Data driven Markov Models to study congestion formation in transport systems

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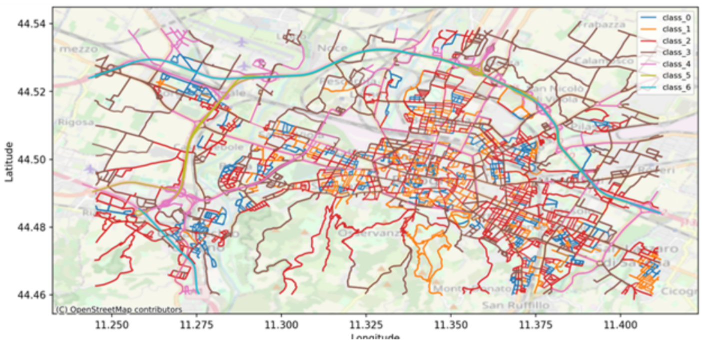
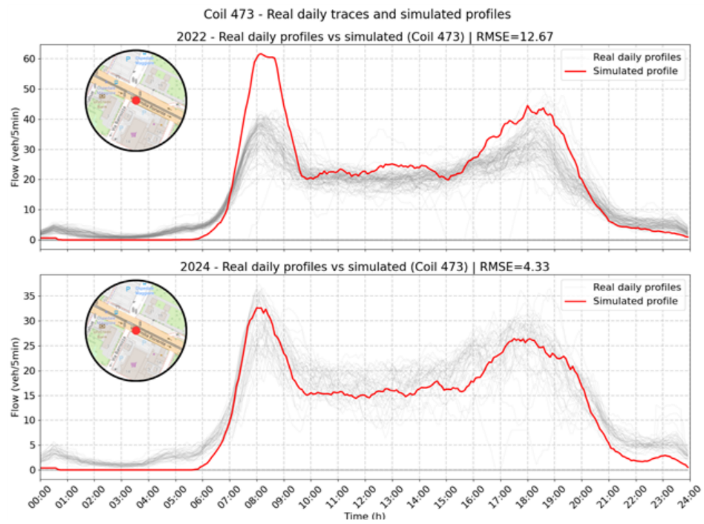
The possibility to collect large data sets by the Information and Communication Technologies allows to study the individual mobility, but one has to take into account the restrictions imposed by privacy legislation, especially in Europe. Recent studies have suggested the existence of universal properties that characterize the congestion formation in transport networks using the percolation theory. These results open the possibility to develop a data driven reductionist approach using Markov models that simulate the traffic dynamics at crossing points, taking into account the finite traffic flows and the finite road capacity. In this work we illustrate the road map to build a data driven Markov process that simulates the congestion formation on a transport network, using a-priori information, that are usually available in many European cities. More specifically, we consider data on traffic flows and the average travel velocity along the roads, and a small sample of individual trajectories reconstructed by recording the GPS positions of mobile phones.





Being interested in the urban mobility, we initially highlight the existence of a multilayer structure for the road networks (see Fig. 1) that determines the individual behavior at crossing points and we study the distribution of the Origin-Destination of the empirical paths in the city to check how an uniform OD distribution is suitable to reproduce the empirical distribution. We simulate the urban mobility of the city of Bologna (500,000 inhabitants in the North of Italy) using a stochastic model and we study the relation with the transition rates of a Markov process proposing an approach that maximizes the dynamical entropy (Parry Theorem) with initial weights based on the betweeness centrality and the free speed.

The comparison of the model simulations with the empirical flows recorded a by magnetic coil system each 5 minutes provides a good qualitative agreement (cfr. Fig. 2) suggesting that most of the traffic in the city has a random nature.

We have simulated the congestion formation by increasing the traffic load and we have compared the results with data recorded in presence of construction sites on the road network. The traffic Markov model allows to develop a statistical mechanics approach to the urban traffic taking advantage of the results of stochastic thermodynamics.

Even if to justify the use of Markov systems to simulate the urban mobility would require further studies, our results show as an approach based on stochastic processes and statistical mechanics provides an effective description of congestion formation and it is able to give predictions to improve traffic governance.