Guest Editorial Skin Lesion Image Analysis for Melanoma Detection

MELANOMA is the deadliest form of skin cancer, with roughly 91,000 new cases reported every year in the US and more than 9,000 deaths. Unlike many other cancer types, the incidence rate of melanoma has been steadily increasing in the past several decades. Early diagnosis is crucial since melanoma can be cured with a simple excision, if detected early. In the past, the primary form of diagnosis for melanoma was unaided clinical examination, which has limited and variable accuracy, leading to significant challenges both in the early detection of disease and the minimization of unnecessary biopsies. In recent years, dermoscopy, a high-resolution skin imaging technique that allows visualization of deeper skin structures by reducing surface reflectance, has improved the diagnostic capability of trained specialists. Unfortunately, dermoscopy remains difficult to learn and several studies have demonstrated limitations of dermoscopy when proper training is not administered. In addition, even with sufficient training, visual analysis remains subjective.

Newer imaging technologies such as infrared imaging, multispectral imaging, and confocal microscopy, have recently come to the forefront in providing the potential for greater diagnostic accuracy. In addition, various studies since the late 1990s have been focused on developing algorithms for the automated analysis of dermoscopy images. Combinations of such technologies have the potential to serve as adjuncts to physicians, improving clinical management, especially for high-risk patients.

The goals of this special issue are to summarize the state-of-the-art in the automated analysis of skin lesion images and to provide future directions for this exciting subfield of medical image analysis. The intended audience includes researchers and practicing clinicians, who are increasingly using digital analytic tools.

For this special issue, which has been organized in the framework of the IEEE International Symposium on Biomedical Imaging (ISBI 2016), we received 63 submissions from around the world. After a rigorous, multiple-round peer review process, we accepted 12 papers for publication, resulting in a 19% acceptance rate. All papers except for one involve dermoscopy, reflecting the growing use of this modality in clinical practice throughout the world. Therefore, this issue is essentially one about *dermoscopy image analysis* (DIA). Eight of the 12 papers (67%) use the International Skin Imaging Collaboration (ISIC) Archive dataset (https://isic-archive.com), highlighting the significant impact of this dataset on the DIA literature. Five papers (42%) are related to deep learning, a topic that has become increasingly popular in DIA since 2015.

The issue contains articles that address a wide variety of topics, including segmentation, feature extraction, classification, and registration.

The issue opens with six articles on segmentation. In SDI+: A Novel Algorithm for Segmentation Dermoscopic Images, Guarracino and Maddalena present a three-stage segmentation algorithm. In the preprocessing stage, the authors detect dark areas of the image and highlights based on thresholding and hairs based on morphological filtering. In the segmentation stage, two color channels (one from the normalized RGB color space and the other from the HSV color space) are separately thresholded using Otsu's method and then the best segmentation is selected based on multiple criteria such as centrality and solidity of the object, and relative contrast. Finally, in the postprocessing stage, the initial segmentation mask is expanded using morphological dilation and then its interior is filled. In Active Contours Based Segmentation and Lesion Periphery Analysis for Characterization of Skin Lesions in Dermoscopy Images, Riaz *et al.* propose an active contour based segmentation approach. The lesion contour is initialized using thresholding and then evolved by maximizing the KL-divergence between the gray level distributions of the lesion and the surrounding skin. The authors also investigate the importance of the inner peripheral lesion on classification. In Accurate Segmentation and Registration of Skin Lesion Images to Evaluate Lesion Change, Navarro *et al.* describe a superpixel based segmentation algorithm. The algorithm eliminates artifacts such as hairs and bubbles using Hough transform and then partitions the image using superpixels. Salient parts of the lesion are partitioned more finely by means of smaller superpixels. In Supervised Saliency Map Driven Segmentation of Lesions in Dermoscopic Images, Jahanifar *et al.* investigate a three-stage saliency based approach. In the preprocessing stage, the authors perform color normalization and hair removal respectively using the shades of gray algorithm and threshold-set decomposition followed by morphological filtering. In the segmentation stage, a saliency mask is first computed using a multi-level approach based on various descriptors including contrast, shape, texture, and color. The final segmentation is obtained by refining the convex hull of the initial saliency mask by distance regularized level set evolution. In Improving Dermoscopic Image Segmentation with Enhanced Convolutional-Deconvolutional Networks, Yuan and Lo propose a convolutional-deconvolutional neural

Digital Object Identifier 10.1109/JBHI.2019.2897338

network (CDNN) architecture for segmentation. The proposed architecture is deeper than a typical CDNN architecture, employs smaller (3×3) kernels and a Jaccard distance based loss function. The authors use multiple color spaces including RGB (R, G, and B channels), HSV (H, S, and V channels), and CIELAB (only L channel). Finally, in Dense Deconvolutional Network for Skin Lesion Segmentation, Li *et al.* present a dense deconvolutional neural network architecture for segmentation. The proposed architecture consists of dense deconvolutional layers (DDLs), chained residual pooling (CRP), and hierarchical supervision (HS). DDLs allow the dimensions of input and output images to remain unchanged; CRP captures contextual information and fuses multi-level features; whereas, HS refines the prediction mask.

As the technologies to address segmentation, feature extraction, and classification often can have a significant degree of overlap, the issue contains several articles that simultaneously address these tasks in varying combinations. In 7-Point Checklist and Skin Lesion Classification Using Multi-Task Multi-Modal Neural Nets, Kawahara *et al.* present a multi-modal approach combining dermoscopic images, clinical (macroscopic) images, and metadata, into a multi-task framework that jointly learns to extract dermoscopic criteria (7-point checklist), as well as disease states, over a variety of combinations of inputs, making the technique robust to potentially missing data. Interestingly, the authors compare strict adherence to the automated 7-point checklist to diagnose melanoma, versus direct classifier training, and demonstrate respectable performance from the 7-point alone. In DermaKNet: Incorporating the Knowledge of Dermatologists to Convolutional Neural Networks for Skin Lesion Diagnosis, Gonzalez-Diaz presents an approach for performing segmentation, dermoscopic feature detection, and disease classification. Dermoscopic features are learned with an objective function that makes use of weak annotations at the whole image level rather than at the pixel level, making this type of annotation easier to acquire.

The issue continues with three articles on feature extraction. In Statistical Detection of Colors in Dermoscopic Images with a Texton-Based Estimation of Probabilities, Saez *et al.* propose a color detection algorithm based on maximum *a posteriori* probability estimation. The training probability distributions are obtained using k-means clustering of color-texture features extracted from 3×3 neighborhoods. In Biologically Inspired QuadTree Colour Detection in Dermoscopy Images of Melanoma Sabbaghi *et al.* present a color detection based quadtree decomposition. The authors first enhance the image contrast and remove hairs using morphological filtering. After detecting the lesion border using thresholding, they partition the lesion into concentric quintiles using Euclidean distance transform. These quintiles are divided into small square blocks, each of which is assigned a color label based on its similarity to a set of color patches prepared by three dermatologists. Finally, these blocks are grouped using a quadtree structure. The authors also conduct classification experiments using multiple classifiers. Finally, in Fully Convolutional Neural Networks to Detect Clinical Dermoscopic Features, Kawahara and Hamarneh describe their system that won the 2017 ISIC Challenge for Part 2: Feature Classification Task. For training, the task is reformulated as a segmentation task, with direct application of fully-convolutional networks based on VGG16.

An article on registration completes the issue. In An Improved Skin Lesion Matching Scheme in Total Body Photography Korotkov *et al.* present two novel skin lesion matching algorithms. The simpler algorithm involves successive rigid transformations on 3D point clouds, whereas the more advanced one involves nonrigid coordinate plane deformations in ROIs around the lesions. Both algorithms feature a robust outlier rejection procedure based on progressive graph matching.

ACKNOWLEDGMENT

The guest editors thank all those who helped make this special issue possible, especially the Editor-in-Chief, editorial staff, and the authors and reviewers of the contributions.

M. EMRE CELEBI
Department of Computer Science
University of Central Arkansas
Conway, AR 72035 USA
ecelebi@uca.edu

NOEL CODELLA
IBM T. J. Watson Research Center
Yorktown Heights, NY 10598 USA
nccodell@us.ibm.com

ALLAN HALPERN
Dermatology Service
Memorial Sloan Kettering Cancer Center
New York, NY 10065 USA
halperna@mskcc.org

DINGGANG SHEN
Department of Radiology
University of North Carolina
Chapel Hill, NC 27599 USA
dinggang_shen@med.unc.edu