OrNet - a Python Toolkit to Model the Diffuse Structure of Organelles as Social Networks

Mojtaba Fazli1,*, Marcus Hill1,*, Andrew Durden1, Rachel Mattson2, Allyson T. Loy3, Barbara Reaves4, Abigail Courtney3, Frederick D. Quinn4, Chakra Chennubhotla5, and Shannon Quinn1,6

1 Department of Computer Science, University of Georgia, Athens, GA 30602 USA
2 Institute for Artificial Intelligence, University of Georgia, Athens, GA 30602 USA
3 Department of Microbiology, University of Georgia, Athens, GA 30602 USA
4 Department of Infectious Diseases, University of Georgia, Athens, GA 30602 USA
5 Department of Computational and Systems Biology, University of Pittsburgh, Pittsburgh, PA 15232 USA
6 Department of Cellular Biology, University of Georgia, Athens, GA 30602 USA

* The two first authors made equal contributions.

DOI: 10.21105/joss.01983

Software
- Review
- Repository
- Archive

Summary

Fluorescent microscopy videos are vital for analyzing the morphological changes that subcellular protein structures undergo after exposure to external stimuli. Changes in organelle structures offer crucial insight into the manner in which cells respond to viral or bacterial infections, cellular invaders, or even the organelles themselves malfunctioning (Stavru & Cossart, 2011). Generally, modeling organellar structures involve manually inspecting each video then denoting time points and regions that demonstrate anomalous behavior. However, manual analyses lack objective metrics to assess morphological changes, and thus hinder the ability to perform secondary analyses and quantitative comparisons. Thus, arises the need to find a methodology that generates quantitative models capable of accurately describing the data (Eliceiri KW, 2012). Prior works have demonstrated success in the generation of static models for subcellular modeling (Chen et al., 2018; Murphy, 2015; Ruan et al., 2019). Such advancements have inspired us to propose a novel framework, OrNet, that models both the spatial and temporal morphology changes that organelles undergo as dynamic social networks.

OrNet is an open-source python package (Rossum, 1995) that is built-upon the libraries of Scikit-Learn (Pedregosa et al., 2011), NumPy (Oliphant, n.d.), SciPy (Virtanen et al., 2019), and Matplotlib (Hunter, 2007). Our tool accepts as input microscopy videos of cells with fluorescently tagged organelles, and outputs quantitative descriptions of the morphological changes. Modeling these dynamic structures is no trivial task because many organelles are amorphous, and the lack of rigidity renders traditional shape-based, parametric modeling techniques ineffective. Our framework addresses such difficulties by modeling organelles as social networks to capture the spatio-temporal relationships via a dynamic edge management process. The graphs are constructed by fitting gaussian mixture models to every frame of an input video; the final means become the vertices, while a divergence metric is applied to every combination pair of mixture components to create the edges. Once graphs are created for each frame, spectral decomposition is utilized to track the leading eigenvalues to understand the time-points and frame regions where organellar structures are demonstrating significant changes.

The viability of OrNet has been illustrated by (Durden, 2019) when the framework was utilized to model mitochondria found in HeLa cells that were exposed to various stimuli. We hope that our tool will be utilized by any project seeking to model subcellular organelles.
Acknowledgements

The project that yielded this software was supported in part by a grant from the National Science Foundation (#1458766).

We gratefully acknowledge the support of NVIDIA Corporation with the donation of the Titan X Pascal GPU used for this research.

References


Durden, T Loy, Reaves, Fazli, Courtney, D Quinn, Chenubhotla, S. Chakra, et al. (2018). Dynamic Social Network Modeling of Diffuse Subcellular Morphologies. In Fatih Akici, David Lippa, Dillon Niederhut, & M. Pacer (Eds.), Proceedings of the 17th Python in Science Conference (pp. 1–7). doi:10.25080/Majora-4af1f417-000


