From pixels to patterns: AI-driven image analysis in multiple domains

Javanmardi, S.

English Summary

The objective of this thesis is to study the application of deep learning techniques in image analysis across various domains, focusing on four themes, i.e. feature extraction, classification, segmentation and integration. The research presented in this thesis explores diverse applications to augment technological capabilities in these fields, illustrating the wide-ranging applicability and transformative potential of deep learning models.

The first theme of this thesis addresses the challenges of feature extraction and classification in agricultural biotechnology. We develop efficient deep Convolutional Neural Networks (CNNs) as feature extractors to automate the classification process, which traditionally relies on basic computer vision techniques and additional post-processing. Our pipeline, including feature extraction followed by machine-learning-based classification, significantly improves the accuracy and efficiency of corn seed classification, showcasing the ability of the model to capture detailed and nuanced features critical for discriminating between varieties with a high similarity.

As the second theme, we employ deep learning approaches for classifying the ripeness stages of mulberries from images using advanced Convolutional Neural Networks. This approach streamlines the sorting process. Moreover, it enhances the accuracy of ripeness classification and improves post-harvest processing. And as such potentially increases the economic value of the harvests and removes the necessity for specialist assessment.

As third theme we explore the application of CNNs in segmentation of microscope images, and in particular focus on the assessment of zebrafish larvae images in a high-throughput setting. We demonstrate that CNNs can effectively differentiate these larvae in the images with high accuracy and speed. This is crucial for supporting high-throughput screening (HTS) as well as facilitating 3D reconstruction processes that further enhance understanding in biological research.

The fourth and final theme of the thesis concerns the integration of deep learning from images with Natural Language Processing (NLP) to describe the content of images and thus improve the techniques for image captioning. We design this combination of visual data processing and language processing to generate more accurate, context-aware descriptions of images. The pipeline we develop is beneficial and applicable in fields ranging from biomedical imaging and biotechnology to digital media and surveillance.

Throughout all the themes addressed in this thesis, we employed state-of-the-art deep learning models to tackle distinct, challenging problems, showing substantial improvements over existing methods. The findings set new benchmarks in the respective domains and pave the way for future research, potentially extending these techniques to other complex image processing tasks.

Our research confirms the efficacy of deep learning in enhancing image analysis, classification, and processing across various applications, thereby revolutionizing industries such as agriculture, biotechnology, and healthcare. Future endeavors inspired by our findings have the potential to expand the integration of artificial intelligence into diverse scientific and industrial domains, fostering innovation and positively impacting societal well-being while progressively pushing technological advancement.