Modeling spatial and temporal mobility patterns with an adaptive memory approach

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Understanding how people move within a geographic area, e.g. a city, a country or the whole world, is fundamental in several applications, from predicting the spatio-temporal evolution of an epidemics to inferring migration patterns. The possibility to gather information about the population through mobile phone data —recorded by mobile carriers triggered a wide variety of studies showing, for instance, that mobile phones heterogeneously penetrated both rural and urban communities, regardless of richness, age or gender, providing evidences that mobile technologies can be used to build realistic demographics and socio-economics maps of low-income countries, and also provide an excellent proxy of human mobility, showing for instance, that movements exhibit a high level of memory, i.e. the movements of the individuals are conditioned by their previous visited locations.

However, the precise role of memory in widely adopted proxies of mobility, as mobile phone records, is unknown. We have used 560 millions of call detail records from Senegal to show that standard Markovian approaches, including higher-order ones, fail in capturing real mobility patterns and introduce spurious movements never observed in reality. We introduce an adaptive memory-driven approach to overcome such issues. At variance with Markovian models, it is able to realistically model conditional waiting times, i.e. the probability to stay in a specific area depending on individual's historical movements, Figure 1.

Our results demonstrate that in standard mobility models the individuals tend to diffuse faster than what observed in reality, whereas the predictions of the adaptive memory approach significantly agree with observations. We show that, as a consequence, the incidence and the geographic spread of a disease could be inadequately estimated when standard approaches are used, with crucial implications on resources deployment and policy making during an epidemic outbreak.
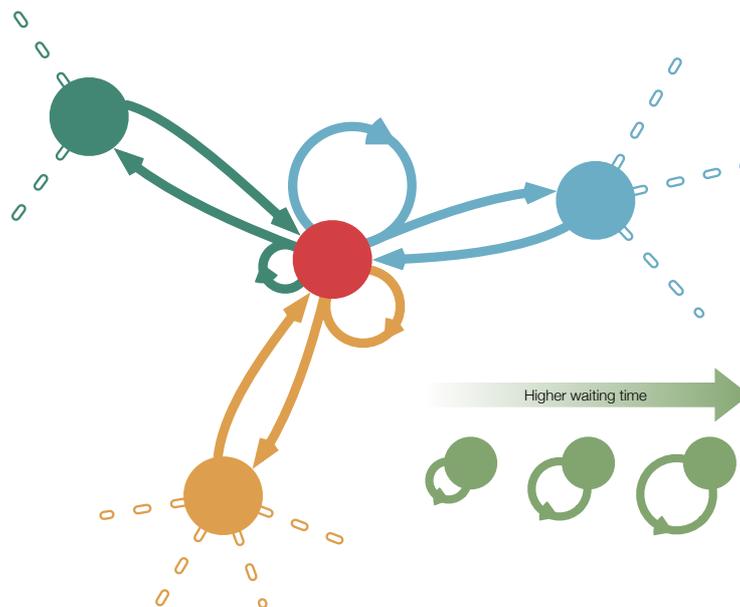

Figure 1. An example of human mobility between four different places. Individuals from green, blue and orange nodes move to the red central node and, after some time, go back to their previous location. The amount of time spent in the red node by individuals coming from the other nodes depends on their previous location, and it is represented by self-loops of different size.