Understanding predictability and exploration in human mobility

Predictive models for human mobility have important applications in many fields including traffic control, ubiquitous computing, and contextual advertisement. The predictive performance of models in literature varies quite broadly, from over 90% to under 40%. In this work we study which underlying factors - in terms of modeling approaches and spatio-temporal characteristics of the data sources - have resulted in this remarkably broad span of performance reported in the literature. Specifically we investigate which factors influence the accuracy of next-place prediction, using a high-precision location dataset of more than 400 users observed for periods between 3 months and one year. We show that it is much easier to achieve high accuracy when predicting the time-bin location than when predicting the next place. Moreover, we demonstrate how the temporal and spatial resolution of the data have strong influence on the accuracy of prediction. Finally we reveal that the exploration of new locations is an important factor in human mobility, and we measure that on average 20-25% of transitions are to new places, and approx. 70% of locations are visited only once. We discuss how these mechanisms are important factors limiting our ability to predict human mobility.
Data Mining and Visualization of Large Human Behavior Data Sets

Traditional methods for studying human behavior such as surveys and manual collection are expensive, time-consuming and therefore cannot be easily applied at large scale. In recent years an explosive amount of digital traces of human activity – for example social network interactions, emails and credit card transactions – have provided us new sources for studying our behavior. In particular smartphones have emerged as new tools for collecting data about human activity, thanks to their sensing capabilities and their ubiquity. This thesis investigates the question of what we can learn about human behavior from this rich and pervasive mobile sensing data. In the first part, we describe a large-scale data collection deployment collecting high-resolution data for over 800 students at the Technical University of Denmark using smartphones, including location, social proximity, calls and SMS. We provide an overview of the technical infrastructure, the experimental design, and the privacy measures. The second part investigates the usage of this mobile sensing data for understanding personal behavior. We describe two large-scale user studies on the deployment of self-tracking apps, in order to understand the patterns of usage and non-usage. Moreover we provide some design guidelines for facilitating reflection in self-tracking systems. Finally we propose a model for inferring sleep patterns from smartphone interactions.

In the third part, we focus on a specific aspect of collective behavior: human mobility. We perform an experiment to verify the feasibility of inferring places from location traces using mobile sensing data. We develop a hierarchical model for human mobility, which is able to measure mobility properties at multiple scales. We perform a study on the factors influencing the accuracy of nextplace prediction models. Finally we present an open-source tool for creating geographical visualizations.
Four Data Visualization Heuristics to Facilitate Reflection in Personal Informatics

In this paper we discuss how to facilitate the process of reflection in Personal Informatics and Quantified Self systems through interactive data visualizations. Four heuristics for the design and evaluation of such systems have been identified through analysis of self-tracking devices and apps. Dashboard interface paradigms in specific self-tracking devices (Fitbit and Basis) are discussed as representative examples of state of the art in feedback and reflection support. By relating to existing work in other domains, such as event related representation of time series multivariate data in financial analytics, it is discussed how the heuristics could guide designs that would further facilitate reflection in self-tracking personal informatics systems.

Inferring Human Mobility from Sparse Low Accuracy Mobile Sensing Data

Understanding both collective and personal human mobility is a central topic in Computational Social Science. Smartphone sensing data is emerging as a promising source for studying human mobility. However, most literature focuses on high-precision GPS positioning and high-frequency sampling, which is not always feasible in a longitudinal study or for everyday applications because location sensing has a high battery cost. In this paper we study the feasibility of inferring human mobility from sparse, low accuracy mobile sensing data. We validate our results using participants’ location diaries, and analyze the inferred geographical networks, the time spent at different places, and the number of unique places over time. Our results suggest that low resolution data allows accurate inference of human mobility patterns.
Measuring Large-Scale Social Networks with High Resolution

This paper describes the deployment of a large-scale study designed to measure human interactions across a variety of communication channels, with high temporal resolution and spanning multiple years—the Copenhagen Networks Study. Specifically, we collect data on face-to-face interactions, telecommunication, social networks, location, and background information (personality, demographics, health, politics) for a densely connected population of 1,000 individuals, using state-of-the-art smartphones as social sensors. Here we provide an overview of the related work and describe the motivation and research agenda driving the study. Additionally, the paper details the data types measured, and the technical infrastructure in terms of both backend and phone software, as well as an outline of the deployment procedures. We document the participant privacy procedures and their underlying principles. The paper is concluded with early results from data analysis, illustrating the importance of multi-channel high-resolution approach to data collection.
The Long Tail Issue in Large Scale Deployment of Personal Informatics

We describe the challenges and the open questions arising during the design and deployment of SensibleJournal, a mobile personal informatics system with interactive visualizations of mobility and social interactions based on data acquired from embedded smartphone sensors. The SensibleJournal system was evaluated in a large scale (N=136) mobile sensing field study. We report issues in deployment, limitations in user engagement and uptake, and the challenges in measuring the effect of the system.

Visualizing multi-channel networks

In this paper, we propose a visualization to illustrate social interactions, built from multiple distinct channels of communication. The visualization displays a summary of dense personal information in a compact graphical notation. The starting point is an abstract drawing of a spider’s web. Below, we describe the meaning of each data dimension along with...
Visualizing QS Data Using Time Spirals

A Mobile Personal Informatics System with Interactive Visualizations of Mobility and Social Interactions

We describe a personal informatics system for Android smartphones that provides personal data on mobility and social interactions through interactive visualization interfaces. The mobile app has been made available to N=136 first-year university students as part of a study of social network interactions in a university campus setting. The design of the interactive visualization interfaces enabling the participants to gain insights into own behaviors is described. We report initial findings based on device logging of participant interactions with the interactive visualization app on the smartphone and from a survey on usage with response from 45 (33%) of the participants indicating that the system allowed new insights into behavioral patterns.

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QS Spiral: Visualizing Periodic Quantified Self Data

In this paper we propose an interactive visualization technique QS Spiral that aims to capture the periodic properties of quantified self data and let the user explore those recurring patterns. The approach is based on time-series data visualized as a spiral structure. The interactivity includes the possibility of varying the time span and the time frame shown, allowing for different levels of detail and the discoverability of repetitive patterns in the data on multiple scales. We illustrate the capabilities of the visualization technique using two quantified self data sets involving self-tracking of geolocation and physical activity respectively.

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