

# Summary

Performing epidemic inference at the individual scale is a difficult task because of the complex interactions that are present. As the size of the considered system grows, its inherent complexity makes the task practically infeasible, even with the computational capabilities available today. This thesis is then devoted to the study of inference methods grounded in statistical physics, that can perform this task efficiently and provide a good approximate solution to the problem when an exact one is out of reach from the practical point of view.

The structure of the thesis follows the order in which the PhD program unfolded. In the first chapter, after briefly discussing some of the theory of network science, the models for epidemic spreading used in the thesis are introduced. In particular, the probabilistic individual-based version of the Susceptible-Infected-Recovered model is defined and analysed, and the epidemic inference problem is introduced on this particular model.

Then, the application of Autoregressive Neural Networks (ANNs) to this problem is discussed. This technique involves training artificial neural networks in order to generate epidemic cascades that are compatible with the observations made on a single outbreak. This approach is applied to three problems of epidemic inference, the patient zero detection problem, the epidemic risk evaluation and the inference of epidemic parameters.

The following chapters deal with one of the challenges put forward by the COVID-19 pandemic. During the first and second epidemic waves of the disease (both in Europe and the world), digital contact tracing has been developed as a mechanism to track the transmission of the disease and isolate infectious individuals. However, in order to perform these task efficiently, the evaluation of the epidemic risk of every individual in the population is required. A large part of the work of the PhD, then, has been dedicated to the application of epidemic inference techniques derived from statistical physics, in order to show how they can improve the detection of infected individuals during an epidemic outbreak.

In the third chapter, the methods are first applied to one particular agent-based model for COVID-19. The focus of this investigation is on the containment capability of the methods, that is their ability to identify the infectious individuals, who are then isolated preventing new infections from occurring. In order to make the containment experiments more realistic, several features are introduced, such as the isolation of households, the test error rate and the impartial collection of the individual contact network. The methods derived from statistical physics are compared here to contact tracing, along with a control method.

In the next chapter, the analysis is expanded to other two agent-based models for COVID-19. The containment performance is investigated in these two other models, with the same features introduced previously. Then, the statistical physics methods are applied to two other tasks, the identification of super-spreaders (the individuals that are able to infect many others) and to

the reconstruction of the propagations from the observations, both forward and backward in epidemic time.

Finally, another method for epidemic inference is described, based on a small coupling approximation of the dynamic cavity approach to Susceptible-Infected epidemic process. After its derivation, the method is tested for the prediction of the dynamics without observations, and in the risk inference setting, in both synthetic and real contact graphs.