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## Maximum entropy models for financial systems

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# Summary

Complex systems, from financial markets to the brain, exhibit heterogeneous structures and non-stationary dynamics. These characteristics manifest themselves in the diversity of the elements in a system, and in the changing behaviour over time. Capturing and understanding this heterogeneity via appropriate models, can have important implications not only for science, but also for societal challenges like predicting the next financial crisis or developing advanced brain imaging techniques. In this thesis, we use the maximum-entropy approach to introduce a new class of statistical models, which captures part of the observed structural and/or temporal heterogeneity in the system. The models are applied to various real-world complex systems, and are used to address different problems.

First, we explore some applications of our maximum-entropy approach to the analysis of financial time series. We introduce a new class of maximum-entropy time series ensembles, which enable us to characterize and quantify information encoded within the binary signatures, i.e., the signs, of the increments of financial time series. Next, using one of the models, we mathematically characterize the observed non-linear empirical relations between binary and non-binary properties in financial time series. The analysis suggests that binary signatures of financial time series encode significant information with respect to their complete weighted counterparts. It also allows to identify which measured properties are most informative about the original time series.

Second, we focus on modelling economic networks, in particular the International Trade Network. We adopt again a maximum-entropy approach, which in this case turns out to be powerful in reproducing the empirical complex topology of the real-world system, and integrate it with the known macroeconomic approach. Indeed, the main limitation of macroeconomic models is the fact that they generate an unrealistically uniform topology. Combining the two approaches together leads to a new set of topologically invariant network models for the ITN, which represent a significant improvement when modelling the entire structure of the system. Remarkably, the mechanism through which the model enforces a complex topology, i.e., the principal of topological invariance, can be generalized to any economic network model.

Finally, we use the maximum-entropy approach to develop a new technique to filter empirical correlation matrices. The maximum-entropy models represent random benchmarks in this case, which still preserve part of the dependencies in the system. The properties which are not reproduced by the null model are considered non-random and are used to filter the empirical correlation matrix. Our method is able to detect functional modules in the system, which are internally correlated and mutually anti-correlated. We successfully apply our method to financial markets and functional brain data to detect the internal hierarchical organization of these systems with a level of resolution previously unavailable.