An Economic Assistance Strategy for Autonomous Driving System

Chao-Yang Lee
Green Vehicle Development Division
Automotive Research & Testing Center
Changhua County, Taiwan (R.O.C.)
nelsorn@artc.org.tw

Chia-Fu Lee and Hsin-Mu Tsai
Department of Computer Science and Information Engineering
National Taiwan University
Taipei, Taiwan (R.O.C.)
chiafu1123@gmail.com and hsinmu@gmail.com

***Abstract*—Recently autonomously driven vehicle technologies become the potential researches in order to increase road safety, driving comfort, fuel efficiency and so on. This study focuses on the fuel-saving issue in automatic vehicle within the scope of the decision maker layer. An intelligent economic assistance strategy (EAS) is explained and aims to reduce fuel cost when the vehicle is driving autonomously. The EAS has performed in decision marker layer which includes three components, mission component, behavior component and motion component. First, the mission component decides the shortest route from present location to destination. Next, in behavior component, the EAS receives the scene information and ego-vehicle information from data acquisition unit in perception. Due to the development the different economy schemes based on different driving scenarios can provide more fuel efficiency, the system analysis the whole information and adopts the driving scenario classifier to classify the immediately driving behavior. Then, in motion component, the EAS presents an economic driving pattern to guidance automatic vehicle to achieve low fuel consumption. Based on the result of the EAS system, the action layer drives the automatic vehicle according to suggest of economy driving speed and adjusts the speed and acceleration within limited of safe and economy. Finally, the proposed economy assistant strategy can successfully guide automatic vehicle in an economic driving style.**

Keywords—Economic Assistance Strategy; Autonomous Driving System; Eco-driving; Advanced Driver Assistance System

I. INTRODUCTION

Recently, intelligent vehicle technologies have the potential for innovating driving automation since the US Defense Advanced Research Projects Agency (DARPA) Grand Challenge and Urban Challenge. The issues of the autonomous driving vehicles become a key point research in order to improve vehicle safety, driving comfort, fuel efficiency and so on. The autonomic vehicle is capable of sensing, deciding and driving automatically without human control. The development of autonomous driving system requires state-of-the-art technologies. Some research on autonomous driving system (ADS) [1] is focus on intelligent function, such as lane keeping warning (LKW) [2], forward collision warning (FCW) [3], blind spot warning (BSW) system [4] and so on. These warning systems can be merging into ADS.

Many studies have been conducted on perception and decision for autonomous driving. K. Chu *et al.* [5] presented a real-time path-planning algorithm that provides an optimal path for off-road autonomous driving with static obstacles avoidance. The path planning was effectively implemented. Y. Kuwata [6] devised a real-time motion planning algorithm, based on the rapidly-exploring random tree (RRT) approach, applicable to autonomous vehicles operating in an urban environment. The algorithm was implemented for Talos, the autonomous Land Rover LR3 that was MIT's entry in the 2007 DARPA Urban Challenge. C.R. Baker and J.M. Dolan [7] designed an autonomous robotic software subsystem for managing mission execution and discrete traffic interaction in the 2007 DARPA Urban Challenge.

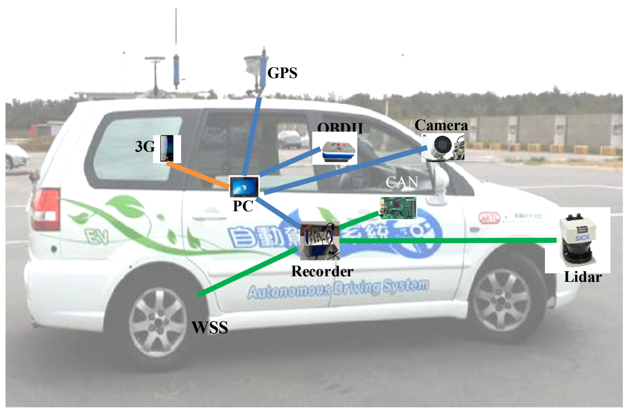

Fig. 1. The equipment of the ARTC's automatic vehicle.

In the recently years, the economy technologies have been getting more and more attentions because of global warming. One of the well-known economy technologies for fuel-saving in vehicle is eco-driving. Eco-driving is a great way to reduce fuel consumption. It is related to the implementation of the eco-driving rules, such as maintaining a steady speed, driving in high gear, decelerating smoothly, and reducing the use of the heavy acceleration. To satisfy the eco-driving rules, driving can save up to 25% [8]. Several studies deal with the development of eco-driver feedback systems or eco-driving assistance system [9] in advanced driver assistance systems (ADAS).

Mario and Víctor [10] validated the impact in fuel saving of using an ecodriving assistant based on anticipation of upcoming static traffic signals that can potentially make the vehicle stop. The system estimates the distance required to stop the vehicle when releasing the accelerator pedal to minimizing the use of braking. S. Trommer and A. Höltl [11] presented the perceived usefulness from economic advanced driver assistance systems (ecoADAS) in different regions of Europe. The survey results show that drivers rate the deployment of eco-driving assistance systems as useful, but the acceptance of additional costs for the user is very low. P. A. Mendoza et al. [12] developed an ecological interface design framework to decrease the complexity of the interface design for advanced driver assistance systems. M.A.S. Kamal et al. [13] designed to measure relevant information of instant vehicle–road–traffic utilising advanced sensing and communication technologies. It estimates fuel consumption and generates the optimal control input necessary for ecological driving.

Based on the above studies, the eco-driving technologies can help the driving more energy-efficient significantly. Based on the concept of the eco-driving assistant system, this study aims to deal with the economy fuel driving in the autonomous driving system. The economic assistance strategy has been describe in this paper. The rest of this study is organized as follows. Section 2 introduces preliminaries and system architecture. Next, Section 3 elucidates the proposed economic assistance strategy in autonomous driving system. Section 4 summarizes the simulation results. Section 5 draws conclusions.

II. PRELIMINARIES AND SYSTEM ARCHITECTURE

The autonomous driver system, which built in vehicle, is one of the solutions to make transport more safety, more reliability, more comfortable and more environmentally friendly. This study build an automatic vehicle in Automotive Research & Testing Center (ARTC) . Autonomous driving system sense the environment with the techniques such as ladar, camera, GPS, OBDII, CAN and so on. All equipment of autonomous driving system had install in the ARTC's automatic vehicle is shown in Fig. 1. The system diagram of the autonomous driving system on ARTC's automatic vehicle is shown in Fig. 2. The structure of automatic vehicle includes the sensor layer, perception layer, decision maker layer, and action layer. The sensor layer haves sensors, such as wheel speed sensor, LADAR and so on. The ARTC's automatic vehicle has a wheel speed sensor (WSS) to count the traveling distance. The recorder obtains the information which collected from WSS via controller area network (CAN). The recorder also collects the LADAR information. The information which has collected in recorder transmits to PC and stores it. The vehicle status information, such as mobile speed, engine revolution per minute, accelerator pedal position, and fuel used, has collected through the vehicle's diagnostic port (OBDII) or recorder via controller area network (CAN). Two GPS has installed in the vehicle, one of the GPS equipment is real time kinematic GPS (RTK-GPS) and the other is 5HZ GPS. The RTK-GPS provide the real-time GPS position and the data rate is 20Hz. The 5HZ GPS connects and sends information to the recorder. The RTK-GPS is more accurate than 5HZ GPS, but it also more expensive than 5HZ GPS. A camera has built on automatic vehicle for driving observation.

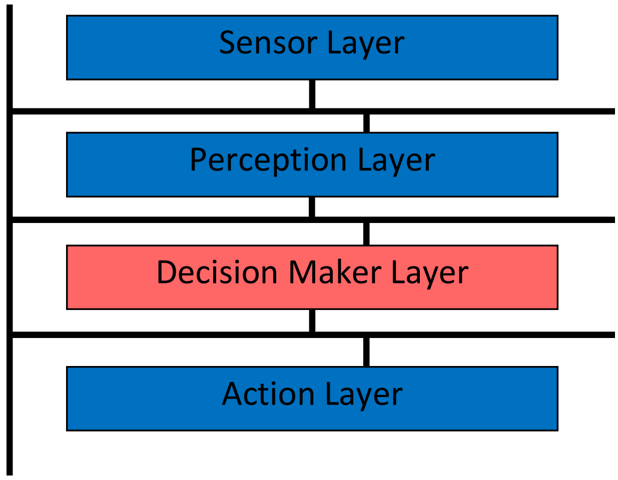

Fig. 2. System diagram of the ARTC's automatic vehicle.

The perception layer collects the sensor information from sensor layer. The inputs of the decision maker layer are the environment status data which collected from sensor layer. The decision maker layer calculates an economy driving pattern for automatic driving in real time. A PC collects data and acts the calculation center of decision maker, and it also transmits data to the cloud-based server through 3G network. An action layer has built in a microcontroller unit (MCU). It acts the, where signals of steering wheel, gear, ultrasonic sensor, brake, and throttle are delivered on the controller area network (CAN). The action layer keeps the driving on economy driving pattern which obtained from decision maker layer.

III. ECONOMY ASSISTANT STRATEGY

Autonomous vehicles capable of driving safely have been a vision for many years. This study focus on the economy issues in automatic vehicle. The structure of autonomous driving system includes perception layer, decision maker layer, and action layer, as shown in Fig. 3. The perception layer in autonomous driving system consists of pose component, road shape component, and object component. The pose component collected the sensor information from GPS and wheel speed sensor (WSS) to estimate the vehicle pose. The vehicle pose includes vehicle position, velocity, orientation, and acceleration. It indicates the vehicular pose information. Then, the road shape component shows the road finder via lidar, road map (RNDF), camera and velodyne. It indicates the road information, such as curvature, edge, lane marking, and orientation. Finally, the object component in perception layer describes the list and characteristics of objects. In this component, it shows the numbers of obstacle, location of obstacle, classification of obstacle, recognition of obstacle, motion of obstacle, and the tracking. The information which calculated in perception layer sends to decision maker layer, and then calculates an economy driving pattern in decision maker layer.

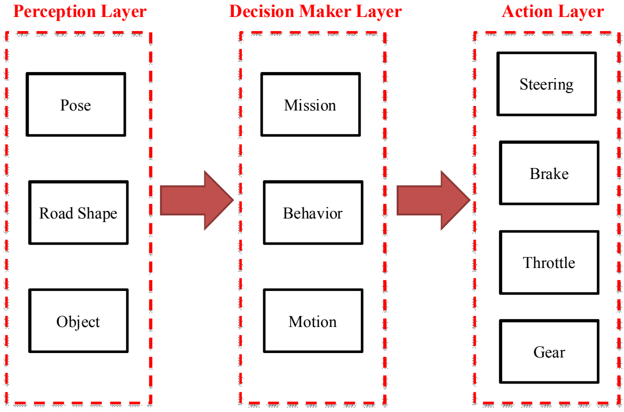

Fig. 3. The structure of autonomous driving system.

A motion component in decision maker layer acts a route planner provides information about the prospective planned route. The problem of finding the minimum cost of route for driving in mission component can be formulated as the following.

$$\text{Objective:} \quad \text{Min } \Sigma_{l \in L}\, x_l c_l \tag{1}$$

subject to

$$\Sigma_{p \in P}\, y_p = 1 \tag{2}$$

$$\Sigma_{p \in P}\, y_p \delta_{lp} \leq x_l \quad \forall l \in L \tag{3}$$

$$x_l = 0 \text{ or } 1 \qquad \forall l \in L \tag{4}$$

where L denotes the sets of link, cl denotes the cost of link, P is the set of the total available route, l_p is the indicate variable of the binary, y_p and x_l are binary variables.

In the behavior component, the system judges the vehicle's behavior status. This study divides the vehicular behavior into four behaviors, which is acceleration, deceleration, cruising and turning. The behavior component consists of two phase, training a behavior model and building a behavior classification. First, in the training a behavior model phase, the vehicle information which obtained from perception payer has twenty nine features, such as speed, location, torque, fuel cost, and etc. The principal components analysis (PCA) [14] had applied in behavior component to reduce the dimension of features while preserving data information. Principal component analysis (PCA) is a well-known method which is a statistical procedure for data analysis. Through the PCA, the system has the capability of real time. Then, the system adopts the support vector machine (SVM) to learn a behavior model and to build a behavior classification.

Finally, the motion component calculates a driving pattern according to the current driving behavior which obtained via behavior component. This study used the support vector regression (SVR) method to obtain the economy driving pattern and to build a fuel regression model. The support vector machine can also be used as a regression method which called SVR. SVR learns a regression model based on the fuel cost. Thus, the system performs the SVR to calculate an economy pattern. All equipment of the autonomous driving system on ARTC's automatic vehicle shows in Fig.1.

IV. EXPERIMENTS

In this section, we show the results of experiments. The experiment vehicle for autonomous driver system has built in Mitsubishi Savrin at Automotive Research & Testing Center (ARTC) as shown in Fig. 4. The ARTC was established in 1990 by the Ministry of Economic Affairs together with the Ministry of Transportation and Communication, the Environmental Protection Administration and representatives of the enterprises based on the Automotive Industry Development Policy, which was approved by the Executive Yuan on March 15, 1985.

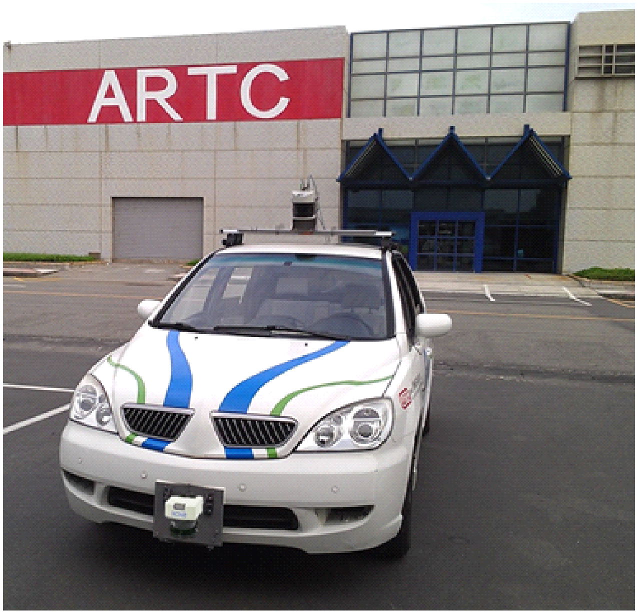

Fig. 4. The automatic vehicle in ARTC.

The results of decision maker layer decides a driving pattern of economy driving behavior for autonomous driving system, as shown in Fig. 5. This study built a behavior classification model and a fuel regression model by using support vector machine (SVM) algorithm and support vector regression (SVR) method, respectively. The behavior classification model judge the driving behavior in real-time. Then, the fuel regression model estimates the economic driving pattern. The value of real fuel consumption and the value of prediction fuel consumption are very close. This phenomenon shows that the fuel regression model in this study is available.

In the autonomous driving system, this study also builds a user interface to show the vehicular information for driver, as shown in Fig. 6. The user interface built in a tablet in android OS. It shows the current classification status of the result of the behavior component. Based on the current driving behavior and driving speed, the motion component in decision maker layer decides an economy pattern. The suggestion speed which obtained from motion component had shown in user interface. The driving can observe the status of the economic assistance strategy system in real time.

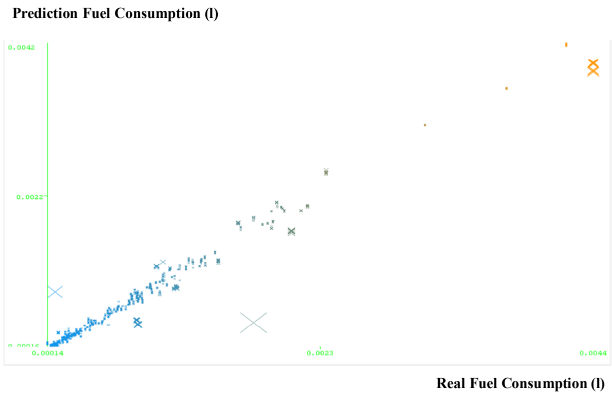

Fig. 5. The fuel regression model in autonomous driving system.

V. Conclusion

In this study, we proposed an economic assistance strategy for autonomous driving system to guarantee the economy driving behavior while automatic driving. The autonomous driving system includes the sensor layer, perception layer, decision maker layer, action layer, and global system layer. This paper is focus on deal with the fuel-saving control method on the decision maker layer. Thereto, an intelligent economic assistance strategy (EAS) system is explained and aims to reduce fuel cost when the vehicle is driving autonomously. The economy assistant strategy in decision maker layer divided into three component, which is motion component, behavior component, and motion component. The EAS system utilizes the environment and vehicle information to identify the driving behavior in real time, and then decides a driving behavior pattern with low fuel economy cost through fuel regression model. Finally, the action layer control the automatic vehicle according to the economy driving pattern which is generation form EAS system. The experiment results show that the proposed system can successfully guide vehicle in an economy driving.

References

[1] T. Luettel, “Autonomous Ground Vehicles Concepts and a Path to the Future,” *Proceedings of the IEEE*, Vol. 100, pp. 1831–1839, 2012.

[2] S.-J. Wu, H.-H. Chiang, J.-W. Perng, C.-J. Chen, B.-F. Wu, and T.-T. Lee, “The Heterogeneous Systems Integration Design and Implementation for Lane Keeping on a Vehicle,” Vol. 9, Issue 2, pp. 246-263, 2008.

[3] K. D. Kusano and H.C. Gabler, “Safety Benefits of Forward Collision Warning, Brake Assist, and Autonomous Braking Systems in Rear-End Collisions,” *IEEE Transactions on Intelligent Transportation Systems*, Vol. 13, Issue 4, pp. 1546-1555, 2012.

[4] B.-F. Wu, H.-Y. Huang, C.-J. Chen, Y.-H. Chen, C.-W. Chang, Y.-L. Chen, “The Blind Spot Warning System for Daytime and Nighttime,” *Proceedings of the 2012 IEEE International Conference on Industrial Technology (ICIT)*, pp. 591-597, 2012.

[5] K. Chu, M. Lee, M. Sunwoo, “Local Path Planning for Off-Road Autonomous Driving With Avoidance of Static Obstacles,” *IEEE Transactions on Intelligent Transportation Systems*, Vol. 13, No. 4, Dec. 2012.

[6] Y. Kuwata, S. Karaman, J. Teo, E. Frazzoli, J.P. How, and G. Fiore, “Real-Time Motion Planning With Applications to Autonomous Urban Driving,” *IEEE Transactions on Control Systems Technology*, Vol. 17, No. 5, Sep. 2009.

[7] C. R. Baker and J.M. Dolan, “Traffic Interaction in the Urban Challenge: Putting Boss on Its Best Behavior,” *Proceedings of 2008 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 1752-1758, 2008.

[8] O. H Koskinen, “Improving Vehicle Fuel Economy and Reducing Emissions by Driving Technique,” *Proceedings of the 15th World Congress on Intelligent Transport Systems and ITS America's 2008 Annual Meeting*, 8 pages, Aug. 2008,

[9] J. Tulusan, L. Soi, J. Paefgen, M. Brogle, and T. Staake, “Eco-efficient Feedback Technologies: Which Eco-Feedback Types Prefer Drivers Most?” *Proceedings of the 2011 IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks* (WoWMoM), pp. 1–8, June, 2011.

[10] Mario Muñoz-Organero and Víctor Corcoba Magaña, “Validating the Impact on Reducing Fuel Consumption by Using an EcoDriving Assistant Based on Traffic Sign Detection and Optimal Deceleration Patterns,” *IEEE Transactions on Intelligent Transportation Systems*, Vol. 14, No. 2, pp. 1023-1028, Jane, 2013.

[11] S. Trommer and A. Höltl, “Perceived Usefulness of Eco-Driving Assistance Systems in Europe,” *IET Intelligent Transport Systems*, Vol. 6, Issue 2, PP. 145-152, 2012.

[12] P. Alvarado Mendoza, A. Angelelli and A. Lindgren, “Ecological Interface Design Inspired Human Machine Interface for Advanced Driver Assistance Systems,” *IET Intelligent Transport Systems*, Vol. 5, Issue 1, pp. 53-59, 2011.

[13] M.A.S. Kamal, M. Mukai, J. Murata, and T. Kawabe, “Ecological Driver Assistance System Using Model-Based Anticipation of Vehicle–Road–Traffic Information,” *IET Intelligent Transport Systems*, Vol. 4, Issue 4, pp. 244–251, Dec. 2010.

[14] R.P. Good, D. Kost, and G.A. Cherry, “Introducing a Unified PCA Algorithm for Model Size Reduction,” *IEEE Transactions on Semiconductor Manufacturing*, Vol. 23, Issue 2, pp. 201-209, 2010.