Proposal for Master's degree project in Mathematical Statistics

Random trees in population evolution and infectious diseases dynamics

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Two well-known examples of random trees are branching processes and coalescent processes. These two types of trees have proven to be useful in the study of the growth and evolution of populations. Each vertex of these trees represents an individual and each branch represents a relationship between individuals (e.g. parent-offspring, ancestor-descendant).
Branching processes can also be used to approximate the initial phase of an epidemic, in this case instead of parent and offspring we think of infector and infectees. Coalescent processes can be used to model the phylogeny of pathogens, i.e. the tree representing evolutionary relationships among disease-causing microbes (viruses, bacteria, etc.). A phylogeny of a certain pathogen is embedded in a *transmission tree*, i.e. the tree describing who infected whom during the course of an epidemic caused by that pathogen.

This project focuses on transmission trees arising from well-known epidemic models, e.g. the SIR (susceptible-infected-recovered) stochastic epidemic model. As is customary for phylogenies, it might be helpful to consider transmission trees as evolving backward-in-time, that is, going from the infectees to their infectors and the infectors of these infectors, etc.

Several questions can be studied in this setting, for example:

- Is the distribution of simulated transmission trees similar to that of well-known random trees (such as branching and coalescent processes)?
- How do transmission trees change across different epidemic models (SIR, SEIR, etc.)?
- How do transmission trees vary as epidemic parameters change?
- How does a transmission tree differ between the epidemic models and their branching-process approximation?

The analysis could be mostly based on simulations or more theoretically oriented. In any case, a good understanding of stochastic processes is needed, as well as simulation skills.

If you are interested, feel free to contact me for any questions. Different directions and details can be discussed to march your interests.