Accuracy Analysis of User Location Prediction using Lagrange Polynomial

Rehenuma Tasnim Rodoshi, Wooyeol Choi*
Chosun University

Abstract

User location prediction is an important field of research in different communication environments. It means forecasting the future location of the user by the use of a technique following past movement history. In this work, we have utilized the extrapolation capability of the Lagrange polynomial method to get the future location of a moving user for the next timestamp. We have taken into account the location of the user as coordinates in two-dimensional space with respect to time. Analyzing the previous timestamp location coordinates, we have predicted the future location of the next timestamp using Lagrange polynomial.

Ⅰ. Introduction

With the improvement of technology, the population of users is also exponentially growing. In a mobile network environment, the mobility of users has a significant impact on the performance of the network. The mobility of users is not purely random, preferably direction oriented, which can be learned after monitoring the movement pattern. The future location of a user is predictable on a spatial and temporal basis [1].

Lagrange polynomial is a useful method for producing an approximation for an arbitrary function [2]. In this work, the applicability of the user location prediction is considered for the communication environment. With the prediction result, different tasks such as resource allocation, user association, and handover management can be done. There are some research works using Lagrange polynomial that predicted user trajectory for ultra-dense networks [3, 4]. They performed interpolation-based calculations for generating trajectory and derived the direction of a moving user from the slope of the trajectory.

Unlike these works, we performed an extrapolation-based calculation for deriving the future location of a user. The location is calculated in a two-dimensional space with respect to time. Using the past location record of a user from a few consecutive time stamps, we utilize the extrapolation capability of the Lagrange method to get the future location of the next timestamp. Generating future locations can be very useful for developing algorithms in different communication environments.

Section II discussed the Lagrange polynomial generation for user location prediction. The performance of the proposed method is evaluated in Section III. Lastly, the paper is concluded in Section IV.

Ⅱ. Lagrange Polynomial for Location Prediction

For the mobility pattern of the user, we have used the directional random walk model of the user. In this model, a user travels to a randomly selected destination with randomly selected speed and direction. We considered the user speed and direction following a normal distribution. For analytical convenience, we have initialized the user position as polar coordinates and then converted the position to Descartes coordinates. Based on the position of the user obtained, we simulate the path of the user using Lagrange polynomial. For the calculation of position with respect to time, the user
location is considered in a two-dimensional plane. Lagrange method can generate a polynomial using these coordinates to describe a user’s moving path.

At time $t$, the location of a user with respect to time in the 2D space is $(t_i, (x_i, y_i))$, where $i = 1, 2, ..., n$. We can get the position coordinates of the user for $n + 1$ number of data points for degree $n$, where $n = 1, 2, ..., t - 1$. We can generate a polynomial function $P(t)$ of degree $n$ using the Lagrange method. The formula of the polynomial for degree $n$ to calculate the $x$-axis of user location can be written as

$$P(t_x) = \sum_{i=1}^{n} x_i \prod_{j \neq i}^{n} \frac{(t - t_i)}{(t_i - t_j)}$$

where $j = 1, 2, ..., n$, and $j \neq i$. Here $t$ is the time for which we will approximate the location of the user. Similarly, the formula for $y$-axis calculation with respect to time can be written as

$$P(t_y) = \sum_{i=1}^{n} y_i \prod_{j \neq i}^{n} \frac{(t - t_i)}{(t_i - t_j)}$$

where $t$ is the timestamp value in seconds.

III. Performance Evaluation

The performance of our proposed approach is evaluated by simulation in MATLAB. We have taken four data points as the time and location coordinates of the user. The effect of the number of data points is analyzed in [4]. Increasing the number of data points result in decreasing the accuracy of the result [4]. The original user trajectory and the predicted user trajectory is shown in Figure 1.

In figure 1, the red circle represents the predicted future location using the extrapolation by the Lagrange method. The blue line is the original random walk trajectory of the user. The red line is the predicted trajectory using 4 data points by Lagrange extrapolation. As we can see from the figure, the extrapolated trajectory is very close to the original trajectory. Although Lagrange cannot approximate the accurate coordinates, it is still significant because it is very close to the original trajectory. It can be used to decide on the user or networking environment based on the predicted future location.

IV. Conclusion

User location prediction can be very effective in communication environments. In this work, we have utilized the extrapolation capability of the Lagrange method to predict the future location and trajectory of a user. We have validated the theory and showed the result of performance evaluation by simulation. The predicted user location and trajectory can be used for resource management, user association, handover management, and other tasks in different networking environments.