Trajectory Aggregation for a Routable Map

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Abstract. In this paper, we compare different approaches to merge trajectory data for later use in a map construction process. Merging trajectory data reduces storage space and can be of great help as far as data privacy is concerned. We consider different *distance measures* and different *merge strategies*, taking into account the cost of calculation, the connectivity of the results, and the storage space of the result. Finally, we give a hint on a possible information loss for each approach.

Keywords: Trajectory Summarization, Trajectory Data, Subtrajectories, Movement Patterns, GPS.

1 Introduction

The amount of available trajectories of mobile users, in the form of GPS tracks, is rapidly increasing. A major underlying reason is the availability of cheap GPS receivers connected to the Internet. We assume that nearly every current smartphone has integrated GPS. According to [1], there were a total of 173.7 million smartphones shipped in the 3rd quarter of 2012, which was an annual increase of 44%. On the basis of these numbers, we can conclude a potential increase in users which are able to record GPS trajectories of 173.7 million quarterly.

The merging of trajectories is important for answering non-individual questions. Our motivation is the construction of a map based on trajectories. Map construction has recently gained popularity in scientific research. The ACM Digital Library lists 12719 publications with the keywords “map construction” for the period between 2008 and 2012 compared to 8196 in the period between 2003 and 2007 [2]. Nowadays, road maps are available in good quality. However, map construction can still be used to detect changes in the road network for various application. Additionally, map construction can be used for company territories and to create maps used in various outdoors activities such as sports, e.g., maps for racing bicycles. This has already been done for taxi driving directions [3]. Merged trajectories can help ensuring privacy requirements as well as reducing storage effort while still providing enough correct data to create a confident map with lower calculation effort.

One use of our approach is a further anonymization of data. Work has already been done in the anonymization of trajectory data. Nevertheless, this work often

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has another scope and the data is afterwards not used for map construction, but for other tasks, e.g., data mining of crowd movements [4–6]. In these approaches, one motivation is urban planning, and therefore complete trajectories are used. In our approach we split trajectories in order to be able to build a subtrajectory based on a larger set of trajectories and a lower distance in between.

We first need to define what we consider as merging of trajectories. A trajectory is the path that a moving object follows through space as a function of time. In our case, we consider a set of linear movements as a trajectory with the condition that every end point of a linear movement is a start point of another linear movement, except for the start and the end point of the whole trajectory. As the input to the merging process we have 2 or more trajectories. We define the output as the network of trajectories. Trajectories in a network can be connected at a node. The trajectories in the network have additional information, namely the number of trajectories which were integrated in the merged trajectory and the variance of the integrated trajectory. We abbreviate the network of trajectories as an aggregation and for clarity we call a trajectory which is a candidate to be merged with trajectories in the aggregation as a single trace.

The merging process is divided into two major tasks: the first task is the *selection of trajectories* or parts of trajectories to be merged and the second task is the merging itself.

This paper is organized as follows. Related work is dicussed in section 2. Section 3 discusses the selection of trajectories. Section 4 focuses on the problem of the merging of trajectories. In Section 5, we present our prototypical implementation. Finally, we present the evaluation of our system (Section 6) and our conclusions (Section 7).

2 Related Work

We consider methods from the field of computational geometry (such as spatial *distance measures*) as related work, as well as different approaches for map construction. The Fréchet distance is an important measure for the closeness of two trajectories. Its computation is described in [7]. In our case, it has to be applied for partial curves or subtrajectories [8]. Another spatial distance measure is the Hausdorff distance [9]. In [10], there is a comparison of trajectory *merging strategies* and a new merge process based on the Fréchet distance. The focus of this work is on objects in Geographic Information Systems(GIS) and their integration.

The most comparable approach to the trajectory aggregation discussed in this paper is the approach of incremental data acquisition [11]. In this approach, there is a road map as precondition and additional information from trajectories is added incrementally. The main difference in comparison to our approach is that we first build an aggregation and this is the input for constructing a map. Conclusively, our iteration step refines an aggregation and the iteration step described in [11] refines a road map. Other approaches rely directly on a set of GPS traces and have no iteration or refinement steps [12]. There are also