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Investigating ride sharing opportunities through mobility data analysis

Nicola Bicocchi [a,*], Marco Mamei [b]

[a] Dipartimento di Ingegneria "Enzo Ferrari", University of Modena and Reggio Emilia, Italy

[b] Dipartimento di Scienze e Metodi dell'Ingegneria, University of Modena and Reggio Emilia, Italy

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ABSTRACT

Smart phones and social networking tools allow to collect large-scale data about mobility habits of people. These data can support advanced forms of sharing, coordination and cooperation possibly able to reduce the overall demand for mobility. Our goal is to develop a recommender system – to be integrated in smart phones, tablets, and in-vehicle platforms – capable of identifying opportunities for sharing cars and rides. We present a methodology, based on the extraction of suitable information from mobility traces, to identify rides along the same trajectories that are amenable for ride sharing. We provide experimental results showing the impact of this technology and we illustrate a Web-based platform implementing the key concepts presented.

1. Introduction

Travel has become an indispensable aspect of our lives. The current level of personal mobility was unheard of just 50 years ago, and it has shaped the way in which we build our communities, where and how we work and spend our leisure time. People travel more often and over longer distances than in the past—whether for commuting between home to work or school, shopping or going on holidays [1]. But the freedom of personal mobility has brought it into a collision course with the boundary of finite resources. On a global scale, personal mobility is now responsible for 26% of carbon dioxide (CO2) emissions [1]. In Europe, mobility has the fastest growing energy demands of all sectors and, despite international agreements, is the only sector with consistently increasing emissions in most countries [1].

In response to these problems, improvements are expected from vehicle-to-vehicle or vehicle-to-infrastructure coordination schemes. Moreover, autonomous cars currently being developed promise to further improve fuel efficiency by removing the human factor. Another, more radical solution, could be based on a radical shift to renewable energy sources and the development of fully electric vehicles.

In this work we investigate a social, more than a technical, solution tackling the issue by reshaping the demand for mobility by supporting car sharing and ride sharing practices. Such an approach looks promising in that it can provide viable and high-impact solutions in a short time frame, and can address several issues related to personal mobility at the same time [2]. As reported in [1], mobility demand spans all aspects of our life and by no means it reduces to home–work commute. Accordingly, effective systems to reshape mobility demand have to consider all aspects of our life, including free time and leisure.

* Corresponding author. Tel.: +39 3478004903.
E-mail address: nicola.bicocchi@unimore.it (N. Bicocchi).

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The increasing adoption of smart phones and social networking tools allow to collect large-scale information about the mobility habits of people, and can support advanced forms of sharing, coordination and cooperation that can drastically reduce the overall demand for mobility [3–5]. Specifically, our proposal is to develop a recommender system – to be integrated in smart phones, tablets, and in-vehicle platforms – capable of identifying opportunities for sharing cars and rides. In particular, such a system would:

1. Collect mobility information.
2. Identify routine behaviours.
3. Identify sharing opportunities (e.g., two users who do not know each other but live and work close by—familiar strangers [6]).
4. Recommend users about mobility alternatives.

The key novelty of our proposal is that our system is fully autonomous. Users do not enter their availabilities and needs explicitly. Sharing opportunities are automatically identified by analysing people mobility patterns, and are recommended when suitable conditions arise. This kind of unobtrusive and proactive approach could facilitate the application diffusion and improve its effectiveness [7].

The contribution of this paper is twofold: on the one hand, we present a methodology to extract suitable information from mobility traces. On the other hand, we describe the implementation of a prototypical system offering ride sharing opportunities on the basis of the extracted information.

The rest of the paper is structured as follows: Section 2 discusses related work in the area both in terms of data mining mechanisms for mobility data, and in terms of ride sharing applications. Section 3 introduces our approach for automatically discovering and labelling routine behaviours and describes some experiments conducted with two complementary real-world datasets. Section 4 discusses our proposals for identifying possible shared rides on the basis of the discovered routines, illustrates our implementation and discusses about privacy issues associated with these systems. Section 5 concludes the paper and illustrates further developments.

2. Related work

An increasing number of research proposals applies advanced data mining techniques on mobility data with the goal of improving mobility services in smart city scenarios. In this section, we analyse related work in the areas of both mobility analysis and innovative mobility services.

2.1. Mobility analysis

The availability of affordable localisation mechanisms and the recognition of location as a primary source of context information has stimulated a wealth of work trying to extract high-level information from raw mobility traces. While a complete survey is outside the scope of this paper, we present some exemplary researches trying to emphasise the novel aspects of our work.

The CitySense project (www.citysense.com) uses GPS and WiFi data to cluster people's whereabouts and discover hotspots of activity in the city area. In a similar work based on extremely large anonymised mobility data coming from Telecom operators authors were able to extract the spatio-temporal dynamics of the city, highlighting where people usually go during the day. The authors were able also to identify the most visited areas by tourists and the typical time of the visit (see for example [8,9]). While these works focus mainly on hot-spot identification, our approach goes further and is able to identify and label patterns and routine behaviours that will be useful to identify ride-sharing opportunities.

The approach proposed in [10] uses Principal Component Analysis (PCA) to identify the main components structuring daily human behaviour. The main components of the human activities, which are the top eigenvectors of the PCA decomposition are termed *eigenbehaviours*. Similarly, the work presented in [11] compares different data mining techniques to extract patterns from mobility data. In particular, they found that Principal Component Analysis (PCA) and Independent Component Analysis (ICA) are best suited to the task of identifying daily patterns. In comparison with these techniques, the topic model we propose has the advantage of capturing characteristic trends occurring over parts of the day (such as lunch time only), whereas eigenbehaviours tend to capture features over the entire day (see Section 3.4 for more discussion with this regard).

In [12,13] authors propose the use of probabilistic topic models to capture human routines from cell tower connections. Our work uses a more complex dataset, thus allowing to analyse the topic models method at a finer-grain scale with a higher number of places. As mentioned above, the geographic coordinates provided by our GPS and CDR datasets allow to enrich the location vocabulary with a higher number of places (in contrast with the 'home', 'work' and 'elsewhere' labels used in [12]). In addition, in our work we also present algorithms to automatically label topics in order to make them more understandable and useable. The M-Atlas approach is a recent proposal to extract patterns from mobility data [14]. M-Atlas creates an origin–destination matrix counting the number of repeated trips in the dataset. High-values in this matrix