Chapter 13
Understanding Urban Dynamics from Taxi GPS Traces

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ABSTRACT

The GPS traces collected from a large taxi fleet provide researchers novel opportunities to inspect the urban dynamics in a city and lead to applications that can bring great benefits to the public. In this chapter, based on a real life large-scale taxi GPS dataset, the authors reveal the unique characteristics in the four different trace stages according to the passenger status, study the urban dynamics revealed in each stage, and explain the possible applications. Specifically, from passenger vacant traces, they study the taxi service dynamics, introduce how to use them to help taxis and passengers find each other, and reveal the work shifting dynamics in a city. From passenger occupied traces, they introduce their capabilities in monitoring and predicting urban traffic and estimating travel time. From the pick-up and drop-off events, the authors show the passenger hotspots and human mobility patterns in a city. They also consider taxis as mobile GPS sensors, which probe the urban road infrastructure dynamics.

1. INTRODUCTION

With the recent advances of sensing, computing, networking and storage, the digital footprints left by people while interacting with the cyber-physical world are accumulating at an unprecedented rate. The abundance and richness of large scale digital traces collected from huge groups of individuals provide us new opportunities to understand the collective human behaviors and probe various aspects about our society, showing great potential to revolutionize the services in various areas

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ranging from public safety, urban planning and monitoring, to transportation management and so on (Paulos, Honicky, & Hooker, 2009, Zhang, Guo & Yu, 2011). In this chapter, as an illustrative study we try to investigate the urban dynamics by exploiting the taxi GPS traces collected from a large taxi fleet running in a real city.

Nowadays in many modern cities, taxis are equipped with GPS devices for navigation and dispatch, which report the status of the vehicle, such as the GPS location, speed, orientation and passenger status, to a central sever via telecommunication network in a real time manner. Generally speaking, the operation of taxis is under many physical constraints in the city, such as the road infrastructure, traffic situations and passenger demand distributions. And thus the collected GPS traces potentially reflect many aspects about the city, revealing its status and dynamics over time. For example, the running taxis generally follow the traffic flow on the road, and their speeds well represent the real time traffic situations (Giannotti et al. 2011, Schäfer, Thiessenhusen & Wagner, 2002, Wen, Hu, Guo, Zhu & Sun, 2008). And by gathering the real time speeds from a large taxi fleet, we can obtain a comprehensive picture about the traffics in a city. Besides, as taxis are running on the roads, their GPS traces are able to describe the road infrastructure in a city and thus can be used to detect the road network changes, such as the newly built, opened, or blocked road segments. Meanwhile, the large collections of the pick-up and drop-off events directly tell the human dynamics in a city, showing the high transportation demand areas (*i.e.*, those pick-up hotspots) and human mobility among them.

If we look further inside the taxi GPS traces, we will find that, unlike private vehicle, taxis have unique characteristics at different passenger status. Specifically, in passenger finding process, the target of the drivers is to efficiently find the passengers to achieve high profits. They are under the influences of passenger distributions, competitions from other taxis, traffic situations and so on. They may hunt around the city, following whatever routes they prefer, or wait at some hotspots. Besides, they also serve the passenger requests broadcasted from the dispatch center. While in passenger delivery process, their targets shift to the efficient delivery of the passengers to their destinations. They try to avoid the jammed roads. Additionally, a few dishonest taxi drivers commit fraudulent driving, mainly detours, to charge more money. Meanwhile, the passenger status changes between occupied to vacant denote pick-up and drop-off events, which directly tell the transportation demands in a city. All these characteristics provide useful clues for us to understand the urban dynamics.

In this chapter, we separate the taxi GPS traces into 4 stages according to the passenger status, study the urban dynamics revealed in each stage and explain the possible applications. Besides, we also consider taxis as mobile GPS sensors, which probe the urban road infrastructure dynamics. Before going to the detail, we first introduce the scopes of the urban dynamics studied in this chapter. Then we introduce the taxi GPS traces and its intrinsic characteristics with a real life dataset collected from thousands of taxis in Hangzhou, China for one year.

1.1 Urban Dynamics

Urban dynamics (also called as city dynamics) describes the evolvement about various aspects of the functioning of a city, ranging from urban land use[1], human mobility, traffic flow, to the evolvement of energy consumptions, environment, economics[2], public services, and so on. The aspects which state-of-the-art work already explored based on the taxi GPS traces can be summarized in the following groups:

1. **Urban Human Dynamics:** Which describes the human mobility happened in a city. Specifically, it tells that at different time periods of day, how people move around