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# Personalized location prediction for group travellers from spatial–temporal trajectories

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## HIGHLIGHTS

- Investigation of the location prediction problem with consideration of travel group types.
- Proposing a novel group discovery approach taking the people movement behaviour into consideration.
- Proposing a classification model to predict the type of the discovered groups.
- Proposing a novel location prediction model taking the general and group based rules into account.

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## ABSTRACT

In recent years, research on location predictions by mining trajectories of users has attracted a lot of attentions. Existing studies on this topic mostly focus on individual movements, considering the trajectories as solo movements. However, a user usually does not visit locations just for the personal interest. The preference of a travel group has significant impacts on the places they visit. In this paper, we propose a novel personalized location prediction approach which further takes into account users' travel group type. To achieve this goal, we propose a new group pattern discovery approach to extract the travel groups from spatial–temporal trajectories of users. Type of the discovered groups, then, are identified through utilizing the profile information of the group members. The core idea underlying our proposal is the discovery of significant movement patterns of users to capture frequent movements by considering the group types. Finally, the problem of location prediction is formulated as an estimation of the probability of a given user visiting a given location based on his/her current movement and his/her group type. To the best of our knowledge, this is the first work on location prediction based on trajectory pattern mining that investigates the influence of travel group type. By means of a comprehensive evaluation using various datasets, we show that our proposed location prediction framework achieves significantly higher performance than previous location prediction methods.



## 1. Introduction

With the rapid development of mobile devices and location acquisition technologies, an enormous amount of trajectory data recording the movement of people is available. These overwhelming amounts of data is tremendously useful for the rapidly growing location-based applications market. Due to various requirements of these applications, e.g., system efficiency and marketing efficacy, accurately predicting the next location to which a user may move is essential. The location prediction technique identifies the next location that is most likely to be visited by the user, according to a set of application-dependent locations or pre-determined locations. By knowing the next movement of users, resources can be efficiently allocated to the most possible location, rather than the blind resource allocation. Efficient resource allocation to mobile users would lead to higher resource utilization and lower latency in accessing the resources. In addition, predicting the subsequent location can provide the insights for many existing pervasive applications, such as targeted advertising and services recommendation [1].

The problem of predicting the next location where a user will move has received many research interests in recent years. As the location prediction process is very similar to the location

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recommendation, many existing works [2–4] intuitively applied a location recommendation approach as their location prediction model. However, there are a few difficulties in adopting the location recommendation for the location prediction. First, the location recommendation process is a non-real-time estimation which means that the recent movements of the user are not taken into account in making the recommendations. Second, conventional location recommendation methods only consider the interest of the user such that they suggest a new location that a user may be interested in. However, the problem of next location prediction focuses on inferring the next location that a user will visit which not only considers the user's interest, but also the intention of the user. People do not solely visit locations because they are interested, they also go to places because they have to. Consequently, it is not straightforward to apply these recommendation techniques in location prediction.

On the other hand, considering the fact that human movement exhibits sequential patterns, various sequential pattern mining techniques [5–8] have been developed for location predictions. These approaches address the location prediction as a historical movement matching problem. They usually consider the user's movement trajectory as a sequence of locations, and then, extract the frequent movement patterns from the set of trajectories. These frequent patterns then will be used as the prediction rules to be matched with the previous movement of the user. The difference of these approaches is mainly about the type of the movement pattern they discover. However, they did not take the personalization into account as their approaches just return the same sequence patterns for all the users.

To extract the significant movement patterns, the existing methods mine the frequent sequences of locations from individual user trajectories, such that they assume all the movements as the solo movements. Accordingly, the extracted movement patterns only reflect the individual intention/interest. However, it has been shown that people do not visit locations just for their personal intention/interest. They also go to places which are motivated by the group's intention/interest they travel with [9,10]. The preferences of the travel group, which may comprise very diverse people, have significant impacts on the places that users visit. Taking a family comprising two adults and a child who walking in a shopping mall as an example, considering only the individuals, i.e. parents, may lead to the different location prediction than when the group type, family, is taking into account.

In this paper, we propose a personalized framework to predict the next location of the users. The core idea underlying our proposal is the discovery of significant movement patterns by considering not only the individual movements, but also the group movements. We first, extract the groups of people who travel together, group travellers, from the spatial–temporal trajectories. Second, the profile information of the users will be used in order to identify the type of the extracted group. Third, the significant movement patterns will be discovered taking into account the group specific movements and individual movements. Finally, the problem of location prediction will be formulated as an estimation of the probability of a given user visiting a given location based on his/her current movement and his/her group type.

In order to extract the group travellers from spatial–temporal trajectories, we propose a novel group pattern, Loose Travelling Companion Pattern (LTCP), with taking into account the properties of human movement behaviour. Extracting the significant movement rules to support the prediction model is also a critical and challenging issue. We define two categories of significant movement rules: General sequential rules (SR) which refers to the movement rules considering the individual movement pattern, and Group-based sequential rules (GSR) which refers to movement patterns associated with the group types. Discovered movement rules then are utilized to construct the prediction model with further incorporating the distribution of places and group types.

The main contributions of this paper are summarized below:

- To the best of our knowledge, this is the first work that investigates the location prediction problem with consideration of group movement;
- We propose a novel group discovery approach to identify the groups of people who move together considering the human movement behaviour;
- We apply a classification model to predict the type of the discovered groups, utilizing the profile information of the users;
- We propose a novel location prediction model that takes into account the general movement rules and the group-based movement rules to predict next location of the user;
- We present comprehensive experimental results over various datasets. The results demonstrate that our proposed framework significantly outperforms the widely used sequential prediction technique.

The remainder of this paper is organized as follows. First, we briefly review the related work in Section 2 and present an overview of our proposed prediction framework in Section 3. Next, our proposed group pattern discovery approach and group type prediction technique are described in detail through Sections 4 and 5, respectively. The movement rules are discovered in Section 6, and the prediction model is constructed in Section 7. A real case study is introduced in Section 8. The performance of our proposal through an empirical evaluation study is discussed in Section 9. Finally, conclusion and directions for the future works are given in Section 10.

## 2. Related work

The problem of predicting the future location has been variously formulated in the literature. The first strategy is Vector Based Prediction model which estimates the object's future location through applying the motion functions. These approaches can be divided into two types: (1) linear models assume that object's movement follows a linear pattern [11–15], and (2) non-linear models, on the other hand, take into consideration both linearity and non-linear patterns in modelling the object's movement [16,17]. As the non-linear methods apply more sophisticated functions, they result in the higher prediction precision than the linear models. However, the motion functions are only able to predict the near future location. They also cannot differentiate between the random movement and regular movement of the object. These approaches are highly sensitive to the change in an object's movement, they cannot capture the sudden changes of the object as the function is only affected by the previous locations.

The movements of people contain a high level of regularity [18]. According to this fact, researchers have discovered the usefulness of extracting these regularities and applying them in order to predict the next movement of people. Accordingly, two prediction approaches have been raised: (1) discrete-time Markov model-based methods [19–22], and (2) trajectory pattern based approaches [23–26]. Markov model-based approaches extract a statistical method to estimate the next locations of the object among the spatial cells. They take which cell the object belongs currently into account, and then, calculate the next cell that the object is likely to be there in future. However, these approaches do not take the full movement history of the user into account. The new location depends on not only the last visited location but also on the previously visited locations.