Lappeenranta University of Technology
Faculty of Industrial Engineering and Management
Degree Program in Computer Science

Bachelor's Thesis

Teemu Huovinen

SENSITIVITY OF RETINAL IMAGE SEGMENTATION ON GROUND TRUTH ACCURACY

Examiners: Professor Esim Esimerkki
Lasse Lensu D.Sc. (Tech.)

Supervisor: Lasse Lensu D.Sc. (Tech.)

ABSTRACT

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Sensitivity of retinal image segmentation on ground truth accuracy

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2014

24 pages, 64 figures, 1 table, and 2 appendices.

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Keywords: keyword, key, word

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TIIVISTELMÄ

Lappeenrannan teknillinen yliopisto
Tuotantotalouden tiedekunta
Tietotekniikan koulutusohjelma

Teemu Huovinen

Silmänpohjakuvien segmentoinnin herkkyys pohjamerkintöjen tarkkuudelle

Kandidaatin työ

2014

24 sivua, 64 kuvaa, 1 taulukko ja 2 liitettä.

Tarkastajat: Professori Esim Esimerkki
TkT Lasse Lensu

Hakusanat: avainsana, avain, sana
Keywords: keyword, key, word

Tähän kirjoitetaan ytimekäs tiivistelmä: tausta, tavoite, tulokset ja johtopäätökset. Tiivistelmässä kannattaa käyttää lyhyen nasevia lauseita. Itse tekstissä voi käyttää monimutkaisempia lauseita. Tiivistelmä-sivu on yksi sivu ja tiivistelmäteksti on yksi kappale, ei useita kappaleita. On hyvä kertoa työn tavoitteet. Mikäli työ sisältää oleellisia aiheen rajauksia, ne kannattaa mainita jo tiivistelmässä. Työn tulokset ja johtopäätökset luetellaan lukijan mielenkiinnon lisäämiseksi. Opinnäytetyö kirjoitetaan passiivissa tyyliin “tässä työssä tutkitaan..” aktiivin sijaan “minä tutkin...” ja marginaalit tasataan aina sekä vasemmalle että oikealle. Työn numerointi aloitetaan kansilehdeltä, mutta tätä roomalaista numeroa ei merkitä näkyviin.

PREFACE

Tässä voidaan mainita työn tekopaikka, kiittää työtä tukeneita henkilöitä ja muita tahoja, jne. tyyliin “Työ on tehty Lappeenrannan teknillisen yliopiston ... Kiitän työkavereita ja rakasta vaimoani tuesta ...”

Lappeenranta, October 19th, 2014

Teemu Huovinen

CONTENTS

ABBREVIATIONS AND SYMBOLS

TP	True Positive
TN	True Negative
FP	False Positive
FN	False Negative
FPR	False Positive Rate
FNR	False Negative Rate

1 INTRODUCTION

1.1 Background

The growing amount of diabetes patients and (arguably) more importantly the estimated amount of undiagnosed patients motivate the research for an effective mass screening method for early detection of diabetes. Diabetic retinopathy is a complication of diabetes that causes abnormalities in the eye, and detecting these abnormalities in the eye fundus is a promising mass screening method. Images where ophthalmologists have marked these abnormalities, such as exudates, are used as ground truths in eye fundus image segmentation research.

Optimal ground truth would be a pixel-accurate binary representation of the abnormalities, but as ground truths are done by a human hand, such accuracy is unrealistic. Because the marking of an accurate ground truth takes a good amount of time and patience, we often have to settle for rough markings of the present abnormalities. Clusters of exudates are circled, rather than each small finding specified separately.

1.2 Objectives and Restrictions

The objective of this thesis is to evaluate how big of an impact inaccurate ground truth has on various image features and segmentation methods.

Ground truth accuracy is explored only from the perspective of exudate detection, and Bristol database is used as it has accurate ground truths of exudates. Blood vessel detection is explored only to create a mask for them. A rough method for optic disk detection is also implemented as a preprocessing step for masking reasons.

Both supervised and unsupervised segmentation methods are used. In supervised methods, ground truths are used to label observations as either exudate or background. In unsupervised methods, ground truth is used to evaluate segmentation results. Best parameters for each method are chosen based on their performance.

1.3 Structure of the Thesis

Section 2 takes a look at the different features of eye fundus images, and how they are relevant in this thesis. It also explains the theory behind the applied pre-processing and segmentation methods. Section 3 details how sensitivity analysis is done in this thesis, and also explains the used evaluation methods. Section 4 describes the experiments in detail, and presents the results for each experiment. Section 5 sums up and interprets the results, and discusses the impact of this thesis and possible future work this thesis might invoke.

2 SEGMENTATION OF RETINAL IMAGES

Korkeemmalta tasolta, mikä työssä on tehtävä (myös herkkyysanalyysi). Kirjallisuuskatsaus.

2.1 Optic disc detection

Optic disc is very similar to exudates in terms of color and intensity, so detection and masking of the optic disk is an important preprocessing step in exudate detection. There are papers dedicated to the localisation of the optic disk [1], and it is also covered in papers concerning the detection of other parts of the eye fundus, such as exudates [2].

This method is based on the brightness of the optic disk, and the vertical blood vessels inside it. The horizontal image gradient is calculated using Sobel gradient operator, the result is shown in Figure 1a. Image is then divided into slightly overlapping square areas with a side of 140 pixels (size is adjusted when operating close to image borders). The area with the highest sum of gradients is considered as region of interest, i.e. to hold the optic disk. This is because the dark blood vessels inside the bright optic disk result in a strong horizontal gradient. Images with a “camera glare“,i.e. a high intensity strip in the corner of the eye fundus are problematic, as that area also has a high horizontal gradient. Region of interest is shown in Figure 1b.

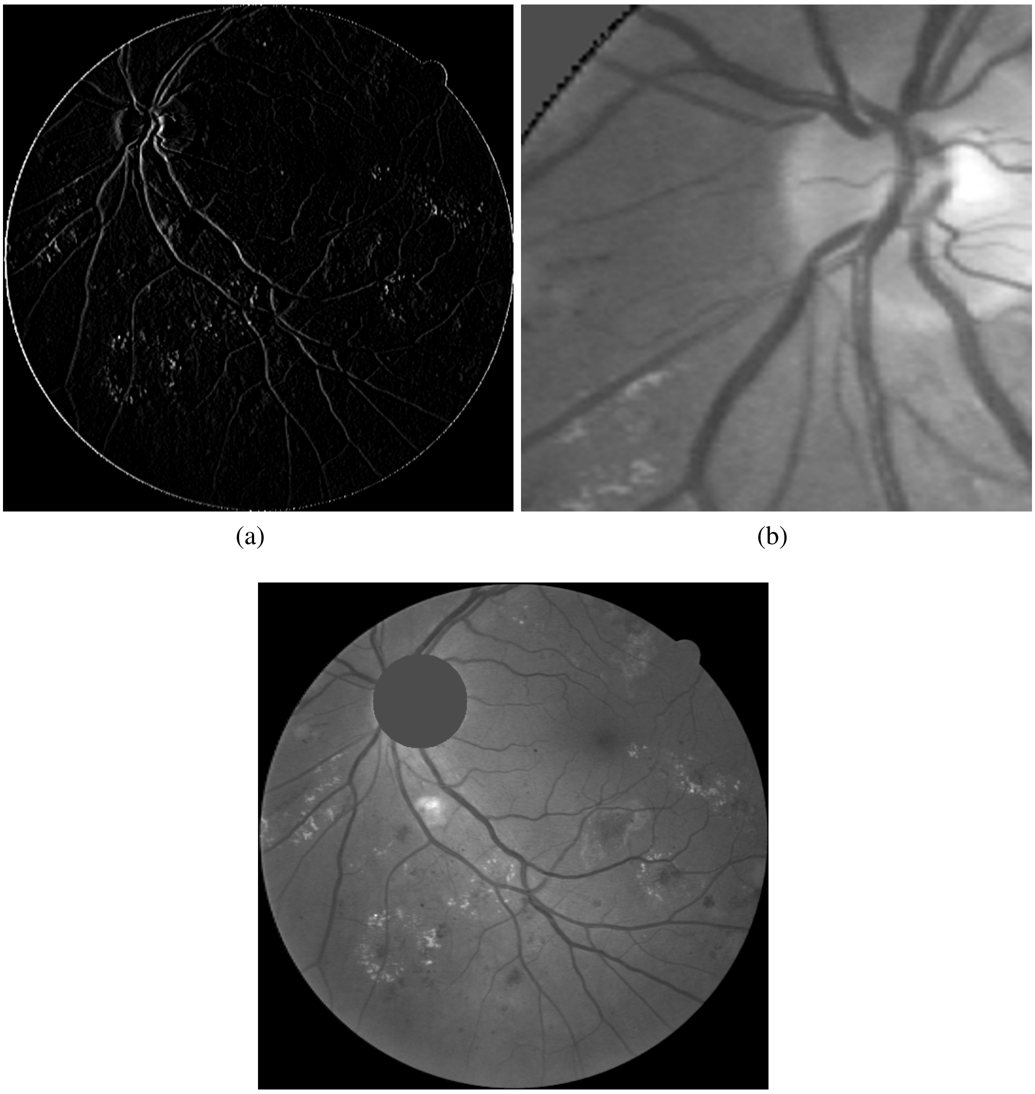
Inside this area of highest sum of horizontal gradients, the pixel with the highest intensity is considered to be inside the optic disk. This pixel is then used as a center of a circle that will mask out the optic disk. Final masking result is shown in Figure 1c.

2.2 Blood vessel detection

+ image outline

The purpose of blood vessel detection in this thesis is to create a mask, and to use that mask to remove false positives from exudate segmentation results. For example, edge detection techniques often highlight the borders of vessels as well as exudates.

The mask is formed by first using adaptive histogram equalization to enhance contrast in



(a)

(b)

(c)

Figure 1. Locating and masking the optic disk: (a) Horizontal gradient (b) Region of interest (c) Optic disk masked out

the green channel of the image, the result for this is shown in Figure 2a. This contrast enhanced image is then thresholded with Otsu's method [4], which separates the image into foreground and background by minimizing the intra-class variance. This results in all the vessels and other darker areas showing as black (or background), and all brighter areas as white (foreground). This is shown in Figure 2b. To create a binary mask of the darker areas, we use the complement of this thresholded image. Final version of the mask is shown in Figure 2c.

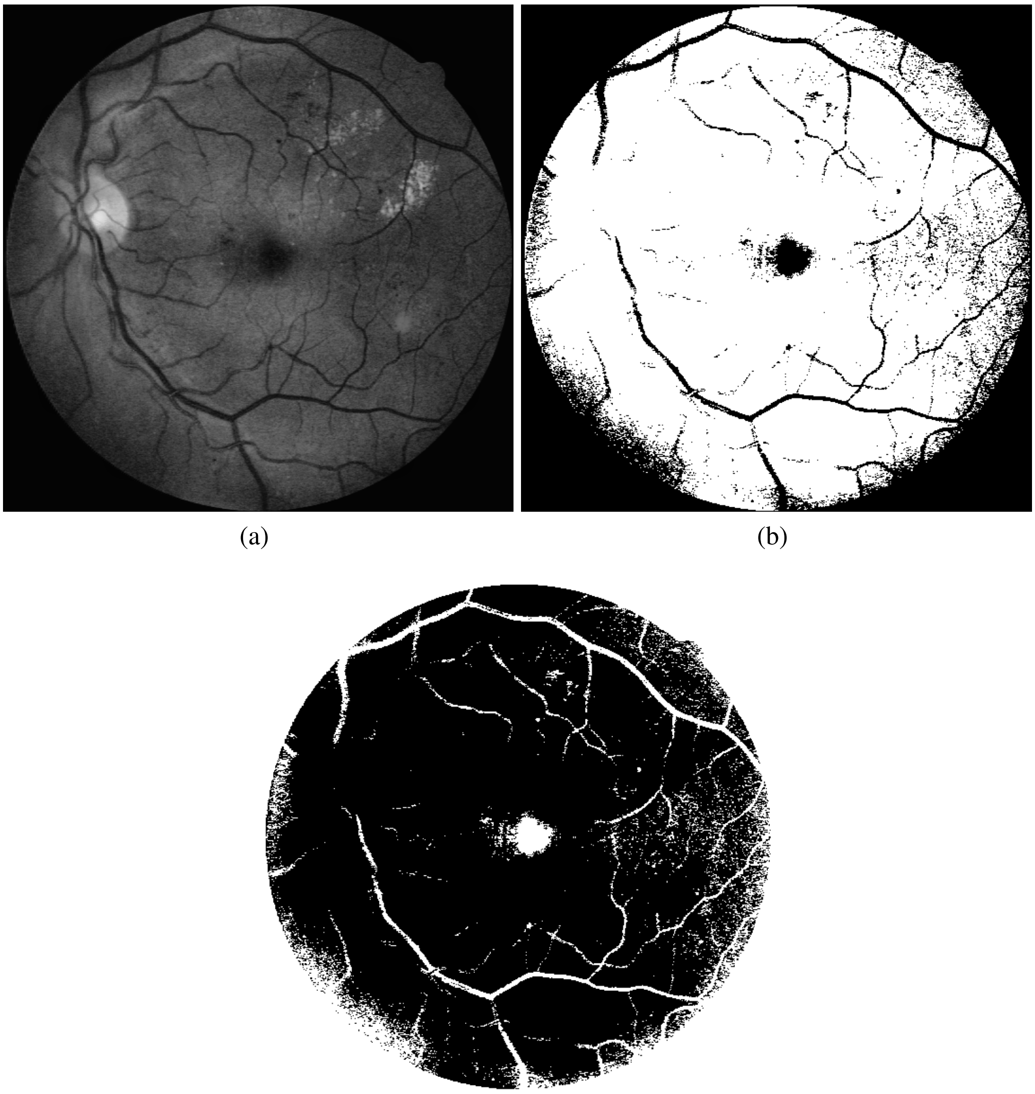
This method is inadequate for blood vessel detection as it also includes other darker areas of the image, such as the fovea. As a mask however, it clearly reduces the amount of false positives in exudate segmentation results. It also doesn't remove true positives, as only the darker areas of the image are included in the mask.

2.3 Used methods

Edge: Kirsch Tophat Mehdi

Jaafar (kmeans?) ravishankar sauvola

naive-bayes / gmmbayes



(a)

(b)

(c)

Figure 2. Phases in creating the blood vessel mask: (a) Adaptive histogram equalization (b) Thresholding using Otsu's method (c) Final mask, complement of thresholded image

3 SENSITIVITY ANALYSIS OF IMAGE FEATURES

3.1 Evaluation methods

In evaluation, correctly classified samples can be split into true positives and true negatives. Errors are then similarly split into false positives and false negatives. In this thesis, true positives are findings correctly classified as exudates in the segmentation results, and true negatives are consequently findings correctly classified as background. False negatives are classified as background in results, but are actually positive (classified as exudate) in ground truth, and false positives are classified as positive in results, when they are in fact background [3]. These terms are illustrated on Table 1.

Table 1. Illustration of terms

		Ground truth	
		Positive	Negative
Tests	Positive	True Positive (TP)	False Positive (FP)
	Negative	False Negative (FN)	True Negative (TN)

There exists a multitude of ways to evaluate segmentation results. In this thesis, a single numbers was used to describe the ”goodness” of segmentation results to enable easier comparison and ranking of results. Dice coefficient was used, as it is very simple to implement and understand. It can have values from the range [0,1], where 0 indicates no similarities, and 1 indicates perfect agreement. Other coefficients, such as sensitivity, specificity and precision [3] were also considered, but Dice was chosen as it best described the ”goodness” of the result as a whole, not just the amount of positives / negatives. Dice is defined as follows:

HUOM. DICE == F-MEASURE, VAIHDA?

$$D(A, B) = 2\frac{A \cup B}{A + B} \tag{1}$$

Dice coefficient can also be described using true positives, true negatives, false positives and false negatives:

$$D(A,B) = 2\frac{TP}{(FP+TP)+(TP+FN)} \tag{2}$$

3.2 Parameter selection for unsupervised methods

When researching feature sensitivity to ground truth accuracy, standard segmentation with unsupervised methods isn't really useful as it doesn't use the ground truth. In this thesis, the ground truth is used in finding the best parameters for unsupervised methods. First, the images used for teaching are segmented with each method and a large set of parameters. The results are then evaluated with the ground truth. Parameters with the highest Dice (see Eq. 1) coefficient are then selected to be used in experiments.

4 EXPERIMENTS AND RESULTS

4.1 Retinal Image Databases

4.2 The Ground Truth

Miten tehtiin: periaate, mitä kuvia käytettiin, softa.

The ground truth of exudates in Bristol database is very accurate, and to enable comparison of results and sensitivity analysis, more inaccurate ground truths were made by hand. Instead of the original color images, markings for the inaccurate ground truth were made on the black-and-white images of Bristol ground truth. This was to ensure every exudate present in the Bristol ground truth was also present in the inaccurate ground truth. Markings were done in a way that estimated the way doctors marked their findings when given the freedom to make inaccurate markings. Essentially this means that clusters of exudates are grouped together, and single exudates were more loosely circled. This is illustrated in image (KUVA VIITTAUS TÄHÄ).

4.3 Experiment 1

First experiment was done with minimal preprocessing; only the green timestamp was removed. In unsupervised methods, the mask described in 2.2. was used to reduce the amount of false positives. In supervised methods, features describing color values and the presence of edges were used. The original value of red channel and the contrast enhanced values of green and blue channel were used to describe color. For edge detection, local standard deviation of a 3-by-3 neighborhood of each channel was used.

4.4 Experiment 2

5 DISCUSSION

We have to discuss what we learned.

Notice the automatic page breaks.

5.1 Segmentation Results

5.2 Sensitivity of Image Features

5.3 Future Work

Tehtiin laitokselle osana projektia, tulevaisuudessa saatu ground truth on todennäköisesti epätarkkaa ja piti tietää miten se vaikuttaa tuloksiin. It is always nice to give some ideas for the future.

6 CONCLUSIONS

Finally the conclusions. This is more compact that the Discussion, a sort of summary about how things went on a general level.

Now you can delete all this crap content and write your own. Have fun!

REFERENCES

[1] Sribalamurugan Sekhar, Waleed Al-Nuaimy, and Asoke K Nandi. Automated localisation of retinal optic disk using hough transform. In *Biomedical Imaging: From Nano to Macro, 2008. ISBI 2008. 5th IEEE International Symposium on*, pages 1577–1580. IEEE, 2008.

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Appendix 1. Appendix Guidelines

The appendices part starts with the command `\appendix`. Then, each appendix must be started with `\section{Appendix Name}` and ended with `\sectionend` to have the continues/continued markings right. For example, see the multi-page appendices after this one.

Appendix 2. Frame Schematics

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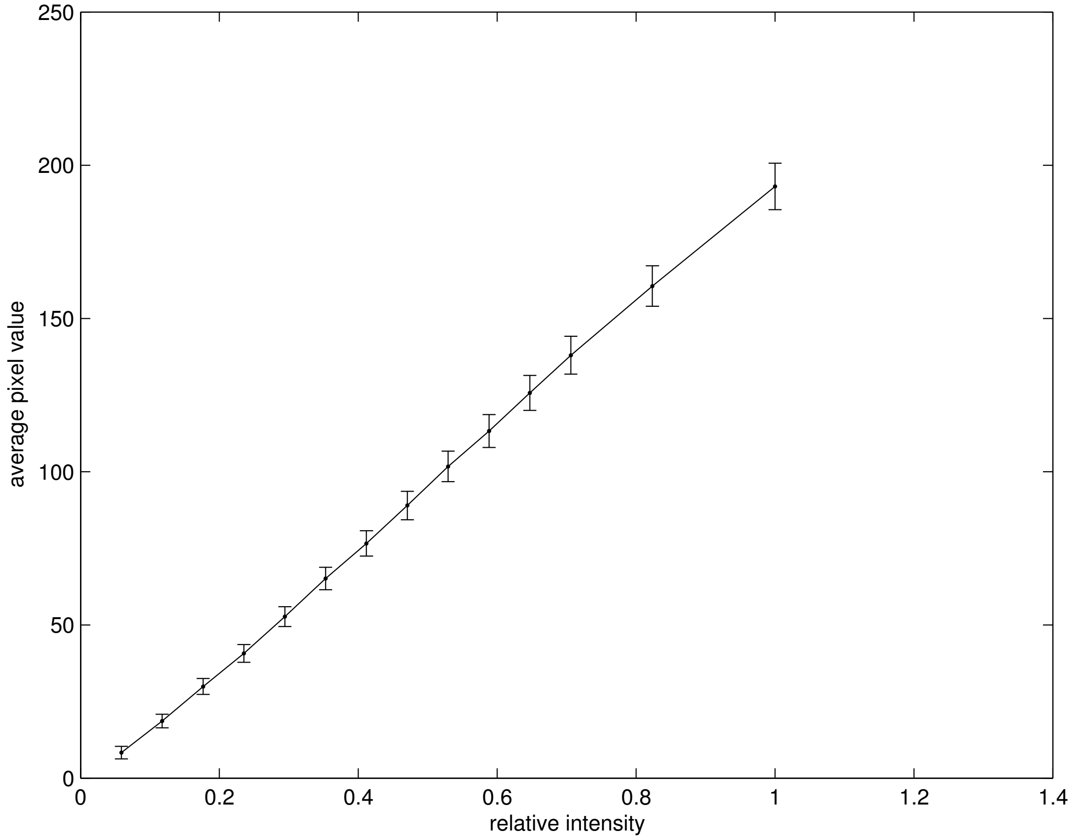

Figure A2.1. Overall design, only one half drawn.

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Reference testing: Figures A2.1, A2.2, and A3.1. Table A3.1.

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Appendix 2. (continued)

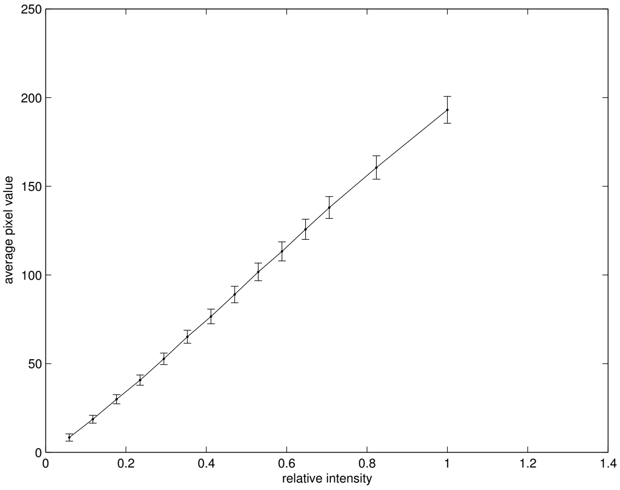

Figure A2.2. Another picture.

Appendix 3. The Second

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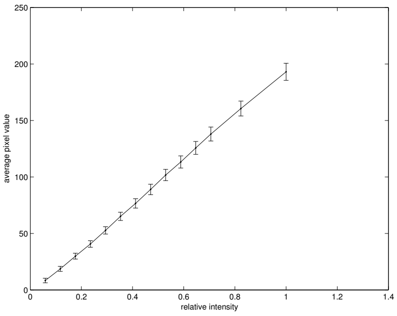

Figure A3.1. The same picture once more.

Table A3.1. Appendix test table.

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Appendix 3. (continued)

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Appendix 3. (continued)

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