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A Novel Optic Disk Segmentation in Retinal Images by using Markov Random Field

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Abstract:

Different efforts have been carried out for the prevention of the blind condition due to a retinopathy. The analysis of retinal images represents a non invasive process to perform the diagnosis and control of patients. Interactive and automatic systems for the analysis of retinal images have been designed. Early models are based on supervised systems. These systems have probed their efficiently in different methods. Unfortunately supervised systems require high processing time and hand labeled image as part of the training process. Due to the systems have been training using images with specific characteristics the system comprises its performance to image with similar features. The state of the art on retinal image analysis has the need of an unsupervised systems that perform the analysis of retinal images without human supervision or interaction. A system that take advantage of high image processing techniques, a flexible system that incorporate prior knowledge and that can perform without parameter adjustments for different dataset images was proposed in this project. Retina vascular tree is extracted using the graph cut technique .The optic disc segmentation is performed using the Markov Random Field (MRF) image reconstruction method and graph cut technique.

INTRODUCTION

The research on medical science field has been and will always be of the common interest for the humankind. Since ancestral time the study of the human body has been concentrate to understand how it works in order to prevent diseases and heal the sickness.

With the invention of new systems and the developing of new technologies the research in the medicine field have had a great impulse. In particular, the development of the medical imaging field has been revolutionary with the availability of new techniques to acquire and process digital images. This revolution have required of significant innovation in computational techniques for the different aspects of image processing. In addition medical images analysis represents an excellent option as non invasive process for the diagnostic and control of diseases.

BLOOD VESSEL SEGMENTATION

Implementation of blood vessel segmentation can be divided into two main stages: preprocessing and graph construction. Figure 2.1 shows an overview of the method, which is described with detail next.

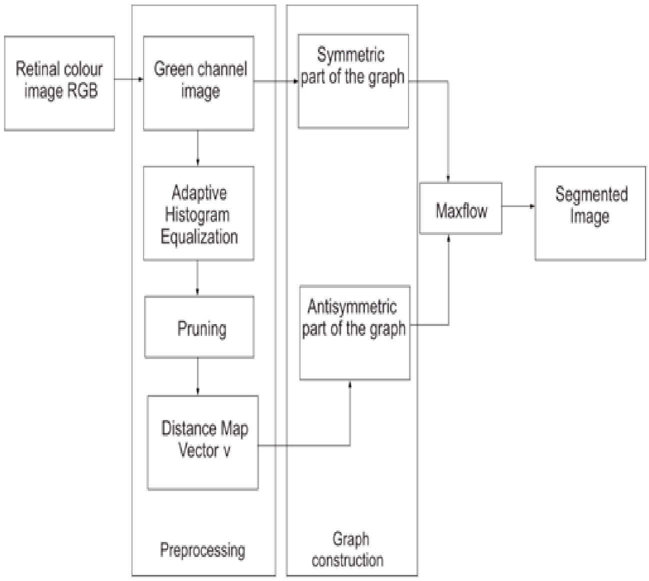

Figure 2.1: Blood vessel segmentation algorithm scheme

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ALGORITHMS/TECHNIQUES

Graph cut technique

The segmentation of retinal structures is based in the minimization of a energy function. This energy function represents the relationship of the elements in the image (pixels) with their neighbour hood, and with prior knowledge of the foreground and background.

The use of this technique, known as Graph Cut, permits the incorporation of prior knowledge into the formulation in order to guide the model and find the optimal segmentation. This feature is particularly useful in medical image analysis, where prior information (e.g. shape) about the object to segment is available.

As applied in the field of computer vision, graph cuts can be employed to efficiently solve a wide variety of low-level computer vision problems, such as image smoothing, the stereo correspondence problem, and many other computer vision problems that can be formulated in terms of energy minimization. Such energy minimization problems can be reduced to instances of the maximum flow problem in a graph. Under most formulations of such problems in computer vision, the minimum energy solution corresponds to the maximum a posteriori estimate of a solution.

Graph cut is a widely used technique for interactive image segmentation in computer vision and medical image analysis. Graph cut is a energy based object segmentation technique. Energy based segmentation methods are characterized by the optimization technique designed to minimize the energy function generated from the image data. Graph cut technique is characterized by the optimization of a cost function defined on a discrete set of variables. The general idea is to map the image onto a graph with weighted connections. The graph is then cut (separating foreground and background), minimizing the energy function and producing the optimal segmentation for the image.

The energy function consists of regional (computing likelihoods of foreground and background) and boundary terms (calculated by pixel intensity, texture, color, etc). Discrete graph cut is easy to implement, and is flexible to include various forms of regional, boundary, or geometric constraints.

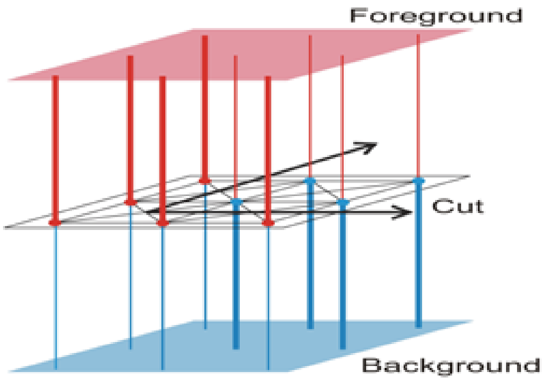


Figure 2.11: Example of a graph, terminals S (foreground) and T (background)

We have used different approximations to assign weights to the edges: flux incorporation for blood vessel segmentation and the traditional boundary and regional terms for the optic disc segmentation Also, in the course of our experiments we developed an special foreground t-link weight for the specific application of the optic disc segmentation.

In general the process to solve a problem using the energy minimization theory consists of two stages. The first one is to formulate the energy function, which is usually the combination of terms that correspond to different constrains of the problem. In the second stage the energy function is minimized and the graph is separated in two parts, background and foreground.

The constraints imposed by the regional and boundary terms in the set of labels A = (A1,Ap,…AP) assigned to each pixel p in the image P are described by the cost function E(A).The energy function consisting of regional (computing likelihoods of foreground and background) and boundary terms (calculated by pixel intensity, texture, color, etc).

$$E(A) = \lambda . R(A) + B(A) \quad (2.10)$$

Where,

$$R(A) = \sum_{p \in P} R_p(A_p) \quad (2.11)$$

$$B(A) = \sum_{p.q \in N} B_{p,q} . \delta(A_p, A_q) \quad (2.12)$$

And

$$\delta = (A_p, A_q) = \begin{cases} 1 & if A_p \neq A_q \\ 0 & otherwise \end{cases} \quad (2.13)$$

B(A) and R(A) represent the boundary and regional constraints. Bp,q shows the discontinuity between pixel p and its neighborhood, and generally has a large value when the pixels p and q are similar and close to zero when they are very different. At the same time the value of Bp,q will depend on the distance between pixels p and q. Pixels in the immediate neighborhood are considered with more relevance than the ones in the distant neighborhood.

Medical image analysis models based on Graph Cut technique

Graph cut segmentation is based on the minimization of an energy function. This energy function represents the relationship between pixels within an image and is subject to regional and boundary constraints. Graph Cut algorithms use a global cost function to find the optimal segmentation, but it is possible to constrain the solution space of the segmentation problem.

In the field of medical image segmentation a significant amount of prior knowledge is available and can be used for this purpose.

The segmentation of medical images represents a challenge within the image processing field. The poor contrast between different tissues, the overlapping of structures and the non well defined boundaries are some of the problems to deal with. In general the traditional formulation of the graph cuts technique based only on pixel intensity results in poor segmentation when applied to medical images. So, why is graph cut technique a recurring algorithm used for in the medical images analysis? We can highlights three major reasons:

- Additional constraints. Image segmentation is an ill-posed problem, therefore it is possible there exists more than one acceptable solution. Additional constrains need to be imposed in order to achieve the desired segmentation . Graph cut formulation is an excellent option due to its facility to add prior knowledge into the energy function as regional and boundary constraints. Prior shape templates have been successfully added into the graph formulation constraining the solution space of the segmentation problem and generating good segmentation results.
- Interaction or automatic segmentation. Because of the nature of graph cuts formulation it is possible create an interactive system where the user can initialize foreground or background seeds, as well as control parameters in the energy function(e.g. λ). On the other hand if those parameters have been set up and the initialization of seeds is automatic, the technique will result in an automatic segmentation system. The opportunity of being able to select between interactive or automatic system gives the graph cut the flexibility needed in the case of medical images analysis.
- N-D segmentation. Graph cut segmentation is easy to extend to a N dimension images.

After the publication of the first work for the interactive segmentation of medical images using graph cuts , a great number of proposals using this technique on specific medical structures segmentation have been published.

Frequently prior shape models are incorporated into the graph cuts formulation as an additional energy term. The first proposal to incorporate prior shape into the graph cuts algorithm is presented in [Freedman and Zhang]. The work proposes a graph cut algorithm for interactive segmentation that incorporates shape priors. In addition to regional and boundary terms, the algorithm uses information about a level set function of a template to define the graph weight links. The method uses a fixed shape template aligned with the image by the user input. The success of this method is limited to when the fixed template and the desired segmentation match under an uncertain threshold.

MinCut/MaxFlow Algorithm

The min-cut/maxflow algorithm used in our research implementation belongs to the group of augmenting paths based algorithms. It builds two search trees for detecting augmenting paths, one from the source and one from the sink. The algorithm does not start the trees from scratch, instead it reuses the previous trees.

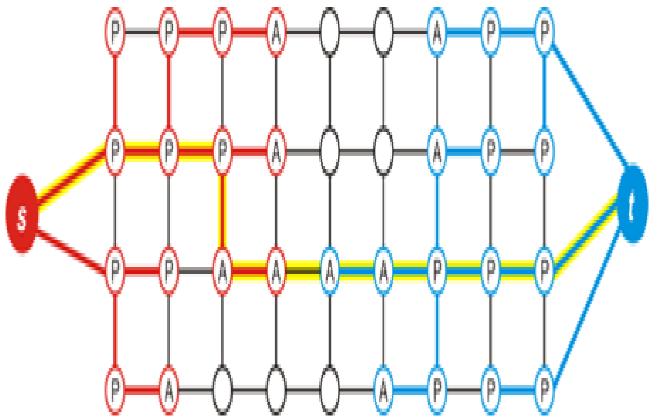


Figure 2.12: Example of search tree S (red) and T (blue) at the end of the growth stage when a path (yellow line) from the source s to the sink t is found.

The max flow algorithm

The algorithm iterates repeating the following three stages:

- “growth” stage: search trees S and T grow until they touch givint ans → t path
- “augmentation” stage: the found path is augmented, search tree(s)break into forest(s)
- “adoption” stage: trees S and T are restored

In the “growth” stage the search tree expands. The active nodes explore non saturated adjacent nodes ans acquire new children from the set of free nodes. These new nodes become active members of the corresponding search tree. When all the neighbours of an active node haven explored the active node become passive. This stage finishes if an active node finds a neighbour that belongs to the opposite tree.

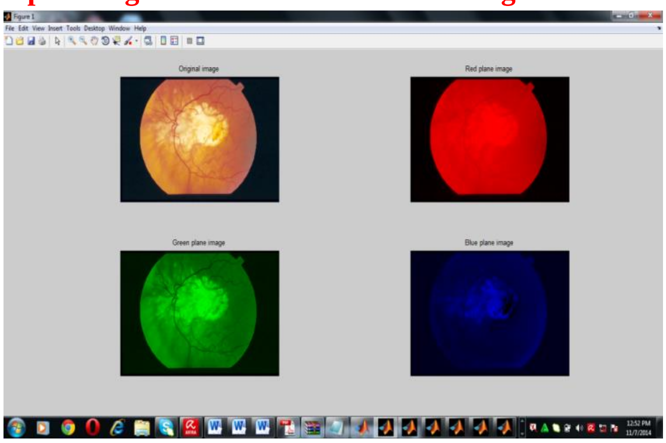
In the augmentation stage the path found in the growth stage is augmented. Because the largest possible flow is pushed some edges in the path become saturated. As a consequence, some of the edges linking the nodes to their parents are not longer valid and the nodes in the trees S and T become “orphans”. The augmentation phase may split the search trees S and T into a “forest”. Terminals s and t are still roots of two of the search trees, and the orphans form roots of all other trees.

Finally the “adoption” stage restores the single tree structure S and T with roots in the source s and in the sink t. A new valid parent for each “orphan” is found. The new parent and the “orphan" should belong to the set S ot T. The parent also should be connected through a non saturated edge. If a no qualified parent is found the “orphan” is removed from S or T and is declared as free node altogether with its children. The “adoption” stages terminates when no “orphans” are lefand the search trees structures S and T are restored.

After the “adoption” stage the algorithm returns to the “growth” phase. The algorithm finishes when the search trees cannot grow (no active nodes) and the trees are separated by saturated edges. In this point the maximum flux has been reached, and the minimum cut is determinated by S = S and T = T.

SIMULATION RESULTS:

Input image and individual channel image



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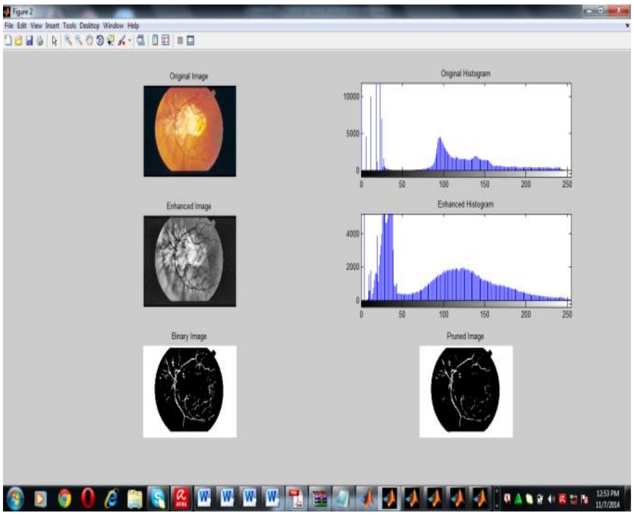
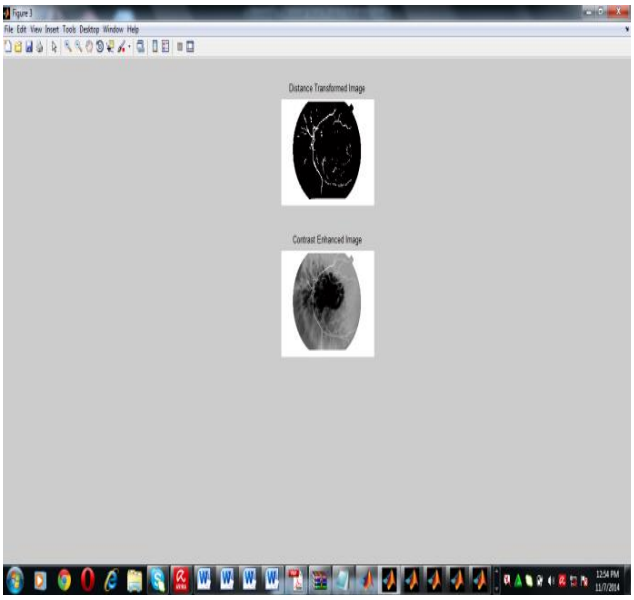
The individual Red , Blue , Green channel images are segmented from the input retinal images.

Enhanced histogram image



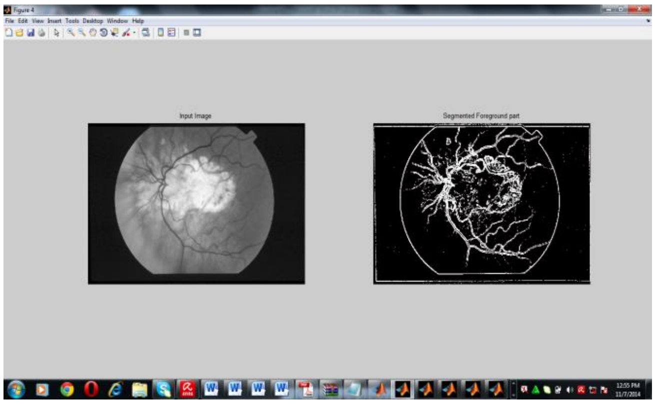
The Image Enhanced using Adaptive Histogram Equalization and The Image Pruned using Binary morphological open process.

Distance Transformed Image and Contrast Enhanced Image



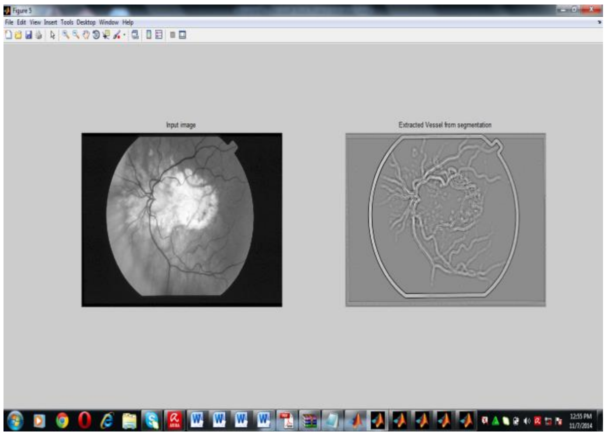
Distance map image is created using Distance transform and again the image is contrast enhanced using Adaptive Histogram Equalization.

Segmented Foreground Part



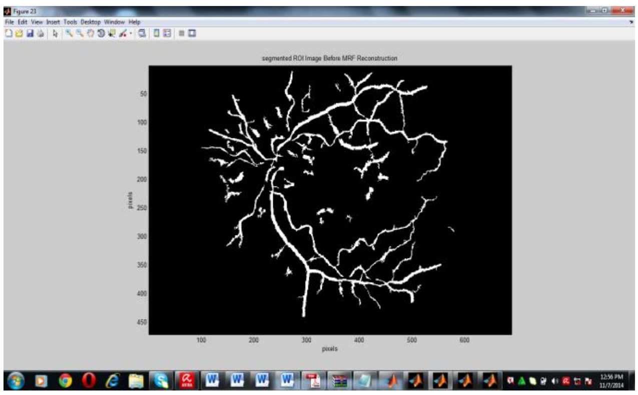
The foreground part is segmented by using Contrast Enhanced Image.

Extracted vessel from segmentation



Extracted Blood vessels are segmented by using the graph cut technique

Segmented ROI Image Before MRF Reconstruction



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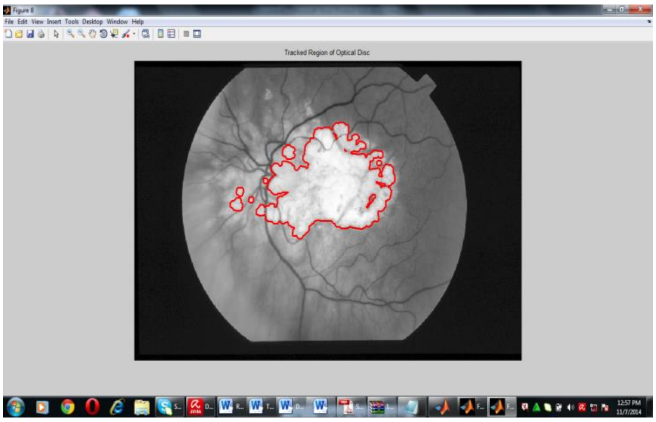
Segmented Region of interest before the MRF based image reconstruction.

Tracked Region of Optic Disc



Tracked region of optic disc using MRF based image reconstruction

ADVANTAGES:

Addresses one of the main issues in medical image analysis, "the overlapping tissue segmentation". Without a need for training. Our proposed method achieves better overall average TPR performance than all the methods.

APPLICATION:

Assessing the presence and severity of retinal diseases such as diabetic retinopathy, hypertension, glaucoma, haemorrhages, vein occlusion and neo-vascularisation.

CONCLUSION:

An automatic system to assist the control and diagnosis of retinal diseases was developed by integrating the mechanism of flux, MRF image reconstruction and the graph cut method. A system with not need of user interaction or tunning of parameters. At the same time our selection of use the graph cut technique provides to our model the flexibility to move from automatic to semi automatic system if is required.

FUTURE WORK

The segmentation of retinal diseases (lesions) known as "exudates" using the segmented structures of the retina (blood vessels and optic disc) has been carried out. Thus a background template can be created using these structures. Then this template can be used to perform the detection of suspicious areas (lesions) in the retinal images.

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