic retinopathy detection is quite cumbersome but provides significant levels of accuracy. However, this is achieved at the cost of increasing manual labor and time consumption.
- Conventional methods of image processing involving morphological operations like erosion, dilation, filling, segementation etc. are quite convincing. However, ability to reach expected standards of accuracy in detection remains to be a challenging issue of research.
- There has been an emerging utility of nature inspired or evolution algorithms for wide range of problems demanding convergence towards optimal solutions. They have been quite rapidly emerging due to their ability to mimic real time problem fomrulations.
- Feature extraction is an important stage in DR detection. It is the optimal set of features that dictate the detection accuracy. Hence, applicability of evolutionary algorithms to find the problem of minimization of false detection or maximization of true positives proves to be a motivating factor behind its applicability on retinal fundus images.
- Prominent algorithms in both stand alone and hybrid combinations have been discussed. Swarm intelligence algorithms appear to provide convincing solutions in the near future through carefully selected hybrid algorithms for the remainder of the image processing stages like classification, feature extraction etc

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