Abstract

Biomedical imaging, including MRI, CT, X-rays, ultrasound, and microscopy, is vital for diagnosing and treating medical conditions. Advances in imaging and computational technology have greatly increased data volume, creating challenges in data analysis and management. Traditional methods are slow and require specialists, leading to delays, and with rising demand, efficient solutions are needed. Deep Learning (DL), using techniques like Convolutional Neural Networks (CNNs) and Vision Transformers (ViT), offers a way to automate and speed up image analysis, achieving human-level accuracy in detecting and diagnosing abnormalities.

This doctoral dissertation examines the adaptation of Deep Learning to two areas of biomedical imaging, light and fluorescent microscopy. It showcases the potential of Deep Learning to enhance diagnostic accuracy, speed, and efficiency while reducing the cost. Additionally, this work emphasizes the importance of explainability in the presented methods, which is essential for providing accurate medical diagnoses and effectively communicating results to doctors and patients. Explanations play a key role in verifying the model's decisions and fostering trust between the system and the user.

In the context of light microscopy, this dissertation includes multi-MIL, a novel multi-label classification approach based on Multiple Instance Learning (MIL) to identify bacterial species in polyculture images. This method significantly shortens the time required for microbiological diagnosis by reducing the need of obtaining monoculture images. Additionally, we propose an innovative adaptation of DL techniques to distinguish between bacterial clones using only microscopic images, a task previously deemed impossible due to their high visual similarity.

In the realm of fluorescent microscopy, the dissertation presents a weakly-supervised method using Multiple Instance Learning with a Self-Supervised framework, SSMIL, to classify active and inactive microglia cells, crucial for understanding neuroinflammation. This approach reduces the need for manual cell labeling, making it more cost-effective and less labor-intensive. Moreover, the research addresses the challenge of developing a universal model for a fluorescent image representation, comparing various supervised and self-supervised learning techniques to identify the most effective strategies. The findings offer valuable insights for employing Deep Learning in analysis of cell morphology and the drug discovery process.

This dissertation is a result of the Industrial PhD program conducted in collaboration with Ardigen SA, where the PhD candidate is employed as Senior Data Scientist. This facilitated the transfer of research into the industry, evidenced by the development and presentation of services and products at five major industry events. As a result, the company expanded its offerings, grew its client base, and established collaborations with leading pharmaceutical companies Janssen R&D and Merck KGaA, as well as renowned research groups such as The Carpenter–Singh Lab, part of the Imaging Platform based at the Broad Institute of MIT and Harvard. Additionally, the PhD candidate's research led to a patent application to the European Patent Office. Due to expertise gained during the PhD program, the PhD candidate was promoted to lead the development of Ardigen phenAID platform for phenotypic screening.

In conclusion, this doctoral dissertation focuses on analysis of light and fluorescent microscopy images with Deep Learning methods. It consists of four publications, two at A conferences according

to CORE ranking and two in reputable journals with impact factors 7.7 and 4.4. The PhD candidate is the first author of all aforementioned publications which highlights her substantial contributions. As this dissertation is a part of the Industrial PhD program, we highlight notable achievements in product development, transferring research to industry, and establishment of business relationships.

Keywords: deep learning, light microscopy, fluorescent microscopy, self-supervision.