Face Orientation Recognition for Electric Wheelchair Control

Chanlit Noiruxsar and Pranchalee Samanpiboon
Department of Control System and Instrumentation Engineering, King Mongkut's University of Technology Thonburi, Bangkok, Thailand
E-mail: c.noiruxsar@gmail.com, pranchalee.rat@kmutt.ac.th

***Abstract*—This paper proposes face orientation recognition for electric wheelchair control application, which is a non-contact control system supports the elderly and disable peoples who are not able to operate via joystick. USB camera was fixed in front of user's face. Face area was detected based on AdaBoost learning algorithm. Then facial landmarks were detected using Flandmark Detector. Finally, face orientations were classified by the normalized distance difference in horizontal and vertical axes between eyes, nose and mouth. Face orientation, which is used for commands electric wheelchair, consists of frontal, right, left, up and down. The 5 face orientations of 5 persons were provided for training. The results of proposed method achieve overall accuracy 92.03% when testing with the 5 persons whose information are used for training, and achieve overall accuracy 90.53% when testing with the other 2 persons outside the training set.**

***Index Terms*—face orientation recognition, face detection, Flandmark detection, electric wheelchair control.**

I. Introduction

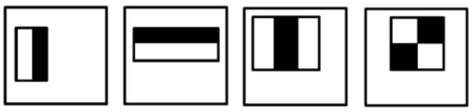
Electric wheelchair is an important support facilities for assist the elderly and disabled people to have convenient mobility. In general, most of electric wheelchairs use a joystick for control the direction. However there are many researches and developments about electric wheelchair control for support the elderly and disabled people who are not able to operate the joystick such as; Ref. [1] proposed a brain controlled wheelchair which based on P300 (brain signal). Ref. [2] presented EMG-based hands-free wheelchair control with EOG attention shift detection. That bio-signal needs to put bio-sensor on user body. So it is not be comfortable for user. Thus, Non-contact electric wheelchair control based on face orientation from camera is developed. Ref. [3] proposed head gesture based control of a wheelchair using Boosted Cascade of Simple Features integrated with Camshift object tracking algorithm to achieve face region. After that face orientation was estimated by using nose template matching. Ref. [4] presented face and mouth shape recognition for wheelchair control. Face region was detected based on AdaBoost learning algorithm. The eye regions are localized by Neural Network based texture classifier. And then the mouth is localized by edge information. Experiments were performed both indoor and outdoor situation. Ref. [5], [6], the changes in the darkness area of the both nostrils were utilized for recognition of the face orientations. Upward and downward face determine by increasing and decreasing of darkness areas of both nostrils. Difference between two nostril's areas is used for detecting left and right orientation. Ref. [7] developed head gesture recognition for wheelchair control by comparing the location of the lip with fixed rectangular windows. AdaBoost learning algorithm is used for face and lip detection.

In this paper, face orientation recognition is proposed for electric wheelchair control application. The face image was taken to laptop through USB camera (Logitech Webcam Pro 9000), which is fixed in front of user. Face area was detected based on Haar-like features and AdaBoost learning algorithm [8]. Then the detection of facial landmarks such as both-canthus, nose and mouth were implemented by using Flandmark Detector [9]. After that, the normalized distance difference in horizontal and vertical axes between eyes, nose and mouth were used for classify face orientation to 5 classes consist of frontal, right, left, up and down.

II. Face Detection and Facial Landmarks Detection

A. Face Detection

Pual Viola and Michael Jones proposed face detection based on AdaBoost learning algorithm, which rapidly and achieving high detection rates [8]. This research used Haar-like features as shown in Fig. 1. Two-rectangles are shown in Fig. 1(a) and Fig. 1(b), three-rectangle is shown in Fig. 1(c) and four-rectangle is shown in Fig. 1(d).



(a) (b) (c) (d)

Figure 1. Examples of Haar-like features.

Haar-like features is determined by sum of the pixel in white rectangles and subtracted from the sum of pixels in the black rectangles. Each rectangle is extracted from sub windows of sample image. A large quantity of features comes out after perform Haar-like features calculation.

Manuscript received October 20, 2012; revised December 8, 2013.

doi: 10.12720/joace.2.4.402-405

However, only a few features is useful. AdaBoost learning algorithm was used to select a few proper features which are able to separate face and non-face sub windows. Finally, cascading of classifier was constructed for increasing detection performance while reducing computation time. The cascade classifier at each stage is trained to classify training sub windows that passed all previous states. If any sub windows fails in any classifier stage, then it is immediately classified as non-face. The sub windows that pass through all cascaded stages are classified as face. The schematic of cascade classifier is shown in Fig. 2.

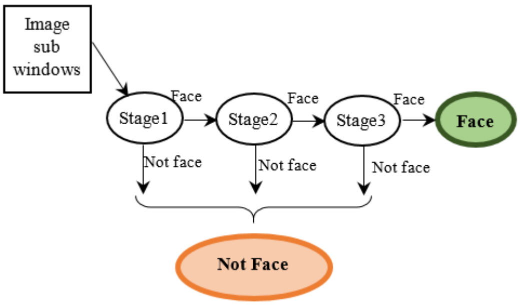
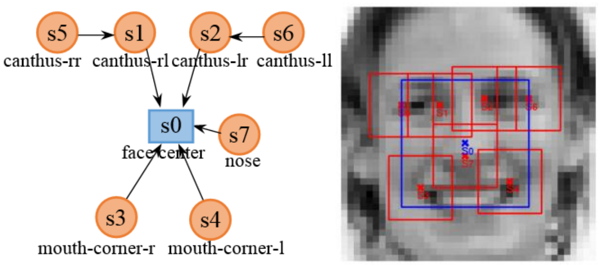


Figure 2. Schematic of cascaded classifier.

B. Facial Landmarks Detection

After face area was detected by previous section. Flandmark Detector [9] is the method that estimated set of facial landmarks such as both-canthus (s5, s1, s2 and s6), nose (s7) and mouth-corner (s3, s4). The landmarks configuration is identified by scoring function. The scoring function is defined as sum of Local Appearance model and Deformation cost. In Local Appearance model term, Local Binary Pattern (LBP) pyramid [10] was used as a feature that characterizes the image texture. In Deformation cost term, the quadratic function of a displacement vector between landmarks position were used to representation [10]. That describes the distance and direction depends on relative positions as shown in Fig. 3(a). For example, s5 (begin arrow) with respect to s1 (end arrow). Each landmark is search in region as shown in Fig. 3(b). Size of each region was determined by experiment.



(a) (b)

Figure 3. (a) Graph constraints (b) Components [9].

Finally, the landmarks position was calculated by maximizing the scoring function. Fig. 4 show block diagram of Flandmark Detector. The joint parameter vector was learned by Structure Output Support Vector Machine algorithm.

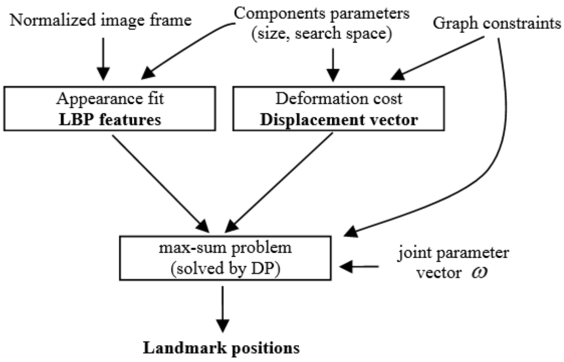


Figure 4. Flandmark Detector block diagram [9].

III. FEATURE EXTRACTION

After the position of facial landmarks (s1 to s7) were detected by Flandmark Detector. These positions were used to calculate the distance between eyes, nose and mouth in horizontal and vertical axes as shown in Fig. 5. However, the distances are normalized by distance of user frontal face because each person has different facial characteristic.

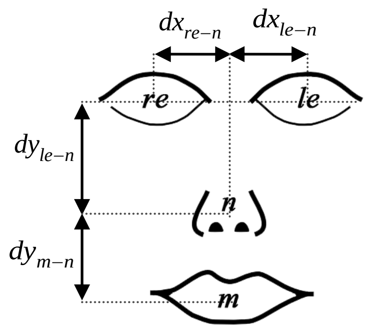


Figure 5. Distance between eyes, nose and mouth in horizontal and vertical axes.

First, the position of eyes and mouth are identified by center of their corners as in (1)-(3). And the nose position is equal to s7 position as shown in (4).

$$re_{(x,y)} = \left(\frac{x_{s1} + x_{s5}}{2}, \frac{y_{s1} + y_{s5}}{2}\right) \quad (1)$$

$$le_{(x,y)} = \left(\frac{x_{s2} + x_{s6}}{2}, \frac{y_{s2} + y_{s6}}{2}\right) \quad (2)$$

$$m_{(x,y)} = \left(\frac{x_{s3} + x_{s4}}{2}, \frac{y_{s3} + y_{s4}}{2}\right) \quad (3)$$

$$n_{(x,y)} = (x_{s7}, y_{s7}) \quad (4)$$

where re, le, m and n are the positions of right eye, left eye, mouth and nose respectively. x, y denote the coordinates on horizontal and vertical axes, respectively. Next, calculate the horizontal distance from right eye to nose, dx_{re-n}, and left eye to nose, dx_{le-n}, as shown in (5),(6).

$$dx_{re-n} = |x_{re} - x_n| \quad (5)$$

$$dx_{le-n} = |x_{le} - x_n| \quad (6)$$

Then, the horizontal distance difference, $\triangle x$, is calculated by (7).

$$\triangle x = dx_{re-n} - dx_{le-n} \quad (7)$$

Assume that, the horizontal distance from right eye and left eye to nose are equal, while user's face turns to frontal. So the frontal horizontal distance is calculated by sum of the horizontal distance and divides by two as (8).

$$dx_{e-n,f} = \frac{|x_{le_f} - x_{n_f}| + |x_{re_f} - x_{n_f}|}{2} \quad (8)$$

And $\triangle x_{norm}$ is normalized horizontal distance difference which is calculated by (9).

$$\triangle x_{norm} = \frac{\triangle x - dx_{e-n,f}}{dx_{e-n,f}} \quad (9)$$

Assume that, right and left eyes are in the same plane. Equation (10) is used to find the vertical distance from eye to nose.

$$dy_{le-n} = |y_{le} - y_n| \quad (10)$$

And the vertical distance from mouth to nose, dy_{m-n}, is calculated as (11).

$$dy_{m-n} = |y_m - y_n| \quad (11)$$

The vertical distance from right eye and left eye to nose of frontal face are equal. So the frontal vertical distance from eye to nose is define as (12).

$$dy_{le-n,f} = |y_{le_f} - y_{n_f}| \quad (12)$$

And the frontal vertical distance from mouth to nose is calculated by (13).

$$dy_{m-n,f} = |y_{m_f} - y_{n_f}| \quad (13)$$

Then the normalized vertical distance difference, $\triangle y_{norm}$, is determined by subtracting normalized dy_{le-n} from normalized dy_{m-n} as (14).

$$\triangle y_{norm} = \left(\frac{dy_{le-n} - dy_{le-n,f}}{dy_{le-n,f}}\right) - \left(\frac{dy_{m-n} - dy_{m-n,f}}{dy_{m-n,f}}\right) \quad (14)$$

From the hypothesis, changes of normalized horizontal distance difference, $\triangle x_{norm}$, is able to separate right-turn and left-turn from frontal face. When face is turned to right, $\triangle x_{norm}$ will be decreased. And when face is turned to left, $\triangle x_{norm}$ will be increased. Correspondingly, changes of normalized vertical distance difference is able to separate up-turn and down-turn from frontal face. When face is turned to up, $\triangle y_{norm}$ will be decreased. And when face is turned to down, $\triangle y_{norm}$ will be increased.

IV. Experiment and Result

$\triangle x_{norm}$ and $\triangle y_{norm}$ are features which use to classify face orientation to frontal, right, left, up and down. We recorded face images of 5 persons including 4 males and 1 female. 1856 frames of 5 persons were used for training. Fig. 6 shows examples of 5 face orientations. Distance between eyes, nose and mouth on different orientation can be seen from the Fig. 6 below.

Figure 6. Examples of face orientation from the first row to last row are frontal, right, left, up and down, respectively.

From the examples of face orientation, the four threshold value ($tx1$, $tx2$, $ty1$ and $ty2$) for classify face orientation is chosen by manual. After choose threshold value, face orientation recognition is performed by (15).

$$class = \begin{cases} f & ; tx1 \le \triangle x_{norm} \le tx2 \text{ and } ty1 \le \triangle y_{norm} \le ty2 \\ r & ; ty1 \le \triangle y_{norm} \le ty2 \text{ and } \triangle x_{norn} < tx1 \\ l & ; ty1 \le \triangle y_{norn} \le ty2 \text{ and } \triangle x_{norn} > tx2 \\ u & ; \triangle y_{norm} < ty1 \\ d & ; \triangle y_{norm} > ty2 \end{cases} \quad (15)$$

where f, r, l, u and d are frontal, right, left, up and down, respectively.

Table I shows result of training set including 1856 frames of 5 face orientations. This proposed algorithm achieves overall accuracy 92.02 % with threshold $tx1$ = -1.35, $tx2$ = -0.7, $ty1$ = -0.3 and $ty2$ = 0.28.

TABLE I. RESULT OF TRAINING SET

#frame		Class label				
		frontal	right	left	up	down
Input label	frontal	435	11	12	1	4
	right	5	273	0	3	0
	left	7	0	216	7	3
	up	18	2	0	470	0
	down	49	15	11	0	314

After that, 1056 frames of 2 male persons, who are not in the training set (5 persons), were provided for testing set. This proposed algorithm achieves overall accuracy 90.53 %. The result is displayed on Table II.

TABLE II. RESULT OF TESTING SET

#frame		Class label				
		frontal	right	left	up	down
Input label	frontal	171	0	10	0	2
	right	0	209	0	0	13
	left	0	0	136	1	47
	up	22	0	2	211	0
	down	3	0	0	0	229

V. CONCLUSION

In this paper, face orientation recognition is proposed for electric wheelchair control application. USB camera was used as the input device to laptop. The system was begun with a face detection based on Haar-like features and AdaBoost learning algorithm. Then Flandmark Detector was used for facial landmarks detection composed of both-canthus, nose and mouth corners. The facial landmarks coordinate (s1 to s7) was used to locate left and right eyes, nose and mouth position. After that, the distance between eyes, nose and mouth were calculated. The frontal horizontal and vertical distance was provided for normalization. Finally, the normalized distance difference in horizontal and vertical axes is the features for face orientation classification. The 5 face orientations of 5 persons were provided for training. The results achieve overall accuracy 92.03% when testing with the 5 persons whose information are used for training, and achieve overall accuracy 90.53% when testing with the other 2 persons outside the training set. However, the detection of facial landmarks position is not good enough. So our future research will be improve facial landmarks detection, and implement the improved algorithm until the electric wheelchair practically operated.

ACKNOWLEDGMENT

This work was supported in part by a grant from ministry of social development and human security.

REFERENCES

[1] B. Rebsamen, E. Burdet, C. Guan, H. Zhang, C. L. Teo, Q. Zeng, *et al*. "A brain-controlled wheelchair based on P300 and path guidance," in *Proc. 1st IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics*, 2006, pp. 1101-1106.

[2] C. S. L. Tsui, P. Jia, J. Q. Gan, H. Hu, and K. Yuan. "EMG-based hand-free wheelchair control with EOG attention shift detection," in *Proc. IEEE International Conference on Robotics and Biomimetics*, 2007, pp. 1266-1271.

[3] P. Jia, H. Hu, T. Lu, and K.Yuan, "Head gesture recognition for hands-free control of an intelligent wheelchair," *Journal of Industrial Robot*, 2006.

[4] J. S. Ju, Y. H. Shin, E. Y. Kim, and S. H. Park, "Intelligent wheelchair using face and mouth shape recognition," in *Proc. IEEE International Conference on Consumer Electronics*, 2008, pp. 1-2.

[5] N. Nakazawa, Y. Shibamiya, T. Iwata, I. Kim, T. Matsui, and K. Yamada, "Development of an interface based on face orientations for operation of auto-wheelchair," in *Proc. IEEE International Symposium on Optomechatronic Technologies*, 2010, pp. 1-5.

[6] N. Nakazawa, T. Mori, A. Maeda, I. Kim, T. Matsui, and K. Yamada, "Hand-free interface based on facial orientations," in *Proc. 38th Annual Conference on IEEE Industrial Electronics Society*, 2012, pp. 2719-2724.

[7] Z. f. Hu, L. Li, Y. Luo, Y. Zhang, and X. Wei, "A novel intelligent wheelchair control approach based on head gesture recognition," in *Proc. International Conference on Computer Application and System Modelling*, 2010, vol. 6, pp. 159-163.

[8] P. Viola and M. J. Jones, "Rapid object detection using a boosted cascade of simple features," in *Proc. IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, 2001, vol. 1, pp. 511-518.

[9] M. Uřičář, V. Franc, and V. Hlaváč, "Detector of facial landmarks learned by the structured output SVM," in *Proc. International Conference on Computer Vision and Theory and Application*, 2012, pp. 547-556.

[10] M. Uřičář, "Detector of facial landmarks," M.S. thesis, Dept. Electrical Eng., Czech Technical Univ., Czech Republic, 2011.

Chanlit Noiruxsar was born in Bangkok, Thailand on 11th September, 1988. In 2007, he joined King Mongkut's University of Technology Thonburi, Thailand and got Bachelor of Engineering degree in Control System and Instrumentation Engineering. Currently, he is a master degree student in Control System and Instrumentation Engineering. His research interests are image processing and assistive technology engineering.

Pranchalee Samanpiboon is an assistant professor in the Department of Control System and Instrumentation Engineering at the King Mongkut's University of Technology Thonburi. Her professional interests focus on assistive technology engineering, control systems and image processing.