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Research on Prediction of Vehicle Distance Based on Adaptive Kalman Filtering Principle

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Abstract:More than 1 million people die from traffic accidents each year around the world, which hasar-ose public concerns to the vehicle safety. This paper examines improvement plan on the existent system of avoiding automobile rear-end collision.Based on the distance measurement millimeter-wave radar, the paper make predictions about relative distance and speed of the vehicle and the external substrate by principle of Kalman filtering. In order to predict the real distance of the vehicle and the outer,the author will correct t-he predicting process to the optimal estimation by comparing the predicted value with the observed value. That can improve vehicle safety and early warning mechanism accuracy.

Keywords:Millimeter-wave radar;Kalman Filtering;prediction;deviation

1 Introduction

With the rapid development ofthe automobile industry, people's attention is gradually increasing, especially inits security.In terms of driving safety, the advanced driver assistantsystems (ADAS) includes adaptive cruise control(ACC), lane departure warning (LDW), Adaptive high beam control (AHBC),driverdrowsiness detection, rear-end collision system and so on[1]-[4].Based on the existent system of avoiding automobile rear-end collision, the author examine the solution to the deviation reduction of the vehicle’s measured distance caused by the external substrates due to the outer factors and the auto-body inner factors.

To solve this problem, domestic and foreign scho- lars have conducted some researches, among whom Lv Xingxing, Wu Botao and others detected vehicles ahe- ad of road with infrared distance measurement, and predicted the results ofmeasurement by Kalman filter [5].On this basis,this paper applied a more stable and fine millimeter-wave radar and the adaptive Kalman fi- ltering to improve the prediction accuracy andstability of the vehicle distance.

2 Range tools

The first problemin design of anti-rear-end pre- warning systems is distance measurement. At present, the ranging tools widely used in cars are ultrasonic, laser, millimeter-wave radar and so on.

2.1 Ultrasonic ranging

Ultrasonic wave is a kind of mechanical wave whose frequency is more than 20 kHz.Ultrasonic distance measurement use launcher to emit ultrasonic continuously, which will be reflected back to receiving devicewhen ultrasonic encounter obstacles. And then,distance can be calculated by the time difference between the two things.Althoughthe studyon ultrasonic ranging method is mature, such as variable threshold detection method, envelope peak detection method and phase detection method [6], [7], butthe best ranging distance is about 4 meters, because ultrasonic will be affected by temperature, humidity, air pressure, etc.in the process of transmission. So ultraso-nic ranging applicationis mainly applied in automotivecollision avoidance system.

2.2 Laser ranging

Principle of laser ranging is that laser emitsa laser beamreceived by detector willreturn when aim at obstacles, and then round-trip distance by multiplied round-trip time and speed of light will be calculated [8].This method will cause damage to people's vision andnot conducive to universal because GaAs LED emits high-power laser beam in long-distance ranging.

2.3 Millimeter-wave radar ranging

When using radar to measure distance, electroma- gnetic interference, caused by the surrounding vehicles or obstacles, will cause inaccurate measurement of the distance, somillimeter-wave radar ranging is generated.Relatively speaking,the millimeter-wave radar that la-unches the millimeter-wave between 21.65 ~ 26.65GHz and 76 ~ 81GHz hashigh application value because ofhigh precision resolution, less affection by climate, miniaturization and higher stability.

3 Vehicle distance prediction

3.1 Principle of millimeter-wave radar ranging

The methods of millimeter-wave radar ranging are pulse radar ranging andcontinuous wave radar ranging [9].For pulse radar ranging, receiver cannot operate inthe transmission process because of sharing transmit and receiveantenna, so it is impossible tomeasure the veryshort distance.This paper mainly studies continu- ous wave radar ranging.

The basic principle of frequency modulated conti- nuous wave ranging (FMCW),the way of continuous wave radar ranging, is that FM signals (this study is triangular wave signal)will be continuously transmitted through FM oscillator.When meets with the obstacles in transmitting,an echo signal will reflect to the receiv- ing antenna,and then beat signal will be gainedby directional coupler and mixer, after which ideal beat signal can be got byamplifier and filter. Finally, relati-ve speed and distance between vehicle and obstacle can be obtained by digital signal processing.As shown is continuous wave radar ranging in figure 1.

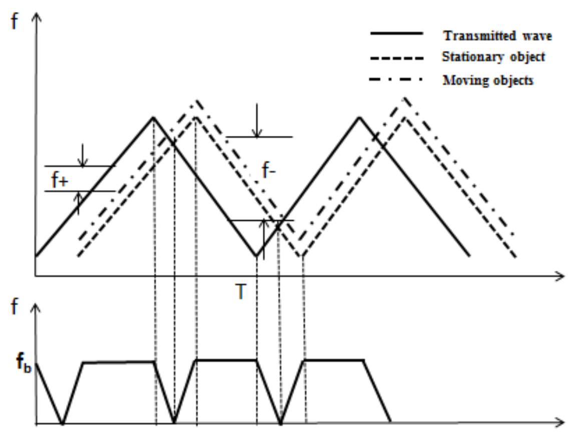

Figure 1 continuous wave radar ranging

The formula fortransmission frequency $f_t$and echo frequency f_e ofcontinuous wave radar is as follows.

$$f_t = f_0 + \frac{2F_m}{T}t \tag{1}$$

$$f_e = f_0 + f_d \pm \frac{2F_m}{T}(t - t_r) \tag{2}$$

Where f_0 is center frequency of transmitted wave, F_m is the maximum deviation of transmitted frequency, t_r is lag time between echo signal and transmitted signal (t_r = 2D / c, D is relative distance between vehicle and obstacle, c is speed of light). Assuming relative distance between vehicle and obstacle is v. If v> 0, Doppler effect needs to be considered, and f_d is the Doppler frequency in (2).And beat signal can be obtained by subtraction between (1) and (2).

$$f_+ = f_t - f_e = \frac{4F_m}{Tc} D - f_d \qquad (3)$$

$$f_- = f_e - f_t = \frac{4F_m}{Tc} D + f_d \qquad (4)$$

So, relative distanceand relative speed can be found.

$$D = (f_+ + f_-)Tc/8F_m \qquad (5)$$

$$v = f_- - f_+)c/4f_0 \qquad (6)$$

From that, relative distance and velocity can be calc- ulated as long as the f_+ and f_- are known. The key to obtaining beat signal is studying its center frequency, so it is necessary to perform frequency spectrum ana-lysis. At present, the commonly used methods are fast Fourier transform(FFT) and linear frequency modul- ations Z transform (Chirp-Z).

3.2 Adaptive Kalman filtering prediction

Kalman filtering, a Bayesian model similar to the hidden Markov model,seeks a recursive estimation algorithm by taking an optimal criterion that minimum mean squared error as an estimate [10].The main idea of Kalman filtering is using a current estimate and a recent observation to estimate current value, and the following is a classic formula of Kalman filtering.

$$\hat{x}_t^- = F_t \hat{x}_{t-1} \qquad (7)$$

$$P_t^- = F_t P_{t-1} F_t^T + \alpha_{t-1} \qquad (8)$$

$$Z_t = H_t \hat{x}_t + \beta_t \qquad (9)$$

$$K_t = P_t^- H_t^T (H_t P_t^- H_t^T + R_t)^{-1} \qquad (10)$$

$$\hat{x}_t = \hat{x}_t^- + K_t (Z_t - H_t \hat{x}_t^-) \qquad (11)$$

$$P_t = (I - K_t H_t) P_t^- \qquad (12)$$

Where x_t=[D_t v_t],F_t=[1 Δ t;0 1],α isprediction model noise,β is observation noise (in this paper,α andβ are Gauss white noise), $Z_t$isobservation matrix, K_t isKalman coefficient. (7)and (8) are one step prediction equations, whichpredict state ofcurrent timeby state of last time, but it is not the best estimate.(10), (11) and(12), state update equations, use current state values to update the state ofx_t and noise covariance matrix P_t.In order to solve the problem that the noise is changing constantly and value of R is changed so that value of K is changed, adaptive genetic factor λ_t is introduced in this paper, which makes estimation reach better[11],[12].The following isadaptive Kalman filter equations thatintroduceλ_t.

$$P_t^- = \lambda_t F_t P_{t-1} F_t^T + \alpha_{t-1} \qquad (13)$$

$$\lambda_t = \max\left\{1, \frac{trace(N_t)}{trace(M_t)}\right\} \qquad (14)$$

$$N_t = W_t - H_t \alpha_t H_t^T - R_t \qquad (15)$$

$$W_t = \begin{cases} \dfrac{\lambda_{t-1}\beta_t\beta_t^T}{1+\lambda_{t-1}} & (t > 2) \\ \dfrac{1}{2\beta_1\beta_1^T} & (t = 1) \end{cases} \qquad (16)$$

$$M_t = H_t F_t P_{t-1} F_t^T H_t^T \qquad (17)$$

It can be seen from (13) to (17) , when state changes abruptly, $\beta_t$and N_t become larger, which causes $\lambda_t$increase and thereby increasing filtering effect and reducing estimated bias.

4 Simulation

Calculation steps of predicting distance byusing adapt- ive Kalman filtering theory are shown in figure 2.Set initial value before simulation.x_0=[0;0],α_0=[0.04 0;0 0.04],P_0=[1 0;0 1],R_0=0.25,H=[1 0].And the simulation results are obtained from initial values and calculation formulas.

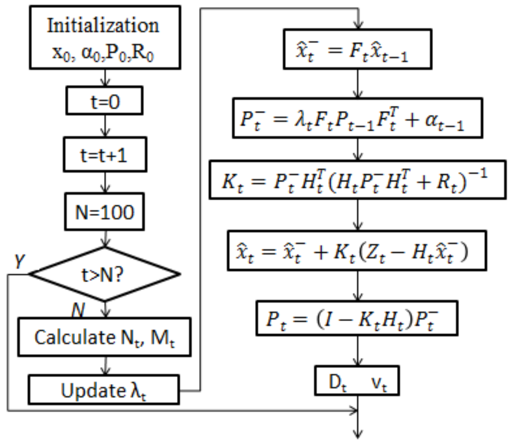

Figure 2 predict vehicle distance based on adaptive Kalman filter

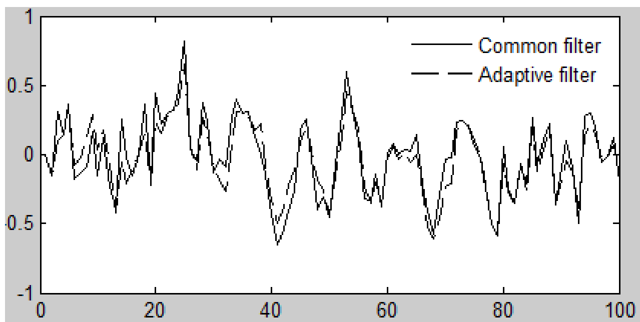

Figure 3 the Deviation between common and adaptiveKalman filter

From figure 3, it can be seen that adaptive Kalman filter produces less deviation, and the deviation can be redu-ced by half in the maximum case. That makes the vehi- cle distance closer to true value.

5Conclusions

In order to achieving safe avoidance, this paperexamines how to gain more accurate early warning me- chanism of automobile by correct selection to the range tool, adaptive Kalman filter and analyzing the results of measurement and prediction. It will also provide feasib- ility for researching on anti-rear-end system.

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