Revolutionizing iPSC Research: AI-Powered Insights from Multicentred Microscopy Imaging

Supervisor(s):

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Project description:

Aims:
The primary objective is to create and implement foundational model-based algorithms for the segmentation and automatic analysis of iPSC morphology, specifically in the context of POLG-related mitochondrial disorders. Incorporating 'foundation models', such as SegmentAnything, into this research project is a crucial strategy.
Motivation:
The integration of these foundation models will notably reduce the necessity for extensive human labelling traditionally required for ground truth establishment in conventional deep learning algorithms. Foundation models also bring the advantage of being pre-trained on diverse, large datasets, which allows a general model applicable to all diverse microscopy modalities and staining.
Method:
1. Preprocessing of iPSC Images: Standardizing iPSC images to ensure uniformity across different protocols. The data in this project is provided with our collaborators from Bergen, including iPSCs from patients with mitochondrial disorders, both pre- and post-drug screening.
2. Implementation and Fine-Tuning of Foundation Models: Deploying and refining large-scale foundational models for the segmentation and analysis of iPSC images and adapting these models to fit into existing iPSC research workflows.
3. Method Comparison: The proposed method will be benchmarked against other state-of-the-art methods to confirm its superior performance. Metrics such as Dice coefficient, Jaccard index, and Intersection over Union (IoU) will be evaluated for this purpose.
4. Method Validation: This step involves the interpretation and quantification of complex morphological patterns in iPSCs, specifically those linked to mitochondrial diseases. The quantification results can contribute to further disease phenotyping and treatment planning.

Timeline (tentative):

2024.10.31: 1-page plan
2024.11.30: Data curation, literature review
2024.12.31: Fine-tuning and post-processing of the baseline segmentation model
2025.03.31: Development of the automated system for iPSC morphology analysis
2025.06.30: Assessment of the morphology analysis system in relation to disease progression and treatment efficacy metrics; poster presentation
2025.08.31: Final thesis

Minimum viable thesis:

A "minimum viable thesis" could consist of implementing a modified version of an existing foundational model for iPSC image segmentation, followed by a systematic empirical comparison with standard models. The focus would be on demonstrating improved accuracy in identifying mitochondrial disease-related morphological changes.

Required background & skills:

Students should possess a strong background in mathematics and programming, particularly in Python (PyTorch). Familiarity with machine learning, especially deep learning techniques like CNNs, and a basic understanding of cellular biology or microscopy imaging would be highly beneficial for this project.

Representative References:

[1] Xing, Xiaodan, et al. "SegmentAnything helps microscopy images based automatic and quantitative organoid detection and analysis." arXiv preprint arXiv:2309.04190 (2023).
[2] Feng, Huibao, et al. "Deep-learning–assisted Sort-Seq enables high-throughput profiling of gene expression characteristics with high precision." Science Advances 9.45 (2023): eadg5296.