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**Abstract** – In this paper, we present the Q-learning method for adaptive traffic signal control on the basis of multi-agent technology. The structure is composed of sixphase agents and one intersection agent. Wireless communication network provides the possibility of the cooperation of agents. As one kind of reinforcement learning, Q-learning is adopted as the algorithm of the control mechanism, which can acquire optical control strategies from delayed reward; furthermore, we adopt dynamic learning method instead of static method, which is more practical. Simulation result indicates that it is more effective than traditional signal system.

**Key Words** : agent; cooperation; Q-learning; reinforcement learning; dynamic; practical;

## 1. Introduction

Dead reckoning is a frequently used technique for mobile robot positioning and navigation. This navigation system can provide short term very precise navigation information. But since the errors of wheel/motor sensor and heading sensor accumulate as time growth without limitation DR navigation system cannot be used to navigate mobile robot alone without any validation.

GPS is a most widely used global positioning system which has many applications including positioning, locating, navigating, surveying and determining the time. Much work has been done about using GPS and GPS/DR navigation system to navigate mobile robot and autonomous vehicles [1-3]. In [4] an adaptive joint Kalman filter based on Kalman filtering technology was set up to realize the data fusion of GPS/DR integrated navigation system and improve the precision and reliability of GPS/DR system. Lin and He designed the GPS/Loran C/ SINS/ AHRS integrated system to ensure the precision and reliability of the proposed navigation system [5].

DGPS can provide the navigation information with the error less than 1 meter. But the price of DGPS is very high and it needs a base station to provide difference data. In this paper we use a cheep single GPS receiver to provide the positioning information. The error of that GPS is about 10-15 meters. In some cases when the satellites in the sky change or the GPS receiver cannot receive the signal of the satellites the output of GPS will jump a lot which makes the navigation error very big. In this paper we use a BP neural network to predict current time GPS output and propose a Kalman filter based data fusion method to fuse the navigation data of GPS and DR system. By modifying the belief of the GPS and DR system the proposed data fusion method can provide an accurate navigation result. Simulation using real GPS data is done to validate the proposed data fusion method. The simulation result shows the good potential of this method for navigating mobile robot.

This paper consists of the following sections to explain the results of the study. Section to give the information about GPS navigation system and the neural network used to predict the GPS output. Section 3 describes the proposed data fusion method. Section 4 demonstrate the proposed data fusion method by conducting a simulation and Section 5 provides the conclusion of this study.

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## 2. GPS navigation system

A GPS receiver use the pseudoranges obtained from the signals sent from several satellites that are not geostationary [6]. The accuracy of GPS relies in the precise knowledge of the satellite orbits and the time. In

GPS applications, the main goal is to get the position of a receiver as accurately as possible, based on its distance to GPS satellites. Since GPS works in a real environment many sources of disturbances and noise can affect the precision of GPS. The geometry of the receiver with respect to the satellites can also influence the accuracy of the GPS. For two dimensional navigation system horizontal dilution of precision (HDOP) is used to indicate the effect of the geometry of the satellites. The estimate of the position is more accurate when the satellites broadcasting the signals being received are geometrically well distributed, as indicated by a small HDOP factor.

Standard DGPS can be used to get an accuracy of under one meter. Basing on the information sent from DGPS base station there are several ways to operate in differential mode. The most straightforward methods rely on having a base station receiver and a mobile receiver, then analyzing differences between the signals received in real time at each receiver [7]. DGPS can provide very precise positioning service but the cost of HDOP is very high and it need a base station. In this paper we use a cheep single frequency GPS receiver to provide the positioning information. The error range of that GPS is about 10 meters and 15 meters. We use a BP neural network to predict the current time output of GPS and propose a new Kalman filter based data fusion method which is presented in next section to obtain much better positioning results.

Neural networks have the ability to "learn"the system characteristics through nonlinear mapping and provide a strong degree of robustness because of their ability to exhibit fault tolerance. By means of both off-line and on-line weight adaptation, neural networks can improve the adaptability. We adapt a back propagation neural network to do the prediction job. Fig. 1 shows the configuration of the input-output relation of the neural network used in this paper. Herein, the neural network consists of three layers: an input layer, a hidden layer and an output layer. Fig. 2 depicts this model structure.

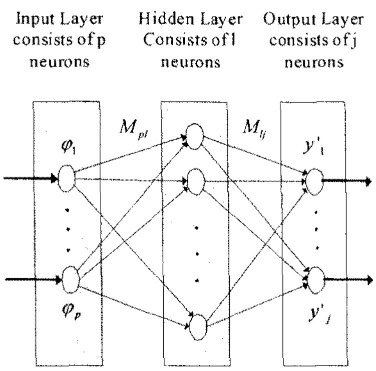


Fig. 1 Configuration of the neural network

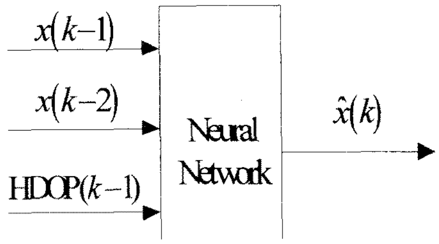


Fig. 2 The neural network model structure

The neural network has 4 neurons in the input layer, 5 neurons in the hidden layer and 1 neuron in the output layer. The transfer function of the hidden layer is TANSIG and the transfer function of the output layer is PURELIN. The error signal used to adjust the weights of the neural network is the difference between the real GPS output and the neural network output. The training and test results are shown in Fig. 3.

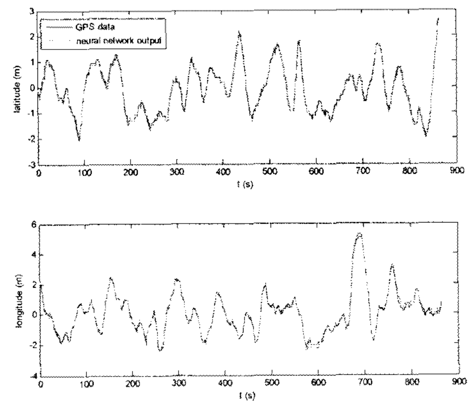


Fig. 3 Neural network output

## 3. Data fusion method

The neural network result can be used to do the GPS/DR system data fusion. DR system can provide precise short-term navigation information. The error of the DR system used in the experiment (magnetic encoders and e-compass) is very small but can accumulate and drift without limitation; on the other hand the error of the single GPS receiver is big but with limitation. Since GPS has the synergistic characteristic with the DR system GPS/DR system can be used to navigate the mobile robot. A data fusion method using neural network is proposed to use DR system to provide accurate short-term navigation information and the single GPS to modify the long term navigation information. The characteristic of the single GPS receiver is that the error drifts small (no more than three times of the single GPS receiver resolution). A neural network is trained to predict the current sampling time GPS data based on the previous two sampling time GPS data and the HDOP values. We assume that the covariance of DR system errors in latitude and longitude direction is Q and the covariance of the single GPS receiver errors is R. Fig. 4 shows the sketch of the GPS/DR navigation system, and Fig. 5 shows the GPS/DR system data fusion process.

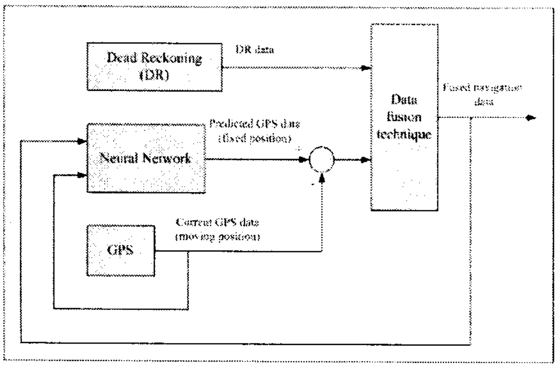


Fig. 4 the sketch of the GPS/DR navigation system

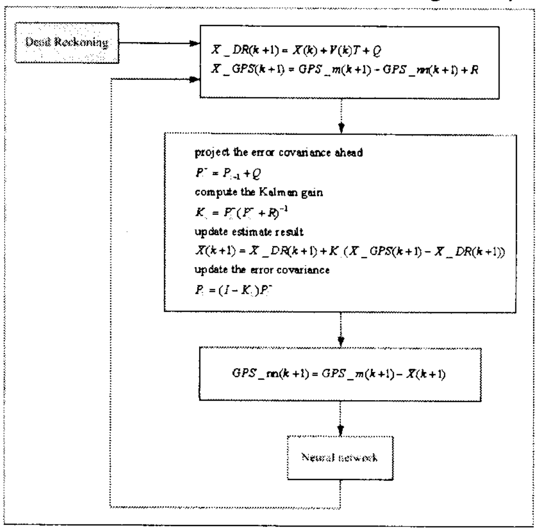


Fig. 5 the GPS/DR system data fusion process

## 4. Simulation

In this paper we use MATLAB to do the GPS/DR navigation information data fusion simulation. Fig. 6 shows the fusion simulation results.

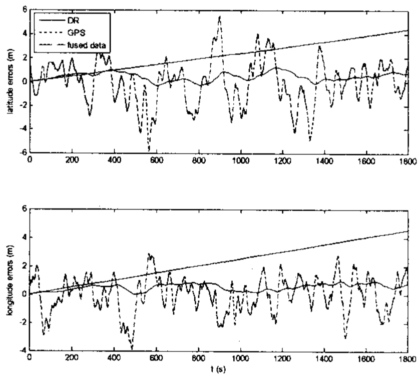


Fig. 6 errors of GPS, DR and GPS/DR systems

From Fig. 6 we can see that the new fusion method can reduce and bound the error accumulation of DR system and provide more accurate positioning information than GPS. By using this data fusion method GPS/DR system can provide long term accurate navigation service for the mobile robot.

## 5. Conclusion

DR navigation system can provide short term accurate navigation information. But the error of DR can accumulate without limitation. DR cannot be used to navigate mobile robot alone in a long term. GPS is generally used in outside to offer positioning and navigation service. DGPS can be used to provide a less than 1 meter positioning information. But the cost of DGPS is very high. The error of the cheep single frequency GPS receiver used in this paper is about 10 meters. This paper propose a new Kalman filter based data fusion method. This proposed method can navigate the mobile robot using GPS/DR precisely in a long term.

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