Online CryoEM Study Group

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Contents

1 Dates and Topics

Meetings are generally on Thursdays (morning Pacific time, afternoon Eastern time, evening Europe)

Date	Time	Topic
Th 20 Jan 2022	8:30 AM PST	advanced rotations
Th 27 Jan 2022	8:30 AM PST	Guest: Qinwen (Wendy) Huang
Th 3 Feb 2022	8:30 AM PST	mathy cryoem paper
Th 10 Feb 2022	8:30 AM PST	advanced rotations
Th 17 Feb 2022	8:30 AM PST	mathy cryoem paper
Th 24 Feb 2022	8:30 AM PST	advanced rotations
Th 3 Mar 2022	8:30 AM PST	mathy cryoem paper
Th 10 Mar 2022	8:30 AM PST	advanced rotations
Th 17 Mar 2022	8:30 AM PST	mathy cryoem paper
Th 24 Mar 2022	8:30 AM PST	advanced rotations

2 General Information

2.1 Archived material

Meetings from 2020-2021 are archived here. The audience was a mix of beginners and advanced practitioners, and computational methods developers.

2.2 Audience and Streams

Feel free to share this document and direct people to sign up at `https://forms.gle/BUeUW14vV4pyQbDDA` so I have the emails in one place. Online meeting links are emailed to those on this list. **Please join the Slack group and ask questions there, rather than emailing me.**

2.3 Audience

In 2022, I am catering to a computational methods development audience. I see this group as a way for computational methods developers to get together in a ”pre-competitive” learning environment.

Practitioners → computational methods developers: You are a structural biologist, or biochemist, and perhaps an advanced cryo-EM practitioner. You would like to train in computational methods development, either to do very advanced data processing, or develop your own methods.

Pure computational discipline → cryo-EM computational methods developers: You have a background in computer science (computer vision, deep learning, statistics, electrical/computer engineering) and would like to develop methods for the ”killer application” of cryo-EM.

2.4 Pre-requisites

The bar is quite high, and this group is not for all. There are very good resources out there for self-study; see this annotated a bibliography. If you have done an undergraduate degree in an advanced computational program (physics, chemistry, computer science, statistics, applied math) or are a PhD student in a computational field, then you are in good company in this group.

2.5 Scope

2.5.1 Math / Computer science

1. amortized inference, model learning
2. physics aware/inspired/infused deep learning

3. deep learning of the image formation model (rotation, etc)
4. computationally modelling uncertainty in the image formation model
5. geometric deep learning and invariance/equivariance in cryo-EM
6. computational optimal transport
7. computational differential geometry
8. optimization
9. custom GPU kernels, including gradient for backprop/autodiff

2.5.2 Physics

1. Electron optics
2. Higher order CTF aberrations
3. Multi-slice
4. Sample damage
5. Detector physics
6. Solvation
7. Poisson-Boltzmann equation
8. Modelling choices to encode coulombic density

2.6 Meeting Format

The meetings are meant to be more informal that is typical in research talks. The point is to learn and discuss with other learners, experienced practitioners, and experts. They are also more comprehensive than typical journal clubs. We may stick with a papers or series of papers for multiple weeks to sufficiently learn the material.

2.7 Slack

We will use the Slack channel 'cryoem_study_group' for asynchronous chat. Please join the Slack group and ask questions there, rather than emailing me. You can request a link to join by emailing me.

2.8 Testimonials

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3 Learning Resources

1. A good place to start is Grant Jensen's popular online course 'Getting Started in Cryo-EM' .

2. After getting up to speed on the prerequisites, another good next step is the content developed by Dr Frederick Sigworth and others at `https://cryoemprinciples.yale.edu/video-lectures`. If you are having problems with links, then try viewing his content on YouTube.

3. Also, I highly recommend the interactive learning material developed by Arjen Jakobi, for a course on High-Resolution Imaging at TUDelft: "The practicals are computational assignments in the form of interactive Jupyter notebooks hosted in a virtual learning environment. These notebooks contain code that can be executed to perform certain tasks or visualize results; you do not need any active knowledge of coding to work through the notebook." For the curious, the code that generates the visualizations is available on the repository.

4. I have made an annotated bibliography organized thematically here.

5. Coding notebooks to play around with are here. If there is incompatibility between the notebook and the code base in the repo, that is because the code base has been updated. Older version of the code are available via past commits.

4 Upcoming Meetings

4.1 2022 - advanced treatment of rotations

–Pre-reading

1. (2020). A Smooth Representation of Belief over SO(3) for Deep Rotation Learning with Uncertainty. `https://arxiv.org/pdf/2006.01031.pdf`
2. (2021). Eliminating Topological Errors in Neural Network Rotation Estimation Using Self-selecting Ensembles. `https://dl.acm.org/doi/pdf/10.1145/3450626.3459882`
3. (2021). On the Continuity of Rotation Representations in Neural Networks. `https://arxiv.org/pdf/1812.07035.pdf`
4. (2013). Rotation Averaging. `https://link.springer.com/content/pdf/10.1007/s11263-012-0601-0.pdf`
5. (2021). Learning Rotation Invariant Features for Cryogenic Electron Microscopy Image Reconstruction. `https://arxiv.org/pdf/2101.03549.pdf`
6. (2020). SE(3)-Transformers: 3D Roto-Translation Equivariant Attention Networks. `https://arxiv.org/pdf/2006.10503.pdf`
7. Falorsi, L., de Haan, P., Davidson, T. R., & Forr, P. (2020). Reparameterizing distributions on Lie groups. AISTATS 2019 - 22nd International Conference on Artificial Intelligence and Statistics, 89. `https://arxiv.org/pdf/1903.02958.pdf`

4.2 2022 - assorted mathy cryoem papers

–Pre-reading

1. Tagare, H. D., Kucukelbir, A., Sigworth, F. J., Wang, H., & Rao, M. (2015). Directly reconstructing principal components of heterogeneous particles from cryo-EM images. Journal of Structural Biology, 191(2), 245?262. `http://doi.org/10.1016/j.jsb.2015.05.007`
2. Zivanov, J., Nakane, T., & Scheres, S. H. W. (2019). A Bayesian approach to beam-induced motion correction in cryo-EM single-particle analysis. IUCrJ, 6(1), 5?17. `http://doi.org/10.1107/S205225251801463X`
3. Katsevich, E., Katsevich, A., & Singer, A. (2015). Covariance matrix estimation for the cryo-em heterogeneity problem. SIAM Journal on Imaging Sciences, 8(1), 126?185. `http://doi.org/10.1137/130935434`

4. Penczek, P. A. (2010). Resolution Measures in Molecular Electron Microscopy. In Methods in Enzymology (1st ed., Vol. 482, pp. 73?100). Elsevier Inc. http://doi.org/10.1016/S0076-6879(10)82003-8

5. Ede, J. M. (2020). Review: Deep learning in electron microscopy. ArXiv. http://doi.org/10.1088/2632-2153/abd614

6. Qinwen Huang, Ye Zhou, Hsuan-Fu Liu, & Alberto Bartesaghi (2021). Weakly Supervised Learning for Joint Image Denoising and Protein Localization in Cryo-EM https://www.mlsb.io/papers_2021/MLSB2021_Weakly_Supervised_Learning_for.pdf

4.3 2022 - advanced microscopy

–Pre-reading

1. Glaeser, R. M., Hagen, W. J. H., Han, B. G., Henderson, R., McMullan, G., & Russo, C. J. (2021). Defocus-dependent Thon-ring fading. Ultramicroscopy, 222(October 2020), 113213. http://doi.org/10.1016/j.ultramic.2021.113213

2. Russo, C. J., & Egerton, R. F. (2019). Damage in electron cryomicroscopy: Lessons from biology for materials science. MRS Bulletin, 44(12), 935?941. http://doi.org/10.1557/mrs.2019.284

3. Russo, C. J., & Henderson, R. (2018). Ewald sphere correction using a single side-band image processing algorithm. Ultramicroscopy, 187, 26?33. http://doi.org/10.1016/j.ultramic.2017.11.001

4. Electron optics textbook chapters (Hawkes and Kasper; Spence; Reimer and Kohl)

4.4 27 Jan 2022 - computational methods development - Qinwen (Wendy) Huang

–Pre-reading

- Qinwen Huang, Ye Zhou, Hsuan-Fu Liu, & Alberto Bartesaghi (2021). Weakly Supervised Learning for Joint Image Denoising and Protein Localization in Cryo-EM https://www.mlsb.io/papers_2021/MLSB2021_Weakly_Supervised_Learning_for.pdf

–Questions

1. This paper exploits analytical likelihood-prior-posterior conjugacy between gaussian distributions. How could we extend this to Poisson noise with Poisson-Gamma conjugacy? What would be Poisson, and what would be Gamma?

5 Past Meetings