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2013 IOP Conf. Ser.: Mater. Sci. Eng. 53 012025

(http://iopscience.iop.org/1757-899X/53/1/012025)

A Fusion of Sensors Information for Autonomous Driving Control of an Electric Vehicle (EV)

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Abstract. The study uses the environment of the road as input variables for the main system to control steering wheel, brake and acceleration pedals. A camera is installed on the roof of the Electric Vehicles (EV) and is used to obtain image information of the road. On the other hand, users or drivers do not have to directly contact with the main system because it will autonomously control the devices by using fuzzy information of the road conditions. A fuzzy information means in the preliminary experiments, reasoning of the various environments will be done by using fuzzy approach. At the end of the study, several existing algorithms for controlling motors and image processing technique could be combined into an algorithm that could be used to move EV without assist from human.

1. Introduction

Autonomous driving is increasingly attracting public interest due to various research projects over the past years [1-7]. Usually, conventional cars are converted with significant effort and many different sensors are placed on the roof. The advance of electro-mobility provides the chance for completely new vehicle concepts. By breaking away from classic approaches, it is possible to consider and integrate autonomous driving into the vehicle architecture with respect to Information Technology (IT) and sensor network systems, energy management and design. These kinds of cars are the upgrade version of the EV.

Recently a lot of EVs and related vehicles such as a hybrid car have been developed to solve environment and energy problems caused by the use of an internal combustion engine vehicle. Developing such vehicles for solving the environment and energy problems is a great idea. Currently, many researches publish technical papers in journals, which are related to autonomous EV. In their researches, steering wheel, brake and acceleration pedals are control by using computers [8-10]. On the other hand, users and drivers do not have a direct contact with them. A touch panel is installed in the EV and it serves a user Graphical User Interface (GUI) for users and drivers interact with controlling devices. Unfortunately, based on current outcomes more effort should be done for making

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sure that autonomous EV could move with safety. Although mechanism of mechanical could be used to solve safety and reliability issues of an autonomous EV, the computational approach is also very important. The computational approach for example the algorithm for controlling motor device, the capacity of data transmission device, image processing technique and etc. [11-13].

2. Literature Review

The focus of current research towards electric, hybrid electrics, and fuel cell vehicles has been on increasing energy efficiency and reducing emissions. Future vehicles will include electric drive-train components that must be capable of performing conventional anti-lock braking, traction control, and active yaw control safety functions. From the viewpoint of electric and control engineering, Hybrid electric vehicles (HEVs) have evident advantages over conventional internal combustion engine vehicles (ICVs). Firstly, torque generation is very quick and accurate, for both accelerating and decelerating. This should be the essential advantage. In Hybrid electric vehicles, motor and traction control system (TCS) should be integrated into Hybrid Traction Control System (HTCS), since a motor can either accelerate or decelerate the wheel. Its performance should be advanced one, if we can fully utilize the fast torque response of motor. Secondly, output torque is easily comprehensible. There exists little uncertainty in driving or braking torque inputted by motor, compared to that of combustion engine or hydraulic brake.
In recent years fuzzy logic control techniques have been applied to a wide range of systems. Many electronic control systems in the automotive industry such as automatic transmissions, engine control and traction control systems are currently being pursued. These electronically controlled automotive systems realize superior characteristics through the use of fuzzy logic based control rather than traditional control algorithms. Fuzzy Logic Control is a type of control, which is based on Fuzzy set theory and reasoning. David Elting and Mohammed Fennich in their research told that automotive systems realize superior characteristics through the use of fuzzy logic controllers [14] especially in nonlinear cases. The brake system is a challenging control problem because the vehicle-brake dynamics are highly nonlinear with uncertain time-varying parameters [15]. Fuzzy controllers have the benefit of not requiring a mathematical model of the plant [16], while still being highly robust [17]. Also, certain fuzzy control designs can be implemented that have the ability to learn [18] or to adapt [19] themselves to improve its performance. Because of these features, fuzzy controllers have been successfully implemented in the automotive field for controlling both wheel dynamics and vehicle dynamics.

3. Methodologies

In this study, a pure differential drive of the electric vehicle is considered as shown in figure 1 and it is assumed that the posture and the orientation of the vehicle are known at each instant. By referring to the figure, L is the base width of the vehicle and R is the distance between the centres of the wheel. The orthonormal inertial basis is $\{x, 0, y\}$, which is called the world coordinate system that is fixed to cartesian workspace. The centre of gravity of the mobile vehicle is the point C, and the basis $\{M_1, C, M_2\}$ is attached to the EV, which is called the local coordinate system. M_1 refers to longitudinal direction, while M_2 is the vertical direction, and $OC=xI_1+yI_2$. The location of EV could be determined by three variables, which are the spatial positions x and y of the reference point C, and its orientation. The vector Ps describing the EV posture and is defined as in equation (1).

$$p_s(t) = \begin{bmatrix} x(t) \\ y(t) \\ \theta_c(t) \end{bmatrix} \quad (1)$$

Where $t_0<t<t_n$ and t_0 is the initial moment of motion and t_n is a final moment of motion. For example, in the perspective of brake control of the EV, two degree of freedom is considered, which is velocity V_C and angular velocity θ_c as shown in figure 2. The vehicle kinematic associated with the Jacobean matrix and the velocity vector is defined in equation (2).

$$\begin{bmatrix} \dot{x}_c \\ \dot{y}_c \\ \dot{\theta}_c \end{bmatrix} = \begin{bmatrix} \cos\theta_c & 0 \\ \sin\theta_c & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v_c \\ \omega_c \end{bmatrix} \tag{2}$$

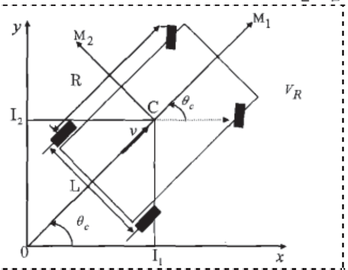

Figure 1. A pure differential drive of the EV model

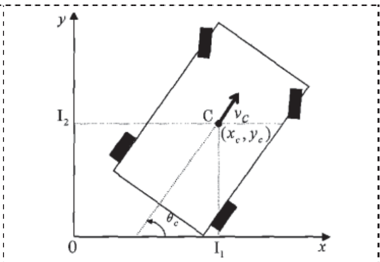

Figure 2. **T**wo degree of freedom of EV model.

Besides brake and acceleration pedals, a steering wheel also needs to be considered in an autonomous EV. Directions of the EV depend on the current degree of the steering wheel. By extracting a rear wheels as shown in figure 2 as the driving wheel, figure. 3 give the description of the steering wheel. In the autonomously control of the EV, the input images from the camera are used to control the degree of the steering wheel. On the other hand, β(t) and α(t) must be adjusted for the EV to move straight in a straight road, and for the EV to turn left or right in the curvature condition.

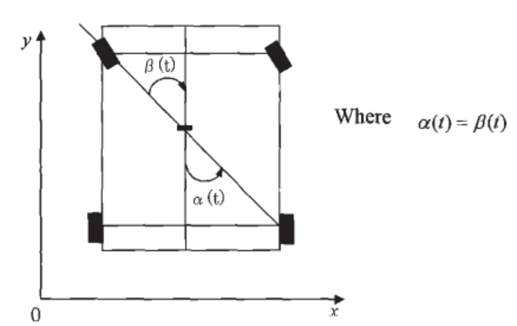

Figure 3. Description of the steering wheel.

Figure 4 shows an electrical configuration of the proposed EV. Two personal computers will be installed in the EV. The first PC will be employed for the motor control included I/0 board, motor control board. The second PC is for image processing included image process board. These two PC is connected through Ethernet hub or a wireless data transmission device. The on-board computer via mouse and touch panel is installed to operate steering wheel, gear shift, brake and acceleration pedals. On the other hand, the computer must control the vehicle brake pedal without having direct access to the steering mechanism, drive motor, and the transmission of the vehicle. The computer must be able to control the vehicle brake in the same manner as a human being does. The accelerator and the brake use stepping motor and the steering wheel part uses AC servo motor.

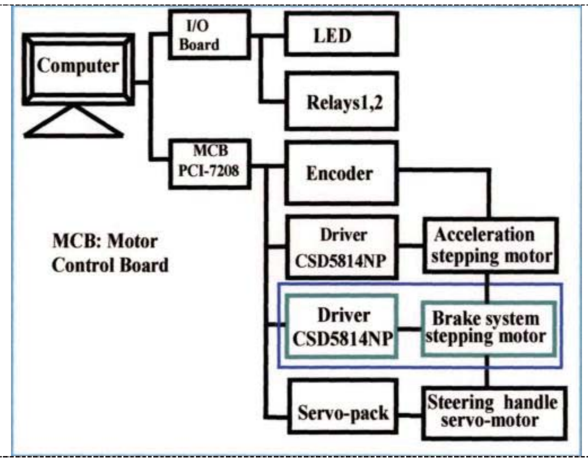

Figure 4 Electrical configuration of the proposed EV.

4. Results and discussions

This paper presents the design and implementation of an autonomous Electric Vehicle (EV) with intelligent driving control to provide the driver assistance as well as unmanned driver. It is an automatic guided vehicle and able to move automatically along the tracks in a given region. For the purpose of prototyping, a buggy car will be re-designed and several sensors are installed. The camera will be installed to the EV as a vision system and connects to the personal computer (PC) for the processing of image information. Image processing algorithm will be employed for the detection of the signage and the centre of gravity (COG) of the road. Another PC will be installed for controlling motors to operate acceleration pedal, brake pedal and steering wheel. Information from several sensors is fused to move the EV intelligently without control by the human.

Figure 5. Buggy Car.

In the experiment, the EV will follow the line in the middle of the road, and the line drawn in both left and right of the road. A CCD camera is used to capture images of the road while EV moves. The fuzzy information of the image captures is transferred to the second PC to control stepping and servo motors. The control mechanisms are stepping motors for brake and acceleration pedals, and a servo motor for the steering wheel. Figure 5, shows the image at time *t* captured by the CCD camera. The CCD camera is controlled by the first PC, and the image information is sent to the second camera for the main system to make a decision and produces command to the motor control board. For the purpose of reducing a computational cost, the image information contains the centre of gravity of the line and the values of θ. The image information captured by the CCD camera is processed by using image processing technique. The centre of the gravity of the line and the angle of the current location of the EV are sent to the second PC. Here, a predictive algorithm is needed to move the EV to the correct position at the time *t*+1. A Kalman filter technique is proposed to predict the future location of the EV. To move toward correct location, steering wheel, brake and acceleration pedals will be controlled.

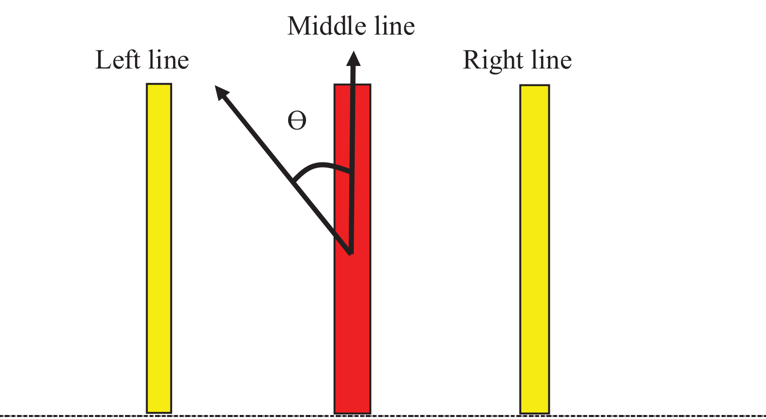

Figure 5. The road condition with the middle and side lines. Image information captures by a CCD camera.

5. Conclusions

The research of the electric vehicle (EV) in the proposal is developed in two fields. One is the control of the accelerator and the brake, the other is the controls of the steering wheel. Both of them are interfaced with stepping and servo motors with controllers. Needing the control of the accelerator and the brake is combined with the control of steering wheel is running at a constant speed. This becomes a necessary, indispensable technology in doing the driving support and actually running on the road. Therefore, we will set a speed control as a basic research to combine the control of the accelerator and the brake with the steering control by an image processing technique. The control of the steering wheel is done by referring to input images captured by using a CCD camera equipped on the EV. In this paper we produce the theory and conceptual of further experiment on Autonomous Driving Control of an electric vehicle EV. Hopefully after the future research and experiment, the results will appear as what we discuss on discussion and expected results.

Acknowledgements
Special thanks to all members of UniMAP Advanced Intelligent Computing and Sustainability Research Group, COEUAS and School Of Mechatronics Engineering, Universiti Malaysia Perlis, Malaysia for providing the research equipment and internal foundation. This work is also supported by the fundamental research grant scheme (FRGS) awarded by the Ministry of Higher Education to Universiti Malaysia Perlis (FRGS 9003-00313).

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