An innovative platform for Reliable Deep Learning Management of Time-Lapse Videos in Lab-on-Chip Experiments

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One of the main challenges in bioimaging is ensuring that the features extracted for pattern recognition tasks are resistant to unpredictable changes that may occur during the image acquisition process. This issue becomes even more significant when dealing with deep learning features, as they lack of explainability. With the increasing use of organ-on-chip applications, a large amount of video data needs to be analyzed, leading to an urgent demand for machine learning architectures for data mining and information retrieval. However, reproducibility of experiments in lab-on-chip devices is still hindered by various factors, including cell heterogeneity and difficulties in maintaining controlled experimental settings. These challenges lead to alterations in acquired images, such as changes in brightness or texture, focus shifts, autofluorescence, and photobleaching, among others. In this talk, we introduce a software platform called Deep-Manager (DM), which efficiently selects features that are less sensitive to undesired disturbances while maintaining high discriminative power. We apply this platform to various biological investigations, specifically analyzing videos of tumor-on-chip experiments captured using phase contrast and fluorescence microscopy. The results, measured in terms of the accuracy in discriminating different experimental conditions (e.g., drug vs. control), demonstrate the platform's superiority in selecting deep features that are robust against image degradation effects. The proposed approach basically consists of extracting deep-learning-based features (via transfer learning) from a set of normal images and a set of artificially modified images, with the alteration mimicking some real-world artifact (e.g., out-of-focus, brightness alteration, autofluorescence, photobleaching). The Discriminative Power (DP) and Sensitivity (SENS) to the alteration of each feature are then computed. Only features with high discriminative power and low sensitivity are selected. This grants a high generalizability of the predictive models built on those features. To showcase the effectiveness of our proposed Deep-Manager platform, we conducted two specific use cases. The first involved phase contrasts time-lapse microscopy videos of immune cells moving in a 3D collagen gel within microfluidic tumor-on-chip devices replicating the tumor microenvironment. The second use case concerned 3D fluorescence microscopy tumor-on-chip videos of cancer cells undergoing apoptosis due to the cytotoxic T cells effect. To evaluate the performance of our feature selection approach, we compared it with state-of-the-art methods. The results demonstrated significant improvements in the DP (Discriminative Power) and sensitivity values, ranging from 6% to 10% and 56% to 69%, respectively also reducing the initial feature set.