Human Mobility from theory to practice: Data, Models and Applications

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ABSTRACT
The inclusion of tracking technologies in personal devices opened the doors to the analysis of large sets of mobility data like GPS traces and call detail records. This tutorial presents an overview of both modeling principles of human mobility and machine learning models applicable to specific problems. We review the state of the art of five main aspects in human mobility: (1) human mobility data landscape; (2) key measures of individual and collective mobility; (3) generative models at the level of individual, population and mixture of the two; (4) next location prediction algorithms; (5) applications for social good. For each aspect, we show experiments and simulations using the Python library ‘scikit-mobility’ developed by the presenters of the tutorial.

CCS CONCEPTS
• Information systems → Data mining; • Computing methodologies → Modeling methodologies.

KEYWORDS
Human Mobility; Artificial Intelligence; Data Science; Generative Models; Predictive Algorithms

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1 TOPIC AND RELEVANCE
The availability of geo-spatial mobility data (e.g., GPS traces, mobile phone records, social media records) is a trend that will grow in the near future. In particular, this will happen when the shift from traditional vehicles to autonomous, self-driving, vehicles, will change individual and public transportation, transforming our society, the economy and the environment. For this reason, understanding and modeling human mobility is of paramount importance for many present and future applications such as traffic forecasting, urban planning, estimating migratory flows, and epidemic modeling [12]. In this tutorial we will present a concise and intuitive overview on both the fundamental modeling principles of human mobility and artificial intelligence models applicable to specific mobility-related problems1. Starting from the general laws that govern human mobility, we will drive the audience through the main models for human mobility highlighting the parallelism between statistical and deep learning models, presenting the recent advances of the latter that are nowadays representing the state-of-the-art in many human mobility tasks, like next location prediction. To this end, we will review the state of the art of five aspects:

(1) The human mobility data landscape
A natural starting point is to describe the nature of empirical data which has been used in mobility research. In this part, we outline the main data sources available for mobility research and the relevant information that can be extracted from them. [3, 4, 6, 17, 35]

(2) Under the microscope: Measuring individual and collective mobility patterns
In this part, we will review some of the fundamental metrics and representations used to characterize human mobility, such as trip distance [8, 13], radius of gyration [13, 24, 25], mobility entropy [19, 34], origin-destination matrix [7], mobility motifs [30], and more.

(3) Agents on the move: simulating mobility patterns
This part will review the state of the art for generative models at both the individual level (i.e., generation of individual spatio-temporal trajectories) [2, 15, 23–25, 33] and the population level (i.e., generation of mobility flows) [16, 31, 32, 39].

(4) Where’s next? AI for human mobility
After a short review of various artificial intelligence and machine learning models for human mobility [21, 22, 36, 38, 43] we will review recent advances based on deep learning, with particular focus on next location prediction [10, 18, 40, 41, 44].

(5) Human mobility for Social Good and future challenges
In this part, we will show how developing accurate predictive and generative mobility models can be greatly beneficial for several aspects of social good, from mobility in emergency

1The online version of the tutorial and all the updated material can be found at https://humanmobility-tutorial.github.io/
REFERENCES


