An Occupant Sensing System Using Single Video Camera and Ultra-sonic Sensor for Advanced Airbag

Seok-Min Chae,[1] Jong-Won Lee,[1] Su-Young Ha,[1] Young-Choon Kim,[2] Sang-Ho Ahn,[2] and Kyu-Ik Sohng [1]

[1]School of Electrical Engineering and Computer Science, Kyungpook National University, Korea
[2] Dept. of Information and Communication Engineering, Youngdong University, Korea
[3]School of Electronic Telecommunication, Inje University, Korea

Abstract - *In this paper, we proposed an occupant detection system using single video camera and a distance sensor for an advanced airbag deployment. We detected occupant face using skin color and motion information in real time. The proposed method acquired the color and size of the occupant face using single video camera and calculated the distance information between the occupant and airbag using a distance sensor. The skin color is acquired by influence of surrounding illuminance. In case of night, we detected occupant face using luminance information in a camera image. And we used a distance sensor to calculate the three-dimensional position information of occupant at day and night. We performed various experiment with camera and vehicle jig to evaluate performance of proposed occupant detection system for smart airbag. Our experiments showed that proposed occupant detection system is able to be put to practical use in smart airbag. And proposed face detection algorithm is more simple and faster than the previous algorithms.*

Keywords: occupant detection system, face detection, smart airbag

1 Introduction

The automobile airbag was developed as one of supplemental restraint system appropriately to protect the adult who wears the safety belt.[1] At the time of a head-on collision, airbag system is able to reduce remarkably death and fatal injuries. However, an inadequate operation of the airbag causes fatal injuries. Recently, the smart airbag which controls the output of the airbag according to accident situation and position of the occupant is actively developed.[2],[3]

Our proposed method uses the face detection using single camera and distance information using the ultra-sonic sensor and recognizes the size and location of the occupant. The size and location of the occupant which decides from NHTSA (National Highway Traffic Safety Administration) are as follows. The occupant's size classifies with 3 years old children, 6 years old children, 5% adult females and 50% adult males. The right and left location classifies with the left side, the right side and a center region. And the front and rear location classifies with IP (in-position: the occupant who is sitting in right position), OOP (out-of-position: the occupant who is not sitting in right position), and COOP (critically out-of-position: the occupant who from the airbag is sitting in very near location) regions. This information is used to decide the degree of strength of airbag deployment and whether it will be deploy or not.

We performed various experiments with an IEEE 1394 video camera and ultra-sonic sensor to evaluate performance of proposed occupant detection system for smart airbag. The experiment about many people in various circumstances is performed at day and night. As a result, proposed occupant detection system using vision and distance information for smart airbag is satisfied with research goal of smart airbag in form of occupant, face position recognition and face detection probability. Our experiments show an efficient occupant detection system. And the proposed face detection algorithm is more simple and faster than the previous algorithms.

2 Smart Airbag System

The airbag system is composed with SDM (sensor diagnostic module) and airbag module. The SDM is classified as the sensor, the battery, and diagnosis system etc. And the airbag module is classified as the airbag and operation gas expansion system.

The smart airbag means more safely controlling airbag system according to the body size of the occupant. For example, when children sits in the occupant seat, smart airbag system dose not deploy. The airbag system attaches the weight sensor in occupant seat and the sensor judges the occupant who is adult or child. We divide the location of the airbag and the occupant in several regions in order to judge the location of the occupant is safe or dangerous when the airbag was deployed. Fig. 1 shows various location of the occupant with IP, OOP, and COOP regions. The various states of the occupant, for example IP, OOP, and COOP regions and empty seat is shown in Fig. 2.[4]

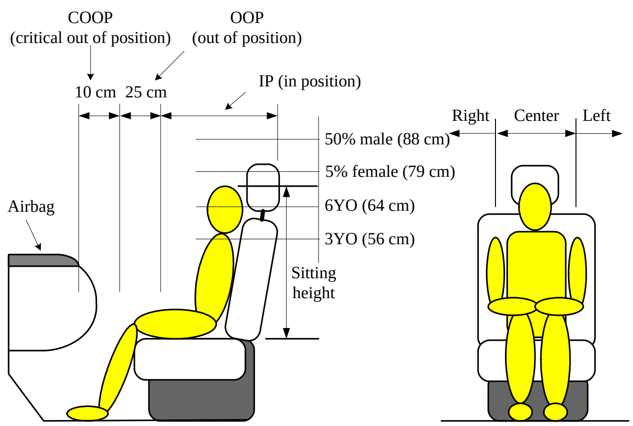

Fig. 1. The IP, OOP, and COOP regions of the occupant.

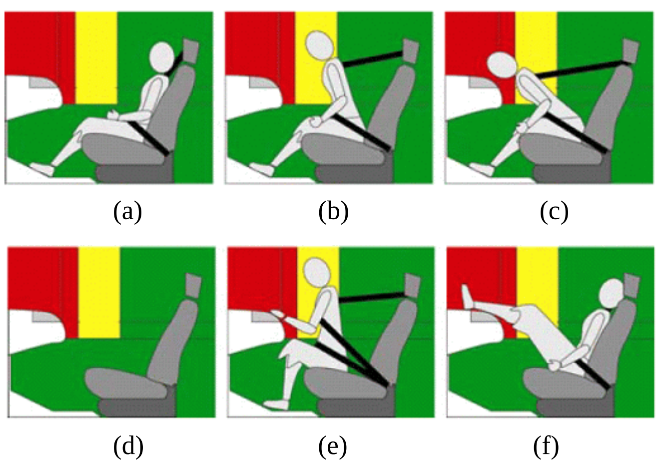

Fig. 2. Variable occupant states: (a) IP; (b) OOP; (c) COOP; (d) empty seat; (e) OOP; (f) COOP.

3 Face Detection Method

The smart airbag system requires face detection of occupant to recognize position of occupant. Recently, the vision-based method is researched actively with face detection method. The representative methods are Adaboost,[4],[5] PCA (principle component analysis),[6],[7] and SVM (support vector machine) methods.[7],[8] Adaboost algorithm uses five kinds of Haar-like feature. Adaboost algorithm is performed the process of two step. First step is the process which learns weak classifier from training data set of face image and non-face image. Next step is the process which classifies face and non-face using weak classifier and one strong classifier. PCA method represents several principal component value which express low-dimensional vector from high-dimensional input vector. PCA face detection method acquires several eigenfaces from test face image for learning and extracts feature value to linear projection from input image. SVM method is proposed to solve binary pattern classification. SVM method divides two classes after extracting support vector which has representative feature of each region. These vision-based face detection methods respect a person photo shoot is used in the digital camera. But these methods have some problems to apply in smart airbag system. These image base methods are caused by with complexity of algorithm and there is a problem point where the hardware embodiment for a real-time process is difficult.

4 Proposed Occupant Detection System

In this paper, we proposed the occupant position detection method using single video camera and a distance measurement sensor. We acquired the size and position of the occupant using single video camera and calculated the distance information between the occupant and airbag using ultra-sonic sensor. At first, we need face detection to judge the size and position of the occupant. We used the face color and motion information which are easy for real-time detection. The face color and motion information are used together to raise reliability. The flowchart of the face detection method using the face color and motion information and ultra-sonic sensor is shown in Fig. 3. In case of day, the face which combine candidate face block image is detected by *U/V* boundary value and motion information. In case of night, the face is detected by *Y* boundary value of infrared LED image and motion information. And also ultra-sonic sensor measures between the airbag and the occupant distance and judges the location (IP, OOP, and COOP) of the occupant. This method enhances face detection probability adding motion information of the occupant.

The flowchart of proposed face detection algorithm is represented in Fig. 4. The single video camera which is affixed front side of the occupant acquires color image. .

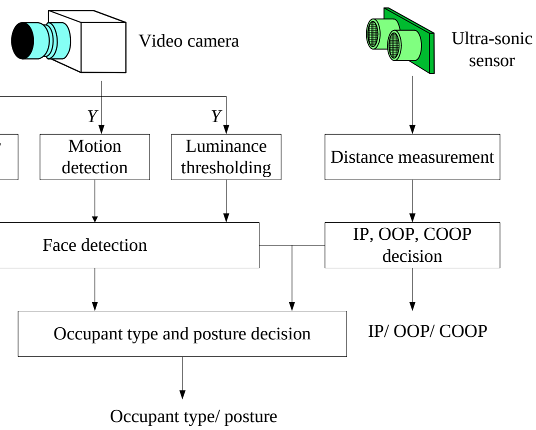

Fig. 3. Flowchart of proposed method.

The analog video signal transforms *YUV* digital data through decoder.One frame resolution of the *Y* signal is 720×480, color signal *U/V* are 320×240. Our algorithm uses Gaussian filter in order to reduce noise about acquired *Y* and *U/V* image. First, the boundary value of *Y* signal processed images of color difference signal, motion information and infrared LED illumination are divided into blocks of voluntary pixel unit.

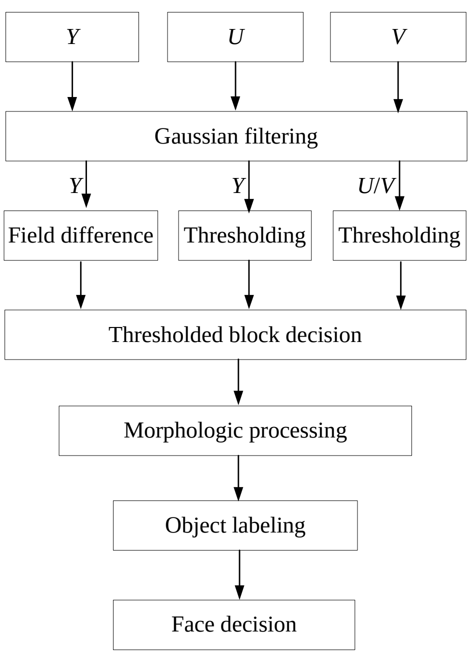

Fig. 4. Flowchart of proposed face detection algorithm.

The *U/V* boundary values which decide a face color from *U* and *V* image are used to detect the face with face color. The input image from the camera is divided with the block of pixel unit. *U/V* value are computed as

$$UV_n(x,y) = U_n(x,y) + (255 - V_n(x,y)) \quad (1)$$

where $UV_n(x, y)$ is pixel value of (x, y) coordinates, $U_n(x, y)$ and $V_n(x, y)$ are pixel value of (x, y) coordinates each image *U* and *V*. *U/V* boundary value are computed as

$$F_{uv}(x,y) = \begin{cases} 255, & if \ \ UV_n(x,y) < th_1 \\ 0, & otherwise \end{cases} \quad (2)$$

where th_1 is the boundary value of *U/V* value, $F_{uv}(x, y)$ is binary value of *U/V* image. If the number of the pixel which is satisfied a respectively boundary value is greater than boundary value, this block become a candidate face block. Unless the block is candidate face block, the block is non-face block. The isolated small blocks of acquired images at the day and night are removed using morphology image processing. Next step is the labeling process for the detected candidate face blocks. The block information is assigned respectively for the detected candidate face blocks. The label of the blocks has width, height, a size of square, the rate of length and breadth and the information of the block number. This information uses to search real face block in the candidate face blocks. Because the occupant face has similar size and the rate of length and breadth, the blocks which are not satisfied of the minimum face size exclude from label. The motion information is used because face detection is difficult in case of dynamic luminance or hidden face.

The face detection using color information undergoes the influence of external illuminance. We used motion information because the external illuminance changes the face color. The face detection equation using motion information is

$$F_M(x,y) = \begin{cases} 255, & if \ \ Y_n(x,y) - Y_{n-1}(x,y) < th_2 \\ 0, & otherwise \end{cases} \quad (3)$$

where $Y_n(x, y)$ and $Y_{n-1}(x, y)$ are current and past pixel value of (x, y) coordinates in *Y* image, th_2 is the boundary value of the frame difference image, and $F_M(x, y)$ is binary value of *Y* image. If the number of the pixel which is satisfied a respectively boundary value is greater than boundary value, this block become a candidate face block.

Like Fig. 5, when the luminance change occurs, uses only a color difference signal boundary value and when presumes the candidate face block, will not be able to detect the face. However, with the candidate face block image by color difference signal boundary value when unites the candidate face block image by motion information, the face detection is possible. The occupant's size recognition using proposed face detection method is able to judge 3 years old children, 6 years old children, 5% adult females and 50% adult males. When the airbag is deployed, it is information which is very important decides the airbag output.

In this paper, we used ultra-sonic sensor to measure distant between occupant and airbag. The Ultra-sonic sensor measures a distance using ultra-sonic wave which fires on the object in the time when comes back. The distance between sensor and occupant is expressed as

$$D = \frac{T \times 340m/sec}{2} \; [m] \qquad (4)$$

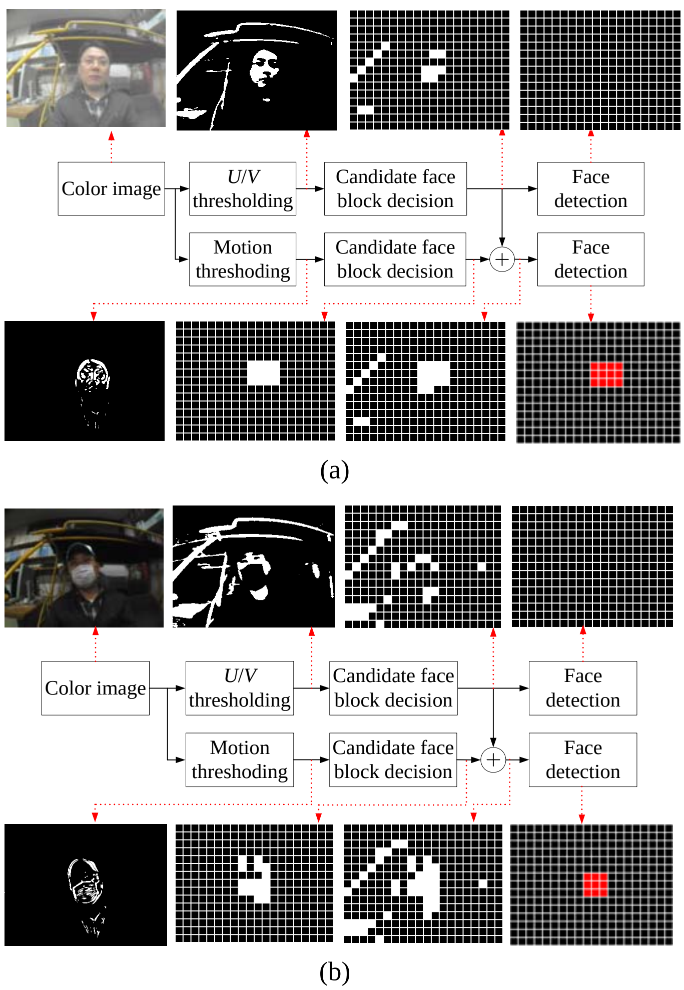

Fig. 5. Example of face detection added by color and motion information;
(a) Example of illuminance change; (b) example of hided face.

where T is echo time which is the time interval of ultra-sonic to take from transmitter to receiver.

5 Experimental Result

In this paper, the occupant perception method in smart airbag was proposed using a single camera and a distance sensor. In order to classify the size, position and distance of the occupant, PC simulation was performed. The vehicle jig was used to perceive the occupant position in the experiment. The camera which is IEEE 1394 video camera was used and *YUV* (320×240) image was used in image processing.

The performance evaluation measurement was used the occupant's size recognition, front and rear location recognition, right and left location recognition and face detection probability. The size and right and left location classified with the face block image which is detected, the error tolerance of one block was ± 40 mm. The classification of front and rear location depended in distance resolution of the ultra-sonic sensor and the error tolerance of recognition around this case was ±10 mm.

The face detection was experimented about IP, OOP, and COOP regions which are a front and rear location region of 3 kinds from under high illuminance (230 lx), low illuminance (40 lx), and dark condition (1 ~ 5 lx). The propose method is satisfactory confirmed in research aim in the occupant's size, front and rear, right and left recognition experiment.

Table I. Face detection probability of the proposed and previous method about each region.

Illuminance [lx]	Method	Detection probability, %		
		IP	OOP	COOP
High Illuminance [230 lx]	Only skin color	78.9	95.3	96.9
	Proposed method	83.8	95.9	97.4
Low Illuminance [40 lx]	Only skin color	66.0	39.3	37.7
	Proposed method	74.8	48.0	43.6
At nigtht [1~5 lx]	Proposed method	72.1	45.5	41.0

The proposed method improved 4.9% and 8.8% the method which uses only a face color from under high and low illuminance, respectively. Table I presents the face detection probability of proposed and previous method about each region.

6 Conclusion

We proposed a new method that unites a face detection using single camera and a distance measurement using ultra-sonic recognizes the size and location of the occupant. To evaluate the performance of proposed occupant position detection system, the experiment using vehicle jig which establishes the video camera, the ultra-sonic sensor and infrared LED was performed. The performance evaluation measure was used the occupant's size recognition, front and rear location recognition, right and left location recognition and face detection probability. The face detection probability from experimental resultant IP region was average 76.9%. Proposed method improved respectively 4.9% and 8.8% the method which uses only a face color from under high and low illuminance.

7 References

[1] http://www.safeny.com/seat-ndx.htm.

[2] Transportation equity act for the 21th century, http://www.fhwa.dot. gov/rtea21/, June 1998.

[3] S, J. Krotosky, S. Y. Cheng, and M. M. Trivedi, "Face detection and head tracking using stereo and thermal infrared cameras for smart airbags: A comparative analysis," *IEEE Intelligent Transportation Systems Conference*, pp. 17-22, Oct. 2004.

[4] M. M. Trivedi, S. Y. Cheng, E.M.C. Childers, and S. J. Krotosky, "Occupant posture analysis with stereo and thermal infrared video: Algorithms and experimental evaluation," *IEEE Transaction on Vehicular Technology*, vol. 53, pp. 1698-1722, Nov, 2004.

[5] I. Craw, H. Ellis, and J. Lishman, "Automatic extraction of face features," *Pattern Recognition Letters*, vol. 5, pp. 183-187, Feb. 1987.

[6] P. Viola and M. Jones, "Robust real-time face detection," *International Journal of Computer Vision*, vol. 57, pp. 137-154, 2004.

[7] M. Turk and A. pentland, "Face recognition using eigenfaces," *IEEE. Conf. Computer Vision and Pattern Recognition*, pp. 586-591, 1991.

[8] X, Zhang, J. Pu, and X. Huang, "Face detection based on two dimensional principal component analysis and support vector machine," *Proc. IEEE. Mechatronics and Automation*, pp. 1488-1492, June, 2006.

[9] C. J. C. Burges, "A tutorial on support vector machines for pattern recognition," *Data Mining and Knowledge Discovery*, vol. 2, pp. 121-167, 1998.