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
Fri 21 Jan 2022	9 AM PST	mathy cryoem paper
Fri 28 Jan 2022	9 AM PST	Guest: Qinwen (Wendy) Huang - Weakly Supervised Learning for Joint Image Denoising and Protein Localization in Cryo-EM
Fri 4 Feb 2022	9 AM PST	advanced rotations
Fri 11 Feb 2022	9 AM PST	mathy cryoem paper
Fri 18 Feb 2022	9 AM PST	advanced rotations
Fri 25 Feb 2022	9 AM PST	mathy cryoem paper
Fri 4 Mar 2022	9 AM PST	advanced rotations
Fri 11 Mar 2022	9 AM PST	mathy cryoem paper
Fri 18 Mar 2022	9 AM PST	advanced rotations
Fri 25 Mar 2022	9 AM PST	mathy cryoem paper

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

- *Shayan Shekarforoush, PhD student with Marcus Brubaker and David Fleet, Jan 2021.* I joined this reading group in mid October and I wish I would have done so much earlier. Although I joined when the group was in the middle of reading a fascinating, recently published book in Single-Particle cryoEM, everyone was so welcome that I did not feel I am way behind others. My background is in CS and I do research as a method developer in this field. With that said, I learned a lot from discussions of people with expertise in experimental side of this area. I believe that this group helped me to build a better intuition and now I feel more comfortable with the underlying math and physics of this topic. This group also provided the opportunity to attend talks of prominent researchers in cryoEM where anyone could openly ask their questions and have clear discussions. Looking forward to having more collaborations with the members of this group.

3 Learning Resources

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

2. 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 21 Jan 2022 - VESPER: global and local cryo-EM map alignment using local density vectors.

–Pre-reading

1. Han, X., Terashi, G., Christoffer, C., Chen, S., & Kihara, D. (2021). VESPER: global and local cryo-EM map alignment using local density vectors. Nature Communications, 12(1). `http://doi.org/10.1038/s41467-021-22401-y`

4.2 28 Jan 2022 - Guest: Qinwen (Wendy) Huang - Weakly Supervised Learning for Joint Image Denoising and Protein Localization in Cryo-EM

–Pre-reading

1. 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 Reading list

5.1 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`

5.2 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`

5.3 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 sideband 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)

6   Past Meetings