ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ

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DETERMINATION OF THE VEHICLE LOCATION IN CASE OF INCOMPLETE GPS DATA

Анотація. Дана робота пропонує рішення для визначення місцерозташування транспортних засобів у разі неповних даних від GPS і маршруту складної форми. Інформація про місцерозташування необхідна для прогнозування часу прибуття транспорту на зупинках. Прогнозований час можна показувати на сайтах та інформаційних табло на зупинках, що є важливим для пасажирів, зменшує час очікування і робить рух транспорт передбачуваним.

У роботі пропонується використовувати нейронну мережу для визначення точного місця локації транспорту на ділянках маршруту складної форми і при неповних даних від GPS.

Аннотация. Данная работа предлагает решение для определения местоположения транспортных средств в случае неполных данных от GPS и маршрута сложной формы. Информация о местоположении необходима для прогноза времени прибытия транспорта на остановках. Прогнозированное время можно показывать на сайтах и информационных табло на остановках - что крайне важно для пассажиров, уменьшает время ожидания и делает транспорт прогнозируемым.

В работе предлагается использовать нейронную сеть для определения точного местоположения транспорта на участках маршрута сложной формы и при неполных данных от GPS.

Abstract. The present paper gives the solution for one particular problem of the transporting system. We determine precise location of the vehicle in case of incomplete GPS data and complex shaped route. Information about real time location is necessary for predicting the arrival time of vehicle on final or intermediate destinations. Predicted arrival times can be shown on information boards and sites in order to reduce wait time of passengers. When GPS data are received rarely, accuracy is low and the route is complicated, determination of the exact location of the vehicle on the route by GPS data is not trivial. The paper suggests using several neural networks, placed in complex shaped segments of the route in order to determine precise location of the vehicle within those segments.

Introduction

The present paper gives the solution for one particular problem of the transporting system. We determine precise location of the vehicle in case of incomplete GPS data and complex shaped route. Information about real time location is necessary for predicting the arrival time of vehicle on final or intermediate destinations. Predicted arrival times can be shown on information boards and sites in order to reduce wait time of passengers. When GPS data are received rarely, accuracy is low and the route is complicated, determination of the exact location of the vehicle on the route by GPS data is not trivial. The paper suggests using several neural networks, placed in complex shaped segments of the route in order to determine precise location of the vehicle within those segments.

Formulation of the problem

GPS tracking technology is used in many countries in order to ease the solving of the issues connected with public transport system. GPS tracking technology helps to predict the arrival times precisely and display on the information boards and information sites. It is especially useful for passengers as they will need less time for waiting their transport in rainy and cold days. Many other issues of the transport system can be solved successfully with good tracking system.

Knowing exact real time location of vehicle is the key for all the tasks that arise in transport systems. The location information is transmitted from vehicle to the information centers. The frequency of transmission of the GPS coordinates is important parameter for tracking system. With more frequent transmission of coordinates we can determine the real time location with more precision. The GPS tracking technology is good, but not cheap solution for transport system. Sometimes the frequency of transmission of GPS data is reduced, in order to reduce costs of tracking system. If the accuracy of GPS equipment is not very good, period between two neighbor coordinates of GPS is quite big, the shape of route is complex - the determination of precise location of the vehicle on the route is not trivial task.

The present paper gives the solution for determining vehicle location in case of above mentioned incomplete GPS data and complex shaped routes.

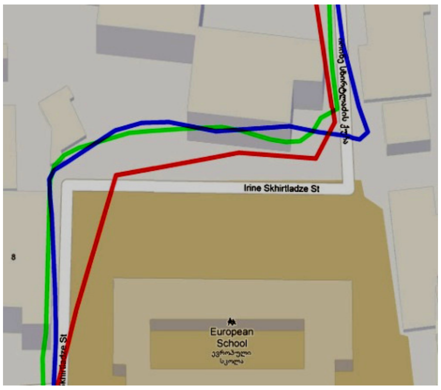
As a tool for solving above mentioned task, we choose the neural network.

GPS accuracy

GPS data can be not very accurate, see picture 1.

There are 3 GPS tracks of one route. All GPS tracks were been taken with same GPS device. Data are taken in different days.

The error is noticeable. GPS track is not along real route (street). Error is bigger when vehicle moves between big houses or on serpentine roads with high bounds. In this picture we use GPS point frequency about 1-2 seconds. In practice, we have time delay between 2 neighbor points about 30 seconds (and even more in some transport systems).

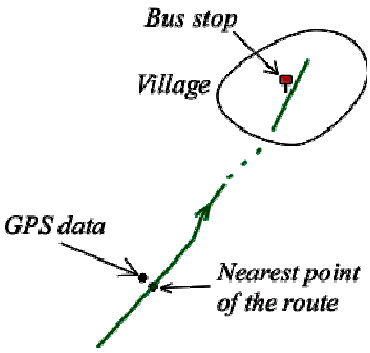


Picture 1 – GPS accuracy

Different types of the routes

In this paper we assume, that location of the bus is needed in order to predict the arrival time on the bus stop.

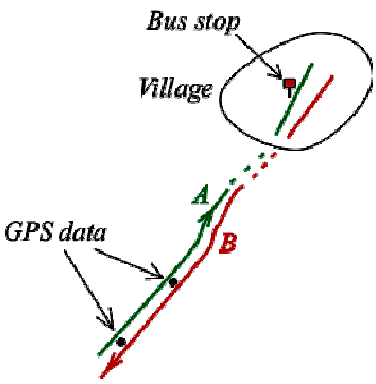
If the route of the vehicle is simple, the location can be determined easily. Assume that we have bus stop in the village and the bus is going from town to village. See picture 2.



Picture 2 – Simple route

Note, that, point received from GPS is not precise location. GPS has level of accuracy and it may be not sufficient in every case when it is used. In this simple case, we can find the point of the route, which is nearest to the point received from GPS device and assume that we found the location. Once we determine the location, we can predict arrival time to the bus stop and show this time on the bus stop board located in the village. I.e. in this case, the nearest point of the route is our solution.

Consider the other situation, which is more common case in real life. See picture 3.



Picture 3 – Common route

In this case, bus can go along two routes:

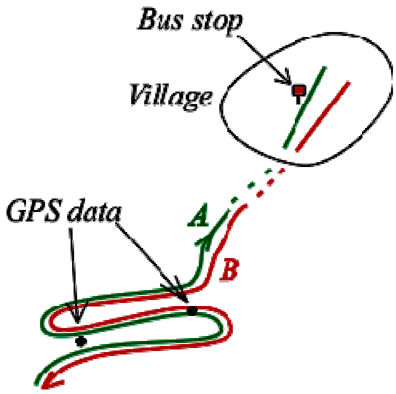
Route to the village,

Route from the village.

At first, we should determine on which route is going the bus. It is obvious, that only one point of GPS data will be insufficient in this situation. We need at least 2 points. Then we should calculate direction of the bus via these two points and compare it with directions of A and B. Comparison of directions of the routes with the direction of the bus is sufficient in order to choose right direction. Note, that directions of moving bus, determined with GPS data (call this direction GPS direction), will not be exactly equal to the direction of route because the GPS data can be not very accurate. So, we should compare GPS direction with both routes and determine closest one.

Consider the other situation. When village located in mountains, there can be serpentine routes to that village. When moving on serpentine routes, GPS receiver accuracy may be less than on straight road and open space.

See picture 4.



Picture 4 – Complex route

In this situation even two GPS points may be insufficient to determine right route of the vehicle. We need more points and new algorithm.

When the route is more complex, more GPS points are needed. The algorithm can be very complex.

In this paper we suggest using the neural networks to determine the location of vehicle in case of complex shaped routes. Our goal was to find the method, which would be work in almost any situation.

Neural network for location determination

It is possible to determine the route on which the vehicle is going, if A and B routes and several (4-5) points from GPS are given. Practically in any case, 4-5 points are enough to be sure in correct result. So, we can take neural network and train it for particular, complex shaped part of the route. This network will be responsible only for its part of the route. The output of the neural network will be route A, or route B (or another route, if such exists).

Once the correct route is determined, the exact location on this route can be found without big problems. We will not discuss latter problem in this document.

We use one layer RBF network [1] and [2]. Network has n inputs $x_1, x_2, \cdots, x_n \in R$. If we want to consider p points of GPS data, we should take neural network with n=2p inputs.

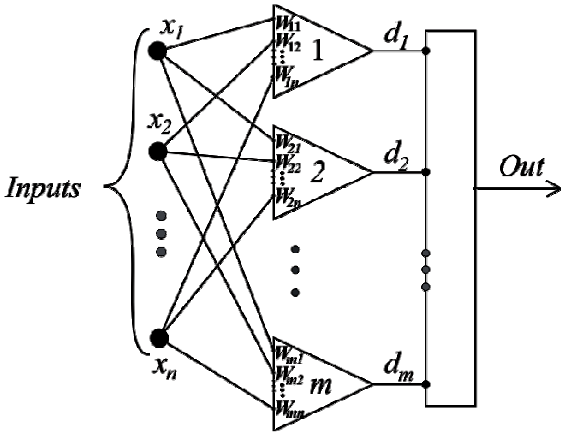
Neural network inputs are connected with neurons of the network. Neuron layer consists of m neurons. The number of neurons can be taken arbitrary but, note, that small count of m may be not enough to represent all the combinations of GPS data.

Neurons have n inputs and n weights for each input. Neuron calculates Euclidean distance between inputs and weights and gives this distance d as output of neuron.

We call neuron active neuron, if weights are calculated during learning process.

Decision making process of our neural network includes following steps:

1. Sample vector with n coordinates $x_1, x_2, \cdots, x_n$ is applied as inputs of the network. If we have 3 GPS points $(p_{1x}, p_{1y}), (p_{2x}, p_{2y}), (p_{3x}, p_{3y})$ the 6 inputs of the neural network will be $x_1 = p_{1x}; x_2 = p_{1y}; x_3 = p_{2x}; x_4 = p_{2y}; x_5 = p_{3x}; x_6 = p_{3y}$.



Picture 5 – Neural network

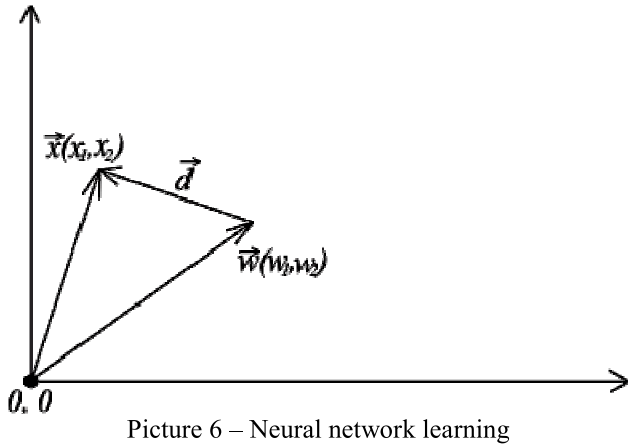
2. All the inputs of the network are connected with all the neurons of the network. First input of network is connected with first input of all the neurons, the second input of network is connected with second input of all the neurons, …, …so, the inputs of all the neurons will are the same $x_1, x_2, \cdots, x_n$.
3. All the active neurons make decision, i.e. calculate Euclidean distance *d* between inputs and corresponding weights and give this distance as neuron output.
4. The winner is the active neuron with minimal distance d.
5. The answer of the neural network is the index of the winner neuron if the output of this neuron is less or equal to *v* (neuron visibility). The answer of the neural network will be undefined if all the neuron outputs are more than *v*.

Each active neuron is associated with route A or route B (or other route if such exists). The answer of neural network is particular route. Finding location of the bus is much easier process when particular route is found.

Neural network learning

Several active neurons are needed inside neural network in order to get network answer. Active neurons are neurons which weights are obtained during neuron training (learning) process. We get p GPS points in order to determine corresponding route, compose n inputs for network and make network to learn this input vector. I.e. we have so called "learning with teacher" process. Particularly learning process includes following steps:

1. We put input vector into neural network inputs.
2. Network inputs are distributed to active neurons.
3. Active neurons calculate their outputs.
4. If minimal output is less or equal than *neuron visibility,* we slightly modify neuron weights – made them closer to input vector.
5. If minimal output is more than *neuron visibility*, or there are no active neurons yet, we take free (not active) neuron and made its weights equal to initial vector. This free neuron becomes active neuron.

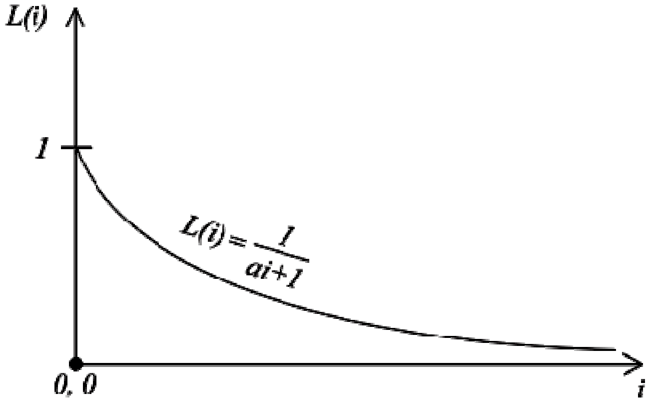


Picture 6 – Neural network learning

The weights of the active neurons are modified during learning process. New weights are obtained from old weights, input vector and the learning step counter. Each neuron has own counter. The counter increases by 1 after each learning step of the neuron. Modification vector size became smaller when learning counter increases.

$$\vec{w}_{i+1} = \vec{w}_i + L(i)\cdot(\vec{x}_i - \vec{w}_i)$$

$\vec{w}_{i+1}$ are the new weights, $\vec{w}_i$ old weights, $\vec{x}_i$ input vector, i is learning coutnter of the neuron, $L(i)$ can be arbitrary decreasing function. We choose $L(i) = \frac{1}{a\cdot i+1}$.



Picture 7 – Neural network

Summary

When we need to find vehicle location on the route, at first we need to find the correct route (if there are several routes near coordinates received via GPS). The route is found via neural network. The radial based function network is used to find the route. For each complex shaped route we take one network and this network is responsible for that region of the route.

We take the data about routes of buses and minibuses in Tbilisi. Time between neighbor GPS points is about 25 seconds. Network with 100 neurons are enough for every complex part of route.

Our approach is simple and effective. The training process is trivial in almost any type of route. The network is trained via real GPS data, therefore, recognition is good.

In more complex cases, we suggest to add the GPS point time data to neural network inputs. In that case, scale the time coordinate in order to make them close to spatial coordinate values.

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