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Research and Implementation of Pattern Recognition Based on Adaboost Algorithm

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Abstract: Pattern recognition and computer vision technology as a long-term subject of concern, which has high academic value and commercial value. Adaboost is an iterative algorithm, and its core idea is to obtain some weak classifier with a training set of training. Finally, a much stronger classifier is obtained by combining weak classifiers. In this paper, we firstly introduce the basic theory of Adaboost algorithm, and then take face recognition as an application example, the training process and the detection process were achieved respectively and independently. Experimental results show the detector based on Adaboost algorithm can accurately detect the location of the face, regardless of their positions, scale, orientation, lighting conditions, expressions, etc., and it has a smaller detection error. Specifically, the detector can effectively detect multiple faces, and it also has much higher detection accuracy. *Copyright © 2013 IFSA.*

Keywords: Pattern recognition, Computer vision, Face detection, Adaboost algorithm.

1. Introduction

Pattern detection algorithm has been developed over the past decades. Each detection algorithm is developed in a particular application context, and so we can analysis these few of detection methods into two main types: image based methods and feature based methods. The first method always uses classifiers trained statically with a given sample set. Then each classifier is scanned through the samples set. The other method locates by detecting particular features. Pattern detection algorithm used is both image based and feature based. It is image based in the sense that the method uses a learning algorithm to train the classifier with some chosen trained positive and negative samples. And it is also feature based because the lots of features chosen by the learning algorithm are directly related to the particular features. The boosting techniques improve the performances of base classifiers by re-weighting the training examples. Learning using Boosting is the main contribution of Pattern detection.

The important issue of face information processing technology has always been the pattern recognition cut the field of machine vision research concern, is one of the important components of this stage based on biometric identification technology. What's more, face as images and video of the most important visual objects, one in computer vision, pattern recognition, multimedia technology research occupies an important position. Face detection and retrieval of information processing of human face and retrieval based on content. In recent years, a very active direction in intelligent man-machine interface, it has a very wide range of applications, content-based retrieval, the digital word video processing, security and other fields [1-2].

In recent years, face detection has made considerable development. Amit et al. had presented a method for shape detection, and then this method was applied to detect frontal-view faces in still intensity images [3]. Viola et al. proposed a new detection method based on the integral image features and Adaboost algorithm [4]. Speed and performance of this cascade classifier is equivalent of ANN method proposed by Rowley [5]. Later, Li's research group developed this method for multi-view face detection [6]. Kauth et al. proposed a blob representation to extract a compact, structurally meaningful description of multispectral satellite imagery. Craw et al. proposed a located method based on a shape template of a frontal-view face, and a Sobel filter is first used to extract edges. These edges features are grouped together to search for the template of a face based on several constraints. These above methods all have better face detection performance.

Recently, many researchers started to use Adaboost algorithm in Pattern detection. Adaboost is an iterative algorithm, and its core idea is to obtain some weak classifier with a training set of training. Finally, a much stronger classifier is obtained by combining weak classifiers. In this paper, we firstly introduce the basic theory of Adaboost algorithm, and then the training process and the detection process were achieved respectively and independently. Experimental results show the detector based on Adaboost algorithm can accurately detect the location of the face, and it has a smaller detection error. Specifically, the detector can effectively detect multiple faces, and it also has much higher detection accuracy.

2.Adaboost Algorithm

2.1. Adaboost Review

Adaboost algorithm is based on gray-scale distribution of target features, which chooses to use the Haar characteristics [4-7]. Haar feature is based on the characteristics of the integral image, and this feature is mainly used in the gray scale image. Its advantages consist of calculation simpler and faster extraction. Adaboost algorithm first extracts image Haar characteristics, and then through the training process to obtain Haar feature is converted into many weak classifiers, and finally these weak classifiers are optimized combination to use for face detection. Fig. 1 shows the flow chart of detection based on Adaboost algorithm.

Integral image snapped original any point in the upper left pixel in the image obtained by adding the pixel value as the current point image. The accumulation of all the pixel values of the upper left portion of the integral image for each point (*x,y*) of the midpoint of the value of the original image (*x,y*):

$$ii(x,y)=\sum_{x\le x_0,\,y\le y_0} i(x,y) \qquad (1)$$

where $i(x,y)$ is the original image, $ii(x,y)$ is the integral image. Fig. 2 shows the process of computing integral image. Fig. 3 shows an example of integral image.

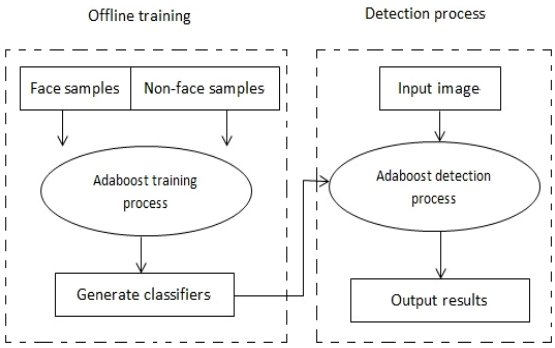


Fig. 1. The flow chart of face detection based on Adaboost algorithm.

1	1	1	1	1	1	···	1
1	1	1	1	1	1	···	1
1	1	1	1	1	1	···	1
1	1	1	1	1	1	···	1
1	1	1	1	1	1	···	1
1	1	1	1	1	1	···	1
···	···	···	···	···	···	···	···
1	1	1	1	1	1	···	1

(a) image data

1	2	3	4	5	6	···	16
2	4	6	8	10	12	···	32
3	6	9	12	15	18	···	48
4	8	12	16	20	24	···	64
5	10	15	20	25	30	···	80
6	12	18	24	30	36	···	96
···	···	···	···	···	···	···	···
16	32	48	64	80	96	···	256

(b) integral image data

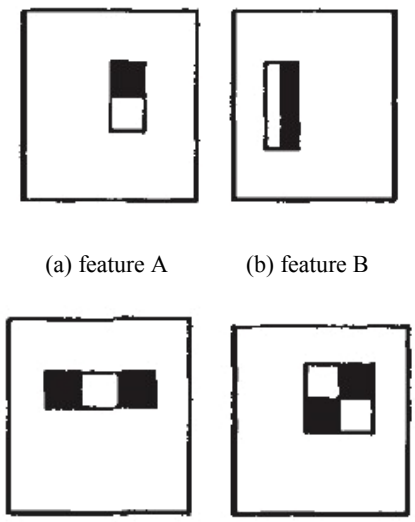
Fig. 2. The data of the integral image.

(a) original image (b) integral image

Fig. 3. A specific example of integral image.

According to the characteristics of the integral image, the sum value of the arbitrary rectangular region of pixels can be calculated by using the formula (1) with a quick computing process and the computation time is fixed. The advantage of this feature to design Haar feature extraction and the machine calculation time fixed. It is because of Haar feature extraction speed is fast enough, it making the Adaboost detection algorithms has become one of the fastest detection algorithms.

As we all know, common Haar feature is designed according to the characteristics of regional gray contrast. Fig. 4 shows four types of classical Haar features. Haar features of this reflects the characteristics of the image in grayscale distribution characteristics bow l into the face detection problem which, the problem is converted into how to find a better Haar feature to describe the characteristics of the image gray distribution. Adaboost algorithm selects from a large number of Haar characterized the optimal characteristics, and convert it into the corresponding weak classifier classification used, so as to achieve the purpose of the target classification. Adaboost algorithm training process is to select the process of the weak classifiers.



(a) feature A (b) feature B

(c) feature C (d) feature D

Fig. 4. Four types of classical Haar features.

2.2. Training Process

Each Haar feature is corresponding with one of the weak classifiers, but not any Haar feature can be better described gradation distribution of certain characteristics. There is a key research object to be solved how to select optimal Haar characteristics and then produce into a classifier for detection from a large number of Haar features in Adaboost algorithm training process. The requirements of the training sample face close-up image, but vastly different face shape, so the training sample selection process to take into account the diversity of the sample. Training samples need to preprocess before using to train. Generally speaking, training samples pre-treatment does not require special algorithm, but the sample human face gesture to try to be consistent. Fig. 5 shows a set of training samples.

Firstly, we can extract Haar feature for face image from training set. Then weak classifiers are generated based on features. Each Haar characteristic is corresponding to a weak classifier, and each weak classifier is based on the parameters of its corresponding Haar characteristics defined. By using the position information of the above Haar characterized statistical training samples can be obtained corresponding to the characteristic parameters. The weak classifiers definition formula is as follows:

$$h_j(x) = \begin{cases} 1 & if \quad p_j f_j \le p_j \theta_j \\ 0 & otherwise \end{cases}, \tag{2}$$

where the characteristic parameters p_j represent inequality direction, θ_j is threshold. Weak classifiers can be divided into different ways according to statistics, the value of single-domain weak classifiers and dual-domain values of weak classifiers.

Fig. 5. A set of ORL face training samples.

As defined in the current Haar characterized by the statistics of the training sample average of positive samples and negative samples: θ_{j_p+1}, θ_{j_p-1}. So we can obtain $\theta_p = (\theta_{j_p+1} + \theta_{j_p-1})/2$. Assume $\theta_{j_p+1} > \theta_{j_p-1}$, so $p_j = +1$, otherwise $p_j = -1$. The output result of the weak classifiers to 1 or 0, and outputs 1 represents a judgment is true, that is a face image; on the contrary, this is false, i.e. a non-face image. Single weak classifier limited capacity, and does not handle objects, so would its group and into a strong classifier.

Next, we will describe the training process. Adaboost algorithm training process is the selection of optimal weak classifiers, and given the weight of the process [8-9]. Fig.6 shows the training process of Adaboost algorithm. The specific training algorithm steps are as follows:

1) Label n training samples, where m samples are labeled $y_j = +1$, and $n - m$ non-face sample are labeled $y_j = -1$;

2) Initialize the weights. The original weights of each face sample are set as: $w_{0_{p+1}} = \frac{1}{2*m}$, non-face samples are set as: $w_{0_{p-1}} = \frac{1}{2*(n-m)}$;

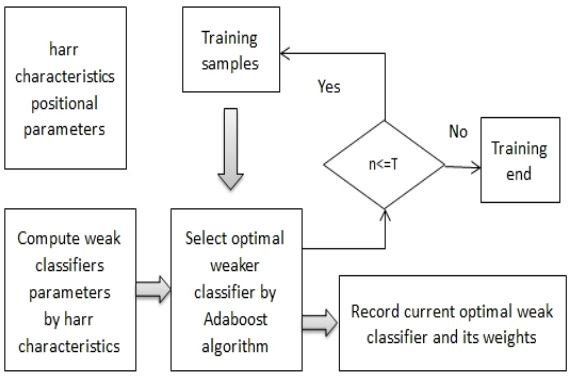


Fig. 6. The training process of Adaboost algorithm.

3) Select *T* weak classifiers (*T* iterations)
   a) In the *t-th* iteration, compute the iteration error sum of the *j-th* weak classifier as: $\varepsilon_j = \sum_{i=1}^{n} w_{ij} \left| h_j(x_i) - y_j \right|$, and choose the minimum iterative error of weak classifiers $h_t(x_i)$. Compute $\beta_t = \frac{\varepsilon_t}{1-\varepsilon_t}$, and set $\alpha_t = \log\frac{1}{\beta_t}$, α_t is the weight of weak classifier;
   b) Use $h_t(x_i)$ and β_t to update all weights: $w_{t+1_p i} = w_{t_p i}\beta_t^{1-\varepsilon_i}$. If *i-th* sample is correct classification, so $\varepsilon_i = 0$; otherwise $\varepsilon_i = 1$;
   c) Normalize weights: $w_{t+1_p i} = \frac{w_{t+1_p i}}{\sum w_{t+1_p i}}$;
   d) Set $t = t+1$.
4) A strong classifier is obtained by linear combination of a number of weak classifiers:

$$h(x) = \begin{cases} 1 & \sum_{t=1}^{T} \alpha_t h_t(x) > \frac{1}{2}\sum_{t=1}^{T} \alpha_t \\ 0 & otherwise \end{cases} \quad (1)$$

Single weak classifier has poor classification results, and the training initial error is 0.15, followed by a gradual rise. So we need the combine the weak classifiers into a strong classifier to make better performance.

2.3. Cascade Classifier

A strong classifier can be obtained through using a combination of some of the weak classifiers by equation (3), and each strong classifier will have more performance to detect face. If a plurality of strong classifiers are cascaded together, then by the strong classifier at all levels of the detected object is the possibility of the human face is also the largest. According to this principle, Adaboost algorithm introduces a waterfall-type classification is an associated classifier. The flow of detection algorithm based on cascade classifiers as Fig. 7.

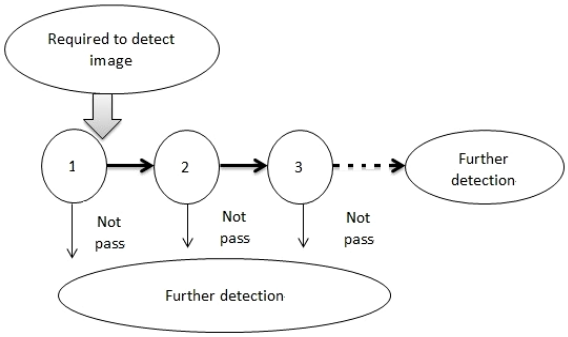


Fig. 7. The flow of detection algorithm based on cascade classifiers.

The cascade classifier combines several strong classifiers to grade series together, and strong classifier level is complex than other and strict than others. Detection of non-face images in the front is ruled out to only face images detected by the strong classifier at all levels. In addition, because the non-face images are eliminated in the first few levels of the cascade classifier, it can speed up the detection speed of detection algorithm.

3. Face Detection Based on Adaboost Algorithm

The cascade classifier performance, in order to be able to use the image detection records cascade classifier needs to design a detection mechanism, and its design processing interface. In Order to be able to detect the size of various scales the human face, the need to introduce here the detection mechanism of the multi-scale. There are several commonly used scale variation methods, but in order to ensure the detection speed, there are two methods available: One method to implement scale transformation to the classification, and also it needs to change the field values of the weak classifiers. Another method is to sample to the image at different scales, and this method is simple to implement, but a little time-consuming than the former method.

A flow of the detection process is shown in Fig. 8. Adaboost algorithm based face detection processing

is a gradation data, so the detection of the first step is to be detected image is converted into a grayscale image.

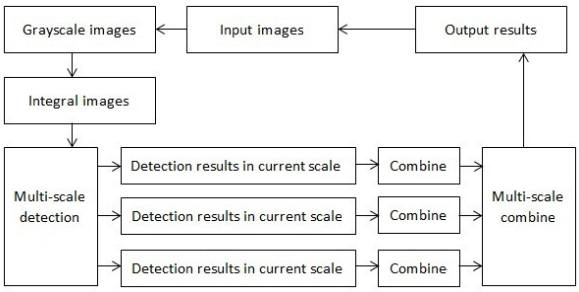


Fig. 8. A flow of the detection process.

As see from Fig. 8, the second step is grayscale images integral image. The third step of the integral image detection at different scales, in different scales, the detection result of the merger.

The fourth step is output after the detection results under different scales.

On the same scale, when the overlapping part of the two sub-windows detected face, you need to consider whether there is the need to merge. According to the experimental results, we need to combine overlapping sub-window when the overlapping part of the face sub-window is over the current window size of 0.5. This combined method is to obtain averaging values.

In addition, we also need to combine when the detected windows are overlapped in different scales. Generally in the vicinity of the location adjacent scales duplicate detection, this will not only lead to repeat testing, but also may cause unnecessary error detection results.

4. Experimental Verification

In this section, many experimental results are showed to verify the effectiveness of Adaboost detection algorithm. Firstly, we implement the detection on IMM face database. Fig. 9 shows some detection results on IMM face database. From Fig. 9, we can see that the detector can accurately detect the location of the face, and it has a smaller detection error. Then the detector is implemented on some network picture. Fig. 10 shows some detection results on faces set from network. We can also find the detector can accurately detect the location of the face.

Then we verify the effectiveness of Adaboost detection algorithm to detect face on some images with multiple faces. Fig. 11 shows some detection results on images with multiple faces. From experimental results, we can easily find the detector can effectively detect multiple faces, and it also has much higher detection accuracy.

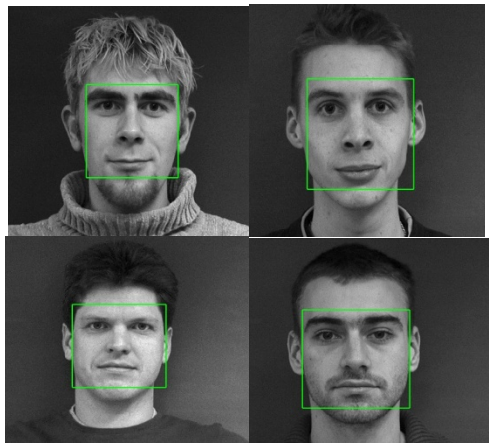


Fig. 9. Detection results on IMM face database.

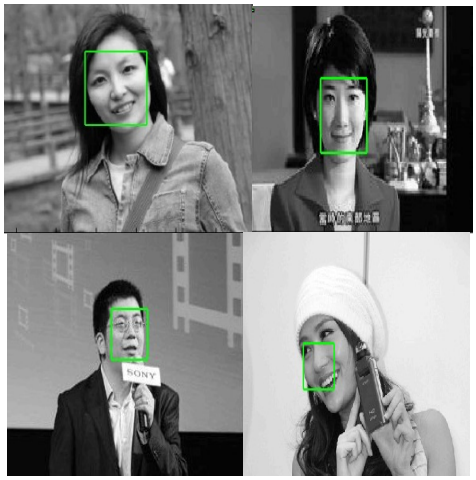


Fig. 10. Detection results on faces set from network.

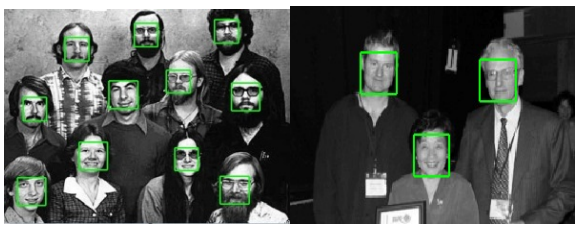
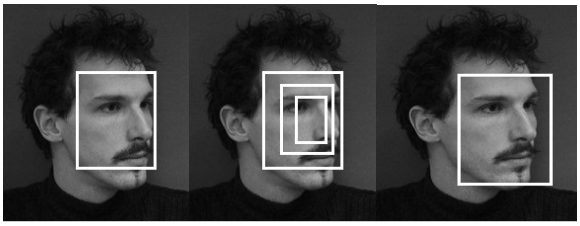


Fig. 11. A few of faces in an image.

In addition, we also need to combine when the detected windows are overlapped in different scales. Generally in the vicinity of the location adjacent scales duplicate detection, this will not only lead to repeat testing, but also may cause unnecessary error detection results. Then some experimental results show the combining process for different windows. Fig. 12 shows an example of how to merge detection result: Fig. 12 (a) is the result of a plurality of windows overlapped in the same scale; Fig. 12 (b) is a plurality of windows overlapped with each other at different scales, and Fig. 12 (c) is the final combining result.



(a) Overlap in same scale | (b) Overlap in different scales | (c) Combine results

Fig. 12. Results of combining windows.

5. Conclusions

Face detection in pattern recognition and machine vision technology as a long-term subject of concern, which has high academic value and commercial value. The rapid development of related face technologies, face detection as a key step, has causing more and more attention of researchers and research. Adaboost is an iterative algorithm, and its core idea is to obtain some weak classifier with a training set of training. Finally, a much stronger classifier is obtained by combining weak classifiers. In this paper, we firstly introduce the basic theory of Adaboost algorithm, and then the training process and the detection process were achieved respectively and independently. Experimental results show the detector based on Adaboost algorithm can accurately detect the location of the face, and it has a smaller detection error. Specifically, the detector can effectively detect multiple faces, and it also has much higher detection accuracy.

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