1. A computational-intelligence-based approach for detection of exudates in diabetic retinopathy images
   * Authors: Osareh et al 2009
   * Objective: Automated identification of exudate pathologies in retinopathy images based on computational intelligence techniques
   * Method: The color retinal images are segmented using fuzzy c-means clustering following some preprocessing steps, i.e., color normalization and contrast enhancement. The entire segmented images establish a dataset of regions. To classify these segmented regions into exudates and nonexudates, a set of initial features such as color, size, edge strength, and texture are extracted. A geneticbased algorithm is used to rank the features and identify the subset that gives the best classification results. The selected feature vectors are then classified using a multilayer neural network classifier.
   * Data: large image dataset consisting of 300 manually labeled retinal images
   * Results: 96.0% sensitivity, 94.6% specificity
2. A novel automatic image processing algorithm for detection of hard exudates based on retinal image analysis
   * Authors: Sanchez et al 2008
   * Method: based on Fisher’s linear discriminant analysis and makes use of colour information to perform the classification of retinal exudates
   * Data: 58 retinal images with variable colour, brightness, and quality
   * Results: sensitivity of 88% using the lesion-based performance evaluation criterion, and accuracy of 100% (sensitivity of 100% and specificity of 100%) image-based classification
3. Assessment of four neural network based classifiers to automatically detect red lesions in retinal images
   * Authors: Garcia et al 2010
   * Objective: detect red lesions (RLs), like haemorrhages and microaneurysms
   * Method: extracted a set of colour and shape features from image regions and performed feature selection using logistic regression. Four neural network (NN) based classifiers were subsequently used to obtain the final segmentation of RLs: multilayer perceptron (MLP), radial basis function (RBF), support vector machine (SVM) and a combination of these three NNs using a majority voting (MV) schema
   * Data: 115 images divided into a training set of 50 images (with RLs) and a test set of 65 images (40 with RLs and 25 without RLs)
   * Results: best results were obtained for RBF. Using a lesion-based criterion, a mean sensitivity of 86.01% and a mean positive predictive value of 51.99% were obtained. With an image-based criterion, a mean sensitivity of 100%, mean specificity of 56.00%
4. Automated Detection and Differentiation of Drusen, Exudates, and Cotton-Wool Spots in Digital Color Fundus Photographs for Diabetic Retinopathy Diagnosis
   * Authors: Niemeijer et al 2007
   * Purpose: To describe and evaluate a machine learning–based, automated system to detect exudates and cotton-wool spots in digital color fundus photographs and differentiate them from drusen, for early diagnosis of diabetic retinopathy
   * Method: Each pixel was classified, resulting in a so-called lesion probability map that indicates the probability that a pixel is part of a bright lesion. Pixels with high probability were grouped into probable lesion pixel clusters. Based on cluster characteristics each probable lesion pixel cluster was assigned a probability indicating the likelihood that the pixel cluster was a true bright lesion. Each bright lesion cluster likely to be a bright lesion was classified as exudate, cotton-wool spot or drusen.
   * Data: Three hundred retinal images from one eye of 300 patients with diabetes were selected from a diabetic retinopathy telediagnosis database (nonmydriatic camera, two-field photography): 100 with previously diagnosed bright lesions and 200 without
   * Results: The system achieved an area under the receiver operating characteristic (ROC) curve of 0.95 and sensitivity/specificity pairs of 0.95/0.88 for the detection of bright lesions of any type
5. Automated detection of diabetic retinopathy on digital fundus images
   * Authors: Sinthanayothin et al 2008
   * Purpose: develop an automated screening system to analyse digital colour retinal images for important features of non-proliferative diabetic retinopathy (NPDR)
   * Method: High performance pre-processing of the colour images was performed. Previously described automated image analysis systems were used to detect major landmarks of the retinal image (optic disc, blood vessels and fovea). Recursive region growing segmentation algorithms combined with the use of a new technique, termed a ‘Moat Operator’, were used to automatically detect features of NPDR. These features included haemorrhages and microaneurysms (HMA), which were treated as one group, and hard exudates as another group
   * Data: 30 retinal images of which 21 contained exudates and nine were without pathology
   * Results: sensitivity and specificity for exudate detection were 88.5% and 99.7%
6. Automated detection of exudates for diabetic retinopathy screening
   * Authors: Fleming et al 2007
   * Method: Candidate exudates were detected using a multi-scale morphological process. Based on local properties, the likelihoods of a candidate being a member of classes exudate, drusen or background were determined. This leads to a likelihood of the image containing exudates which can be thresholded to create a binary decision
   * Data: 13 219 images of which 300 contained exudates
   * Results: sensitivity 95.0% and specificity 84.6%
7. Automated detection of red lesions from digital colour fundus photographs
   * Authors: Jaafar et al 2011
   * Method: After pre-processing, a morphological technique was used to segment red lesion candidates from the background and other retinal structures. Then a rule-based classifier was used to discriminate actual red lesions from artifacts. A novel method for blood vessel detection is also proposed to refine the detection of red lesions
   * Data: standarised test set of 219 images
   * Results: sensitivity of 89.7% and a specificity of 98.6% (at lesion level)
8. Automated microaneurysm detection method based on double-ring filter and feature analysis in retinal fundus images
   * Authors: Mizutani et al 2009
   * Method: After image preprocessing, candidate regions for microaneurysms were detected using a double-ring filter. Any potential false positives located in the regions corresponding to blood vessels were removed by automatic extraction of blood vessels from the images. Twelve image features were determined, and the candidate lesions were classified into microaneurysms or false positives using the rule-based method and an artificial neural network
   * Data: Retinopathy Online Challenge (ROC) database (50 training cases, 50 test cases)
   * Results: sensitivity for detecting microaneurysms was 65% at 27 false positives per image
9. Automated microaneurysm detection method based on eigenvalue analysis using hessian matrix in retinal fundus images
   * Authors: Inoue et al 2013
   * Mehthod: After image preprocessing, the MA candidate regions were detected by eigenvalue analysis using the Hessian matrix in green-channeled retinal fundus images. Then, 126 features were calculated for each candidate region. By a threshold operation based on feature analysis, false positive candidates were removed. The candidate regions were then classified either as MA or false positive using artificial neural networks (ANN) based on principal component analysis (PCA). The 126 features were reduced to 25 components by PCA, and were then inputted to ANN
   * Data: 25 retinal images from the retinopathy online challenge (ROC) database
   * Results: true positive rate was 73%, with eight false positives per image
10. Automated microaneurysm detection using local contrast normalization and local vessel detection
    * Authors: Fleming et al 2006
    * Method: Various methods for contrast normalization are compared. Best results were obtained with a method that uses the watershed transform to derive a region that contains no vessels or other lesions. Dots within vessels are handled successfully using a local vessel detection technique
    * Data: images acquired from diabetic patients attending the Grampian Diabetes Retinal Screening Programme 1441 images were graded by a clinician for the presence of MAs
    * Results: sensitivity 85.4% and specificity 83.1%
11. Automatic detection of diabetic retinopathy exudates from non-dilated retinal images using mathematical morphology methods
    * Authors: Sopharak et al 2008
    * Method: Preprocessing (RGB to HIS, median filter, contrast enhancement, optic disc elimination), exudates detection (closing, local variation, thresholding, morphological reconstruction)
    * Data: All digital retinal images were taken from patients with nondilated pupils taken at Thammasat University Hospital
    * Results: sensitivity and specificity are 80% and 99.5%
12. Automatic detection of microaneurysms in color fundus images
    * Authors: Walter et al 2007
    * Method: The first step consists in image enhancement, shade correction and image normalization of the green channel. The second step aims at detecting candidates, i.e. all patterns possibly corresponding to MA, which is achieved by diameter closing and an automatic threshold scheme. Then, features are extracted, which are used in the last step to automatically classify candidates into real MA and other objects; the classification relies on kernel density estimation with variable bandwidth
    * Data: 21 annotated images
    * Results: sensitivity was 88.5% at an average number of 2.13 false positives per image
13. Automatic detection of red lesions in digital color fundus photographs
    * Authors: Niemeijer et al 2005
    * Method: a new red lesion candidate detection system based on pixel classification. Using this technique, vasculature and red lesions are separated from the background of the image. After removal of the connected vasculature the remaining objects are considered possible red lesions. An extensive number of new features are added to those proposed by Spencer–Frame. The detected candidate objects are classified using all features and a k-nearest neighbor classifier
    * Data: 100 images and was used to train and test composed of data taken from a screening program.
    * Results: sensitivity of 100% at a specificity of 87%
14. Detection of exudates in retinal images using a pure splitting technique
    * Authors: Jaafar et al 2010
    * Method: an adaptive thresholding based on a novel algorithm for pure splitting of the image is proposed. A coarse segmentation based on the calculation of a local variation for all image pixels is used to outline the boundaries of all candidates which have clear borders. A morphological operation is used to refine the adaptive thresholding results based on the coarse segmentation results
    * Data: 50 abnormal images from DIARETDB0 database
    * Results: 91.2% sensitivity, 99.3% specificity
15. Detection of microaneurysms using multi-scale correlation coefficients
    * Authors: Zhang et al 2010
    * Method: a new approach based on multi-scale correlation filtering (MSCF) and dynamic thresholding is developed. This consists of two levels, microaneurysm candidate detection (coarse level) and true microaneurysm classification (fine level)
    * Data: ROC (retinopathy on-line challenge) and DIARETDB1 (standard diabetic retinopathy database)
    * Results: 2nd rank in ROC competition
16. Exudate detection in color retinal images for mass screening of diabetic retinopathy
    * Authors: Zhang et al 2014
    * Purpose: automatically detect normal exams in a tele-ophthalmology network, thus reducing the burden on the readers
    * Method: new preprocessing methods, which perform not only normalization and denoising tasks, but also detect reflections and artifacts in the image. A new candidates segmentation method, based on mathematical morphology. These candidates are characterized using classical features, but also novel contextual features. A random forest algorithm is used to detect the exudates among the candidates
    * Data: A new clinical database, e-ophtha EX, containing precisely manually contoured exudates. It is very heterogeneous. It contains images gathered within the OPHDIAT telemedicine network for diabetic retinopathy screening
    * Results: AUC between 0.93 and 0.95
17. Mixture model-based clustering and logistic regression for automatic detection of microaneurysms in retinal images
    * Authors: Sanchez et al 2009
    * Method: a statistical approach based on mixture model-based clustering and logistic regression. The innovative segmentation approach based on a statistical mixture model based clustering allows a robust separation of the foreground and background scenes and, specifically, a segmentation of MAS in a totally unsupervised manner
    * Data: public database proposed by the Retinal Online Challenge
    * Results: overall score in the ROC competition of 0.332404
18. Neural network based detection of hard exudates in retinal images
    * Authors: Garcia et al 2009
    * Method: an algorithm which includes a neural network (NN) classifier. Three NN classifiers were investigated: multilayer perceptron (MLP), radial basis function (RBF) and support vector machine (SVM)
    * Data: 117 images with variable colour, brightness, and quality. 50 of them (from DR patients) were used to train the NN classifiers and 67 (40 from DR patients and 27 from healthy retinas) to test
    * Results: Using a lesion-based criterion, a mean sensitivity (SEl) of 88.14% and a mean positive predictive value (PPVl) of 80.72% for MLP. With RBF, SEl = 88.49% and PPVl = 77.41%, while SEl = 87.61% and PPVl = 83.51% using SVM
19. Optimal wavelet transform for the detection of microaneurysms in retina photographs
    * Authors: Quellec et al 2008
    * Method: MAs are detected by locally matching a lesion template in subbands of wavelet transformed images. To improve the method performance, the best adapted wavelet within the lifting scheme framework is used. The optimization process is based on a genetic algorithm followed by Powell’s direction set descent
    * Data: 120 retinal images analyzed by an expert
    * Results: sensitivity of 89.62%, positive predictive value of 89.50%
20. Retinal Microaneurysm Detection Through Local Rotating Cross-Section Profile Analysis
    * Authors: Lazar et al 2013
    * Method: MA detection through the analysis of directional cross-section profiles centered on the local maximum pixels of the preprocessed image. Peak detection is applied on each profile, and a set of attributes regarding the size, height, and shape of the peak are calculated subsequently. The statistical measures of these attribute values as the orientation of the cross-section changes constitute the feature set that is used in a naïve Bayes classification to exclude spurious candidates. A formula for the final score of the remaining candidates is given, which can be thresholded further for a binary output
    * Data: The ROC publicly available dataset consisting of 50 training and 50 test images
    * Results: overall score of 0.423, ranked 2nd in ROC competition