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Face Detection Based on Cascading Support Vector Machines

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Abstract: With the development of society, the world's population mobility, mobility speed and mobility area are increasing, and face detection and recognition technology also plays an important role in the management and statistics of mobile population, and has great application prospects in digital entertainment. The aim of this paper is to study face detection based on cascaded support vector machines. The performance metrics specified in the training are reduced, effectively simplifying the structure of the cascading classifier, which is then used as a filter, followed by the introduction of a nonlinear support vector machine main classifier based on rectangular features. Experimental results show that although the detection speed does not reach the real-time level of Viola's method, it is still a significant improvement over the pixel-based method, along with a higher face detection rate.

1. Introduction

In all walks of life, more and more people are questioning the security and trustworthiness of traditional means of identification [1-2]. It is true that effective identification and authentication technology has become an important issue in the field of information intelligence research, as traditional identification methods are easy to forge and lose, and authentication methods such as citizen ID cards, smart access cards and network login passwords are cumbersome to use and not easy to carry or forget [3-4].

In recent years, the study of algorithms related to face detection and their implementation has started to attract the attention of many scholars as an independent research topic [5-6]. Slim Ben Chaabane proposed a histogram (HOG) based and support vector machine directional gradient algorithm for human eye localization. In addition, an image pre-processing method was designed to greatly improve the localization speed of unique grey-scale distribution features of iris images under near-infrared light sources. The human eye localisation algorithm based on HOG and SVM has high real-time accuracy, wide distribution and high performance [7]. Pablo Negri proposed a high accuracy and fast spatial object detection algorithm based on cascading support vector machines (SVM) in order to achieve high accuracy detection of optical image objects for spatial surveillance systems. A first two-stage linear cascade SVM classifier is trained by extracting binary normalised features of spatial objects at different scales. And features such as area, perimeter, greyscale and Hu moment of the objects are used as combined features to train the third stage SVM classifier. In the object detection process, the first two-stage SVM classifier is used for window prediction and scoring of candidate objects, and the third-stage SVM classifier is used to determine the final candidate window to complete the object detection [8].Abdessamad Amir proposed a face detection method based on Adaboost and PCA algorithms to improve the face detection accuracy. The method uses a two-stage detector to detect faces. Firstly, the Adaboost algorithm is used as the primary detector to quickly scan the face image and combine all the recognised face windows, and then the accuracy is finally verified by sending the window features to the secondary detector [9]. Overall, research into face detection based on cascading support vector machines holds great promise.

In this paper, different methods for the detection of face images are introduced, the basic theory of support vector machines is analysed, the classification method of cascading support vector machines is studied in depth, a cascading classifier with rectangular feature-based support vector machines is proposed for face recognition, and the recognition efficiency of the algorithm is verified, and finally, future research is looked into.

2. Research on Face Detection Based on Cascading Support Vector Machines

2.1. Detection of Face Images

Face detection consists of many elements and depending on the type of image, video sequences can be divided into still images and face recognition. In the case of still images, it is important to adapt the detection algorithm to a wider range of image types. In the case of dynamic video sequences, the speed of detection is fundamental [10]. Face detection can be divided into colour images and greyscale images, depending on the classification of the colour information. The former can use skin colour information, so the former is faster than the latter [11]. In the case of static images, the algorithms studied so far are mainly aimed at complex contexts [12-13]. If the number of faces in the image is known, face detection at this point is also called face location and only the position of the face is determined. When detecting faces, it is usually necessary to consider the number of unknown faces in the image, the need to determine whether the image contains faces, and the number of faces and their corresponding positions if the image contains faces [14].

2.2. Cascading Support Vector Machines

Cascaded support vector machines use the idea of multi-level feedback to divide the problem of a global support vector machine into local SVM problems [15-16]. the SVM model is integrated into the final SVM model through a recovery tree. Theoretically, the sub-model algorithm can use currently supported vector machine algorithms, including the interior point method and minimum sequence optimisation [17]. The entire dataset is randomly partitioned into subsets of equal size, as shown in Equation 1.

$$m(m = 2i, i = 1,2,..., N+) \tag{1}$$

Each subcomponent is trained and modelled by the SVM, and the final model of the SVM is obtained by log2m+1 level iterations [18]. If the last layer does not meet the accuracy requirements, it returns to the first layer and starts a new iteration.

2.3. Cascaded Classifier with Rectangular Feature-based Support Vector Machine

Due to the high performance requirements of face detection systems, cascaded classifiers often require a large number of levels to meet them, taking Viola's system as an example, which has 32 levels of cascaded classifiers. On the other hand, the non-face samples used in the training of each level of the strong classifier in the cascade structure are false alarms generated by all the previous classifiers, so the more complex the non-face training samples of the later strong classifiers become, the closer they are to faces, and the more difficult it becomes for the strong classifier to classify, making the convergence process very long.

In order to change this situation, we introduced a non-linear support vector machine classifier with rectangular features as input vectors to reduce the pressure on the cascading classifier. The main improvements are in the following two areas first.

We add a non-linear support vector machine classifier after the cascade classifier, which uses rectangular features in the image as input vectors.

Secondly, we have reduced the requirement for the cascaded classifier to have a false alarm rate F in its training.

3. Investigation and Research on Face Detection Based on Cascading Support Vector Machines

3.1. Training Sample Set

The training sample set has a sample size of 24x24, with 5000 face samples obtained from the Internet and 160,000 non-face samples randomly selected from the CMU test set.

For both training and detection, all samples and detection windows are pre-processed using a variance normalisation method to reduce the effect of lighting conditions on the detection results. We can quickly obtain the variance of the detection window in the integrated image using the following equation:

$$\sigma^2 = m^2 - \frac{1}{N}\sum x^2 \tag{2}$$

where σ is the standard deviation of the detection window, m is the mean value, N is the number of pixels in the window and x is the grey scale value of each pixel point in the detection window. Here the mean value of the detection window can be easily obtained using the integral image, and the calculation of the sum of squares of pixel greyscales can be solved by introducing an integral image of pixel squares (i.e. keeping two integral images at the same time).

3.2. Training Process

In the construction of the cascaded classifier, each level of the strong classifier is trained using all 5000 face samples, except for the first three levels, where the non-face samples are all false positives (up to 10,000) collected by all previous strong classifiers, and the first three levels of the strong classifier directly use 10,000 randomly selected non-face samples from the training set. We specified the minimum acceptable face detection rate d for each level of strong classifier as 99.9% and the maximum acceptable false alarm rate f as 45%; the overall false alarm rate F for the cascaded classifiers was up to 0.1%.

The nonlinear support vector machine still uses a Gaussian radial basis function as its kernel function with g of 0.15 and a constrained optimisation condition . The input vector is the first 200 rectangular features obtained using the strong classifier training algorithm. The training samples are 2000 face samples and 5000 non-face samples randomly selected from the training sample set, and the remaining face samples and false alarms generated by the cascaded classifier are used as its expanded training set. It is also worth noting that the rectangular features fed into the nonlinear support vector machine, both for training and detection, need to be normalised to between 0 and 1.

4. Analysis and Research of Face Detection Based on Cascading Support Vector Machines

4.1. Classifier Structure

The final cascaded classifier obtained has 10 layers with a total of 1127 rectangular features. The strong classifier consisting of two rectangular features in the first - level has a face detection rate close to 100%, while excluding about 60% of the non-face window; the strong classifier in the second level contains five rectangular features, which achieves a face detection rate comparable to that of the first level while filtering out 80% of the non-face, and the number of rectangular features in the subsequent levels is 20, 50, 95 and 152 respectively. The training of the cascaded classifier can be completed in a few hours, which is a significant improvement over the original several days, as the total number of rectangular features is only a quarter of that in the Viola method. The training yielded a total of 746 support vectors for the nonlinear support vector machine classifier.

4.2. Comparison of Classifiers

In order to verify the effectiveness of the two face detection methods in this paper, we conducted test experiments using two sets of tests that were completely independent of the training set: the first was our own test set, which included 150 various images containing faces collected online for a total of approximately 224 fronts, and the second was the CMU frontal test set, which included 150 images for a total of 208 fronts more or less. The experiment assumes that the number, proportion and location of faces in the images are unknown.

Tables 1 and 2 show the statistics of the experimental results on the two test sets respectively.

Table 1. Comparison of the results of the two classifiers on the self-built test set

Algorithm	Face detection rate	Number of error detection
Sampling SVM+pixel based SVM	95	12
Cascading classifier+SVM based on rectangular features	98	6
Viola's method	97	8

A comparison of the three algorithms for self-built test sets is shown in Figure 1.

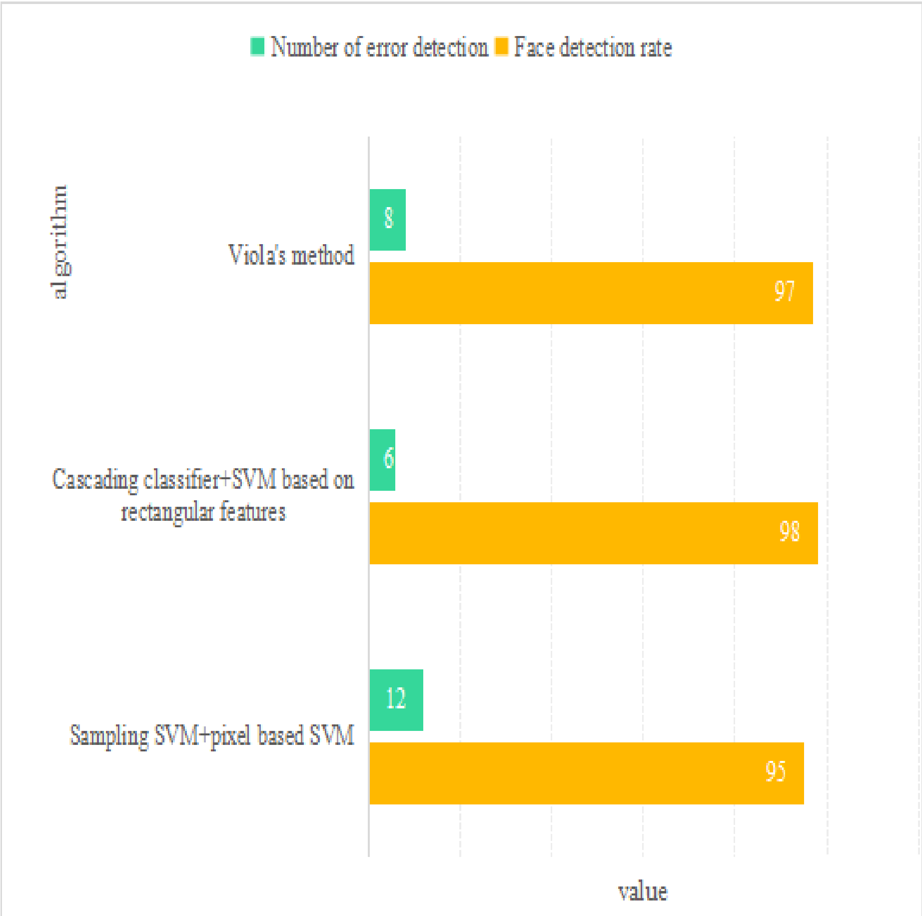

Figure 1. Comparison of three algorithms for self-built test sets

Table 2. Comparison of results of two classifiers on CMU test set

Algorithm	Face detection rate	Number of error detection
Sampling SVM+pixel based SVM	92	18
Cascading classifier+SVM based on rectangular features	96	9
Viola's method	94	13

A comparison of the three algorithms for self-built test sets is shown in Figure 2.

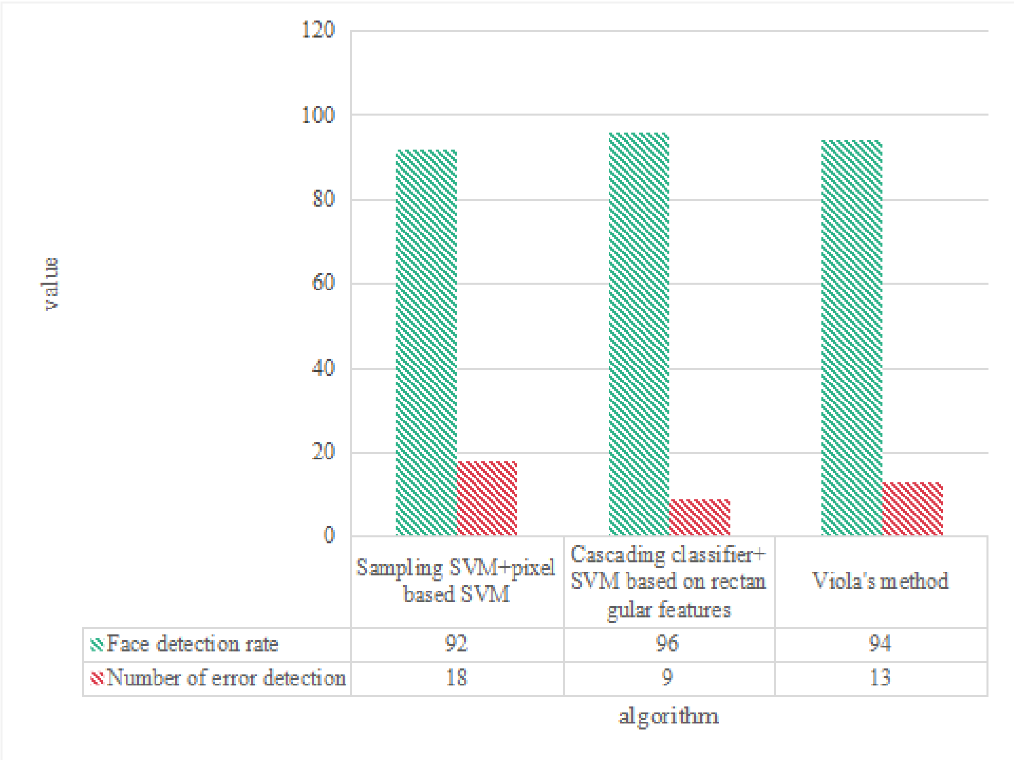

Figure 2. Comparison of three algorithms for CMU test set

The detection times are given in Table 3 for an image size of 256x256, with a total of 128,536 detection windows.

Table 3. Comparison of detection time between two classifiers

Algorithm	Time in seconds
Sampling SVM+pixel based SVM	44
Cascading classifier+SVM based on rectangular features	6

5.Conclusion

Face recognition technology is not only a popular research direction in the field of biometrics, but also a very challenging problem. This paper first introduces the importance, content, difficulties and development of face recognition research. Then the technical problems of face recognition technology are studied and analysed. An improved face recognition algorithm based on hierarchical support vector machines is proposed. Due to the limitation of time and own level, this paper does not study the subject of face recognition to a certain depth, and there are still many areas that need to be improved. Firstly, how to design an algorithm for face detection on colour images with inconspicuous skin colour areas and complex background colours is a technical difficulty and a common and urgent problem to be solved. Secondly, improved algorithms for feature extraction of those face images affected by drastic changes in light intensity, expressions, occlusions and other factors are also a future research direction.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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