論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Hyperspectral Imaging and Analysis for the Diagnosis of Pigmented Skin Lesions during Gross Pathology
著者(和文)	アルポヤニ エレニ
Author(English)	Eleni Aloupogianni
出典(和文)	学位:博士(学術), 学位授与機関:東京工業大学, 報告番号:甲第12260号, 授与年月日:2022年9月22日, 学位の種別:課程博士, 審査員:小尾 高史,山口 雅浩,金子 寛彦,吉村 奈津江,八木 透
Citation(English)	Degree:Doctor (Academic), Conferring organization: Tokyo Institute of Technology, Report number:甲第12260号, Conferred date:2022/9/22, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	情報通信 系 ライフエンジニアリング コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of (Philosophy)
学生氏名： Student's Name	ALOUPOGIANNI ELENI	指導教員（主）： Academic Supervisor(main)	OBI TAKASHI
		指導教員（副）： Academic Supervisor(sub)	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The dissertation entitled "Hyperspectral Imaging and Analysis for the Diagnosis of Pigmented Skin Lesions during Gross Pathology" consists of 8 chapters.

Chapter 1 "Introduction" presents the background, rationale, and goal of the present work. The process and obstacles of gross pathology, the characteristics of skin tissue and the potential of Hyperspectral Imaging (HSI) in diagnosis are presented. The problem statement, research questions, significance and originality are described. This work aims to investigate the particularities for the diagnosis of Pigmented Skin Lesions (PSL) during gross pathology and to propose a framework for tumor margin detection. The goal is to determine the appropriateness of HSI data, tissue condition, preprocessing schemes, and segmentation models for the task of tumor segmentation.

Chapter 2 "Literature Review" investigates in detail previous applications of HSI on skin tissue analysis under the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. Trends in the design of acquisition systems, preprocessing and decision-making are identified. The current research gaps are presented.

Chapter 3 "Materials" introduces the data acquisition systems, a Multispectral Imaging (MSI) and a HSI system, and two respective original datasets of ex-vivo PSL, including the data collection and labeling protocols. The information captured by each acquisition system and examples of data samples are explained. A custom HSI acquisition system with high spectral resolution and wide field of view was designed and calibrated. Evaluation metrics related to further experimentation are presented.

Chapter 4 "Effectiveness of Hyperspectral Imaging for Tumor Classification" investigates the effectiveness of HSI data against RGB data. HSI signatures were reconstructed from both MSI and RGB data. The classification of signatures as tumor or not was validated and evaluated using machine learning. A framework for visualization of the results was proposed. Reflectance and texture features from HSI were superior to RGB for classification as either tumor or non-neoplastic growth.

Chapter 5 "Influence of Formalin-Fixing on Chromophore Concentrations" investigates the two available types of tissue during gross pathology, namely untreated and formalin-fixed tissue. When anti-infective protocols are in place, i.e., during a pandemic, only formalin-fixed samples are accessible. Optical properties of tissue depend on the concentrations of skin chromophores. Maps of relative concentrations of melanin and hemoglobin were generated from HSI image pairs of tissue, before and after formalin-fixing. Melanin content is mostly retained after formalin-fixing, but hemoglobin content is altered. While formalin-fixed tissue might be sufficient for analysis of melanocytic lesions, untreated tissue should be used for HSI analysis of PSL.

Chapter 6 "Effect of Dimension Reduction on Tumor Margin Detection" investigates the influence of dimension reduction on tumor segmentation. HSI spectral signatures are hundred-point long vectors, which introduces redundances and affects complexity. No guidelines are available for dimension reduction of HSI from gross skin tissue. Eleven dimension reduction methods were used to compress spectral signatures and train a classifier. A new method based on clustering and spectral similarity was proposed. The method, training scope and number of retained dimensions affected segmentation performance. Common methods like Principal Component Analysis do not necessarily perform well. The appropriateness of dimension reduction should be confirmed with the target data before further experimentation.

Chapter 7 "Implementation and Feasibility of HSI-based Tumor Margin Detection" investigates the feasibility of non-invasive tumor segmentation for PSL during gross pathology. Segmentation is a new field for HSI analysis in medicine. Two frameworks were proposed, one for pixel-wise analysis and one for patch-based analysis. Both machine learning and deep learning models were investigated as core components of the frameworks. These models were based on abundance maps, clustering, Support Vector Machines and three-dimensional convolutional networks. The pixel-wise framework showed the best performance in terms of Jaccard coefficient but suffered from false positives on tissue edges and cannot be easily scaled for a larger dataset. A custom model based on Xception architecture and 3D convolution performed similar to state-of-the-art classification models. It managed to detect curvy tumor segments, while it has potential for improvement by adjusting the structure depth and kernel for spectral convolution. The patch-based framework managed to segment dense tumor masks, which indicates that the inclusion of both spatial and spectral information is beneficial.

Chapter 8 "Conclusions" culminates this work by summarizing the findings of the study, highlighting the limitations, and providing directions for future research. A custom HSI system and a framework for tumor margin detection of PSL during gross pathology was proposed and achieved promising results. Insights about system- and model-building provide valuable knowledge about the handling of HSI data for computer assisted diagnosis in gross pathology of PSL. The frameworks proposed in this work can be optimized to digitize and automate gross pathology, or even be extended for the early diagnosis of in-situ skin cancers. The focus of system evaluation should shift towards the explainability and robustness of the decision-making process, to use HSI for tumor margin detection in the clinical practice.