Segmentation and Tracking of Organoids in Brightfield Microscopy Image Data

Lucia Hradecká Dupkaníčová | Advisor: Martin Maška
Faculty of Informatics, Masaryk University, Brno, Czech Republic

MOTIVATION
- Organoids are in vitro cultures that mimic living tissues and their dynamics, allowing studies of physiological processes in a controlled environment under various conditions. They are observed using optical microscopy that produces high-resolution time-lapse sequences. Their automated processing requires reliable and robust algorithms that are currently lacking in the field, thus having biologists to rely on manual processing of the acquired image data.
- Common challenges for automated processing of high-resolution organoid images include the presence of spurious objects, collisions, occlusions, and abrupt changes of the organoid location and texture due to manual interventions taken during long-term imaging.

AIMS OF THE THESIS
- To develop a reliable method for automated segmentation and tracking of organoids in high-resolution brightfield microscopy sequences
- To validate the performance of the method over a heterogeneous dataset of mammary epithelial organoids of five different phenotypes
- To deploy the method in an easy-to-use form

METHODOLOGY
- A family of deep-learning-based algorithms
  - Convolutional neural network (U-Net architecture)
  - Tuneable prediction binarisation
  - Adaptive morphological and component filtering
  - A novel segmentation correction procedure

RESULTS
- Algorithm development: real and computer-generated sequences of three distinct organoid phenotypes
  - Six semantic segmentation models (Real, Synth-X)
  - Five postprocessing routines (PP-X)
- Algorithm validation: real sequences of two additional organoid phenotypes with considerably different shape, size, and texture characteristics
- Performance criteria: single-organoid tracking accuracy (DET), segmentation accuracy (SEG), boundary localisation error (HD₉₅), and execution time (TIM)
- Recommended four reliable and robust algorithms
- An easy-to-use application with a practical guide
- One of the algorithms presented also in a manuscript that is under review for publication in a top-tier journal

CONTRIBUTION HIGHLIGHTS
- A group of well-performing and robust algorithms for segmentation and tracking of organoids was developed
- Their performance and robustness were validated using diverse image data with respect to different criteria
- Implementation of the developed methods is available for use in practise (https://is.muni.cz/th/hpuxk/)
- First co-authorship of a journal article presenting one of the recommended algorithms (https://cbia.fi.muni.cz/research/spatiotemporal/organoids.html)