

2023 PhD Projects

Project title	Complex systems with feedback: critical transitions and application for data-driven modeling
Principal supervisor	Ivan Sudakow
Discipline	Applied mathematics
Research area/keywords	complex systems, stochastic processes, statistical mechanics, climate system, ecosystem, social system
Suitable for	Full time applicants, Part time applicants

Project background and description

Complex systems are traditionally described by statistical mechanics, which is a robust mathematical instrument and offers simple and computationally powerful models from percolation to spin dynamics [1]. Besides that, statistical mechanics builds the theory of phase transitions and critical phenomena in physical systems [2]. The critical transitions in pattern formation appearing in a large-scale complex system are involving complex interactions among a pattern and the environment through the feedback.

In this project, we develop novel statistical mechanics models incorporating the feedback between patterns and the environment that could simulate phase changes and the subsequent shift in the complex structure of patterns. These models will be used to study complex climate [3], environmental [4] and social systems [5] involving data analysis.

Background reading/references

1. Bertin, E. *Statistical Physics of Complex Systems*. Springer. (2021).
2. Chew, L.Y. Phase Transition in Complex Systems: A Scientific Journey in *Looking Beyond the Frontiers of Science*. (2022).
3. Ma Y-P., Sudakov I., Strong, C., and Golden K.M. Ising model for melt ponds on Arctic sea ice. *New Journal of Physics*, 21(6), 063029 (2019).
4. Noble, A.E., Rosenstock, T.S., Brown, P.H., Machta, J. and Hastings, A. Spatial patterns of tree yield explained by endogenous forces through a correspondence between the Ising model and ecology. *PNAS*, 115, 1825–1830. (2018).
5. Cajueiro, D.O. Enforcing social behavior in an Ising model with complex neighborhoods, *Physica A: Statistical Mechanics and its Applications*, 390. (2022).