Physics approaches to studying and modeling urban systems

L. Gauvin
Complex Networks and Systems Group, Institute for Scientific Interchange Foundation, Turin, Italy

Approximately 20 % of the world's population reside in cities comprising over one million inhabitants. This urban explosion induces deep changes in human dynamics, due to population density, intense interaction, and new means of communication. High urban densities and people living in close proximity increase opportunities for both conflict and cooperation. The conflicts stemming from this metropolisation often relate to spatial organisation in the city (segregation, gentrification), as well as to human antagonistic interactions and communication. The apprehension of these problems lies at the crossroads between mathematics, physics, economy, sociology, engineering etc. They may be profitably addressed by borrowing and transforming ideas coming from traditionally separated fields of research. In this talk, I will highlight two approaches with regard to the questions of spatial organisation and human interactions but general enough to be extended to other issues: 1) modeling, and 2) analysing data seen as networks. I will first show an example where we improve a socio-economic model while keeping it tractable, using models and tools from physics. I will start from an archetypal model for residential locations, the Schelling segregation model, and relate it to a statistical physics model. I will take advantage of this link to propose an extended version of the original Schelling segregation model. Taking inspiration from these results and some socio-economic theories, I will briefly present a data driven model for housing market.

After showing how cross-disciplinarity can guide the modelling of one aspect of urban systems, I will focus on data analysis. Detailed datasets documenting human behaviour provide an unprecedented insight into some of the driving forces of modern conflicts in cities : human interactions, movement and communication. Again, the sheer size and variability of these datasets put them at the boundaries between several domains of expertise, and it is fruitful to adapt tools coming from network science, complex systems, mathematics and epidemiology in order to analyse them. For instance, the internal structures of cities appear to have a natural representation in terms of networks evolving in time. These dynamic networks can be studied from a network science point of view, and epidemic spreading processes on networks allow to discover identical patterns in seemingly different types of activity. Moreover, their complex and evolving structure can be extracted using the powerful tools of multilinear algebra.

As we shall see, cross-disciplinarity is fueling the research and the understanding of modern city conflicts.