

GENETIC BASED ROAD SELECTION FOR TRACKING SYSTEMS

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ABSTRACT

As land-vehicles almost always moves on roads, most of vehicle tracking systems, projects the vehicle positions on digital road segments. Vehicle tracking systems generally use dead reckoning and global positioning system (GPS) in order to get geographical vehicle position information. These positioning technologies have limitations either in accuracy of the absolute position, accumulated error or availability. Because of the unknown GPS noise, the estimated vehicle positions have undesirable errors. These errors not only cause position uncertainty but also road ambiguity problems in some crossroads. In this paper in order to solve this problem, a genetic map-matching method is introduced, which uses a digital road map to correct the position error.

Keywords: Map matching, Genetic algorithms, GPS

1. INTRODUCTION

Today, vehicle tracking systems, personal navigation assistants and such applications are widely used all over the world. In these applications, its highly important to detect and represent vehicle positions with high accuracy. There are, in essence, three different ways to determine the user's location. The first is to use some form of dead reckoning (DR) in which the user's speed of movement, direction of movement, etc. is continuously used to update her/his location. The second is to use some form of ground-based beacon that broadcasts its location to nearby users. The third is to use some form of radio/satellite positioning system that transmits information that can be used to determine the user's location. This last approach

is by far the most popular, a great many navigation systems use the global positioning system (GPS) to determine the user's location [1-5].

GPS is a satellite based geographical position determination system which is operated by U.S. Department of Defense. GPS satellites are distributed in such a way that at least 4 of them are visible from any point of earth. These satellites always transmits their momentary positions. When the distance from an object to three satellites is known, its possible to determine the vehicle position in three dimensions. However, GPS signals are corrupted by some noise sources lowering the positioning.

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Most of the available positioning technologies have limitations either in accuracy of the absolute position (eg. GPS with Selective Availability), accumulated error (eg. dead-reckoning systems such as odometry), or availability (eg. GPS with or without differential correction). To overcome these limitations, vehicle location systems combine vehicle positioning information (possibly from both an absolute positioning system like GPS and from a dead-reckoning system) with information from a digital map, making use of the fact that the vehicle is travelling on the road network. This map-matching step takes the position in two dimensions and any information that is available regarding the error distribution of the position to determine the most probable location of the vehicle on the road network [6-8].

2. SYSTEM DESIGN

Generally, vehicle tracking systems have three main modules. These modules are control center which observes and receives position information from mobile vehicles, wireless communication system and GPS based position detection device in mobile vehicles. The control center considered in this paper, consists of a Pentium processor based personal computer and a control circuit connected to two way radio which is responsible to data communication and tracking software. In control center, mobile vehicles can be monitored on a digital map in real time. Received vehicle positions can also be stored in a file and these position information can be used whenever needed. Instead of GSM or satellite communication system, Motorola GM 300 two way VHF-UHF radio is used for wireless communication in order to reduce system costs. In fact GM300 two way radios are designed for audio communication. In the purposed system, in order to achieve 1200 baud half-duplex data communication, an FSK modem circuit is linked to audio i/o port of the two way radio. The purposed vehicle tracking system is tested and vehicle positions could be observed in the control center in a range under 10 meters position error level [9]. Positioning unit in mobile vehicle, consist of a GPS receiver [5] which computes the position in 3 dimension, a micro-controller, a two way radio and modulation circuit (Figure 1).

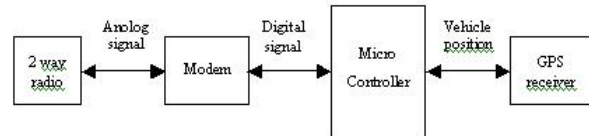


Figure 1. Vehicle positioning module.

This unit computes the vehicle's latitude, longitude and height information by using the GPS satellite signals and transmits the position information to control center.

3. MAP MATCHING

In order to provide continuous, accurate and reliable vehicle location on a given road segment, some map matching algorithms should be used. The map matching algorithm used in this study is based on point to road segment projection. As vehicle position effected by some error sources some positions mismatches occur on digital road map and vehicle position can not be represented on a right road segment. In order to correct position error, first of all the right road way should be determined.

In figure 2, vehicle positions and alternative road segments are represented. The problem here is to find the right road which the vehicle moves on. There are two important issues in order to achieve road segment selection. First one is the distance between estimated vehicle position obtained from the GPS receiver and its projected position on an alternative road segment. The second issue is the angle difference between vehicle trajectory and alternative road segment direction. These distance and angle values are the main parameters of the selection right road segment from digital road network.

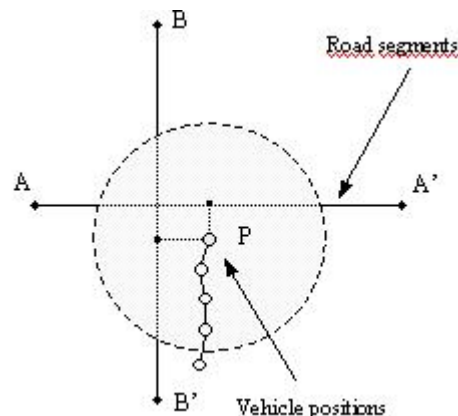


Figure 2. Vehicle position and alternative roads.

In figure 3, there are two alternative roads for right projection. In order to determine the most appropriate road segment, a decision function should be used. Parameters of the decision function are old vehicle positions, angles between vehicle heading and road directions, vehicle position distances from projected positions on alternative roads.

If there is a measure which represents the possibility or certainty of the existence of a car on a specific road, it will be very easy to identify the road on which the car is moving by comparing the C measures of all the roads. The C measure of the n th road represents the certainty of existence of a car on that road. If we define the C measure of the n th road at the k th iteration step as $C_n(k)$, a simple decision rule can be derived as follows:

IF $C_n(k) \geq CT$,

THEN *there exists a car on nth road,*

ELSE *there doesn't exist a car on the nth road*

where CT is a threshold value [10]. Selection appropriate road for moving vehicle procedure as follows.

1. Compute distance (h) and angle (ϕ) values for each road segment on digital road network. (Figure 3).
2. Compute decision function for each road segment and determine certainty values of each road.
3. Sort road segments in descending order and determine the road segment index (n). Road with max certainty value (C_{max}).
4. If max certainty value $C_{max} >$ threshold value (CT), then vehicle position is projected nth road segment.
5. Otherwise there is an uncertainty and vehicle is off-road.

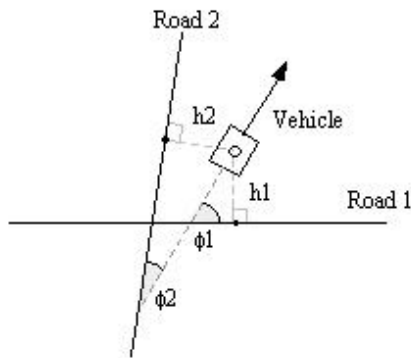


Figure 3. Vehicle position distances from road segments and angle differences.

Certainty values depends on three main parameters. For n th road these parameters are as follows:

$$1. \text{ Distance parameter : } D_n(h) = \frac{1}{1 + \frac{h^2}{\sigma^2}} \quad (1)$$

$$2. \text{ Angle parameter : } A_n(\phi) = \cos^2(\phi) \quad (2)$$

3. C measure of previous road segment

h : distance value from projected road to vehicle position.

ϕ : angle between vehicle heading and projected road.

σ : standard deviation of vehicle position error.

When a car is moving on the road, vehicle positions must be projected on a same road segment. Vehicle can never change a road unless it goes through a junction. This is called as a continuous property of the road. The continuous property can be implemented in a recursive form. So the Certainty function can be written as follows:

$$C_{n+1} = \alpha A_n(\phi) + \beta D_n(h) + \gamma C_n \quad (3)$$

where, α , β , γ are weighting parameters. Success of road selection depends on these weighting parameters. For instance β (distance) parameter should be larger than α and γ should be smaller than one in order to get a steady C_{n+1} value.

In figure 4a, estimated and projected vehicle positions are represented. Numbers in the figure represents vehicle position sequence. C measure variations of alternative roads are also given in figure 4b. Road selection is applied by comparing each road C measure between a threshold value (CT). If there is a road segment with higher C measure from threshold value and C measures of other roads, then it's chosen as a active road on which the vehicle moves.

The weighting parameters should be chosen that there is only one C measure value of a road segment which is higher than CT. In this paper, genetic approach is used in order to find appropriate weighting parameters.

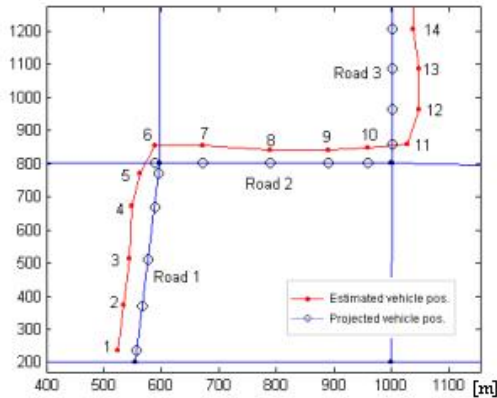


Figure 4a : Vehicle route with GPS position error and map matched positions.

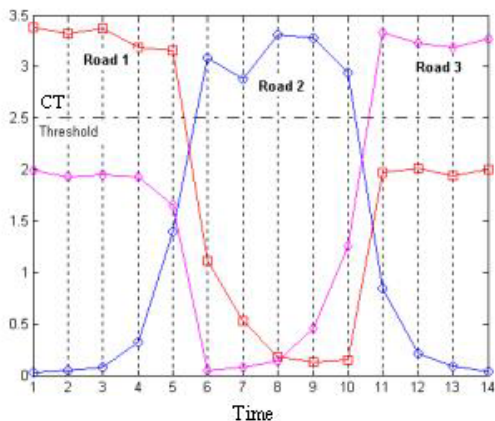


Figure 4b : C measure alteration of road segment 1, 2 and 3.

Generally vehicles move on roads but if a vehicle moves off-road, all C measures of alternative road segments are lower than CT. On off-road mode, map matching and vehicle position projection to active road segment is not applied. Instead of map matching, estimated vehicle position are represented without any correction on digital map (Figure:5).

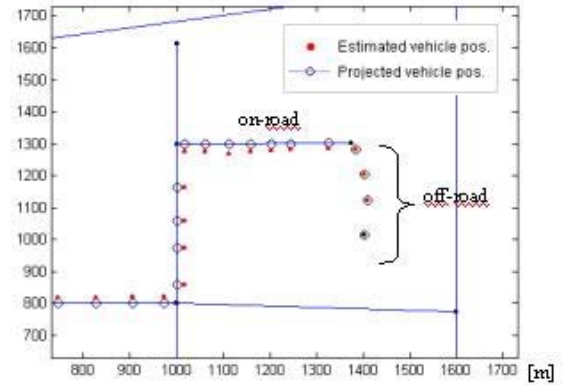


Figure 5 : On-road and off-road modes

4. GENETIC APPROACH

Genetic algorithm begins with a set of solutions (represented by chromosomes) called population. Solutions from one population are taken and used to form a new population. This is motivated by a hope, that the new population will be better than the old one. Solutions which are then selected to form new solutions (offspring) are selected according to their fitness - the more suitable they are the more chances they have to reproduce. Basic genetic algorithm as follows:

1. [Start] Generate random population of n chromosomes (suitable solutions for the problem)
2. [Fitness] Evaluate the fitness $f(x)$ of each chromosome x in the population
3. [New population] Create a new population by repeating following steps until the new population is complete
 - [Selection] Select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to be selected)
 - [Crossover] With a crossover probability cross over the parents to form new offspring (children). If no crossover was performed, offspring is the exact copy of parents.
 - [Mutation] With a mutation probability mutate new offspring at each locus (position in chromosome).
 - [Accepting] Place new offspring in the new population
4. [Replace] Use new generated population for a further run of the algorithm

5. [Test] If the end condition is satisfied, stop, and return the best solution in current population
6. [Loop] Go to step 2

In our approach each chromosomes are 24 bit and carry α , β and γ parameter values. In 2nd step fitness function is evaluated for each chromosome. Fitness function also checks C measure values for each chromosome. If there is only one candidate with higher value from CT, it has higher chance to survive than other chromosomes. In 3rd step roulette selection method is used to find better chromosomes and a new population is created. In proposed study probability of mutation and cross over is selected as pm=0.05 and pc=0.6. In test step, C measures are calculated again for each chromosome. If there is only one road with higher C measure than CT, algorithm ends and related chromosome determines the new α , β and γ parameters. Otherwise, algorithm continues and returns back to the fitness step.

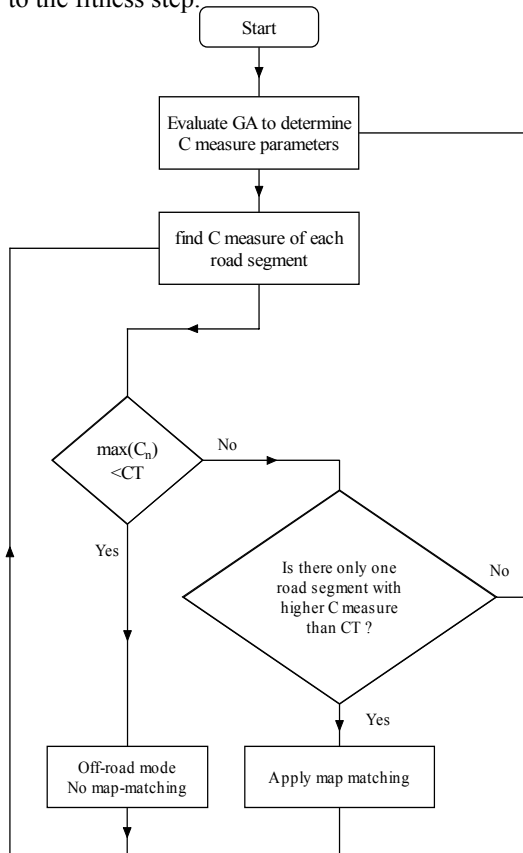


Figure 6. Flow chart of genetic based map-matching process

When the map matching process starts, firstly α , β , and γ parameters are computed via genetic algorithm. Then C measures (C_n) of each road on digital map are calculated. If the maximum of C_n is bigger than CT , the vehicle is off-road and no map matching is applied. Otherwise, it's checked that whether there is only one road with higher C measure than CT or not. If there is only one alternative road, map matching is applied to alternative road segment. Otherwise, C measure parameters should be re-computed and GA is applied again (Figure 6).

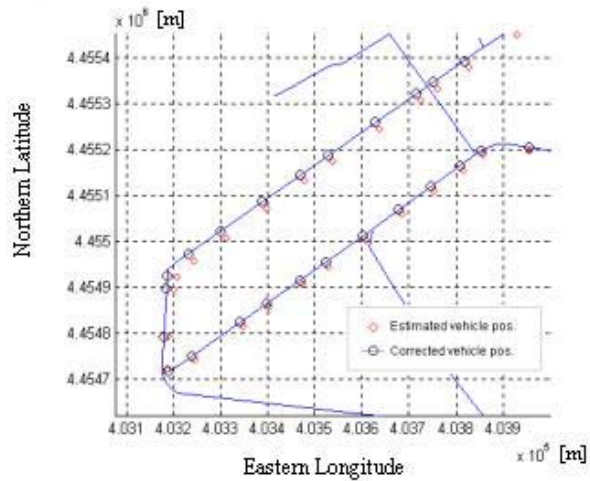


Figure 7 : Application results

5. CONCLUSIONS

In this paper, a genetic based map matching algorithm is proposed for vehicle tracking and navigation systems. Proposed method is also tested in real time. The map-matching algorithm is successfully used project the vehicle location on the digital map 2-dimensional road network. Within the algorithm, the stability is determined and used to judge whether the vehicle is still on the candidate road or off the candidate road to parking lots. The tracking system which is designed for vehicle or object tracking in this study, can observe moving objects in a range under 10 m position error from observation center (figure 7). There are two tracking modes in the system. These are on-road and off-road modes. If a vehicle moves off-road, then the system detect off-road mode and doesn't apply any genetic map-matching (figure 5). Selection the right road which a vehicle or a person moves on, is very important for navigation and tracking applications. Some navigation systems inform

the driver according to vehicle position while vehicle is moving and guide the user on any subject, i.e. places of hospitals, hotels, theaters or historical places. With the proposed genetic based map-matching system, its possible to realize such self guidance and navigation applications.

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