Decision support system for small vessel disease diagnosis, leveraging the synergy of machine learning and radiomics

Small Vessel Disease (SVD) is a complex condition involving pathological changes in the small vessels of the brain, increasing the risk of stroke and dementia with age. Its early detection is crucial for effective treatment and prevention. Currently, SVD is often diagnosed incidentally during examinations with a different purpose. Radiologists rely on neuroimaging to evaluate the lesions resulting from small vessel damage, as the vessels themselves are too small to be visible on CT or MRI scans. However, the lack of structured guidelines for reporting imaging findings has hindered effective communication and evaluation of disease progression. To address this, in 2013 the Standards for Reporting Vascular Changes on Neuroimaging (STRIVE) were established, providing a common framework for reporting SVD-related changes on neuroimaging.

Neuroimaging, particularly MRI, is the gold standard for diagnosing SVD. MRI scans can visualize a range of white matter lesions, including small subcortical infarcts, lacunes, white matter hyperintensities, perivascular spaces, and microbleeds. Interpreting diverse imaging findings can be challenging for human observers, impacting accurate disease monitoring and severity assessment. Nowadays, automated solutions utilizing machine learning algorithms hold promise in providing expert support, expediting diagnosis, and facilitating appropriate treatment decisions.

Due to the complexity of the analyzed disease, developing an automated tool for SVD diagnosis is challenging.. The system must prioritize reliability, trustworthiness, user experience, and practicality. SVD encompasses six distinct lesions: white matter hyperintensities, cerebral microbleeds, lacunes, perivascular spaces, recent small subcortical infarcts, and brain atrophy. Each lesion differs in visual features, timing of occurrence, and MRI visibility. Diagnostic systems must integrate multiple machine learning algorithms, addressing various technical tasks such as detection and segmentation, while considering different MRI sequences, pre-processing, and post-processing methods. Alongside the necessary high performance of the system, it must also be trustworthy and understandable to medical specialists. These properties can be guaranteed by supplementing deep learning methods with features that are known to medical scientists and calculated using a rapidly developing field called radiomics.

The main research objective of SVDiagnose is to propose a decision support system, offering a synergy of powerful deep learning methods and radiomics. Supporting hypotheses include analyzing the ability of radiomics to identify SVD-specific features, the enhanced performance of the system when incorporating radiomics, and the higher reliability provided by a fuzzy-reasoning system based on machine learning and radiomics compared to the machine learning algorithm alone.

The research tasks involve exploring state-of-the-art machine learning-based methods for small object detection in brain lesions caused by SVD, investigating the applicability of radiomics for analyzing these lesions, and researching the synergy of fuzzy-reasoning and multimodal learning for SVD diagnosis. The detection system will focus on three lesions: cerebral microbleeds, white matter hyperintensities, and lacunes. The proposed system will utilize advanced ML algorithms for detection and segmentation. Radiomic features will be extracted from MRI images to identify those indicative of SVD, and the synergistic performance of the decision-support system incorporating radiomics will be evaluated against the baseline ML-based systems.

In conclusion, the proposed research aims to develop an advanced decision-support system for SVD diagnosis, leveraging machine learning algorithms and radiomics. The research tasks will explore small object detection, radiomics analysis, and fuzzy-reasoning approaches to improve system performance, reliability, and usability. By addressing the complex nature of SVD, the research seeks to contribute to more accurate and effective diagnosis of this important cerebrovascular condition.

Additionally, the consultations with radiologists will be conducted for the whole project duration, which makes it more likely to be used in medical practice.