Segmentation of Electron Microscopy Images for Connectomics

Brian Matejek Advisor: Hanspeter Pfister Harvard University

bmatejek@seas.harvard.edu

- 1. Introduction
- 2. Related Work
- 3. Preliminary Methods
- 4. Preliminary Results
- 5. Proposed Work
- 6. Conclusion

References

- [1] Haehn, D., Hoffer, J., Matejek, B., Suissa-Peleg, A., Al-Awami, A.K., Kamentsky, L., Gonda, F., Meng, E., Zhang, W., Schalek, R., et al.: Scalable interactive visualization for connectomics. In: Informatics. Volume 4., Multidisciplinary Digital Publishing Institute (2017) 29
- [2] Kasthuri, N., Hayworth, K.J., Berger, D.R., Schalek, R.L., Conchello, J.A., Knowles-Barley, S., Lee, D., Vázquez-Reina, A., Kaynig, V., Jones, T.R., et al.: Saturated reconstruction of a volume of neocortex. Cell 162(3) (2015) 648–661
- [3] Knowles-Barley, S., Kaynig, V., Jones, T.R., Wilson, A., Morgan, J., Lee, D., Berger, D., Kasthuri, N., Lichtman, J.W., Pfister, H.: Rhoananet pipeline: Dense automatic neural annotation. arXiv preprint arXiv:1611.06973 (2016)
- [4] Lee, K., Zlateski, A., Ashwin, V., Seung, H.S.: Recursive training of 2d-3d convolutional networks for neuronal boundary prediction. In: Advances in Neural Information Processing Systems. (2015) 3573–3581
- [5] Nunez-Iglesias, J., Kennedy, R., Parag, T., Shi, J., Chklovskii, D.B.: Machine learning of hierarchical clustering to segment 2d and 3d images. PloS one 8(8) (2013) e71715
- [6] Parag, T., Tschopp, F., Grisaitis, W., Turaga, S.C., Zhang, X., Matejek, B., Kamentsky, L., Lichtman, J.W., Pfister, H.: Anisotropic em segmentation by 3d affinity learning and agglomeration. arXiv preprint arXiv:1707.08935 (2017)
- [7] Ronneberger, O., Fischer, P., Brox, T.: U-net: Convolutional networks for biomedical image segmentation. In:

- International Conference on Medical image computing and computer-assisted intervention, Springer (2015) 234–241
- [8] Zlateski, A., Seung, H.S.: Image segmentation by sizedependent single linkage clustering of a watershed basin graph. arXiv preprint arXiv:1505.00249 (2015)
- [9] Lee, K., Zung, J., Li, P., Jain, V., Seung, H.S.: Superhuman accuracy on the snemi3d connectomics challenge. arXiv preprint arXiv:1706.00120 (2017)
- [10] Parag, T.: What properties are desirable from an electron microscopy segmentation algorithm. arXiv preprint arXiv:1503.05430 (2015)
- [11] Briggman, K.L., Bock, D.D.: Volume electron microscopy for neuronal circuit reconstruction. Current opinion in neurobiology 22(1) (2012) 154–161
- [12] Kaynig, V., Vazquez-Reina, A., Knowles-Barley, S., Roberts, M., Jones, T.R., Kasthuri, N., Miller, E., Lichtman, J., Pfister, H.: Large-scale automatic reconstruction of neuronal processes from electron microscopy images. Medical image analysis 22(1) (2015) 77–88
- [13] Bogovic, J.A., Huang, G.B., Jain, V.: Learned versus handdesigned feature representations for 3d agglomeration. arXiv preprint arXiv:1312.6159 (2013)
- [14] Ciresan, D., Giusti, A., Gambardella, L.M., Schmidhuber, J.: Deep neural networks segment neuronal membranes in electron microscopy images. In: Advances in neural information processing systems. (2012) 2843–2851
- [15] Jain, V., Bollmann, B., Richardson, M., Berger, D., Helmstädter, M., Briggman, K., Denk, W., Bowden, J., Mendenhall, J., Abraham, W., Harris, K., Kasthuri, N., Hayworth, K., Schalek, R., Tapia, J., Lichtman, J., Seung, S.: Boundary learning by optimization with topological constraints. In: Proc. IEEE CVPR 2010. (2010) 2488–2495
- [16] Vázquez-Reina, A., Gelbart, M., Huang, D., Lichtman, J., Miller, E., Pfister, H.: Segmentation fusion for connectomics. In: Proc. IEEE ICCV. (Nov 2011) 177–184
- [17] Çiçek, Ö., Abdulkadir, A., Lienkamp, S.S., Brox, T., Ronneberger, O.: 3d u-net: learning dense volumetric segmentation from sparse annotation. In: International Conference on Medical Image Computing and Computer-Assisted Intervention, Springer (2016) 424–432

- [18] Turaga, S.C., Murray, J.F., Jain, V., Roth, F., Helmstaedter, M., Briggman, K., Denk, W., Seung, H.S.: Convolutional networks can learn to generate affinity graphs for image segmentation. Neural computation 22(2) (2010) 511–538
- [19] Briggman, K., Denk, W., Seung, S., Helmstaedter, M.N., Turaga, S.C.: Maximin affinity learning of image segmentation. In: Advances in Neural Information Processing Systems. (2009) 1865–1873
- [20] Januszewski, M., Maitin-Shepard, J., Li, P., Kornfeld, J., Denk, W., Jain, V.: Flood-filling networks. arXiv preprint arXiv:1611.00421 (2016)
- [21] Zeng, T., Wu, B., Ji, S.: Deepem3d: approaching humanlevel performance on 3d anisotropic em image segmentation. Bioinformatics 33(16) (2017) 2555–2562
- [22] Andres, B., Kroeger, T., Briggman, K.L., Denk, W., Korogod, N., Knott, G., Koethe, U., Hamprecht, F.A.: Globally optimal closed-surface segmentation for connectomics. In: European Conference on Computer Vision, Springer (2012) 778–791
- [23] Funke, J., Tschopp, F.D., Grisaitis, W., Singh, C., Saalfeld, S., Turaga, S.C.: A deep structured learning approach towards automating connectome reconstruction from 3d electron micrographs. arXiv preprint arXiv:1709.02974 (2017)
- [24] Parag, T., Chakraborty, A., Plaza, S., Scheffer, L.: A context-aware delayed agglomeration framework for electron microscopy segmentation. PLOS ONE 10(5) (05 2015) 1–19
- [25] Jain, V., Turaga, S.C., Briggman, K., Helmstaedter, M.N., Denk, W., Seung, H.S.: Learning to agglomerate superpixel hierarchies. In: Advances in Neural Information Processing Systems. (2011) 648–656
- [26] Beier, T., Pape, C., Rahaman, N., Prange, T., Berg, S., Bock, D.D., Cardona, A., Knott, G.W., Plaza, S.M., Scheffer, L.K., et al.: Multicut brings automated neurite segmentation closer to human performance. Nature methods 14(2) (2017) 101
- [27] Haehn, D., Knowles-Barley, S., Roberts, M., Beyer, J., Kasthuri, N., Lichtman, J.W., Pfister, H.: Design and evaluation of interactive proofreading tools for connectomics. IEEE Transactions on Visualization and Computer Graphics 20(12) (2014) 2466–2475
- [28] Haehn, D., Kaynig, V., Tompkin, J., Lichtman, J.W., Pfister, H.: Guided proofreading of automatic segmentations for connectomics. arXiv preprint arXiv:1704.00848 (2017)
- [29] Knowles-Barley, S., Roberts, M., Kasthuri, N., Lee, D., Pfister, H., Lichtman, J.W.: Mojo 2.0: Connectome annotation tool. Frontiers in Neuroinformatics (60) (2013)
- [30] Rolnick, D., Meirovitch, Y., Parag, T., Pfister, H., Jain, V., Lichtman, J.W., Boyden, E.S., Shavit, N.: Morphological error detection in 3d segmentations. arXiv preprint arXiv:1705.10882 (2017)
- [31] Zung, J., Tartavull, I., Seung, H.S.: An error detection and correction framework for connectomics. CoRR abs/1708.02599 (2017)

- [32] Sato, M., Bitter, I., Bender, M.A., Kaufman, A.E., Nakajima, M.: Teasar: Tree-structure extraction algorithm for accurate and robust skeletons. In: Computer Graphics and Applications, 2000. Proceedings. The Eighth Pacific Conference on, IEEE (2000) 281–449
- [33] Zhao, T., Plaza, S.M.: Automatic neuron type identification by neurite localization in the drosophila medulla. arXiv preprint arXiv:1409.1892 (2014)
- [34] Chatfield, K., Simonyan, K., Vedaldi, A., Zisserman, A.: Return of the devil in the details: Delving deep into convolutional nets. arXiv preprint arXiv:1405.3531 (2014)
- [35] Keuper, M., Levinkov, E., Bonneel, N., Lavoué, G., Brox, T., Andres, B.: Efficient decomposition of image and mesh graphs by lifted multicuts. In: Proceedings of the IEEE International Conference on Computer Vision. (2015) 1751– 1759
- [36] Andres, B., Kappes, J.H., Beier, T., Köthe, U., Hamprecht, F.A.: Probabilistic image segmentation with closedness constraints. In: Computer Vision (ICCV), 2011 IEEE International Conference on, IEEE (2011) 2611–2618
- [37] Takemura, S.y., Aso, Y., Hige, T., Wong, A.M., Lu, Z., Xu, C.S., Rivlin, P.K., Hess, H.F., Zhao, T., Parag, T., Berg, S., Huang, G., Katz, W.T., Olbris, D.J., Plaza, S.M., Umayam, L.A., Aniceto, R., Chang, L.A., Lauchie, S., et al: A connectome of a learning and memory center in the adult drosophila brain. eLife 6 (2017 Jul 18 2017) e26975
- [38] Turaga, S., Briggman, K., Helmstaedter, M., Denk, W., Seung, S.: Maximin affinity learning of image segmentation. In: Advances in Neural Information Processing Systems 22. (2009)
- [39] Glorot, X., Bengio, Y.: Understanding the difficulty of training deep feedforward neural networks. In: Proceedings of the Thirteenth International Conference on Artificial Intelligence and Statistics. (2010) 249–256
- [40] Meila, M.: Comparing clusterings by the variation of information. In: Colt. Volume 3., Springer (2003) 173–187