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Intelligent data fusion system for predicting vehicle collision warning using vision/GPS sensing

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ABSTRACT

In this study, fuzzy approach with fault-tolerance has proposed to fuse heterogeneous sensed data and overcome the problem of imprecise collision warning due to perturbed input signal when processing the pre-crash warning. Meanwhile, another problem relevant to the danger in drowsy driving, involving fatigue level, carbon monoxide concentration, and breath alcohol concentration, was considered and has approximately reasoned to an extra reaction time to modify NHTSA algorithm. A vision-sensing analysis cooperating with global-positioning system is applied for lane marking detection and collision warning, particularly exchanging the dynamic and static information between neighboring cars via inter-vehicle wireless communications. In addition to pre-crash warning, event data recording very useful for accident reconstruction on scene is also established here. In order to speed up data fusion on both quantum-tuned back-propagation neural network (QT-BPNN) and adaptive network-based fuzzy inference system (ANFIS), a distributed dual-platform DaVinci+XScale_NAV270 has been employed. Several tests on system's reliability and validity have been done successfully, and the comparison of system effectiveness showed that our proposed approach outperforms two current well-known collision-warning systems (AWS-Mobileye and ACWS-Delphi).

1. Introduction

Vision difference or inattention to the traffic condition often causes the unnecessary traffic accidents while driving. So people would like to establish a system for a rapid detection of the neighboring vehicles, a fast recognition of the lane marking, and a quick estimation of the headway between neighboring cars so as to improve the long-standing traffic problems such as road traffic monitoring and vehicle location and so on, enabling the effective use of the road. Nowadays, automobile manufacturers have highly concerned about the relevant problems of motor vehicle safety and make more efforts on the solution to this aspect; for example, adaptive cruise control (ACC) (Ganci, Potts, & Okurowski, 1995), antilock brake system (ABS) (Lin & Hsu, 2003; Mirzaei, Moallem, & Mirzaeian, 2005), collision-warning system (CWS), event data recorder (EDR) (Kowalick, 2001), on-board diagnostics (OBD) (Alaoui & Salameh, 2003), and emergency automatic brake (EAB). The causes of the traffic crashes can be categorized into three factors: "people", "vehicle", and "environment" (Lemaire, El Koursi, Deloof, & Ghys, 2002). The report from national highway traffic safety administration (NHTSA) in United States indicated that there are about 80–90% traffic crashes caused by the factor "people" (NHTSA, 2006). Accordingly, active vehicle safety becomes one of major research topics in intelligent transportation system (ITS). Therefore, in this paper the collision-warning system (CWS) and motor vehicle event data recorder (MVEDR) (IEEE Std 1616, 2005) utilized for active vehicle safety have been developed to perform a pre-crash warning and implement an effective event data recording.

Instead of radar or laser sensing, the vision-sensing approach is to analyze a sequence of visual images outside of the car and then estimate the angle, the relative velocity, acceleration, and distance between the host and the neighboring vehicle, which is used to perform land-marking recognition as well as neighboring vehicle detection and then inducing a pre-crash warning if needed. On-board global-positioning system (GPS) receives the information relevant to latitude, longitude, elevation, and the others; GPS information together with the angle, the relative velocity, acceleration, and distance between the host and the neighboring vehicle is disseminated at once to the neighboring cars each other via vehicle-to-vehicle (v2v) wireless communications the dedicated short

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range communication (DSRC, IEEE Std. 1609.3). In other words, exchanging information between vehicles is intentionally to implement motor vehicle event data recording on board which is very useful for accident reconstruction on scene in case of crash. In addition to vision/GPS sensing, in-vehicle drowsiness detection is also taken into account, and thus, heterogeneous data fusion with fuzzy approach is implemented to overcome the problem of imprecise collision warning due to perturbed input signal when processing the pre-crash warning. Furthermore, another problem relevant to the danger in drowsy driving, which involves fatigue level (FL), carbon monoxide concentration (COC), and breath alcohol concentration (BAC) sensed in the car through the CAN bus transmitted to the automobile console, was considered and has approximately reasoned to an extra reaction time to modify NHTSA algorithm. Data fusion approximately reasons a level-specific collision warning that alerts driver for preventing an imminent crash or an inattentive lane departure. We analyze the drowsiness with a quantum-tuned back-propagation neural network (QT-BPNN) to fuse heterogeneous data FL, COC, and BAC to derives the extra reaction time (Chang, Young, Tsai, & Lin, 2008) viewed as part of driver reaction time. Subsequently, an adaptive network-based fuzzy inference system (ANFIS) (Jang & Roger, 1993) performs another heterogeneous data fusion including the extra reaction time and several input signals to approximately reason a certain level of pre-crash warning where this study introduces ANFIS to resolve the problems of the danger in driving drowsy and the imprecise collision-warning level resulted from the perturbed input signals. In order to speed up data fusion, as shown in Fig. 1, a distributed embedded dual-platform DaVinci+XScale_NAV270 (XScale, 2008) is designed to establish a multifunction digital automobile console as shown in Fig. 2. In addition to collision-warning system as shown in Fig. 3, event data recording as shown in Fig. 4 is also implemented concurrently during vision/GPS sensing and vehicle-to-vehicle wireless communications.

2. Vision/GPS sensing

This vision/GPS sensing is primarily applied to capturing image through CCD camera, as well as retrieving localization information from GPS and then disseminating the information to neighboring cars via mobile wireless communication. Image analysis provides the detections for land marking and neighboring vehicles around the host vehicle. Car location about longitude, latitude, and latitude is received from GPS and exchange these data each other via vehicle-to-vehicle communication so that the relative distance, velocity, and acceleration between cars can be estimated. Based on

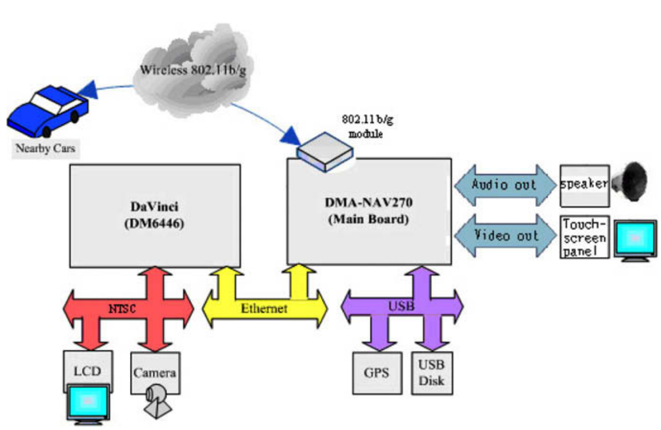

Fig. 1. Block of multifunction digital automobile console.

Fig. 2. Distributed dual-platform DaVinci+NAV270.

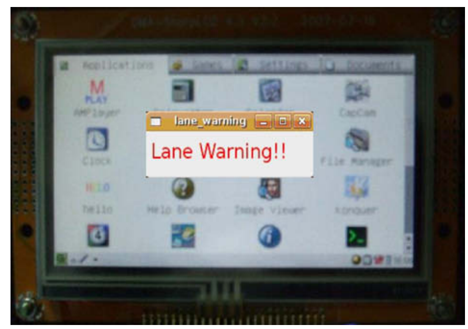

Fig. 3. A snapshot of warning signal.

the aforementioned, data fusion machine derives a proper collision warning to prompt driver.

2.1. Lane-marking detection

If the size of sampled photo is $C \times R$, C is the photo columns, R is the photo rows. It means there are R horizontal scanning lines as well as C vertical scanning lines, we can observe it in Fig. 4, no matter it is white line, double yellow line, or red line; it has the characteristic of maximum in photo. The difference between the lane marking and the brightness of asphalt is obvious; therefore, we use this characteristic to search the preceding driving area. As shown in Fig. 5, when the vehicle drives along the lane marking, we can assume reasonably the left lane marking is on left side of image, and the right lane marking is on the right side of image. Let us halve the horizontal scanning lines and calculate the gradient value. The variation of maximum gradient from high to low in the left side is the left mark; the variation of maximum gradient from high to low in the right side is the right mark. Set the scanning orientation from down to up. We can obtain the possible characteristic points of the left and right marking from the operation of Eqs. (1) and (2), as shown in Fig. 6.

When the scanning line is y, the possible left and right marking points of the y row are defined as followings:

$$\text{The possible left marking point} = \overset{x<\frac{C}{2}-1}{\underset{x=0}{Max}}\, Grad(x,y) \tag{1}$$

$$\text{The possible right marking point} = \overset{x<C}{\underset{x\geqslant\frac{C}{2}}{Max}}\, Grad(x,y) \tag{2}$$

where $Grad(x,y) = pixel(x,y)\text{-}pixel(x+1,y)$ is the gradient variation of coordinates (x,y) on the photo; $pixel(x,y)$ is the gray-level brightness value of coordinates (x,y) on the photo (Wang, Xu, Li, & Zhao, 2002). In fact, when the gray-level value of lane marking is closer to the vehicle, the marking is higher. So, we use the Variable Threshold