Efficacy of PanopticNets for 3-Dimensional Segmentation of Confocal Microscopy Imaging Data

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Background: Live-cell imaging is a widely-used modality of data collection. However, in order to quantify and analyze live-cell imaging data, it must first be annotated. State-of-the-art algorithmic methods suffer from a lack of robustness, and manual annotation can be prohibitively time-consuming. These issues compound when considering 3-dimensional datasets, such as confocal microscopy image stacks. We developed and trained neural networks (PanopticNets) that can accurately and reliably predict volumetric segmentations of cellular nuclei.

Methods: A 2-dimensional model was trained on existing labels and used to make initial predictions on a larger unlabeled set of DAPI-stained mouse brain nuclear data. Predicted 2D segmentations were algorithmically matched along the z-axis based on intersection-over-union and manually corrected to produce a training dataset of approximately 1200 distinct nuclei. 3-dimensional PanopticNet models were trained using a patch-based method to predict inner-distance and outer-distance transforms. Overlapping tiled predictions on test images were composited using 3D spline interpolation. Segmentation masks were generated from composited predictions using a 3D watershed transform, using local maxima of inner-distance predictions as seeds and thresholded outer-distance predictions to define cell boundaries. A model was hosted in the cloud and a custom Redis consumer was developed to enable web-based predictions through the deepcell.org website.

Results: Models trained achieved a net pixel intersection-over-union of > 0.8 for segmentation, and > 95% precision and recall for nuclear identification, matching or outperforming state-of-the-art approaches on similar datasets. A sample test prediction is shown in Figure 1.

Conclusion: These models demonstrate the efficacy of PanopticNets for 3D nuclear segmentation, serving as an effective proof of concept, and supporting the future development of a varied dataset used to train a more robust model meant for wider use. Combined with our cloud-hosting and web interface, this will ultimately provide easy, rapid access to accurate 3-dimensional segmentations to researchers worldwide.

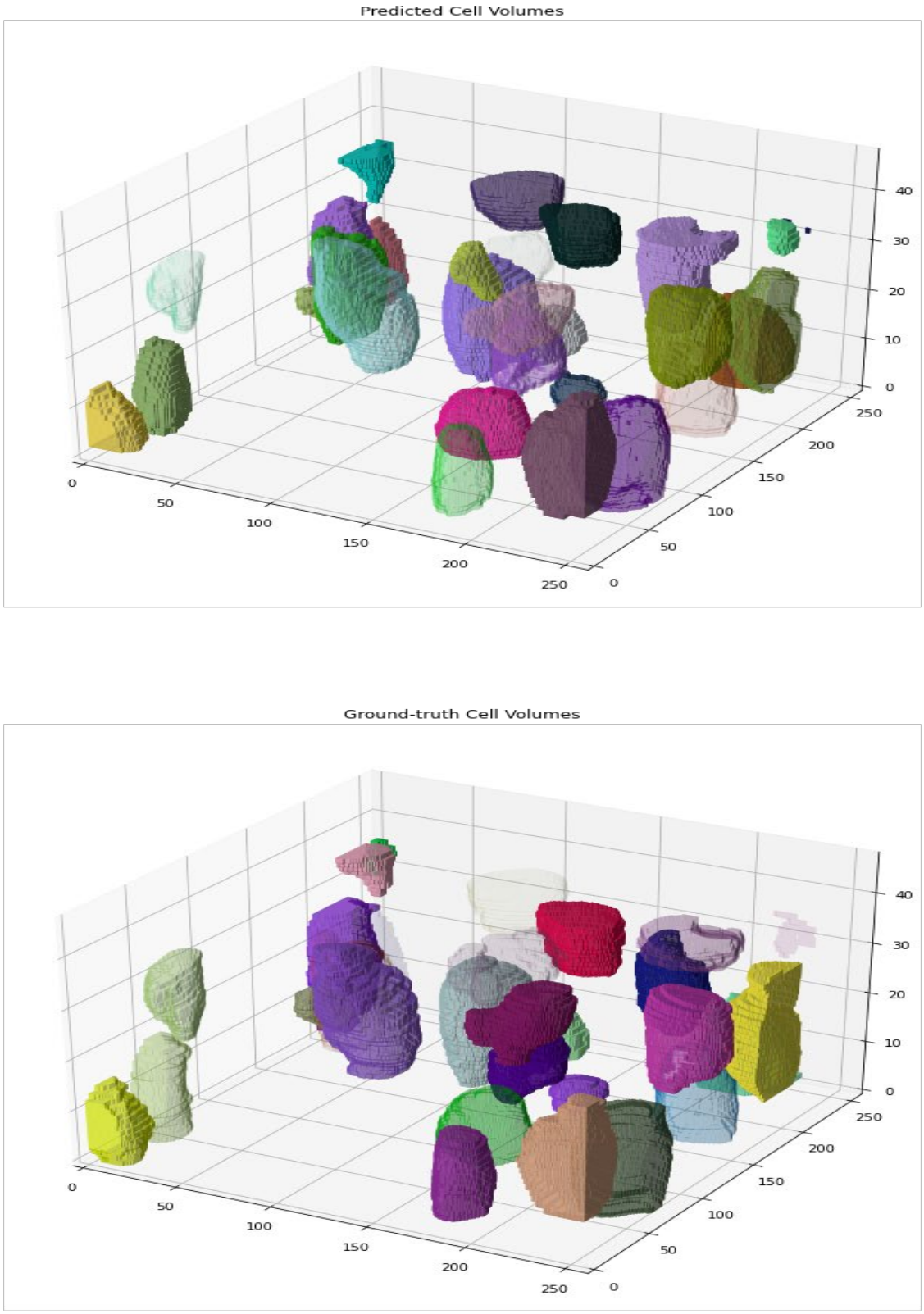
Predicted Cell Volumes
0
50
100
150
200
250
0
50
100
150
200
250
0
10
20
30
40
Ground-truth Cell Volumes
0
50
100
150
200
250
0
50
100
150
200
250
0
10
20
30
40

Figure 1.