PROGRESS IN BIOMEDICAL OPTICS AND IMAGING
Vol. 18 No. 60

Clinical and Preclinical Optical Diagnostics

J. Quincy Brown
Ton G. van Leeuwen
Editors

25–27 June 2017
Munich, Germany

Sponsored by
The Optical Society (United States)
SPIE

Published by
SPIE

Volume 10411

Proceedings of SPIE-OSA Biomedical Optics, 1605-7422, V. 10411

Clinical and Preclinical Optical Diagnostics, edited by J. Quincy Brown, Ton G. van Leeuwen,
Proc. of SPIE-OSA Vol. 10411, 1041101 · © 2017 OSA-SPIE
CCC code: 1605-7422/17/$18 · doi: 10.1117/12.2292243

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Author(s), "Title of Paper," in *Clinical and Preclinical Optical Diagnostics*, edited by J. Quincy Brown, Ton G. van Leeuwen, Proceedings of SPIE-OSA Vol. 10411 (SPIE, Bellingham, WA, 2017) Seven-digit Article CID Number.

ISSN: 1605-7422
ISSN: 1996-756X (electronic)

ISBN: 9781510612808
ISBN: 9781510612815 (electronic)

Copublished by
SPIE
P.O. Box 10, Bellingham, Washington 98227-0010 USA
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SPIE.org
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The Optical Society
2010 Massachusetts Ave., N.W., Washington, D.C., 20036 USA
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Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.

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Automated skin lesion segmentation with kernel density estimation

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Abstract

Skin lesion segmentation is a complex step for dermoscopy pathological diagnosis. Kernel density estimation is proposed as a segmentation technique based on the statistic distribution of color intensities in the lesion and non-lesion regions.

Keywords: kernel density estimation, skin lesion, melanoma, segmentation

INTRODUCTION

Early diagnosis is vital in skin pathologies such as melanoma. Visual inspection and dermoscopy are the most spread procedures for the identification of different skin lesions. When lesions are suspected to be malignant, they are completely excised and biopsied providing the final diagnosis. However, visual analysis is subject to errors in the dermatologist's criteria and perception, being this diagnosis strongly influenced by experience. Different diagnostic procedures have been developed to overcome subjectivity trying to fix a common criterion, such as ABCD or CASH methods [1]. These methods, and others, are based on the skin morphological features, such as size, symmetry, border sharpness and also on color and texture distributions.

The skin lesion segmentation is typically applied by the dermatologist, who can establish reliable lesion borders. These borders are considered the ground truth for computer aided segmentation procedures. Automation of these procedures is a challenging task due to image artifacts such as light reflections, hair, vignetting effect and color variations in the lesion [2].

Kernel Density Estimation (KDE) is a statistical procedure used to estimate the probability density function (PDF) of a given dataset [3]. Here, the lesion and non-lesion PDF are obtained and used to classify pixels based on different color channels of the original RGB dermoscopic image. This procedure separates lesion from non-lesion pixels producing a segmentation mask. The resulting segmentation mask is compared with the ground truth mask provided by the dermatologist through manual delineation.

MATERIALS AND METHODS

Dermoscopic images come from PH^2 database [4]. According to the database, images are acquired using a magnification of 20x, digitalized with 8 bits RGB color channels with a resolution of 768x560 pixels. A segmentation mask is provided for each image. This mask has been segmented by medical experts. Manual segmentation masks are used as the gold standard for testing segmentation algorithms.

Kernel density estimation is aimed to estimate the probability density function of a given dataset. This procedure assumes that each point in the dataset produces a PDF that contributes additively to the PDF of the whole dataset [3]. Each of these contributions is assumed to follow a distribution, typically Gaussian. For every point x, a window of surrounding data is picked and its distribution is added to the global PDF [5]:

$$P(x) = \frac{1}{n}\sum_{i=n}\frac{1}{\left(\sigma\sqrt{2\pi}\right)^d}e^{-\frac{1}{2}\left(\frac{x-x_i}{\sigma}\right)^2} \quad (1)$$

being σ the standard deviation of the Gaussian function, n the number of points in the dataset and d the dimension of the dataspace. Here, KDE is used to estimate the PDF of color pixels belonging to the lesion region and also to estimate the PDF of the non-lesion region. For that aim, images are converted to different color channels.

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Clinical and Preclinical Optical Diagnostics, edited by J. Quincy Brown, Ton G. van Leeuwen,
Proc. of SPIE-OSA Vol. 10411, 104110P · © 2017 OSA-SPIE
CCC code: 1605-7422/17/$18 · doi: 10.1117/12.2283038

Red *R*, green *G* and blue *B* color channels of dermoscopic images are converted into CIE-Luv and CIE-Lab color spaces. The different color representations have different information about luminance and chrominance distributions in the image (Fig. 1).

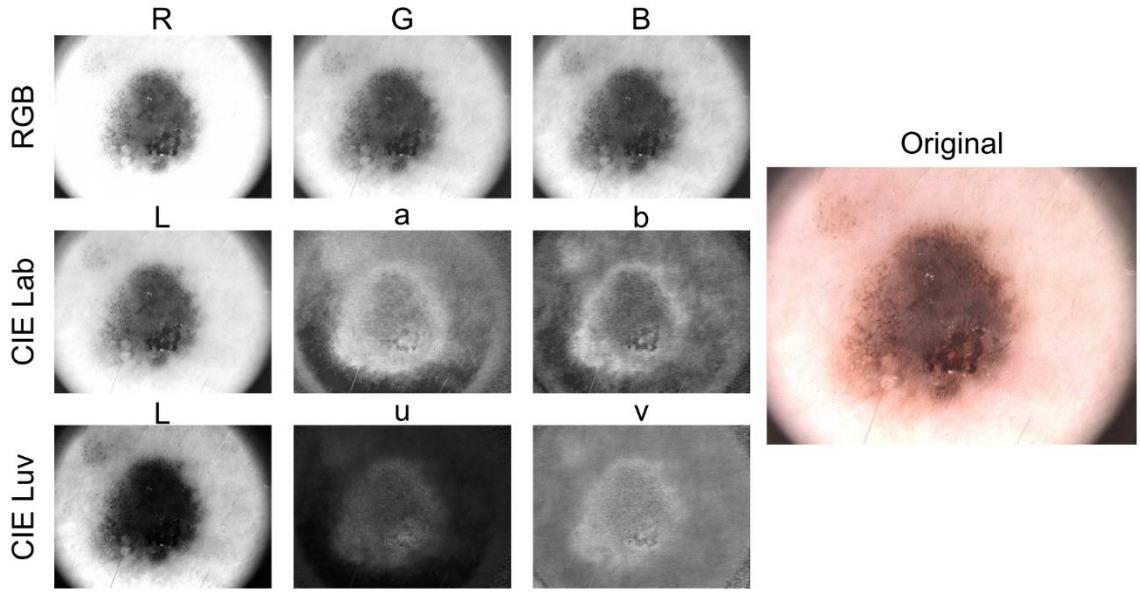

Figure 1. Original image IMD004 from PH2 database [PH2] and different color channels in the RGB, CIE-Luv and CIE-Lab color spaces.

As observed in Fig.1, each color channel seems to enhance a different feature in the lesion. Luminance images (L) are more suitable for segmentation purposes, whilst chrominance a, b, u and v channels are more relevant to determine color features and morphology in the lesion. The R and L channels provide contrast of the lesion borders and the effect of vignetting. The luminance channel from the CIE-Luv color space is used to obtain a vignetting mask (Fig. 2a), as well as a coarse mask for the segmentation of the lesion (Fig. 2b). Otsu's thresholding algorithm [6] is used for this aim, binarizing the luminance according to the intensity histogram of the luminance. This coarse mask is morphological eroded and only the biggest area is considered, obtaining the lesion mask (fig. 2c). The non-lesion mask is obtained as the negative of both, the vignetting mask and the coarse mask (Fig. 2d).

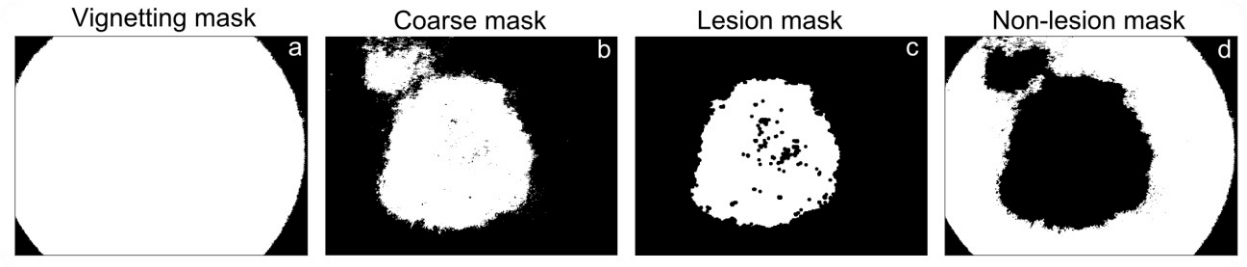

Figure 2. Masks obtained for the delimitation of the vignetting (a), the lesion region (c) and the non-lesion region (d).

A multi-dimensional image is conformed with the color channels *u*, *v*, *a*, *b* and *L* from CIE-Luv. To prepare the classification task for automatic segmentation, a subset of 100 random pixels are selected from the lesion and the non-lesion masks and KDE is applied to obtain the PDF of both, the lesion and non-lesion region respectively in the new multi-dimensional image. Once the *lesion* PDF and the *non-lesion* PDF become calculated, a classification of the rest of pixels in the image is performed based on the conditional PDF considering two hypotheses. Hypothesis H0 where the

pixel belongs to the lesion region, and Hypothesis H1 where the pixel belongs to the non-lesion region. Maximum likelihood classification is used to decide if a pixel belongs to lesion or non-lesion region based on the value obtained for H0 and H1 [7].

RESULTS AND DISCUSSION

The segmentation result obtained for the image of Fig.1 is shown in Fig. 3a, as well as other two examples from the PH^2 database. The automatic segmentation result is similar to the ground truth provided in the database. Slight differences appear in the exact location of the lesion border; however, in the original image it can be observed that the border consists on a color degradation, not a sharp color change. Fig. 3 shows how KDE segmentation is more conservative, i.e. it classifies degraded color as lesion. In the case of manual delineation, human perception can affect the color contrast between light and dark colors in the lesion and non-lesion areas.

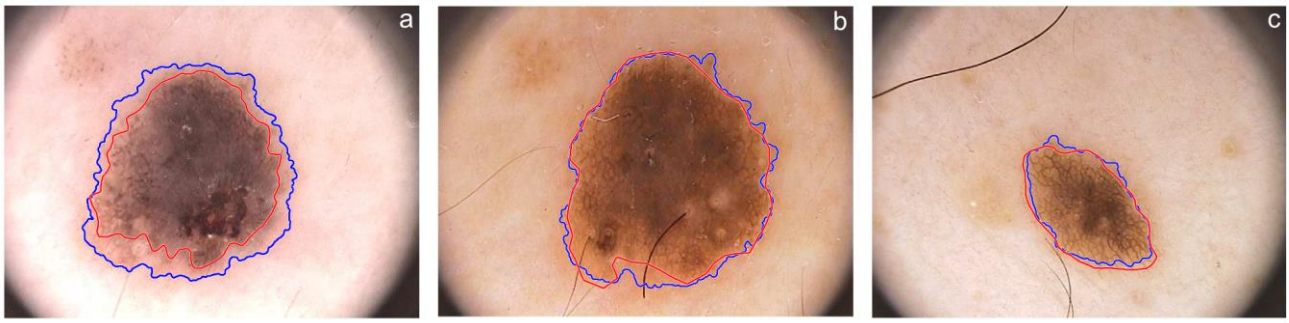

Figure 3. Segmentation result obtained with KDE (blue) compared to manual segmentation provided by the PH2 database (red). Displayed images correspond to skin lesions IMD004 (a), IMD002 (b) and IMD024 (c) from PH2 database [PH2].

CONCLUSIONS

Visual inspection and manual segmentation of skin lesions are dependent on dermatologist's color perception, what makes manual segmentation a subjective task. In the case of the proposed KDE, the automatic segmentation of the lesion is provided by the statistical distribution of pixels that maximize the likelihood of the color probability density functions making the segmentation process more stable and repetitive.

In addition, the KDE method is solely based on the color distribution present within the image, what makes the segmentation process fully independent of extra information or any heuristic approach driving the segmentation process towards a completely unsupervised and automated procedure.

ACKNOWLEDGEMENTS

This work is supported by the "Ministerio de Economía, Industria y Competitividad" (MINECO) under projects DA2TOI (FIS2010-19860), SENSA (TEC2016-76021-C2-2-R), the "Instituto de Salud Carlos III" (ISCIII) through projects FUSIODERM (DTS15/00238) and CIBERBBN and the co-financed by FEDER funds.

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