Recommend Driving Area-Route Based on Taxi Trajectory Experience

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Abstract*—As the era of big data has arrived, it is no longer a problem to obtain sufficient GPS data for research and practical applications. The taxi trajectories contain the driving experience of the taxi driver. In this paper, we will use the trajectory experience of taxis to recommend the driving area-routes. We propose a grid method that can extract the trajectory information of a specific road segment efficiently. Then, we use the processed information to form a probabilistic statistical model of the recommended route. We compare the recommended routes at different times, and compare the recommended routes with the routes in Baidu navigation. It is recommended to select the optimal route according to different time periods, and the recommended routes are basically consistent with the results in the navigation.

***Keywords*—taxi trajectory, grid method, route recommendation**

I. Introduction

Given the increasingly complex traffic network and the increased traffic flow, how to develop an effective driving route recommendation strategy has become an inevitable topic in the transportation field. An efficient recommendation strategy not only allows travelers to reach their destinations faster, but also eases traffic jams. Taxi drivers generally have a wealth of driving experience and will choose the most efficient route to reach their destination to get the most profit. When selecting a route, they will consider distance, potential traffic congestion, traffic lights and other traffic information. These traffic factor considerations are learned by experienced drivers, which imply that the intelligence of experienced drivers may serve as a valuable resource to learn practically fast driving route[1],[2].According to [2], they built the model to learn a user's driving behavior from the user's GPS logs, Web maps, and weather forecast, and customize the fastest route for the user with the help of the Cloud.[3],[4] analyze objects' movement that extracts motion patterns and identifies frequently traveled paths to immediately identify popular routes.

In the past, analysis of traffic flow on the road will map the GPS trajectory data to the vector digital map or the topology of the road. However, there are some problems: First, the accuracy of the matching algorithm cannot be guaranteed due to the instability of the sampling interval of the trajectory; second, the time complexity of the matching algorithm is very high and it is expensive to process a large amount of trajectory data. Actually, the matching algorithm is a process of clustering similar trajectories into the same road. The grid-based method proposed in [4] can efficiently extract similar trajectories from a large number of trajectories. In [6] and [7], grids are used to find patterns in taxi data. In [8], popular routes are constructed using the frequency information of grid cells. And in the absence of a digital map, the topology of the road can be well preserved through a large amount of trajectory data.

So, in this paper, we make the following contributions:

- We propose a grid method to process taxi trajectory data instead of using map match algorithm and digital vector map
- A regional correlation algorithm is proposed to perform statistical analysis on the direction selection of the recommended route.
- We establish an Area-Route recommendation model based on the knowledge of taxi driver to recommend driving Direction.

II. Dataset

A. Dataset Exploration

The dataset includes 500 thousand trajectories each day during a week in Beijing. Each trajectory records longitude, latitude coordinates and acquisition timestamps. The time interval of acquisition varies from 10 seconds to 2 minutes.

B. Dataset Processing

Coordinates in GPS are represented by longitude and altitude, which cannot be applied in plane calculations directly. As UTM is a projected rectangular coordinate system represented by X and Y, we will convert GPS coordinates into UTM coordinates.

Data acquisition frequency plays an important role in the selection of grid size. The selection of the grid size should conform to the principle that the road structure in the grid should be as simple as possible. This makes the grid as small as possible to some extent. However, the smaller the grid, the greater the influence of the time interval of the track point sampling and the sampling error, and the track information cannot be extracted well. We choose the trajectory whose acquisition frequency is not higher than 60 seconds and the grid size of 200 meters multiplied by 200 meters to carry out this experiment. In addition, we extract the index of the grid through which the trajectory passes, the UTM coordinates in and out of each grid, and the corresponding time.

III. Preliminaries

A. Grid Method

The grid method extracts the taxi trajectory and reduces the amount of data describing the trajectory while maintaining the trajectory's characteristics. It converts the original series of coordinates into the index of the grid through which the trajectory passes, and makes the calculation of the massive trajectory data more efficient. In addition, the grid method can effectively map the trajectory to the actual coordinate area instead of the complex and time-consuming map matching algorithm.

The grid method divides the two-dimensional space into n*n square grids, each of which has four equal sides (m meter) for in -out directions. As shown in Fig. 1, the area is divided into 3*3 square grids. G_n is the grid index and each grid has a side length of 1000 m. The track entrance-exit directions are sequentially labeled as 1, 2, 3, and 4 in a clockwise direction.

As shown in Fig. 2, we have gridded the trajectories on the three-ring area of Beijing. The red outline structure of the road network in the figure is formed by a large number of taxi track points.

After the trajectory with a series of coordinates is processed by the grid, the trajectory information $G = \{g_0(d_1, d_2), g_1(d_1, d_2), g_2(d_1, d_2), \ldots\}$ can be extracted, g_n is recorded as the passing grid index, d_1 is the direction into the grid, and d_2 is the direction out of the grid. As shown in Fig. 3, the blue points are the recorded track points, labeled $T_n(x_n, y_n, t_n)$ containing horizontal and vertical coordinates and time point information. The blue line is the real trajectory. The red line uses the line between the two track points to simulate the real trajectory, and the boundary with the grid will form an entry-exit point, denoted as $M_n(\bar{x}_n, \bar{y}_n, \bar{t}_n)$.

B. Area-Route Recommend

In daily life, the driver who is familiar with the road structure, but because of the complexity of the road conditions, does not know which way to go. Area-Route Recommend is a good solution to this problem. It takes experience from the trajectory of a large number of taxi drivers and recommended general direction and route area. This is very in line with the way people think. When recommend the route, usually don't need to express the specific road to go. The driver only needs to remember the key areas and directions to go through. The recommended Area-Route is denoted as Path $= \{G_1, G_2, G_3, G_4 \ldots\}$ and G_n is the passed grid number.

IV. Area-Route Recommend

A. Progressive Region Approach

We propose a progressive region approach to recommend route regions by moving closer to the region where the target grid is located until the target grid is reached. The area around the grid consists of some annular areas surrounding the grid and spreads out. The center grid is the destination grid, and each circle that expands outward is a region R_n. Fig. 4 shows the correlation of the ring region (0 ring refers to the target grid itself) to the target grid, recorded as α_m.

$$\alpha_m = \frac{N(R_m, G_e)}{N(R_m)} \#(1)$$

N() denotes the number of tracks, and $N(R_m, G_e)$ is the number of track that passes through the annular range R_m and reaches the destination G_e. $N(R_m)$ is the number of tracks pass through R_m.

The grid method divides the two-dimensional space into a plurality of square areas, recommending the area to be passed by the user. The recommended path area is denoted as $P = \{G_1, G_2, G_3, G_4 \ldots\}$ and G_n is the passed grid number. Record that the current grid is G_c, there are four optional directions D_1, D_2, D_3, D_4 can choose to enter the next grid G_d, the destination grid is G_e, and we define the annular region R_n around the G_e, as show in Fig. 5, in the right corner. Then the probability of going out from each direction is

$$P_n = \alpha_0 N(D_n, R_0) + \alpha_1 N(D_n, R_1) + \cdots + \alpha_m N(D_n, R_m) \#(2)$$

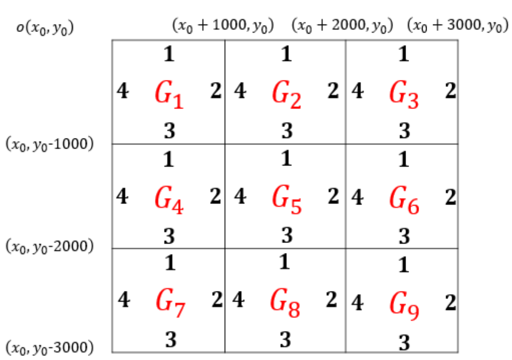


Fig. 1: Area gridding processing method

Fig. 2: Partial picture of regional gridding in Beijing

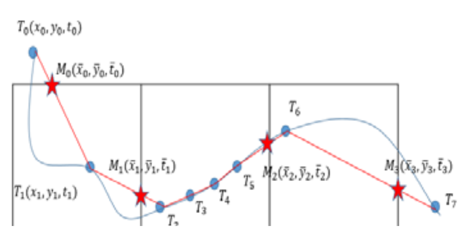


Fig. 3: Grid processing of tracks in the area

$N(D_n, R_m)$ is the number of track that passes through the direction D_n and reaches the destination annular region R_n, as the left picture of Fig. 5.

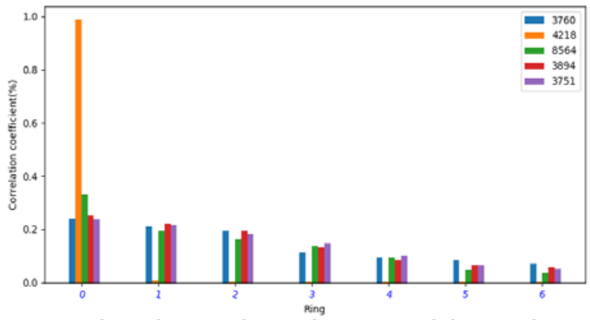


Fig. 4: Correlation between the annular region and the central region (analysis of the 3760, 4218, 8564, 3894, 3751 grids)

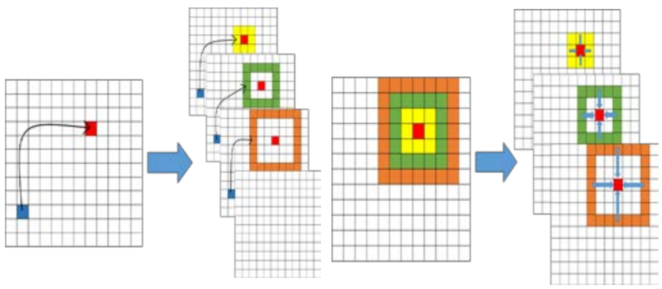


Fig. 5: Ring region decomposition of the destination grid

The motivation for defining a ring-shaped region is that sometimes there is no common trajectory between the two grids and no recommendation can be made. The annular region expands the range of the destination grid and increases the probability of retrieving a common trajectory. In addition, it is very important that the Beijing city road structure is a checkerboard-type vertical intersecting road network. The traffic flow of the central grid and the surrounding annular area will have mutual influence.

B. Trajectory Probability Analysis Over Time

Since the traffic flow is dynamic, the selected path will change over time. Fig. 6 shows the statistics of the number of trajectories from two different directions of one grid to another as time passes.

The distribution indicates that most of the time the taxi will more prone to take the 2 directions to reach the destination grid, but the trajectory in the 1 direction will be slightly more than 2 directions from 16:30 to 15:30. Since we collect data for one week, we can eliminate the accidental situation. The possible reason is that the 2 directions are prone to traffic jams and the number of vehicles in the 1 direction is increased. According to this characteristic, we divide the time period. In the calculation of $N(D_n, R_0)$, we count the number of trajectory within half an hour of the recommended time.

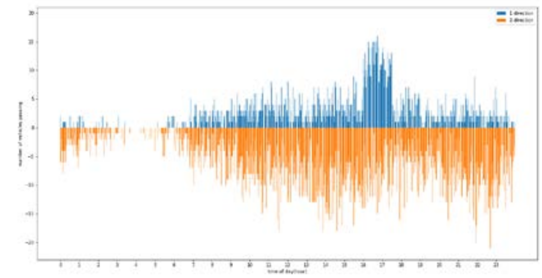


Fig.6: The number of trajectories starting from different directions to the destination grid (From two directions of grid 7587 to grid 5517)

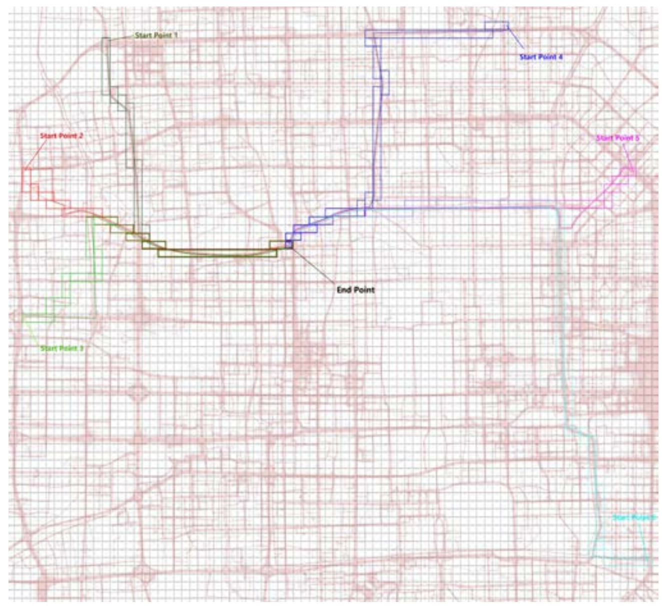
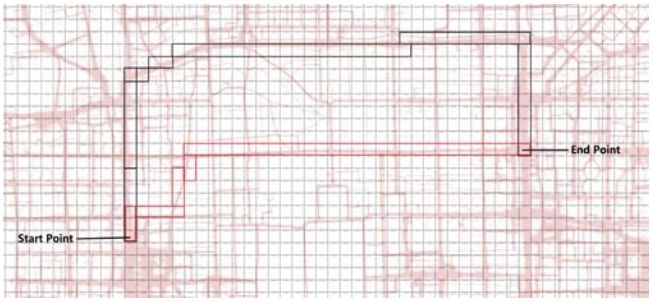


Fig. 7: Recommended test on the ring road

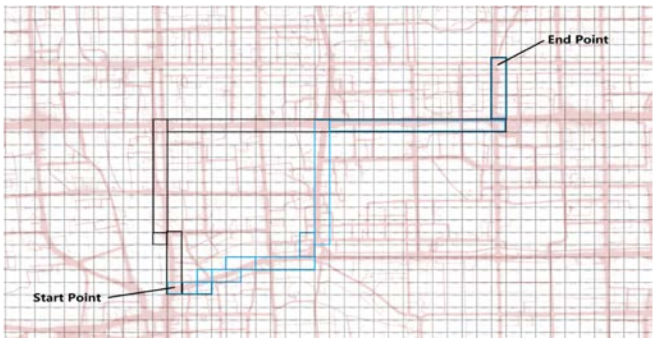
V. EXPERIMENT

We tested on the loop in Beijing and experimented six recommended area-routes for the same endpoints at different starting points at 8:00 am. We compared the recommended results with the recommended results of Baidu map, and the results are shown above (Fig. 7). The continuous color squares are the recommended regional routes of the model, and the solid color lines are the specific routes recommended by Baidu map. The comparison shows that except for the red, green, and pink paths, there are some inconsistencies, and the other routes are consistent.

In addition, we also conducted recommended tests at different time periods, as shown in Fig. 8 (A), during the peak period (approximately 8:00 am to 9:00 am, 16:00 pm to 18:00 pm), the red path is recommended. The black path is recommended for the rest of the time. Although the black path is longer than red, it is a loop and there are fewer red lights, which results in shorter time. Drivers prefer to follow this path. In Fig. 8 (B), the test corresponds to Fig. 6 in which driver is more inclined to take the direction 2, so the blue line is recommended most of the time, but during the peak hours, the driver will gradually turn black because the blue line is getting congested. And the black path will be



A



B

Fig. 8: Recommended test at different time periods

recommended at this time.

VI. CONCLUSION AND FUTURE WORKS

A. Conclusion

In this paper, we propose a model for fuzzy recommendation of driving routes based on a large number of taxi trajectories. We dig the driver's driving experience from the taxi trajectory data to recommend an efficient driving area in a certain time. Because the acquisition of road network structure information and the credibility of map matching algorithm are quite difficult, this paper uses the grid method to process a large amount of trajectory data, and it is faster and more efficient.

B. Future Works

The size of the grid can be compared. The time interval of coordinate acquisition plays a key role in the selection of the grid. How much grid can extract the trajectory features corresponding to the time interval can be further tested. Since some roads are separated by a corner of the square and are difficult to group on one side. The shape of the grid can be further tested, like a hexagon or a shape with more sides. The hexagon can handle such problems better.

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