ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

Scientific Report

First name / Family name	Michael Osadebey
Nationality	Canadian
Name of the *Host Organisation*	Norwegian University of Science and Technology
First Name / family name of the *Scientific Coordinator*	Marius Pedersen & Jon Yngve Hardeberg
Period of the fellowship	01/10/2018 to 30/09/2020

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

The scientific activities are in four categories. They are perceptual quality evaluation, disease diagnosis, supervision of students and agriculture.

- **Perceptual Quality Evaluation**

The study evaluates the contrast quality attributes of magnetic resonance imaging (MRI) images (**REF # 1, 10**) and the colour space that is most suitable for the segmentation of dermatoscopy images (**REF # 4**). Both studies are necessary to optimize the performance of computer-aided systems for the diagnosis of neurological diseases and skin cancer.

- **Disease Diagnosis**

A study in this category proposed the application of unsupervised machine learning based on the online variational learning algorithm to cluster and segment images acquired for the diagnosis of brain tumour, lung tuberculosis and skin cancer (**REF # 3**). In the second study, we propose another unsupervised learning based on the clustering tree algorithm for the segmentation of brain tumour in MRI images (**REF # 8**). The clustering tree algorithm, unlike the traditional clustering, allows generous range in the selection of predefined number of clusters. It does not restrict the user to a specific predefined number of clusters, thereby overcoming a major limitation of the traditional clustering algorithm. The third study combine the clustering three algorithm with local mode filtering in the segmentation of optic disc boundary of retinal images (**REF # 5**). Delineation of the optic disc boundary in retinal images is the first step towards the computation of cup-to-disc ratio, an important indicator of ophthalmic pathologies such as glaucoma. The fourth and fifth studies involved collaboration with physicists and radiologists at the Oslo University Hospital, Oslo, Norway. Both

studies are for the extraction of axillary lymph nodes and lung region from CT images of breast and lung cancer patients, respectively (**REF # 7, 9**).

- **Graduate Student Supervision**

I supervised two masters' students in two separate projects. They are Meeta Kalra from Concordia University, Montreal, Canada and Christopher Berg Kongsness from Norwegian University of Science and Technology, Norway.

- Agriculture

The research also explore the application of unsupervised machine learning based on the combination of k-means clustering algorithm and set theory to agricultural production (**REF # 2**). We extend the principle of set theory applied in the study to skin cancer diagnosis. The proposed method simultaneously eliminate artefact and extract skin lesion in dermatoscopy images (**REF # 6**). This technique reduces algorithm resources by eliminating the need for a pre-processing step and improve the efficacy of a computer-aided diagnostic system for skin cancer diagnosis.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1. **Osadebey, M**., Pedersen, M., Arnold, D., & Wendel-Mitoraj, K. (2019). Local Indicators of Spatial Autocorrelation (LISA): Application to Blind Noise-Based Perceptual Quality Metric Index for Magnetic Resonance Images. *Journal of Imaging*, *5*(1), 20. (**Accepted**)

Abstract

Noise-based quality evaluation of MRI images is highly desired in noise-dominant environments. Current noise-based MRI quality evaluation methods have drawbacks that limit their effective performance. Traditional full-reference methods such as SNR and most of the model-based techniques cannot provide perceptual quality metrics required for accurate diagnosis, treatment and monitoring of diseases. Although techniques based on the Moran coefficients are perceptual quality metrics, they are full-reference methods and will be ineffective in applications where the reference image is not available. Furthermore, the predicted quality scores are difficult to interpret because their quality indices are not standardized. In this paper, we propose a new no-reference perceptual quality evaluation method for grayscale images such as MRI images. Our approach is formulated to mimic how humans perceive an image. It transforms noise level into a standardized perceptual quality score. Global Moran statistics is combined with local indicators of spatial autocorrelation in the form of local Moran statistics. Quality score is predicted from perceptually weighted combination of clustered and random pixels. Performance evaluation, comparative performance evaluation and validation by human observers, shows that the proposed method will be a useful tool in the evaluation of retrospectively acquired MRI images and the evaluation of noise reduction algorithms.

2. **Osadebey, M**., Pedersen, M., & Waaler, D. (2019, July). Plant Leaves Region Segmentation in Cluttered and Occluded Images Using Perceptual Color Space and K-means-Derived Threshold with Set Theory. In *2019 IEEE 17th International Conference on Industrial Informatics (INDIN)* (Vol. 1, pp. 1211-1216). IEEE.(**Accepted**)

Abstract

Presence of clutters and occluding objects within agricultural farm environments challenges accurate segmentation of plant leaves, a prerequisite for an effective machine-visionbased automation of agricultural tasks. In this paper, we propose a plant leaves segmentation method that can be integrated into vision-based robotic harvester and quality inspection systems. The proposed method combines the discriminatory power of color-based technique with the simplicity and computational efficiency of threshold-based technique. Clutters and occluding objects are eliminated by infinitesimal angular displacement of the threshold image, followed by the application of set theory. Performance evaluation shows that the proposed method demonstrate strong robust features and computational efficiency

3. Kalra, Meeta, **Michael Osadebey**, Nizar Bouguila, Marius Pedersen, and Wentao Fan. "Online Variational Learning for Medical Image Data Clustering." In *Mixture Models and Applications*, pp. 235-269. Springer, Cham, 2020. (**Accepted**)

Abstract

Data mining is an extensive area of research involving pattern discovery and feature extraction which is applied in various critical domains. In clinical aspect, data mining has emerged to assist

the clinicians in early detection, diagnosis, and prevention of diseases. Advances in computational methods have led to implementation of machine learning in multi-modal clinical image analysis. One recent method is online learning where data become available in a sequential order, thus sequentially updating the best predictor for the future data at each step, as opposed to batch learning techniques, which generate the best predictor by learning the entire data set at once. In this chapter, we have examined and analysed multi-modal medical images by developing an unsupervised machine-learning algorithm based on online variational inference for finite inverted Dirichlet mixture model. Our prime focus was to validate the developed approach on medical images. We do so by implementing the algorithm on both synthetic and real data sets. We test the algorithm's ability to detect challenging real world diseases, namely brain tumour, lung tuberculosis, and melanomic skin lesion.

4. **Osadebey, M**., Pedersen, M., & Waaler, D. (2020). Evaluation of Color Spaces for Unsupervised and Deep Learning Skin Lesion Segmentation. Accepted for Publication in the 14th International Conference on Computer Graphics, Visualization, Computer Vision and Image Processing 2020 (CGVCVIP 2020), 21 -25 July 2020, Zagreb, Croatia. (**Accepted**)

Abstract

The reliability of skin cancer diagnosis is dependent on accurate lesion segmentation. The choice of a color space in most contributions on skin lesion segmentation for melanoma detection are based on qualitative rather than quantitative approaches. User experience and theoretical properties of the color space are the two major factors influencing the choice of the color space. For this reason, it may be difficult to optimize segmentation accuracy. This paper evaluates the discrimination power of 5 color spaces and 16 color channels for two unsupervised approaches and a deep learning approach on the segmentation of skin lesion in dermatoscopy images. 600 dermatoscopy images with different levels of cluttering and occluding objects from two different databases were utilized. This study suggests that no single color space or color channel is most suitable in real-world scenarios. Therefore, this study can be regarded as a general framework to select a single or combination of color channels that will enhance the segmentation accuracy of images with different level of scene complexities and illumination variations.

5. **Osadebey, M**., Pedersen, M., & Waaler, D. (2020). Learning-based Segmentation of Optic Disc in Retinal Images using Clustering Trees and Local Mode Filtering. Accepted for Publication in the 14th International Conference on Computer Graphics, Visualization, Computer Vision and Image Processing 2020 (CGVCVIP 2020), 21 -25 July 2020, Zagreb, Croatia. (**Accepted**)

Abstract

Delineation of the optic disc boundary in retinal images is the first step towards the computation of cup-to-disc ratio, an important indicator of ophthalmic pathologies such as glaucoma. This paper proposes the combination of learning-based clustering trees with local mode filtering for the segmentation of the optic disc region in retinal images. The algorithm identifies candidate optic disc region by extracting and pooling low-level features at different clustering resolutions from the filtered region-of-interest in two color channels. Thereafter, we use learned geometric properties such as area, eccentricity and solidity to extract high-level features for the identification of connected components, which most likely belong to the optic disc region. The final stage pools and fully connects these connected components into a single segmented region. Performance evaluation on three publicly available datasets from IDRID, DRISHTI-GS and MESSIDOR demonstrate promising results that are comparable to state-of-the-art algorithms.

6. **Osadebey, M**., Pedersen, M., & Waaler, D. (2020). Simultaneous Artefact-Lesion Extraction for Skin Cancer Diagnosis. Accepted for Publication in the 3rd International Conference on Intelligent Technologies and Applications (INTAP 2020), 28-30 September 2020, Gjøvik, Norway. (**Accepted**)

Abstract

Presence of clutters, occlusions and dark corner artifacts in dermatoscopy images causes unsupervised and intensity-based image analysis systems to erroneously segment lesion boundaries required for accurate and reliable skin cancer diagnosis. Preprocessing algorithms designed to address these challenges increase resources, computational cost and introduce extraneous features, thereby reducing the efficacy of the diagnostic system. We propose a new approach to

accurately segment skin lesions without the need for preprocessing steps to eliminate these confounding factors. The proposed method begins by thresholding with a correction factor in a color channel image with optimal discrimination between the target object and background. Next, the output of the preliminary segmentation undergoes angular displacement. Finally, we iterate, a number of times, the set difference between the binarized image and its rotated version, to simultaneously detect lesion borders and eliminate occlusions and clutters. The proposed method outperform selected state-of-the-art segmentation algorithms on 600 images with different types of confounding factors.

7. **Osadebey. M**., Pedersen, M., and Waaler, D., CT-based Detection and Segmentation of Axillary Lymph Nodes in Breast Cancer Patients, **Technical Report** submitted in November 2019, to the Division of Radiology and Nuclear Medicine, Oslo University Hospital (OUH), Oslo, Norway. (**Accepted**)
8. **Osadebey, M**., Pedersen, M., Kalra, M., Waaler, D., and Bouguila, N.,Enhancement of Clustering Techniques by Coupling Clustering Tree and Neural Network: Application to Brain Tumor Segmentation, submitted in Nov. 2019 to Expert Systems Journal.(**Pending**)
9. **Osadebey, M**., Pedersen, M., Handerson, HK., Waaler, D., and Martinsen, ACT.Three-Stage Segmentation of Lung Region from CT images using Deep Learning, submitted to supervisor in Nov. 2020. (**Pending**)
10. **Osadebey, M.,** Pedersen, M., Arnold, D., & Wendel-Mitoraj, K. Variogram Analysis of Scale-Space Contrast in Image Difference Metric for No-Reference MRI quality Assessment, submitted in October 2019 to EURASIP Journal of Video and Image Processing. *(***Pending***)*

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1. **Training Course**: Analysis of Functional NeuroImages (AFNI) BootCamp organized by the National Institute of Health (NIH), Bethesda, Maryland, USA.
   Introduction to the use of AFNI for analysis of functional MRI (FMRI) data and Diffusion Tensor image (DTI) acquisition & processing using TORTOISE and FATCAT software. November 3 – 8, 2019.
2. **Summer School:** Nordic Probabilistic Artificial Intelligence (AI) Summer School organized by the Norwegian Open AI Lab and Norwegian University of Science and Technology (NTNU) June 3 – 7, 2019 Trondheim, Norway.
3. **Conference:** The *17th IEEE* International *Conference on Industrial Informatics* (*IEE-INDIN 2019*) during July 22-25, 2019 in Helsinki, Finland.
4. **Conference:** The 14th International Conference on Computer Graphics, Visualization, Computer Vision and Image Processing 2020 (CGVCVIP 2020), 21 -25 July 2020, Zagreb, Croatia.
5. **Conference:** The 3rd International Conference on Intelligent Technologies and Applications (INTAP 2020), 28-30 September 2020, Gjøvik, Norway.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

One-week research exchange visit (May 13 – May 17) under the ERCIM program to the Computational Imaging Group, National Research Institute for Mathematics and Computer Science (**CWI**), Amsterdam, Netherlands.

During the research visit, the scientific discussion focused on the application of deep learning to dynamic MRI image enhancement.