KEY TECHNOLOGIES IN DEVISING AUTONOMOUS VEHICLE LOCATION AND NAVIGATION SYSTEM

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ABSTRACT

In this paper, a devising scheme of Autonomous Vehicle Location and Navigation System is introduced firstly. Then, several key technologies used in the devising scheme are presented, which includes a data fusion method based on extended decentralized kalman filter technology, a map-matching method used to compensate the positioning error, and a digital map data processing method used to realize route planning algorithm. By this time, a sample machine based on the devising scheme introduced in this paper has already been worked out successfully. The availability and the advantages of these technologies have been demonstrated.

KEY WORDS

Autonomous Vehicle Location and Navigation System (AVLNS), Global Positioning System (GPS), Kalman filter, Map Matching, Route Planning

INTRODUCTION

Autonomous Vehicle Location and Navigation System, which is considered as a kernel part of Intelligent Transportation System, is now being intensely studied all over the world. As an integrated system, AVLNS consists of positioning module, Geological Information System (GIS), route planning module, route guidance module and communication module. The main function of AVLNS is to provide multiple kinds of real-time traffic information to its user.

THE DEVISING SCHEME OF AUTONOMOUS VEHICLE LOCATION AND NAVIGATION SYSTEM

The system structure of the AVLNS devising scheme is shown in Figure 1.

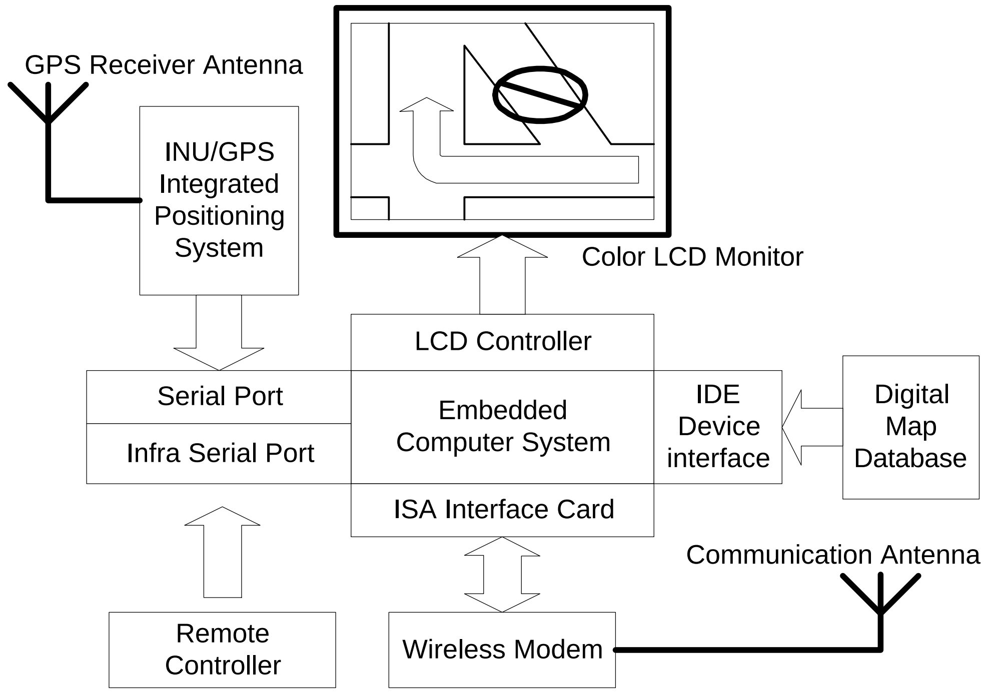

Figure 1. System structure of the AVLNS devising scheme

According to the devising scheme, the kernel part of AVLNS is an embedded computer system, which is used as the central controller of the whole system. In addition, it also provides the hardware in which system software is operated. The positioning module is an integrated positioning system of GPS receiver and Inertial Navigation unit. The digital map database is stored in CD-ROM, and can be replaced or updated conveniently. The communication component is a mobile wireless modem, which is controlled by the computer system through an ISA standard interface card. The AVLNS is also equipped a color LCD as its display device and an infra remote controller through which its user can send operating command.

An important feature of this AVLNS devising scheme is the use of embedded computer system, which provides the system not only with powerful controlling ability needed for running sophisticated software, but also with good expandability that is necessary to connect or communicate with peripheral equipment. In the following section of this paper, several technologies used in realizing the devising scheme will be discussed in detail.

A DATA FUSION METHOD BASED ON EXTENDED DECENTRALIZED KALMAN FILTER TECHNOLOGY

The positioning module is the most fundamental of the various modules needed for AVLNS. Based on the devising scheme, the positioning module is realized through the combination of GPS receiver and inertial navigation unit. The primary positioning method is GPS, which can continually provide real-time information including position, velocity and time. The inertial navigation unit, which is an independent navigation system, is used to provide information for operating dead reckoning in case GPS receiver can not provide valid position information. This multisensor integration method can provide the positioning module with multiple benefits including robust operational performance, improved reliability of operation, and high levels of accuracy and fault tolerance. All these benefits are acquired in the devising scheme by taking the data fusion method, which is described in Figure 2.

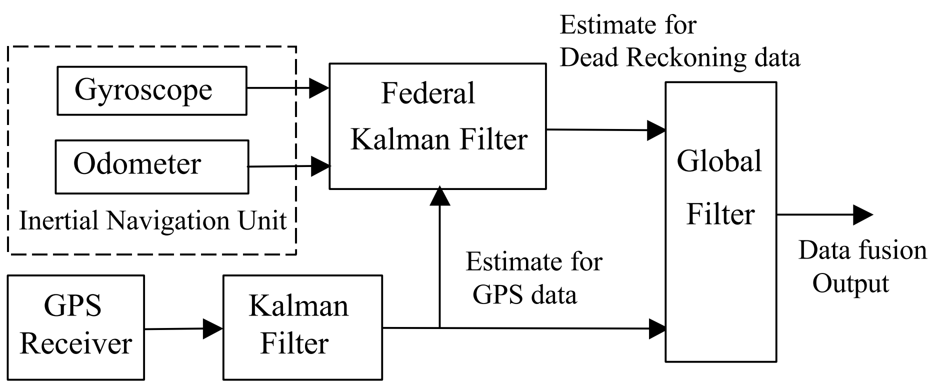

Figure 2. Data fusion process of positioning data

According to this method, the GPS positioning data is introduced to a kalman filter firstly to yield the optimal estimate for GPS data. Then, this estimate, together with the dead-reckoning data from the inertial navigation unit, is send to a federal kalman filter to yield the optimal estimate for dead-reckoning data. Finally, Both the estimate for GPS data and for dead-reckoning data are send to a global filter, and the data fusion output is generated.The advantages of this data fusion method include:

(1) By taking a decentralized kalman filtering approach, a local kalman filter is applied to GPS data, which prevent the estimate for GPS data from the affection of the accumulative error introduced by dead reckoning. In this way, the accuracy of the filtering result is ensured.

(2) In the federal kalman filter, the information of position and velocity from the optimal estimate for GPS data is introduced to compensate the accumulative error of Dead Reckoning. Through this method, the positioning performance of inertial navigation unit gains considerable enhancement.

(3) Based on the optimal estimate for GPS data and for dead-reckoning data, a data fusion approach based on extended kalman filter technology is applied to yield the final positioning data output. Since the source data have already been corrected, the data fusion result is of high accuracy level.

To illustrate the effect of the data fusion method, the positioning data curves in an experiment are showed in the following figures. From Figure 3 we can see that, the curve of the estimate for GPS data is smoother than that of the unprocessed GPS data. In Figure 4, it is obvious that the accumulative error of dead reckoning has been reduced significantly after being compensated. Figure5 shows the fused data curve comparing with the curve of estimate for GPS data. In general, by taking the data fusion method, the positioning accuracy of the positioning module is efficiently improved.

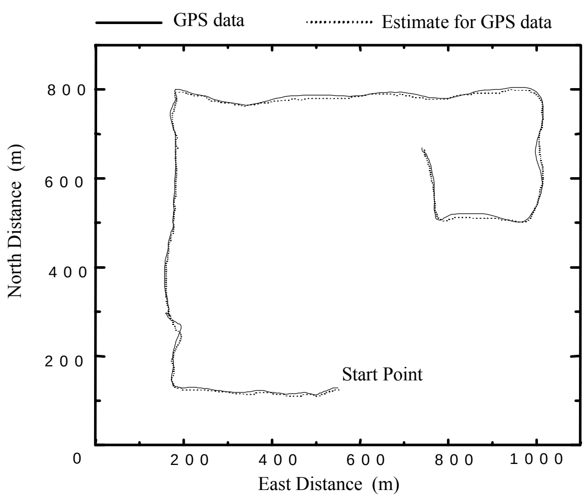

Figure 3. GPS data curves

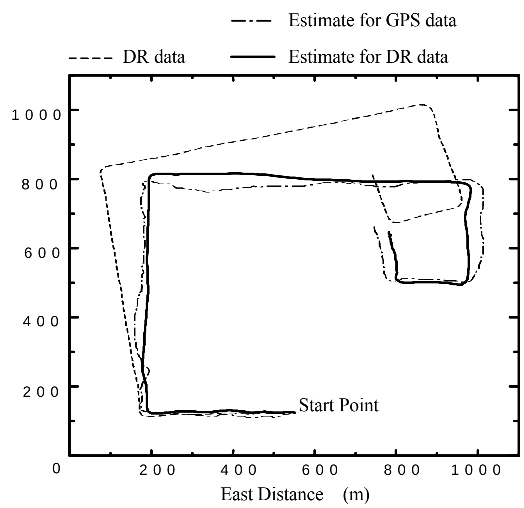

Figure 4. Dead-Reckoning data curves

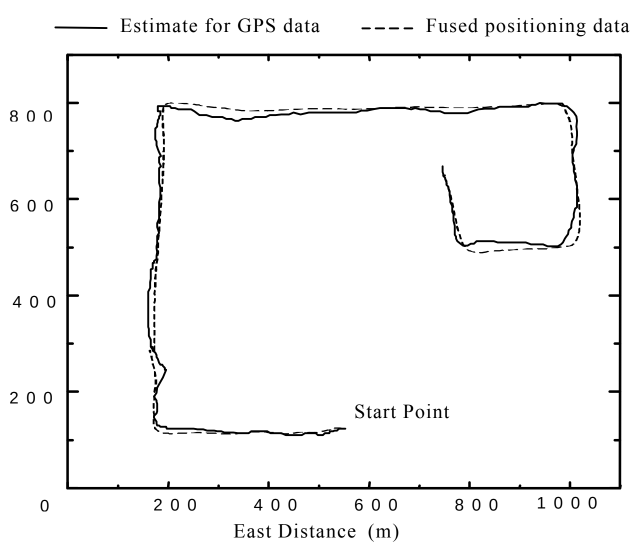

Figure 5. fused positioning data curve

MAP-MATCHING METHOD

The map-matching technology plays an important role in the AVLNS devising scheme. It makes the positioning result more reliable and accurate by employing the information from digital map database. The basic assumption which is made as the prerequisite for operating map-matching algorithm is that the location of vehicles are constrained to a finite network of roads in most cases. The digital map used for map matching must be relatively accurate; otherwise, the map-matching result may be incorrect, which in turn will degrade the system performance.

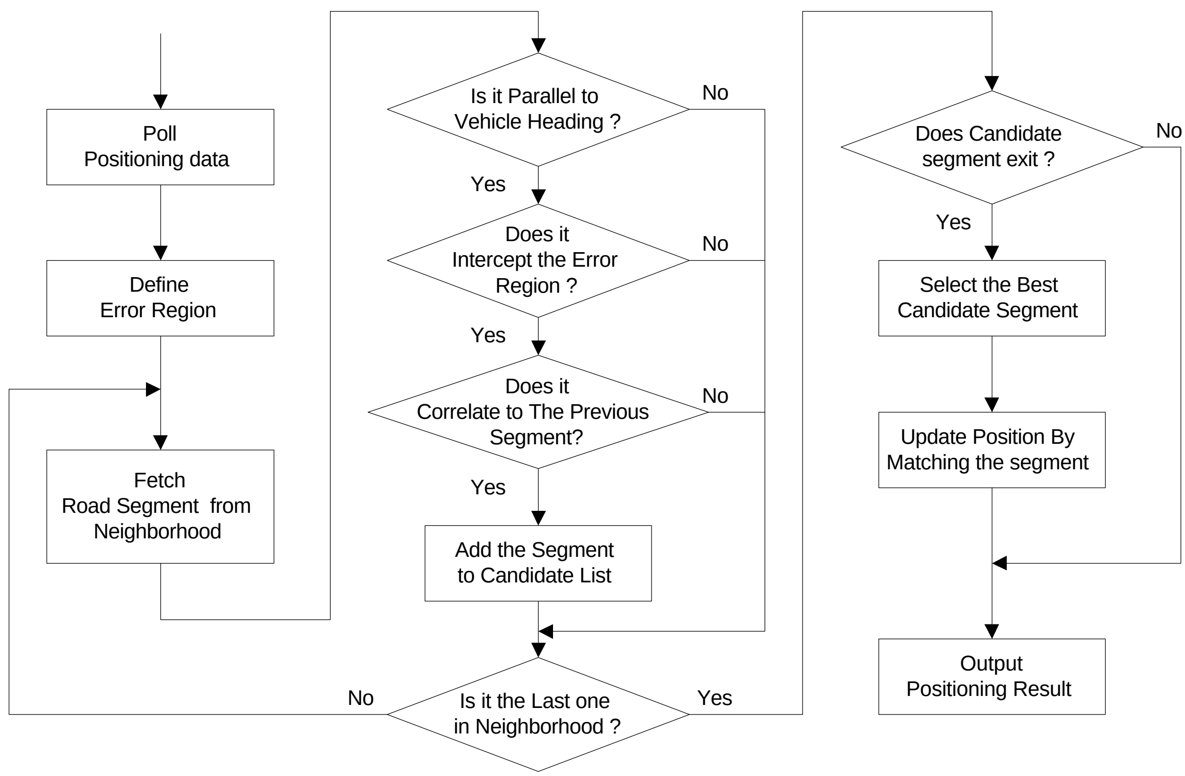

Figure 6. Map-matching algorithm

In the devising scheme, map matching is realized through computer software. The flowchart of the map-matching algorithm is described in Figure 6. The first step is defining an error region based on the current position of the vehicle that is determined by the positioning module. The error region encloses an area with a certain probability of containing the actual position of the vehicle. To save on computation time, a circular error region is used. Once the error region has defined, the algorithm extracts candidate road segments in the neighboring area of the vehicle location from the digital map database. Each segment is first tested to determine if its direction is parallel to the vehicle heading within a specified threshold. If a segment passes the direction test, it is then examined to determine if it intercepts the error region. After passing this intercepting examination, the segment is still need to be tested to determine if it correlates with the previous position of the vehicle. Only the segments that are connect to the segment previously determined to contain the vehicle position or are very close to the previous vehicle position pass the correlatively examination. If a segment fails any of these three tests, it is discarded. The segments that pass all these three tests are then added to the candidate segment list. If this list is not empty after all the segments in neighboring area have been tested, the algorithm selects the most probable segment in the list. If there is only one segment in the list, the task is simple. This segment is the most probable segment. If there are two or more segments in the list, the one that is closest to the current position is selected. The algorithm then updates the current position to the closest position in this surviving segment. Otherwise, if the candidate segment list is empty, the current position is not updated. In this case, it is assumed that the vehicle is off-road. Although the map-matching algorithm is not complicated, it significantly enhances the positioning performance of the whole system when the vehicle is traveling on road network.

A DIGITAL MAP DATA PROCESSING METHOD USED TO REALIZE ROUTE PLANNING ALGORITHM

Route planning is a process that helps vehicle drivers plan a route prior to or during a journey. It is widely recognized as a fundamental function of AVLNS. The shortest path algorithm is used to solve the route-planning problem. In order to operate this shortest path algorithm, the digital map data need to be preprocessed. Firstly, the digital map of road network must be processed so that every road is splitted to the simplest segments. It means that after this processing, any road segment in the digital map only intercept other road segments at its start point or end point, which is defined as node. Then, connecting information of all the segment nodes in the digital map is extracted. This information is recorded in a matrix, which is very large in scale. Considering the fact that the quantity of the nodes connecting with a certain segment node is much smaller than the total quantity of nodes, the information matrix can be converted to a sparse matrix. After this conversion, the matrix can be recorded in a special compact binary format. Through this processing, the storing space used for operating the shortest path algorithm is cut down greatly, while the searching time needed for extracting connecting information data is reduced. In general, by using this data processing method, the route planning can be realized with a reasonable expense.

CONCLUSION

By this time, a sample machine of AVLNS based on the devising scheme has already been worked out. The good performance of this sample machine shows that, the technologies presented in this paper are practical and effective.

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