

**Network science**

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Research: Network science, computational social science, digital epidemiology

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● **Research Purpose and Content**

To understand how a large, complex system works as a whole, you need to zoom out and look from a distance. The society itself is just such a complex system built by people and organizations with different abilities, interests and objectives. Our bodies are another example. Genes code proteins, proteins build cells, cells build tissues, tissues build organs—that seems fairly simple and hierarchical—if it wasn’t that the proteins interact with each other, so do cells, etc. and to understand such lateral connections, we need to find the right level of modeling (or the right distance to look at the elephant). The bigger datasets we can gather, the more important it will be to simplify the right amount. Representing a system as a network is one way of consistently discarding some details, to simplify and zoom out, while still being able to see how the whole system hangs together. Network science can be theoretical—to develop methods for the data analysis outlined above or simulating such networked systems. It can also be applied, using existing network methods to answer domain specific questions.

● **Research Themes**

**1. Network epidemiology**

I am interested in how infectious diseases spread in populations. These processes are all affected by the structure of the underlying contact patterns. As a simple example, any types of networks between people have heavy-tailed distributions of the number of neighbors of people (the degree). This is known to speed up disease spreading, but it also makes it easier to stop an epidemic outbreak (provided one identify the high-degree people and vaccinate them, or otherwise lower their ability to spread the disease). Structures both in the wiring of the networks and the time of contacts affects spreading phenomena. This project thus overlaps with the previous in some ways, but it is more about adding knowledge to a rich existing theory than creating a new. In summary, my research is about relating the contact structure and spreading dynamics, and how to exploit these insights to mitigate or facilitate spreading.

**2. Interaction between diseases and behavior**

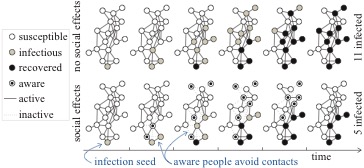
Infectious diseases are a constant threat to public health. Globally they cause around 20% of deaths, while developed countries like Japan are susceptible to outbreaks of new pathogens (like recently SARS or MERS in neighboring countries). To understand infectious disease dynamics with the ultimate goal to create effective interventions for mitigating infectious outbreaks is thus extremely valuable for the society. This is also a question where theoretical science is making continuous contributions to medical science—several concepts, and policies public health practitioners use, come from the type of research we propose.

Figure 1. How social effects can change predictions in epidemic modeling.

There is an increasing amount of evidence that social influence impacts people’s health decisions, such as vaccination or condom use. Such peer influence thus spreads behavior as a social contagion similar to the infectious contagion. This forms a feedback loop between epidemic and behavioral spreading (Fig. 1). In response to perceived risks and social influence, people may take preventative measures such getting vaccinated. These behavioral responses will, in turn, modify the infection spreading and cannot be ignored in a comprehensive theory of epidemic spreading. Our key question is thus: How does social spreading of behavior influence epidemic spreading?

**3. Urban science**

The study of the structure of cities and the movement of people within them is another research topic combining modern data-science approaches and theory. My current research has focused on how traveling patterns are influenced by the spatial structure of the city: how they can be predicted and used to understand the functional organization of a city. For the future, I am interested in temporal patterns of activity in cities, basically to understand how the shape of cities affect the timing of peoples’ movements. A first step would be to make a time-resolved version of out “inness” metric, proposed in Ref. [1] (that captures the propensity of moving towards the center and then outwards when travelling between peripheral locations in a city).

**4. Group dynamics in crime**

Crime is a universal social phenomenon. In almost every modern nation and many old civilizations, there has been a legal system and a notion of crime. It is also a very well documented social phenomenon. Indeed, almost all countries have a police authority whose purpose is not only to find and apprehend criminals but also to document crimes in many aspects—the time, location, type and data about the suspects age, gender and identity are almost universally recorded. This information is usually reported as averages or trends, and occasionally regression analysis, but still rarely analyzed with the modern tools of computational social science. Our project will use new tools and new data to advance the understanding of why, when and where crime is committed.

As a starting point, this work uses a large dataset—unique for academic research—from the Swedish police. It covers all crimes committed in Sweden over 20 years, involving 1.2 million suspects, recording anonymized id-numbers of the suspects, time, location and type of the crimes. We will focus on questions about criminal careers and collaborations:

* Can we see knowledge transfer between criminals who committed crimes together (co-offenders)?
* When a group of co-offenders before do it again, how and why do they recruit new members.
* Are there any statistical laws in the data?
* Can we predict and categorize criminal careers?

● **Message to students**

My laboratory is actively collaborating with overseas research institutes. All students with a keen interest in network science (and some programming skills) are welcome to contact me.

● **Selected publications**

[1] M Lee, H Barbosa, H Youn, P Holme, G Ghoshal, Morphology of travel routes and the organization of cities, *Nature Communications* 8, 2229 (2017).

[2] P Holme, Three faces of node importance in network epidemiology, *Phys. Rev. E* 96, 062305 (2017).

[3] LEC Rocha, N Masuda, P Holme, Sampling of temporal networks: Methods and biases, *Phys. Rev. E* 96, 052302 (2017).

[4] P Holme, N Litvak, Cost-efficient vaccination protocols for network epidemiology, *PLOS Comp. Biol.* 13, e1005696 (2017).