TP-M19 : Dissipation Learning in Active Matter

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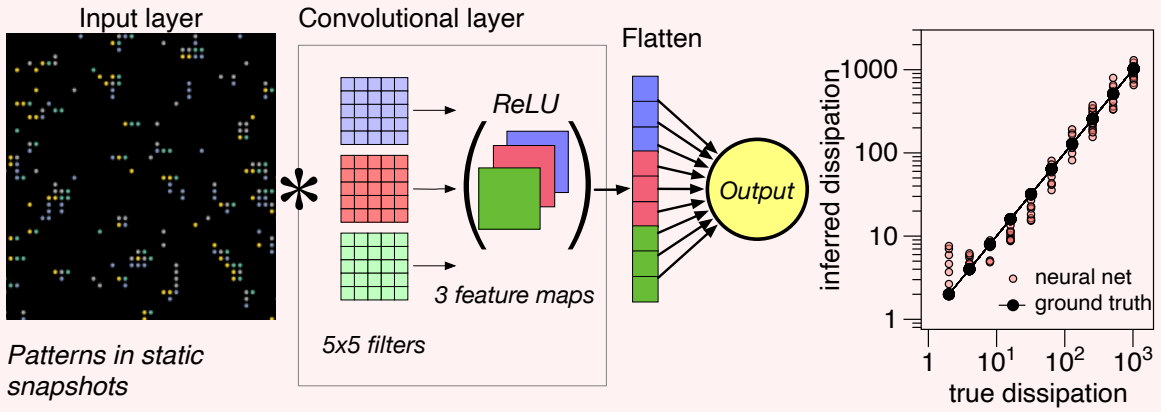
MSci
60/30

Description

Flocks of birds, bacterial colonies as well as swarming robots are examples of systems that achieve complex spatial organisation through local energy dissipation. Collectively, these systems are referred to as *active matter*, distinct from the ordinary soft and hard condensed matter [1]. Nonequilibrium, disorder, sensing and communication are key characteristics of active systems, leading to rich patterns and phase separation. Using suitably designed deep neural networks, recent progress has shown that we can link spatial patterns and local dissipation (e.g. entropy production) [2]. This opens several questions:

- what degrees of freedom are most important to control dissipation?
- how much information is required to learn dissipation accurately?
- how does the architecture of the networks linking structure and dissipation depend on the specific model under consideration?

The project is theoretical and computational: we will simulate on-lattice and off-lattice active models, analytically design structural metrics to link to dissipation, embed them in convolutional networks using state-of-the-art deep-learning APIs (e.g. Keras) and compare their performance for different minimal models.



Static snapshots of the Persistent Exclusion Process model (left) feed a convolutional network (middle) to predict the dissipation. Ground truth vs prediction on the right (preliminary work).

Key References

1. G. Gompper, et al. J. Phys.: Condens. Matter **32**, 193001 (2020)
   `https://doi.org/10.1088/1361-648X/ab6348`
2. G. Rassolov, et al. J. Chem. Phys. **157**, 054901 (2022)
   `https://doi.org/10.1063/5.0097863`

Skills

You will acquire

- Expertise in convolutional neural networks in Python
- A general knowledge of nonequilibrium statistical mechanics