Research on Car Parking Trajectory based on SO-FNN

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Abstract

Along with the increase of the car in modern society, the city road is becoming much more crowded and parking space is very limited. How to complete the parking process in the limited space securely and efficiently will be of great practical significance. To achieve the goal of automatic parallel parking, a method combined fuzzy control with neural network is presented in the paper to optimize parking path. Application the theorem of cluster analysis, correspon ding fuzzy rules are classified by date and discussed. The Rationality of the fuzzy neural network is judged by sensitivity analysis method which determines the growth of neurons or shear. At last, this network is simulated by MATLAB in order to verify the trace.

Keywords

FNN; Automatic parking; SO-FNN.

1. Introduction

With the development of automobile technology and the improvement of people's quality of life, Cars are becoming more and more humane. Driving problem in some complex environment must to be solved and automatic parking technology arise at the moment. Using various control techniques, the automatic parking technology is continuously improved. Some automatic parking technology has been applied to some kinds of vehicle. In this paper, the optimization of the parking path has been carried out for further discussion.

2. Organization of the Text

2.1 Dynamic model of vehicle

2.1.1Analysis of reverse process

According to the actual scaled down model of a four round of front - wheel - drive car, parameters are obtained. Dynamic model just considers the majority of car with three degrees of freedom, namely forward movement, lateral movement and horizontal rotation. The car moves at low speeds, without considering the slip of the wheel, oversteer and understeer. Classic Ackerman Angle can be available as below:

If alignment angle of the front wheel is equal to zero and the moving system is rigid and premise without lateral force during the whole process, all wheel steering must be relative to a circle rolling around the same instantaneous center.

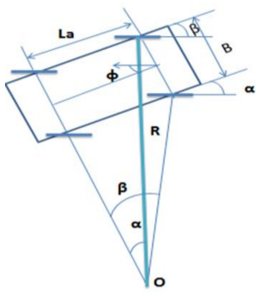


Fig.1 Ackerman Angle

$$\cot\alpha = \cot\beta + \frac{B}{L_a}$$

$$\phi = (\alpha+\beta)/2$$

α : The deflection angle of the external steering wheel;

β : The deflection angle of the internal steering wheel;

L_a : Wheelbase;

B : wheel distance between left and right wheel.

2.1.2 the coordinates of the process of reversing

First, the coordinates of the process of reversing established. The lower left corner of the parking position is the origin and the establishment of X-Y coordinates as follow:

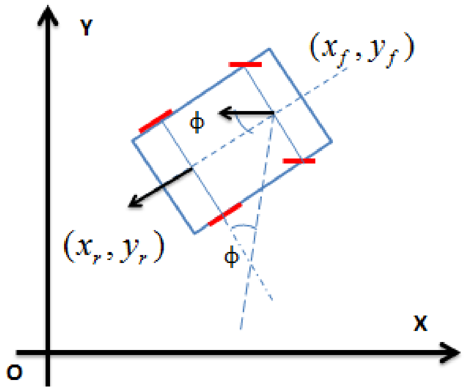


Fig.2 Coordinates of the process of reversing

The parameters of the following definition:

θ : The angle between X axis and main axle of the vehicle

ϕ : The angle between front wheel and main axle of the vehicle, clockwise direction is positive

v_f : Speed of the vehicle

(x_f, y_f) : Center of front wheel

(x_r, y_r) : Center of back wheel

Because the vehicle didn't slip in the process of movement, the center of back wheel meets the following formula:

$$\dot{y}_r \cos\theta - \dot{x}_r \sin\theta = 0 \qquad (1)$$

The relationship between the centers

Front wheel:

$$\begin{cases} x_r = y_f - L_a \cos\theta \\ x_f = y_r - L_a \sin\theta \end{cases} \qquad (2)$$

Time derivative of above

$$\begin{cases} \dot{x}_r = \dot{x}_f - \dot{\theta} L_a \sin\theta \\ \dot{y}_r = \dot{y}_f - \dot{\theta} L_a \cos\theta \end{cases} \qquad (3)$$

After putting the formula (3) into the formula (1), formula can be obtained

$$\dot{x}_f \sin\theta - \dot{y}_f \cos\theta + \dot{\theta} l = 0 \qquad (4)$$

The angle between the X axis and $\dot{v}_f$ is $\theta - \phi$.

$$\begin{cases} \dot{x}_f = y_f \cos(\theta - \phi) \\ \dot{y}_r = v_f \sin(\theta - \phi) \end{cases} \tag{5}$$

After putting the formula (5) into the formula (4), formula can be obtained

$$\dot{\theta} = v_f \sin(\theta) / l \tag{6}$$

The conclusion can be drew above

$$\begin{cases} \dot{x}_r = v_f \cos\theta \cos\phi \\ \dot{y}_r = v_f \sin\theta \cos\phi \\ \dot{\theta} = v_f \sin(\theta) / l \end{cases} \tag{7}$$

Integrative of upper formula.

$$\begin{cases} x_r(t) = \int v\cos\theta\cos\phi dl = l\cot\phi\sin(\frac{v\sin\phi}{l}.t) \\ x_r(t) = \int v\cos\theta\sin\phi dl = -l\cot\phi s\cos(\frac{v\sin\phi}{l}.t) + l\cos\phi \\ x_r^2 + (y_r - l\cot\phi)^2 = (l\cot\phi)^2 \end{cases} \tag{8}$$

The equation can prove that when car move at a low speed, trace only relate to steering angle of front wheel ,wheel width and wheelbase.

2.2 The establishment of fuzzy neural network

The traditional fuzzy control based on expert experience which is very subjective. When the problem is complicated, single expert experience is difficult to establish a complete fuzzy control rules. At the same time lack of the ability of autonomous learning and automatic change are widely criticized.

After the introduction of neural network, FNN can make full use its independent learning ability.

To get fuzzy rules, preliminary data can be obtained through the corresponding data acquisition analysis. According to the fuzzy logic, the corresponding RBF fuzzy neural network model is established. Whether the degree of fuzzy rules is reasonable are judged by sensitive method. If not reasonable, increasing or decreasing the clustering center through the cluster analysis method. The preliminary model of the fuzzy neural network is established by repeating the above steps until it meets the requirements of the sensitivity.

2.2.1 Sample extraction

According to the actual situation of reverse, a coordinate system is established. Corresponding samples are obtained from corresponding data statistics, likely position and inclination.

In this paper, the classical unsupervised learning algorithm k-means is used to analyze the data and obtain the corresponding fuzzy rules.

Initialization of the algorithm: selection of h different initial cluster centers by random;

Calculate the distance between all samples and cluster centers $\| \boldsymbol{X_j} - \boldsymbol{c_i(k)} \|$, i=1, 2, ⋯; h, j=1, 2, ⋯;N;

Classification of the input sample $\boldsymbol{X}_j$ according to the shortest distance principle.($\boldsymbol{X}_j$)=min$\| \boldsymbol{X}_j - \mathbf{c}_i(k) \|$, i=1,2, ⋯;*h*. $\boldsymbol{X}_j$ will be classified as category i.

Recalculate all kinds of new cluster centers. $\mathbf{c}_i(k+1) = \sum_{x \in w_i(k)} x$, i=1,2, ⋯;where Ni is the sample in cluster domain $w_i(k)$.

If $\mathbf{c}_i(k+1) \neq \mathbf{c}_i(k)$turn to step (2).If not, end of calculation.

2.2.2 Fuzzy control and FNN

In most case, triangular or trapezoidal full overlapping part function are used as membership function. Control rules are Summarized to a series of “IF (condition), THEN (conclusion)” form. The control action set is inferred from fuzzy rules and the object or process is controlled. The control action set is a set of conditional statements, and the condition and the control function are a set of fuzzy linguistic sets, Such as "Positive", "negative", "high" and "low", "normal" etc. In the practical application of fuzzy control, most systems are made of fuzzification fuzzy reasoning, defuzzification, fuzzy rules and the controlled object. According to the above part, the fuzzy neural network model is established as follow:

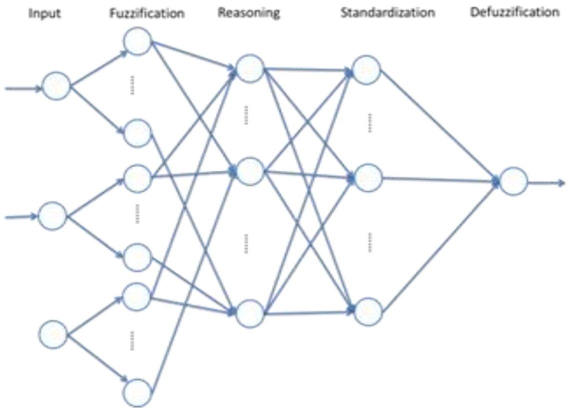


Fig.2 Fuzzy Neural Network

The first layer is the input layer, which completes the task of receiving the signal.

The second layer is the fuzzy layer. To complete the fuzzy task, the input values are converted into fuzzy sets, which belong to the membership of a fuzzy subset. Input U=（u1 , u2, ……, uM, Center value and width are cj=（c1j, c2j, ……, cMj）and σj=（σ1j, σ2j, ……, σMj）.

$$u_j = e^{\frac{(x_i-c_{ij})^2}{2\sigma_{ij}^2}} \quad i=1,2,\ \ldots\ldots,\ M;\ j=1,2,\ \ldots\ldots,\ P$$

The third layer is the reasoning layer. The former part of the rule is completed, that is "if";

$$\varphi_j = e^{-\sum_{i=1}^{M}\frac{(x_i-c_{ij})^2}{2\sigma_{ij}^2}}$$

The fourth layer is the normalized layer. After the completion of the rules, that is, "then" part. Fuzzy reasoning, and the output of fuzzy sets.

$$I_l = v_l w_l = \frac{\varphi_l w_l}{\sum_{j=1}^{P}\varphi_j} = \frac{w_l e^{-\sum_{i=1}^{k}\frac{(x_i-c_{ij})^2}{2\sigma_{ij}^2}}}{\sum_{j=1}^{P} e^{-\sum_{i=1}^{k}\frac{(x_i-c_{ij})^2}{2\sigma_{ij}^2}}}$$

$$y = \sum_{j=1}^{P} v_l w_l = \frac{\sum_{l=1}^{P} w_l e^{-\sum_{i=1}^{k}\frac{(x_i-c_{ij})^2}{2\sigma_{ij}^2}}}{\sum_{j=1}^{P} e^{-\sum_{i=1}^{k}\frac{(x_i-c_{ij})^2}{2\sigma_{ij}^2}}}$$

j=1,2, ……, P; l=1, 2, ……, P. I_l is the input of neuron of the normalized layer; y is the output.

After the preliminary establishment of the neural network, we can adjust the structure of the neural network.

2.3 Dynamic regulation model based on growth and pruning fuzzy neural network

In most case, through dimension decomposition of function, main effect can affect the system mostly. If the nonlinearity of the system is not strong, we can only consider the case of the first order. But when the system is strong, the input parameters of the high order characteristics can't be ignored. So, the introduction of total sensitivity is very necessary. In this paper, the general sensitivity analysis method based on Fourier transform is adopted is adopted.

The following expressions are obtained by the Fourier transform:

$$f(s) = A_0 + \sum_{j=-\infty}^{+\infty} (A_j \cos(js) + B_j \sin(js))$$

The values of A_j and B_j are as follows:

$$A_j = \frac{1}{2\pi} \int_{-\pi}^{\pi} f(s) \cos(js) ds$$

$$B_j = \frac{1}{2\pi} \int_{-\pi}^{\pi} f(s) \sin(js) ds$$

The sensitivity can be expressed as:

$$S_h = \frac{Var_{Z_h}[E(Y \mid Z_h)]}{Var(Y)}$$

Var_{Z_h} is the variance of Z_h . $E(Y \mid Z_h)$ Is the expectation of the variance Y o the input variable. The Fourier vibration is decreased with the increase of k , At the same time, the frequency of the fundamental frequency of the other parameters is similar to that of the harmonic wave.

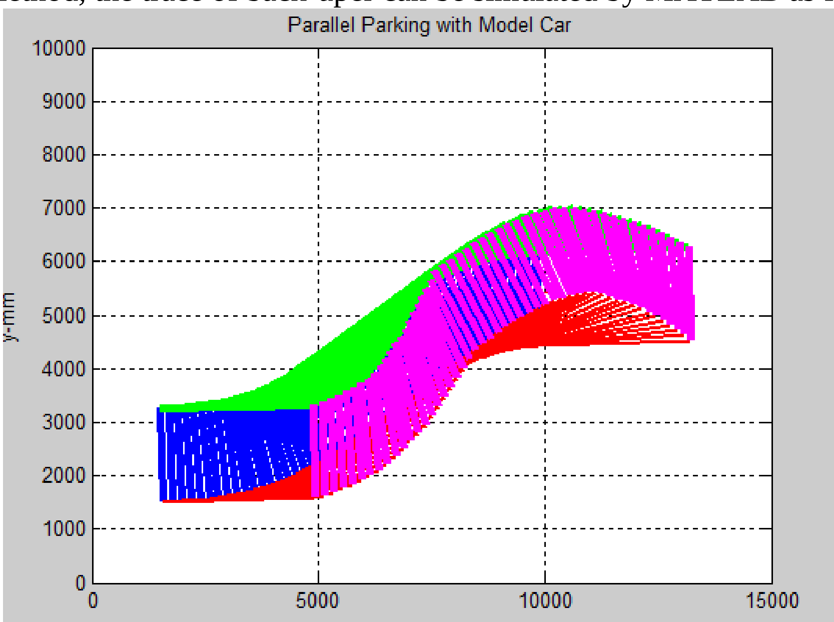
$$\omega_h = 2M \max(\omega_{\sim h})$$

So, the gross sensitivity was

$$SW_h \approx \frac{A_\omega^2 + B_\omega^2}{\sum_{\omega=1}^{M\omega} (A_\omega^2 + B_\omega^2)}$$

3. Conclusion

After using this method, the trace of back-uper can be simulated by MATLAB as follows.



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