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Cell Tracking Using Deep Neural Networks with Multi-task Learning☆

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Abstract

Cell tracking plays crucial role in biomedical and computer vision areas. As cells generally have frequent deformation activities and small sizes in microscope image, tracking the non-rigid and non-significant cells is quite difficult in practice. Traditional visual tracking methods have good performances on tracking rigid and significant visual objects, however, they are not suitable for cell tracking problem. In this paper, a novel cell tracking method is proposed by using Convolutional Neural Networks (CNNs) as well as Multi-Task Learning (MTL) techniques. The CNNs learn robust cell features and MTL improves the generalization performance of the tracking. The proposed cell tracking method consists of a particle filter motion model, a multi-task learning observation model, and an optimized model update strategy. In the training procedure, the cell tracking is divided into an online tracking task and an accompanying classification task using the MTL technique. The observation model is trained by building a CNN to learn robust cell features. The tracking procedure is started by assigning the cell position in the first frame of a microscope image sequence. Then, the particle filter model is applied to produce a set of candidate bounding boxes in the subsequent frames. The trained observation model provides the confidence probabilities corresponding to all of the candidates and selects the candidate with the highest probability as the final prediction. Finally, an optimized model update strategy is proposed to enable the multi-task observation model for the variation of the tracked cell over the entire tracking procedure. The performance and robustness of the proposed method is analyzed by comparing with other commonly-used methods. Experimental results demonstrate that the proposed method has good performance to the cell tracking problem.

Keywords: Cell Tracking, Deep Learning, Convolutional Neural Networks, Multi-task Learning

1. Introduction

Visual tracking is an important research topic in the field of computer vision [1, 2], which aims to track the trajectories of single or multiple objects and is widely applied in many practical visual tasks such as video surveillance, automatic driving systems, and biological living cell pedigree analysis. As a typical visual tracking application, cell tracking [3] aims at tracking cells directly from microscopic images. By the results of cell tracking, we can investigate cell behavior to further construct cell lineage and analyze cell morphology [4, 5]. Cell tracking methods, deployed on a large number of cells, are helpful to facilitate feasible conclusions about cell populations [6]. The inspection of living cells allows researchers to obtain the correlation between many diseases and abnormal cell behavior [7]. Thus, cell tracking with an automatic method is essential.

Challenges of cell tracking are summarized into four categories. The first challenge is cell deformation, e.g., elongation, expansion, and shrinkage [5]. Traditional visual tracking methods handle rigid bodies without significant shapes changes [8]. However, cells are non-rigid bodies and tracking them is more challenging because they always change shapes with time, which are explained in Fig. 1. The second category of challenges is about cell behavior. For instance, cell migration entails complex motion with multiple modes. The complicated cell behavior increases the difficulty of cell tracking. The third challenge comes from the living environment of the cell. There are many particles in the cytochylema, which contains dead cells, germs, and other organic material. Cell tracking methods must distinguish cells from other particles [9] mentioned above. The final challenge is that the cell images are captured at a low resolution and the cell is non-significant in the image because of its small size.

With the development of deep learning, feature learning methods [10] have been successfully applied to computer vision area [11]. In our work, Convolutional Neural Networks (CNNs) [8] are utilized to learn robust features of cells in the cell tracking because the robust cell features can benefit the tracking of the non-rigid and non-significant cells. CNNs are widely used to visual tasks [12]. In traditional image classifica-

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