Workshop on Artificial Intelligence

The Study on Hybrid Intelligent Automatic Guided Vehicles

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Abstract

The purpose of this paper is to study the hybrid intelligent automatic guided vehicles (HIAGV), which guidance and navigation method is composed of vehicle dynamic motion model and mentor model from driving expertise. The vehicles are navigating in a beeline by dynamic motion model, which derived from the turning angle of front wheels of vehicle (δ) with a fixed speed. But, while vehicles are changing a direction or a curve, it's attitude is varied a large-scale range, could be leaded to exceed out the lane boundary unless adjust the vehicle speed appropriately.

A vision-based vehicle dynamic behavior acquisition algorithm (VVDBA) had been developed to capture δ in our previous study. In this paper, we used this achievement to derive the dynamic motion model and incorporated with a fuzzy inference system to guide the vehicle navigating along the lane smoothly. The captured δ from VVDBA was compared by a threshold value to find more efficient ways of utilizing hybrid automatic guided strategy. If δ is below the threshold value, vehicles are guided by dynamic motion model. Otherwise, HIAGV is using the fuzzy inference system to handle the speed of vehicle that can be moving smoothly and avoiding exceed out the lane boundary.

HIVAG was simulated by MTALAB in this paper, and it would obtain robust and precise tracking capabilities along any arbitrary lane.

Keyword: Automatic Guided Vehicle (AGV), hybrid system, Fuzzy Inference System, Attitude Control.

I. Introduction

Automatic Guided Vehicles (AGV) has been in use since the 1950's. Figure 1 depicts three stages of an AGV system. The first stage observes the behavior of vehicle motion. The second stage analyzes the attitude of vehicle. The object of last stage is to control the vehicle to navigate along the lane.

Figure 1 Three stages of AGV system

Several methods of guidance and navigation can be implemented. The early AGVs where tracking an inductive guide wire or an optical visible line, painted or made with tape on the floor. Many AGVs have tried to invent the replacement for the inductive guide wire. In later years AGV guiding and navigation systems with laser scanners, microwave transponders, inertia gyros, ultrasonic sensors, embedded magnets, camera vision systems etc. have been launched [1-5][7][9].

We have been studied many technical literatures about the moving characteristics of vehicles [10]. The turning angle of front wheels is important information in AGV, and the dynamic motion model of vehicle can be derived by this angle. In our previous study, we have been developed a vision-based vehicle dynamic behavior acquisition algorithm (VVDBA) to capture δ by CCD camera, lane boundary detection by histogram-based cooler-difference fuzzy clustering analysis and coordinate transformation method [11].

II. Vehicle Motion Characteristics

The motion of vehicle is involved with two coordinate systems shown as Figure 2. The first is the earth-fixed coordinate system, O^w, X^w and Y^w are represented as the origin, abscissa, and ordinate, respectively. The second is the rigid body coordinate system, which is the coordinate system of vehicle, O^v, X^v and Y^v are represented as the origin, abscissa, and ordinate, respectively. δ is the angle between the moving direction of vehicle front wheel and the vehicle coordinate system. v is the speed per hour of vehicle, which follow the direction of the front wheel. v_{x^w} and v_{y^w} are represented as the horizontal and vertical quantity of v, respectively. θ is the angle between the earth fixed coordinate system and the vehicle coordinate system. L_v is the length of the wheelbase of vehicle.

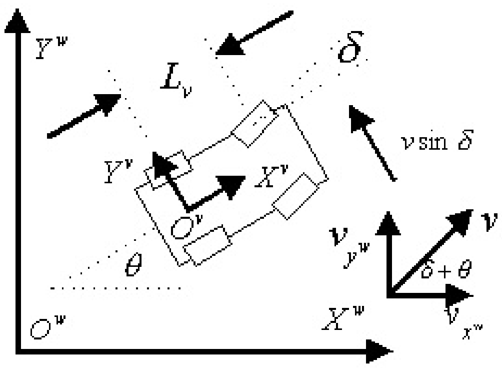


Figure 2 Coordinate systems of vehicle movement

When the vehicle is turning motion and θ is time invariant, it generates an angular velocity $\dot{\theta}$. The relationship among $\dot{\theta}$, L_v, v and δ are represented by Equation (1) and is depicted in Figure 3. Equation (1) is a first order ordinary differential equation, which solution is the current angular of θ. After θ was generated by δ, the motion equations could be derived and were shown as Equation (2) and (3). Where $\dot{X}^w$ and $\dot{Y}^w$ are change rate of X^w and Y^w. While $\delta = 0$ and $\dot{\theta} = 0$, the vehicle is moving as a straight line.

$$\dot{\theta} = \frac{1}{L_v} v \sin \delta \tag{1}$$

$$\dot{X}^w = v\cos(\delta+\theta) \tag{2}$$

$$\dot{Y}^w = v\sin(\delta+\theta) \tag{3}$$

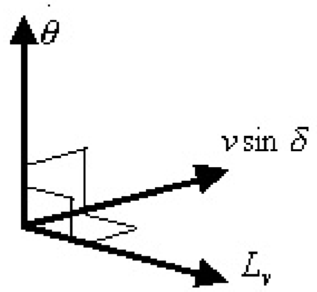


Figure 3 Geometric relationship of vehicle turning motion

III. Hybrid Intelligent Automatic Guided Vehicle

The vehicles are navigating by dynamic motion model in a beeline with a fixed speed. But, while vehicles are changing a direction or a curve, it's attitude is varied a large-scale range, could be leaded to exceed out the lane boundary unless adjust the vehicle speed appropriately. Several researches have been study a hybrid scheme about AGV to solve this problem. [3] [6]. Therefore, the motivation of this study is developing a hybrid intelligent scheme for AGV, we named it Hybrid Intelligent Automatic Guided Vehicle (HIAGV). The guidance and navigation method of HIAGV is composed of vehicle dynamic motion model and mentor model from driving expertise. The δ captured by VVDBA and compared by a threshold value to find more efficient ways of utilizing hybrid automatic guided strategy. If δ is below this threshold value, vehicles are guided and navigated by dynamic motion model. Otherwise, HIAGV is using the fuzzy inference system to manage the velocity of vehicle that can be moving smoothly and avoiding exceed out the lane boundary.

The major object of HIVAG is illustrated as Figure

4, e.g. it executing the attitude control to guide the vehicle navigating along the center of lane.

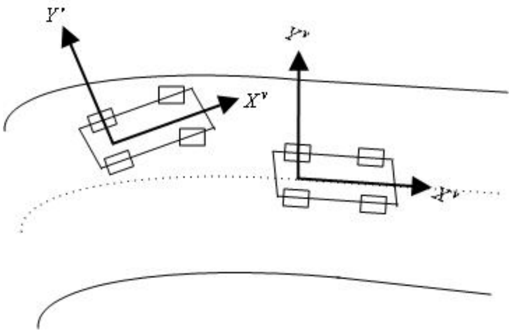


Figure 4 Major object of HIAGV

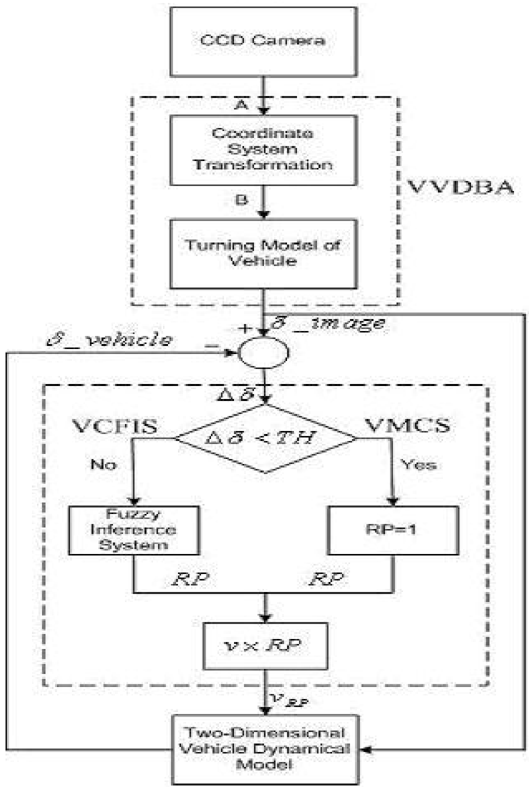
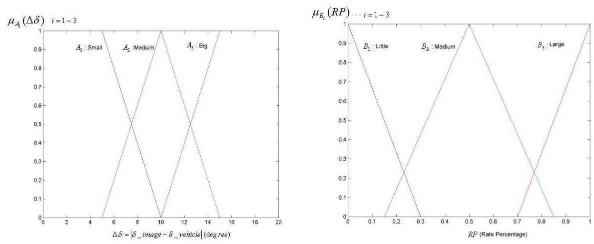


Figure 5 Block Diagram of HIAGV

The block diagram of HIAGV is depicted in Figure 5. The CCD camera captures lane image to observe the behavior of vehicle motion. VVDBA detects the lane boundary from image plane by histogram-based fuzzy clustering analysis [8] [11] and obtains the current turning model of vehicle from δ_image by coordinate transform calculation [11]. The error of turning angle $\Delta\delta$ is the difference value between expectative attitude $\delta\_vehicle$ and δ_image. $\Delta\delta$ is compared by a threshold value TH to decide which guidance strategy could be selected. Vehicle model control strategy (VMCS) is model-based AGV, and the vehicles are guiding along the lane by Equation (1) to (3) in a beeline with a fixed speed, which is labeled as $RP = 1$ in Figure 5. Velocity control fuzzy inference strategy (VCFIS) is selected to obtain an appropriately velocity change rate (RP), which is labeled as $0 \le RP < 1$ in Figure 5. Therefore, while attitude is varied a large-scale range, the velocity of vehicle can be reduced by VCFIS, so that the attitude of vehicle can be modified by means of speed adjustment.

The fuzzy rule base of VCFIS is shown in Equation (4), and the definition of two linguistic variables illustrated as Figure 6.

$$\begin{aligned} &R_1 : IF\ \Delta\delta\ is\ Small\ THEN\ RP\ is\ Large \\ &R_2 : IF\ \Delta\delta\ is\ Medium\ THEN\ RP\ is\ Medium \\ &R_3 : IF\ \Delta\delta\ is\ Big\ THEN\ RP\ is\ Little \end{aligned} \tag{4}$$



(a). input variable $\Delta\delta$ (b). output variable RP

Figure 6. The definition of membership functions

IV. Experiments

Several experiments are demonstrated using MATLAB simulation software in discrete mode of vehicle motion model, and rewrite from Equation (5) to (7). T is sample period and supposes that the vehicle velocity is invariable in the sample interval to simplify the system.

$$\theta[k+1] = \theta[k] + \frac{v[k] \times T \times \sin(\delta[k])}{L_v} \tag{5}$$

$$x[k+1] = x[k] + v[k] \times T \times \cos(\delta[k] + \theta[k]) \tag{6}$$

$$y[k+1] = y[k] + v[k] \times T \times \sin(\delta[k] + \theta[k]) \tag{7}$$

All the experiments are simulated at similar 3.8 meters width lane, which shape is sketched in Figure 7.

The initial attitude of vehicle does not match with the lane center and depicted in Figure 8, where the length and width of vehicle is supposed 3 meters and 1 meter, respectively.

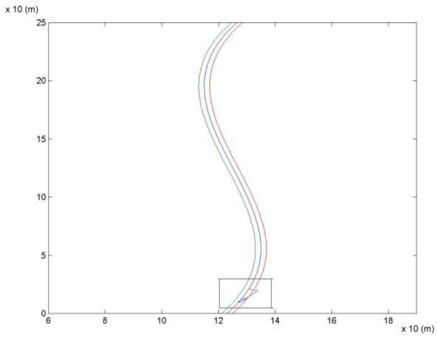


Figure 7 The initial shape of simulation lane

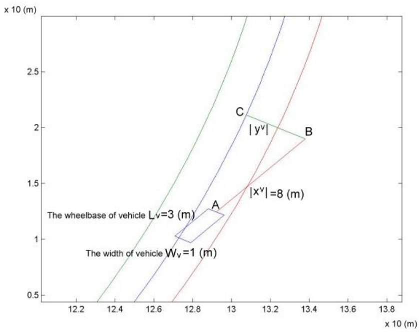


Figure 8 The initial attitude of vehicle

The object of experiment was to demonstrate the performance and stability of HIAGV in different vehicle speed (from 50 to 80 kilometers per hour), and compared with model-based AGV. In this experiment, HIAGV was assumed that the threshold value TH of $\Delta\delta$ was 5°. Each case of different vehicle speed was individually simulated by means of HIAGV and model-based AGV, and illustrated the simulation results with 4-tuple graphics, e.g., δ variation, front wheel depart from center of lane, rear wheel depart from center of lane, and the vehicle changing speed, respectively.

The case of 50 (km/hr) simulation results was shown as Figure 9, where dash lines and solid lines were sketched by model-based AGV and HIAGV, respectively. The variation of δ of the HIAGV was better smooth than model-based AGV, and the departure distance of front and rear wheel also more stable than model-based AGV. While the vehicle was turning along the lane, the speed of HIAGV would adjust adequately by VCFIS, but model-based AGV remain the same speed that leading the vehicle had a vibratile motion.

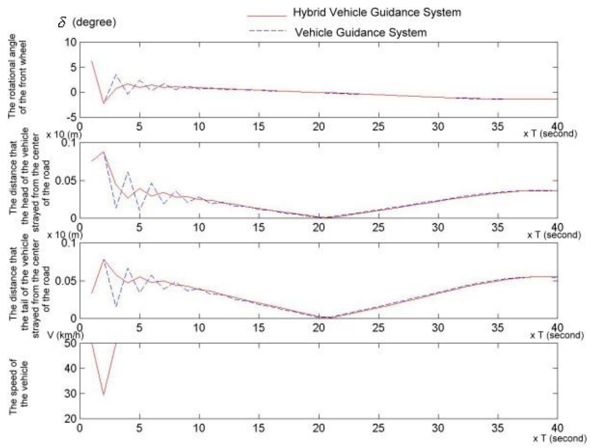


Figure 9 Performance Comparison 50(km/hr)

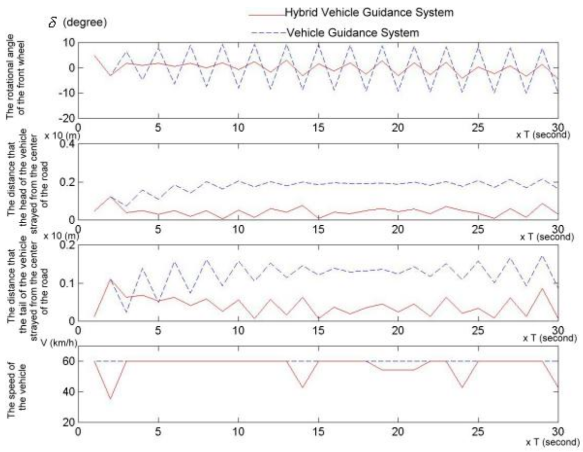


Figure 10 Performance Comparison 60(km/hr)

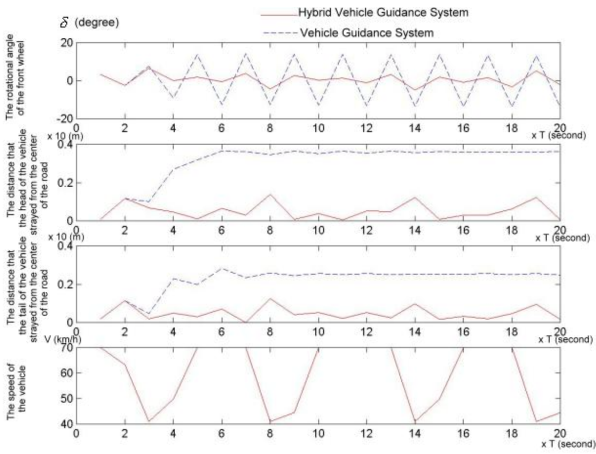


Figure 11 Performance Comparison 70(km/hr)

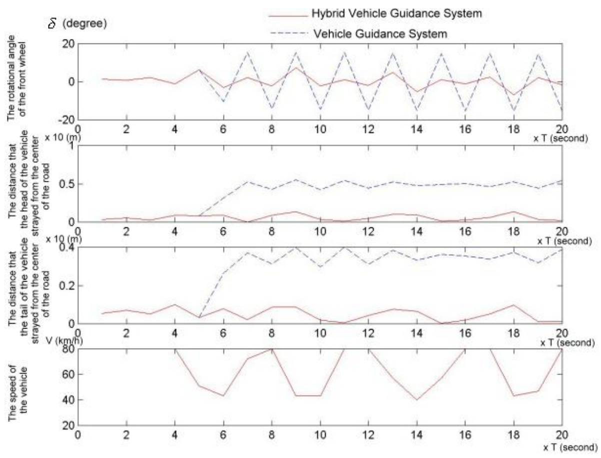


Figure 12 Performance Comparison 80(km/hr)

The simulation results that assigned by different speed of vehicle were illustrated from Figure 10 to 12. The HIAGV retained stable guiding along the lane center no matter what the different speed, since the vehicle speed could be adjusted by VCFIS while the attitude variation. But, model-based AGV could not obtain stable navigation along the lane center, because the vehicle might be leading out the lane.

V. Conclusions

This study deals with a hybrid scheme in automatic guided vehicle system. This hybrid scheme combined the advantages of model-based and fuzzy inference system. The former provided a fast handling of the vehicle to navigating along the lane at small δ. The latter supported a speed adjustment mechanism to control the attitude variant of vehicle.

VI. References

1. M. Nikolova and A. Hero III, “Segmentation of a road from a vehicle mounted radar and accuracy of the estimation,” in Proc. IEEE Intelligent Vehicles Symposium, 2000. IV 2000., pp. 284-289, 2000.
2. R. Behringer and M. Maurer, “Results on visual road recognition for road vehicle guidance,” in Proc. IEEE Intelligent Vehicles Symposium, pp. 415–420, 1996.
3. Y. J. Ryoo and Y. C. Lim “Neuro-fuzzy control system for vision-based autonomous vehicle,” Fuzzy Systems Conference Proceedings, 1999 FUZZ-IEEE '99. 1999 IEEE International vol.3, pp. 1643-1648, 1999.
4. Y. Xu, R. Wang, Libing and S. Ji, “A vision navigation algorithm based on linear lane model,” Intelligent Vehicles Symposium, 2000. IV 2000. Proceedings of the IEEE, pp. 240–245, 2000.
5. R. Aufrere, R. Chapuis and F. Chausse, “A fast and robust vision based road following algorithm,” Intelligent Vehicles Symposium, 2000. IV 2000. Proceedings of the IEEE, pp. 192–197, 2000.
6. S. Y. Oh, J. H. Lee and D. H. Choi, “A new reinforcement learning vehicle control architecture for vision-based road following,” Vehicular Technology, IEEE Transactions, vol.49 Issue: 3 , pp. 997–1005, May. 2000.
7. A. Bensrhair, M. Bertozzi, A. Broggi, P. Miche, S. Mousset and G. Toulminet, “A cooperative approach to vision-based vehicle detection,” Intelligent Transportation Systems, 2001. Proceedings. 2001 IEEE, pp. 207-212, 2001.
8. X. Q. Ye, Z. H. Huang and Q. Xiao, “Histogram based fuzzy C-mean algorithm for image segmentation,” Pattern Recognition, 1992. vol. III. Conference C: Image, Speech and Signal Analysis, Proceedings.,11th LAPR International Conference, pp. 704–707 1992.
9. Q. T. Luong, J. Weber, D. Koller and J. Malik, “An integrated stereo-based approach to automatic vehicle guidance,” Computer Vision, 1995. Proceedings., Fifth International Conference, pp. 52-57, 1995.
10. T. D. Gillespie, “Fundamentals of Vehicle Dynamics,” Society of Automotive Engineers, Inc.
11. Jamous Tsai, “The Study on Vision-based Intelligent Vehicle Guidance,” Master Thesis, Department of Electrical Engineering, National Dong Hwa University, July, 2002.