An Efficient Face Detection and its Application to Mobile Devices

Yeong Nam Chae[1], Yong-Ho Seo[2], Taewoo Han[3] and Hyun S. Yang[1]

[1] Department of Computer Science, KAIST,
335 Gwahak-ro, Daejeon, Republic of Korea
{ynchae, hsyang}@paradise.kaist.ac.kr
[2] Department of Intelligent Robot Engineering, Mokwon University,
Mokwon Gil 21, Seo-gu, Daejeon, Republic of Korea
yhseo@mokwon.ac.kr
[3] Department of Game & Multimedia, Woosong University,
171 Dongdaejeon-ro, Dong-gu, Daejeon, Republic of Korea
bluebird@wsu.ac.kr

Abstract. This paper proposes a means of using facial color to enhance conventional face detectors. To a detect face rapidly, the proposed approach adopts a color filtering based efficient region scanning method. The scanning method skips over regions that do not contain possible faces, based on a facial color membership function. By integrating the proposed face detector with a kernel based object tracker, a real-time face detection and tracking application is implemented for mobile devices. The proposed method considerably reduces the overall computation time and reduces the number of false positives.

Keywords: Face Detection, Facial Color Filtering, Region Selection, Face Tracking

1 Introduction

Face detection is a very important preliminary stage of face localization, face recognition. However, face detection is a time-consuming process due to the enormous search space involved. The face detection model using the AdaBoost learning algorithm proposed by Viola and Jones [1] is a state-of-the-art face detection model that provides outstanding computational efficiency. Many face detection approaches based on Viola and Jones' study have been reported [2][3]. Most of these approaches deal only with gray images. However, to archive a lower false alarm rate, a more complex, strong classifier is needed. For that purpose, to reduce the occurrence of false alarms, facial color information is needed.

2 Proposed method

In this paper, we propose a means to use facial color to enhance any conventional face detectors which use the sliding-window approach and appearance information from a gray image. In order to enhance the conventional face detector, we adapt a color-filtering based region scanning approach and a face/non-face classifier based on facial color density at the preprocessor of the face detector. To use facial color density, we obtain a facial color filtered image and it's integral image [1] to obtain the density of the sub-window quickly. A facial color filtered image is obtained using a facial color membership function that can reflect facial colors under various illumination environments.

$$\mathrm{M(color)} = \frac{\max_{\mathrm{I_i \in face}}(\mathrm{p_i\ (color)})}{\mathrm{p(color)}} \tag{1}$$

In (1), $p_i\ (color)$ refers to the color probability distribution of an image I_i. By merging the color probability distributions of facial images through max operation, rare facial colors in sample space can have high likelihoods. Using $M(color)$, the facial color membership value of each pixel can be obtained. Using this membership information, a facial color filter image whose pixel value is 1 when its color belongs to a facial color is obtained. To calculate facial color information efficiently, we adopt the integral image to this facial color filtered image. Using this facial color integral image, the facial color density of a region is calculated with a relatively light computation load. From this density information, we determine the scan interval, which denotes the position of the next face candidate sub-window.

$$si_h = \begin{cases} \omega\left(1 - \dfrac{density(r)}{\emptyset}\right) & density(r) < \emptyset \\ \Delta & otherwise \end{cases} \tag{2}$$

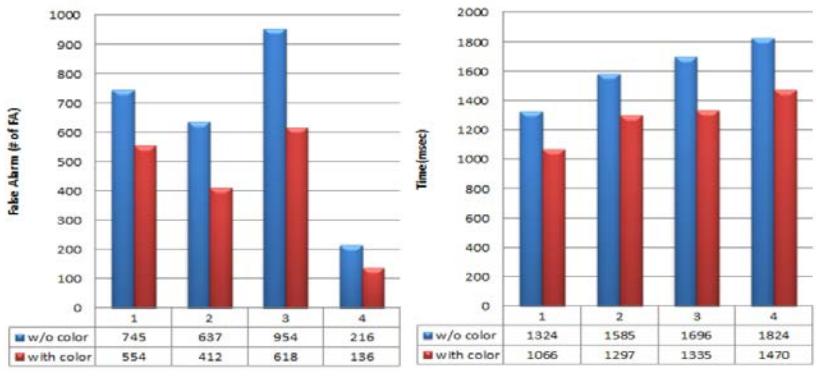
In (2), si_h is the horizontal scan interval, Δ is the minimum scan interval, ω is the width of the region r, and $\emptyset$ is the lower bound of the facial color density, which is determined to be 0.55 by experiment.

The proposed detector skips regions that have lower density than a lower bound of the facial color density by changing the scan interval. A similar method can be applied to the vertical direction. By skipping over the scan interval, the detector can avoid assessing non-candidate regions. We adopt a face/non-face classifier using facial color density that rejects a non-face quickly with high rejection rate. If the density of the region is lower than a certain threshold, that region is rejected. By integrating the proposed face detector with a kernel based object tracker, a real-time face detection and tracking system is implemented for a mobile device. The proposed method contributes to reducing the overall computation time of face detection and to eliminating false alarms.

3 Experimental Results

We compared various frontal face detection models on the same dataset. The dataset is the Caltech frontal face dataset, which consists of 450 color images under different lighting/expressions/backgrounds. We applied the proposed method to the following four frontal face detection models [2].

1. stump-based 24X24 discrete AdaBoost,
2. stump-based 20X20 gentle AdaBoost,
3. tree-based 20X20 gentle AdaBoost,
4. stump-based 20X20 gentle AdaBoost (a tree of stage classifiers).



(a) False Alarm (b) Computational Time

Fig. 1. False alarm and computational time with 4 frontal face detection model

We conducted the experiment on a Pentium 4 2.4 Ghz single core PC. We measured detection ratio, false alarms, and computation time. In the case of detection ratio, all experiments achieved over 99.9%. We compare false alarms and computation time in Fig. 1. In the experiments, the proposed method reduced the number of false alarms to an average of 68\%. Moreover, the computational time was diminished to average 80%.

In the on-line face detection and tracking experiment on an mobile device (800Mhz CPU), we used 240 X 160 image sequences. We use both frontal and profile face classifiers. We measure the computational time of the conventional AdaBoost detector and the proposed detector. The computational time of the proposed detector is reduced to 60% of that of the conventional detector. We measure the computational time of the proposed detecting and tracking model. We change the input image every second and average the whole computational time to measure overall speed. The speed of the proposed system is 3.6 times faster than that of the conventional detector.

4 Conclusion

In this paper, we propose an efficient color filtering-based face detector with sub-window scanning. Our detector scans the image space sparsely based on facial color density. As compared with the conventional AdaBoost face detector, we have shown that the proposed detector has a lower overall computational cost and fewer false alarms, while detection ratio is same with conventional one.

Acknowledgments. This work was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology(MEST) (2011-0018291 and 2011-0013776).

References

1. Viola, P. and Jones, M.: Rapid object detection using a boosted cascade of simple features. In: IEEE Computer Society Conference on Computer Vision and Pattern Recognition, pp.12-14. Hawaii (2001)
2. Lienhart, R., Kuranov, A., and Pisarevsky, V.: Empirical Analysis of Detection Cascades of Boosted Classiers for Rapid Object Detection. In: DAGM 25th Pattern Recognition Symposium, pp.297-304. (2003)
3. Li, S.Z. and Zhang, Z.: FloatBoost learning and statistical face detection. In: IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 26, No. 9, pp.1112-1123.(2004)