

What is claimed is:

1. A method of locating within an image of an eye an outline of an anatomical optic structure, said anatomical optic structure being the optic disc of the eye or the optic cup of the eye, the method comprising:

(i)- dividing a portion of the image of the eye into a plurality of sub-regions, each sub-region being a respective set of a plurality of pixels of the portion of the image;

(ii)- subjecting the portion of the image to respective processing operations, to generate a plurality of feature maps;

(iii) -for each sub-region, deriving a plurality of numerical measures using the feature maps;

(iv)- using the plurality of numerical measures and an adaptive model, to produce data indicative of which of the sub-regions of the image are respectively part of, or not part of, said optic structure; and

(v) performing at least one smoothing step-operation to obtain the outline of said optic structure using the data, said at least one smoothing operation comprising an ellipse-fitting sub-operation.

wherein the method further includes an operation of generating an estimate of the reliability of the identification of the location of the optic structure, by measuring a difference between successive estimates of the position of the optic structure before and after the ellipse-fitting sub-operation during said at least one smoothing operation.

2. A method according to claim 1, comprising a step an operation of deriving the portion of the image as a region-of-interest comprising the optic disc of the eye, said optic structure being the optic disc.

3. A method according to claim 1 in which the portion of the image is a part of the image corresponding to at least part of an estimated optic disc of the eye, said optic structure being the optic cup.

4. A method according to claim 1 in which the at least one smoothing step-operation includes, for each sub-region, allotting a corresponding decision value to all pixels of the sub-region, and then smoothing an image composed of the decisions values of the pixels of the portion of the image to produce a smoothed image.

5. A method according to claim 4 in which the smoothed image is subjected to a thresholding stepoperation, and a stepan operation of finding the largest connected component of the result of the thresholding stepoperation, the largest connected component being an estimate of the position of structure.

6. A method according to claim 1 in which one of said smoothing steps-operations is performed using an elliptical Hough transform, to find an ellipse which best fits an estimate of the position of the structure.

7. A method according to claim 6 in which the output of the Hough transform is subject to a deformation stepoperation.

8. A method according to claim 1 in which in step-operation (iv) said data for each sub-region is obtained by a process including inputting the numerical measures for that sub-region, and the numerical measure for each of a plurality of neighboring sub-regions, into the adaptive model.

9. A method according to claim 1 which further includes for each sub-region determining the number of pixels for which an intensity value falls into each of a plurality of ranges, said numbers being comprises within said numerical measures used by the adaptive model.

~~10. A method according to claim 1 further including a step of generating an estimate of the reliability of the identification of the location of the optic structure, by measuring a~~

~~difference between successive estimates of the position of the optic structure produced during step (v).~~

~~11. A method according to claim 1 in which at least some of said respective processing operations mimic corresponding cortical visual processing operations~~

~~1210. A method according claim 1 in which at least some of the plurality of numerical measures are obtained using:~~

~~intensity feature maps obtained by convolving intensity filters with the portion of the image;~~

~~colour feature maps obtained by convolving colour filters with the portion of the image; and/or~~

~~direction-specific feature maps, each direction-specific features map being obtained by pooling the results of filtering the portion of the image using a plurality of direction-specific filters which filter the portion of the image in the same direction but at different distance scales.~~

~~1311. A method according to claim 1, in which at least some of the plurality of numerical measures for each sub-region model:~~

~~intensity units which produce a value indicative of an average over the sub-region of a centre-surround intensity difference;~~

~~colour units which produce a value indicative of an average over the sub-region of a centre surround colour difference; and/or~~

~~direction-specific units which produce a value using filters which, for each of said direction-specific units, perform a filtering operation in a corresponding direction.~~

~~1412. A method according to claim 13 in which there are a plurality of the intensity units, each intensity unit being modelled by forming an average over the sub-region of the~~

magnitude of a difference $I(c,s)$ between a first intensity function and a second intensity function, each of the intensity functions being defined over the image, and the second intensity function being obtained by sampling the first intensity function and interpolating values between the samples.

4513. A method according to claim 13 in which the derivation of the numerical measures modelling the intensity units comprises:

convolving dyadic pyramids with the intensity channel of a colour image, to generate a plurality of intensity functions $I(c)$, the intensity functions being labelled by an integer index c which takes values greater than 2 and represents of a corresponding scale in the image.

4614. A method according to claim 13 in which there are a plurality of said numerical measures modelling colour units and obtained by:

using dyadic Gaussian pyramids and a colour function obtained from the image, to generate modified colour functions on a plurality of respective distance scales,

obtaining each numerical measure by forming an average over the sub-region of the magnitude of a difference between a first said modified colour function and a second said modified colour function, the first and second modified colour functions having different respective said distance scales.

4715. A method according to claim 13 in which said numerical measures modelling direction-specific units are derived by, for each of a plurality of directions:

filtering said image using a plurality of filters which each perform a filtering operation in that direction, the plurality of filters having different respective distance scales; and

pooling results of said filtering obtained using pairs of said filters.

4816. The method according to claim 17 in which said filters are Gabor filters, the distance scale for each filter being a distance parameter used to define the corresponding filter using a Gabor mother function.

4917. The method according to claim 1 in which the sub-regions are obtained by a clustering algorithm.

2018. A method for obtaining a CDR ratio of an eye from at least one image of the eye, the method including:

(i) deriving estimates of the location of an optic cup and an optic disc in the at least one image of the eye by a process comprising:

(a) for each of the optic cup and optic disc generating a respective set of sub-regions of the at least one image, each sub-region being a respective set of a plurality of pixels of the at least one image;

(b) subjecting the at least one image to respective processing operations, to generate a plurality of feature maps, and from the feature maps obtaining numerical measures for the sub-regions of the eye;

(c) using the plurality of numerical measures and respective adaptive models, to produce data indicative of which of the sub-regions are part of the optic disc and optic cup; and

(d) using the data to form the estimates of the locations of the optic cup and optic disc which including performing at least one smoothing ~~step-operation~~ to obtain the outline of the optic cup and optic disc using the data, said at least one smoothing operation comprising an ellipse-fitting sub-operation; wherein the method further includes, for at least one of the optic cup and optic disc, an operation of generating an estimate of the reliability of the identification of the location of the optic cup or optic disc, by measuring a difference between successive estimates of the position of the optic cup or optic disc before and after the ellipse-fitting sub-operation during said at least one smoothing operation; and

(ii) using the estimates of the locations of the optic cup and optic disc to compute the cup-to-disc ratio (CDR);

2419. A method for treating an eye, the method including:

(i) deriving estimates of the location of an optic cup and an optic disc in at least one image of the eye by a process comprising:

(a) for each of the optic cup and optic disc generating a respective set of sub-regions of the at least one image, each sub-region being a respective set of a plurality of pixels of the at least one image;

(b) subjecting the at least one the image to respective processing operations, to generate a plurality of feature maps, and from the feature maps obtaining numerical measures for the sub-regions of the eye;

(c) using the plurality of numerical measures and respective adaptive models, to produce data indicative of which of the sub-regions are part of the optic disc and optic cup; and

(d) using the data to form the estimates of the locations of the optic cup and optic disc which including performing at least one smoothing step-operation to obtain the outline of the optic cup and optic disc using the data, said at least one smoothing operation comprising an ellipse-fitting sub-operation; wherein the method further includes, for at least one of the optic cup and optic disc, an operation of generating an estimate of the reliability of the identification of the location of the optic cup or optic disc, by measuring a difference between successive estimates of the position of the optic cup or optic disc before and after the ellipse-fitting sub-operation during said at least one smoothing operation;

(ii) using the estimates of the locations of the optic cup and optic disc to compute a cup-to-disc ratio (CDR); and

(iii) using said CDR in a decision of whether the eye exhibits glaucoma; and

(iv) in the case that the decision is positive treating the eye.

2220. A computer system having a processor and a tangible data storage device, the data storage device storing non-transitory program instructions for performance by the processor to cause the processor to ~~locating~~locate an outline of an anatomic optic structure within an image of an eye, said anatomical optic structure being the optic disc of the eye or the optic cup of the eye, by:

(i) dividing a portion of the image of the eye into a plurality of sub-regions by a clustering algorithm, each sub-region being a respective set of a plurality of pixels of the portion of the image;

(ii) subjecting the portion of the image to respective processing operations, to generate a plurality of feature maps;

(iii) for each sub-region, deriving a plurality of numerical measures using the feature maps;

(iv) using the plurality of numerical measures and an adaptive model, to produce data indicative of which of the sub-regions of the image are respectively part of, or not part of, said optic structure; and

(v) performing at least one smoothing ~~step-operation~~operation to obtain the outline of said optic structure using the output of the adaptive model, said at least one smoothing operation comprising an ellipse-fitting sub-operation.

wherein the non-transitory program instructions are operative to cause the processor to generate an estimate of the reliability of the identification of the location of the optic structure, by measuring a difference between successive estimates of the position of the optic structure before and after the ellipse-fitting sub-operation during said at least one smoothing operation.