

Driver-Adaptive Vehicle Interaction System for the Advanced Digital Cockpit

Jin-Kyu Choi, Kyongho Kim, Dohyun Kim, Hyunkyun Choi, Byungtae Jang

Intelligent Robotics Research Division

Electronics and Telecommunications Research Institute (ETRI)

Daejeon, Republic of Korea

{jkchoi, kkh, dohyun, choihk, jbt}@etri.re.kr

Abstract—In this paper, we introduce three key components of the next-generation digital cockpit system to provide the driver-customized driving environment, which indicates automotive sensor network, driver-adaptive interaction engine, and advanced digital cockpit platform. Our concept of driver-adaptive vehicle interaction system includes driving performance evaluation, driver status recognition, and driver emotion recognition. To realize driver-adaptive interaction engine of the advanced digital cockpit system, we explain the hierarchical customization levels and the cycle of the driver-vehicle interaction process.

Index Terms—Driver-vehicle interaction, DVI, driver behavior analysis, digital cockpit

I. INTRODUCTION

IHS Automotive, a global research organization, is forecasting the spread of fully autonomous vehicles for 2025. In order to commercialize autonomous vehicles, several technologies such as environment recognition, position recognition and mapping, judgment, control, DVI (Driver-Vehicle Interaction) are essential. Recently there has been a significant effort in driver behavior modeling and analysis as one of DVI technologies [1]–[5]. Most of these technologies extract vehicle dynamics from CAN (Car Area Network) bus data, driver face video information, and biometric information such as brain waves, electrocardiogram, body temperature and heart-beat, and recognize driver status or emotion using artificial intelligence such as SVM (Support Vector Machine) or CNN (Convolutional Neural Network) [6]–[10]. All drivers operate the steering wheel, accelerating pedal, and brake pedal while driving. If we look closely at these three kinds of simple driving behaviors, we can find out how safely vehicle moves in given traffic or road conditions, and how well driver focuses on driving. In this way, it is the main goal of the driver behavior analysis to infer the driver characteristics or status from basic driving operation information. Three global projects such as UTDrive, UYANIK, and NU-Drive collect driver biometric information, driving behavior information, vehicle dynamics, and road information from 450 people participated from the research of USA, Japan, Turkey, and Italy [2]–[4]. Test cars of these projects are equipped with CAN (Car Area Network) bus device, IMU (Inertial Measurement Unit), GPS (Global Positioning System), front and rear video camera, gas and brake pedal pressure on driver identification and driver distraction detection. In this paper, we briefly introduce our

structure of driver-adaptive vehicle interaction system for the advanced digital cockpit, and driver behaviour modelling for driver status recognition, which is a key element of next-generation DVI system.

II. DRIVER-ADAPTIVE VEHICLE INTERACTION SYSTEM

As the human-vehicle interaction-engine system for digital cockpits is one of the promising automotive technologies, its architectural concept could have a variety of forms. Our concept of driver-adaptive vehicle interaction system is shown in Fig. 1. The interaction engine of this concept plays a role in the brain to communicate with drivers and provide driving information on safety and convenience [10].

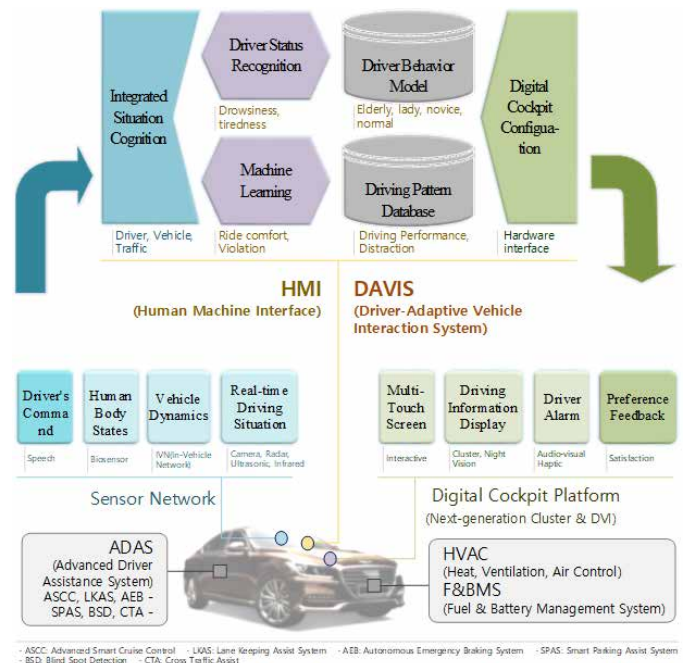


Fig. 1. Concept of customized interaction system for digital cockpit.

A. Automotive Sensor Network

The DVI (Driver-Vehicle Interaction) engine system might require driver's command, human body status, vehicle status,

and real-time driving situation from various sensor network of the car.

- Drivers command includes some touch-inputs on the cockpit display, simple voice command. We suggest that the engine should be able to get some drivers personal information and satisfaction survey. Personal information such as age, gender, and driving experience is used to classify a driver for driver behaviour model. And some feedback such as display preference or voice alert level which is given from the driver is important to determine the criteria for configuration of digital cockpit environments.
- Human body status means the measurement of a variety of biosensors to recognize tiredness, drowsiness, and emotion of driver.
- Vehicle status includes information on an in-vehicle network such as power-train, body control, infotainment, and chassis control sub-network.
- Basic information on the real-time driving situation could be collected from the external camera, radar, lidar, and infrared sensor. Additionally, advanced information could be given by ADAS (Advanced Driver Assistance System) such as ASCC (Advanced Smart Cruise Control), LKAS (Lane Keeping Assist System), AEB (Autonomous Emergency Braking System), SPAS (Smart Parking Assist System) and so on.

B. Customized Driver-Vehicle Interaction Engine

Functional components of this promising interaction engine system include integrated status cognition, driver condition recognition, learning driver propensity, driver behaviour model, driving pattern database, and digital cockpit configuration as shown in Fig. 1.

TABLE I
HIERARCHICAL CUSTOMIZATION LEVELS OF DVI ENGINE SYSTEM

Level	Human-Vehicle Interaction System	
	Service Goal	Inference
lv. 1	Customize automotive cockpit environments including HVAC, FBMS only for one of four driver-groups	Driver behaviour modelling.
lv. 2	Ensure driving safety and convenience by preventing human mistakes and reflect preference feedback	Driver condition recognition.
lv. 3	Personalize automotive environment in terms of personal driving inclinations, traffic situation, and ride comfort by adequate environmental improvement, accident prediction, and risk perception.	Learning the driving propensity

Among these functional components, three inference engines will play a key role in customization for the driver, which are composed of driver behaviour modelling, driver condition recognition, and learning the driving propensity. Moreover, they could be developed or applied in a hierarchical manner as shown in Table. 1.

- The customized interaction engine system classifies the driver in four groups of the elderly, female, inexperienced, and skilled driver for level 1. According to personal information such as age, gender, and driving experience, one of four driver behaviour models can be chosen as configuration baseline of digital cockpit environments. For example, most of the elderly drivers might want simpler display design of cluster, and some female drivers might like to avoid noisy voice alert.
- In level 2, the system tries to ensure driving safety and convenience considering drowsiness, tiredness, as well as the emotion of driver. It will be realized by multi-modal feedback such as preference survey, which affects cockpit environments such cockpit display configuration, and voice alert variation [11].
- Learning the driving propensity such as distraction, violation and driving pattern means to reach level 3. This level of inference engine could customize and personalize real-time driving environments for the individual driver through the successive and repetitive cycle as shown in Fig. 2 [12]–[14].

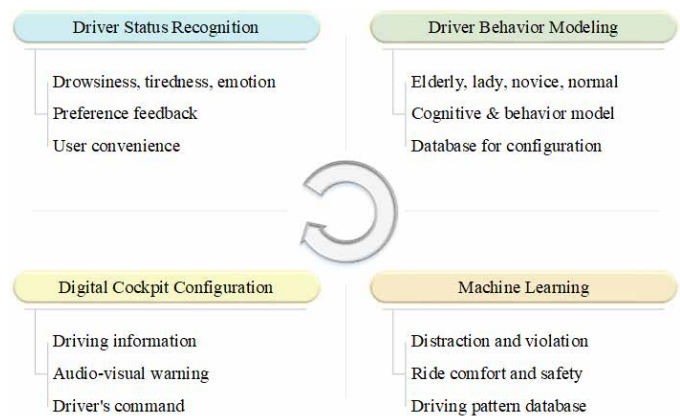


Fig. 2. Concept of customized interaction system for digital cockpit.

Modelling of driver behaviour includes the process of driver identification, maneuver boundary detection, maneuver recognition, deviation detection, and driver state recognition. To recognize maneuver, DVI engine firstly needs training dataset of individual drivers with labeling by analyzing traffic situation through forward and backward images and GPS information for the supervised-learning process. DVI engine must learn the normal driving behaviour of each driver in advance, and calculate each driving deviation by comparing with the current driving information. The driving performance of the current driving behaviour scores and indicates the degree of risk driving for the given task.

C. Digital Cockpit Configuration

Generally, there are a few functional divisions into the cockpit display system: electronic instrument cluster, AVN (Audio, Video, and Navigation) infotainment system, HVAC (Heat, Ventilation, and Air Control), and FBMS (Fuel and Battery

Management System). Next-generation digital cockpit system would be not only futuristic-looking or all-digital, but also fully customizable to the individual driver as shown in Fig. 3. No matter what next-generation cockpit system displays, human-vehicle interaction methodology including inference engines will play a critical role for a driver to customize and personalize every other car to drive as well as ones own car.

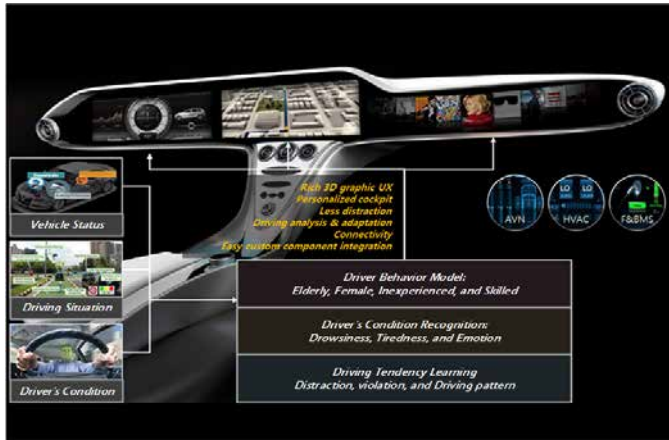


Fig. 3. Service concept of next-generation digital cockpit system.

III. CONCLUSION

In this paper, we introduced three key components of digital cockpit system to provide the driver-customized driving environment, which includes automotive sensor network, driver-adaptive interaction engine, and advanced digital cockpit platform. We described the hierarchical customization levels and the cycle of driver-vehicle interaction process to realize driver-adaptive interaction engine for the next-generation digital cockpit system. Modelling and analysis of driver behaviour evaluate the driving performance ability using the vehicle dynamics obtained from the CAN bus and IMU device and predicts the driver status. In the near future, we will conduct research on driver behaviour based on machine learning using actually measured test dataset.

ACKNOWLEDGMENT

This work was supported by Electronics and Telecommunications Research Institute (ETRI) grant funded by the Korean government and Ulsan Metropolitan City. [18ZS1300, Development of advanced digital cockpit system for smart car].

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Jin-Kyu Choi is a principal researcher of the Intelligent Robotics Research Division, Electronics and Telecommunications Research Institute, Daejeon, Rep. of Korea. He received his B.S. degree in electronic engineering in 1999 and M.S. degree in electronics, communications and electromagnetics engineering from Hanyang University, Seoul, Rep. of Korea in 2001, and his Ph.D degree in electronic engineering from Chungbuk National University, Cheongju, Rep. of Korea, in 2018. Since 2001, he has been with ETRI. His current research topics include vehicular communications, ITS (Intelligent Transport System), HMI (Human-Machine Interaction), and AI (Artificial Intelligence).



Kyong-Ho Kim is a principal researcher of the Intelligent Robotics Research Division, Electronics and Telecommunications Research Institute, Daejeon, Rep. of Korea. He received his BS and MS degrees in electronic engineering from Kyungpook National University, Daegu, Rep. of Korea, in 1993 and 1995, respectively, and his Ph.D degree in computer science from the Korea Advanced Institute of Science and Technology, Daejeon, Rep. of Korea, in 2010. Since 1994, he has been with ETRI. His current research topics include intelligent vehicles, HCI (Human-Computer Interaction), HUD (Head-Up Displays), and AR (Augmented Reality) applications in vehicles.



Dohyun Kim is a principal researcher of the Intelligent Robotics Research Division, Electronics and Telecommunications Research Institute, Daejeon, Rep. of Korea. He received his BS and MS degree degrees in computer engineering in 1995 and 1997, respectively, and his Ph.D degree in computer science from Pusan National University, Pusan, Rep. of Korea, in 2017. His current research topics include LBS (Location-Based Service), Telematics, USN (Ubiquitous Sensor Network), Smart factory, and AI (Artificial Intelligence).



Hyunkyun Choi is a director of ETRI-Ulsan Joint Research Section, Electronics and Telecommunications Research Institute, Ulsan, Rep. of Korea. He received his BS and MS degrees in electronic engineering from Kyungpook National University, Daegu, Rep. of Korea, in 1995 and 1997, respectively, and his Ph.D degree in electronic engineering from Chungnam National University, Daejeon, Rep. of Korea, in 2015. He joined ETRI in 2000. His research interests include ITS (Intelligent Transport System), HMI (Human-Machine Interaction), and V2X (Vehicle to Everything) communications.



Byungtae Jang is a director of Industry IT Convergence Research Group, Electronics and Telecommunications Research Institute, Daejeon, Rep. of Korea. He received his BS degree in atmospheric science from Seoul National University in Korea in 1989 and MS and Ph.D degrees in computer science from Chungnam National University in 1994 and 2001. From 1989 to 1996, he was a Senior Research Member at Software Engineering Research Institute (SERI) in Daejeon, Korea. He joined ETRI in 1997. His current research topics include AR (Augmented Reality), image processing, HCI (HumanComputer Interaction), wireless communications, and smart HSE (health, safety, and environment).