

Density Map Visualization for Overlapping Bicycle Trajectories

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Abstract

The trajectories of moving object include useful information on the traffic situation and user behavior. The visualization of vehicle trajectories aims to provide enhanced understanding of the given data. Recently, technological advances in the satellite tracking system and handheld device facilitated personal log tracking which shows different properties compared to the trajectories of motor-assisted vehicles. In this study, we propose a trajectory visualization method based on the density map which highlights the areas where the trajectories with different kinematic properties are intersecting each other. The proposed method divides trajectories into several groups according to the kinematic properties of the given trajectories and generates the density map for each group. Based on the density map, the intersection map which visualizes the area that the groups are intersecting was constructed. The intersection map was combined with the density map to show the influence of the intersected area. In order to evaluate proposed method, we collected the bicycle trajectories and visualized them. The results showed that our visualization method was able to provide some visual insights which is hard to be noted from previously proposed visualization methods.

Keywords: *Trajectory visualization, Density map, GPS, Bicycle*

1. Introduction

The trajectory of the vehicle contains valuable data on real time traffic which is not shown on a map, and it has been widely studied in transportation research field to analyze the traffic environments, vehicle status, and user behaviors [4-6]. In order to assist the vehicle trajectory analysis, researchers on information visualization suggested some trajectory visualization methods which emphasize the meaningful features of the trajectories in various ways [1, 2]. Most of the previously proposed trajectory visualization methods were focused on the travel path of motor vehicles (i.e. motor vehicle, airplane, and vessel) because of technical limitations. However, as the technology of the satellite tracking system and handheld device improved and came into wide use, it became easy and popular to collect the travel log from daily lives.

The travel trajectories are different for the transportation modes [3]. Suppose a pedestrian, bicycle, and motor vehicle traveled on a same section of a street. Their trajectory outlines could be similar. However because of their different behaviors, the kinematic properties (i.e. speed, acceleration, and heading direction) and the detail of the moving trajectories will be dissimilar to others. In this paper, we propose a trajectory visualization method which is

proper to visualize objects with a complex travel path and overlapping each other. In order to support the understanding of the trajectories, the proposed method divides the trajectories according to the kinematic properties and generates a density map for each trajectory group. The main contribution of this study is to visualize the differences and similarities among the density maps generated based on the trajectory groups and provide information concerning the interaction among the trajectories. The intersection between density maps was examined and utilized as a different type of density map. The proposed method was applied to the visualization of the bicycle trajectories collected from a segregated bicycle track.

Detail of the proposed method and implementation will be shown in Section 2. The experimental visualization results will be shown in Section 3. In Section 4, we draw conclusions and suggest future work.

2. Method

The proposed method divides the trajectories into several groups according to the kinematic properties of the trajectory points. The kinematic properties can be speed, acceleration, or heading direction.

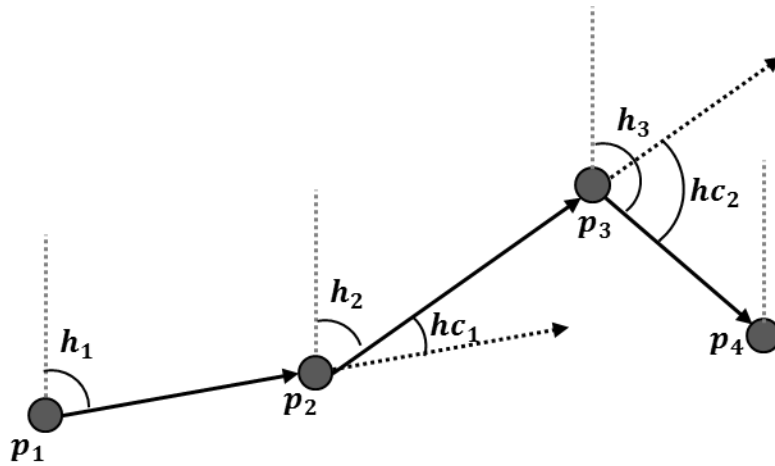


Figure 1. Kinematic properties of trajectory points

Figure 1 shows the kinematic properties which can be calculated with trajectory points. p_{1-4} denotes the positions of the trajectory points and h_{1-3} show the heading directions at each positions. The differences between two adjusting heading directions are shown as hc_{1-2} .

With the divided trajectories, the density maps were generated for each group with the kernel density estimation. The Gaussian density kernel was applied to construct the density map. After the density map generated, the intersection map which represents the intersection area among the density maps was generated.

$$i_{(x,y)} = \begin{cases} d_{(1,x,y)} + d_{(2,x,y)} & \text{if } (d_{(1,x,y)} > 0 \text{ and } d_{(2,x,y)}) \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Equation (1) shows the building process of the intersection map. $i_{(x,y)}$ denotes the value of intersection map at the position of x and y , and $d_{(i,x,y)}$ is that of the density map with group number i . In order to highlight the intersection map values and provide more effective visual information, the intersection map was combined with the density map. The value of the intersection map was subtracted from ($r_{subtract}$) or added to (r_{add}) that of the density map.

$$\begin{aligned} r_{add} &= d_{(i,x,y)} + i_{(x,y)} \\ r_{subtract} &= d_{(i,x,y)} - i_{(x,y)} \end{aligned} \quad (2)$$

3. Experiments

The proposed method was applied to bicycle trajectories collected from the segregated bicycle track in Seoul. Collected trajectories were divided into two groups according to their heading direction which was noted as h_{1-3} in Figure 1. Figure 2 shows the density map of entire bicycle trajectories. The color gradient changing from green to red shows the density of bicycles.



Figure 2. Density map of bicycle trajectories

Figure 3 and 4 show the example of the experimental results. These figures show detailed visualization of marked “A” area on the Figure 1. The marked area is one of the most crowd bicycle paths. The trajectories collected from area A were divided into ‘East to west’ and ‘West to east’ groups. From the top-right image of Figure 3, highly intersected trajectories can be found on the corners. These trajectories were also extracted to the intersection map (image B in the figure). From the intersection map, we can find the area with high density which can be interpreted as the area with many bicycles moving in the opposite directions.

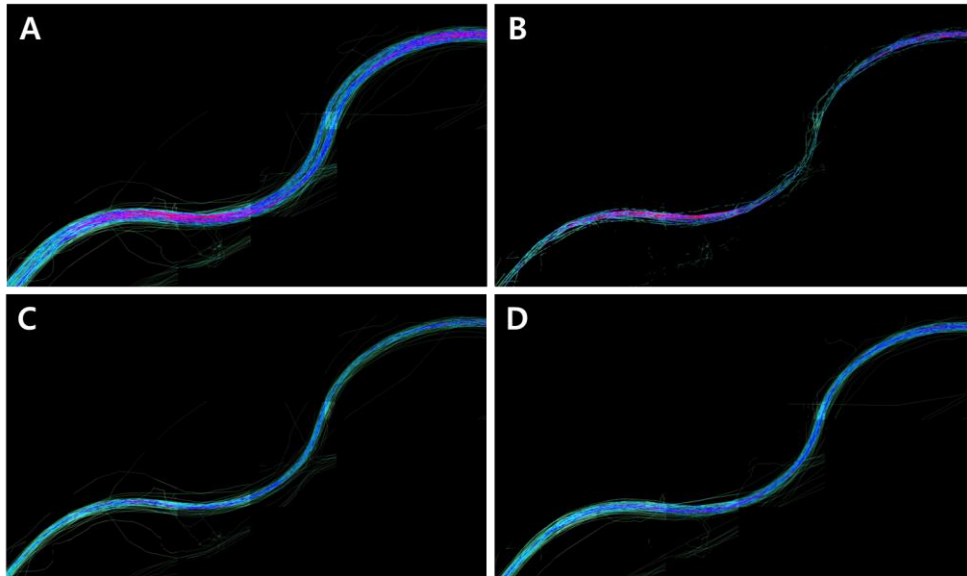


Figure 3. Density map of marked area in Figure 1 (A: density map of whole trajectories, B: intersection map, C: density map of group 1, D: density map of group 2)

The combinations of density map and intersection map are shown on the Figure 4. The images on Figure 4 visually indicate the effect of the intersected trajectories. From these images, we can compare position and distribution of the intersected trajectories with other trajectories, and so the influences between trajectories on the opposite directions can be estimated

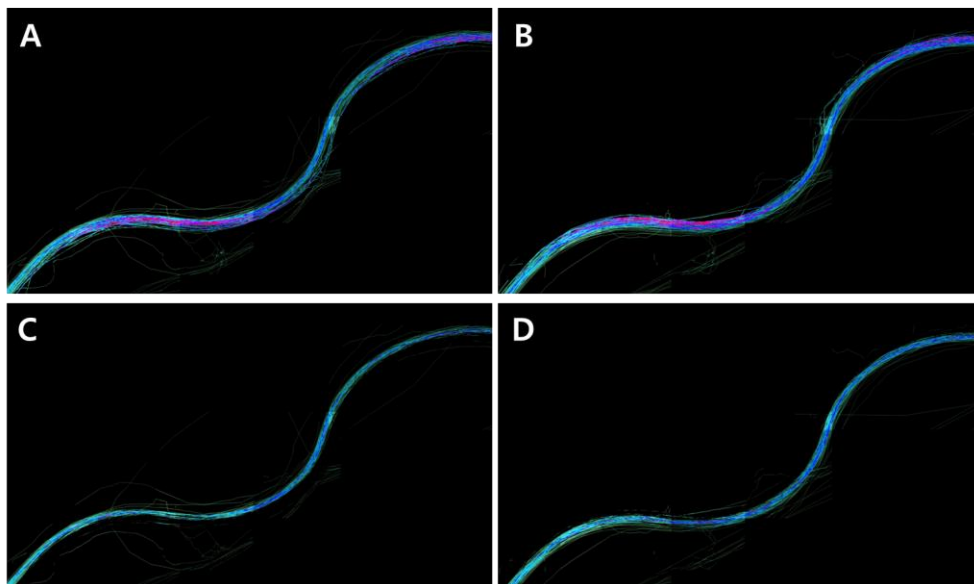


Figure 4. Density maps combined with the intersection map (A, B: intersection map added to group 1 and 2 density map, C, D: intersection map subtracted from group 1 and 2 density map)

The high density area which colored purple to red was about 5% of the whole inspected track. In order to find the extract more meaningful information from the density and intersection map, such as the relationship with bicycle crash risk or safety information, further investigations are needed.

4. Conclusion

In this paper, we proposed a density map visualization method for low speed and intersecting trajectories. The proposed method focused on the fact that the kinematic properties of the low speed objects are more complex than those of the fast speed objects such as a motor vehicle, airplane and vessel. Based on this idea, we divided the trajectories into several groups based on the kinematic properties of the trajectory points. With the grouped trajectories the density maps were constructed. Based on the density maps, the intersection map which shows the intersecting area among the density maps was generated and combined with the density maps to provide more effective visual information. The proposed method was tested with the bicycle trajectories, and showed its usefulness to find the high density areas.

For the future work, we will attempt the relation between the bicycle crash risk and the high density areas. Several risk analysis models will be utilized with the crash spot information.

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