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Rotational Invariant Face Detection On a Mobile Device

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Abstract

In this paper we propose a rotation invariant face detection algorithm to detect the face on the mobile devices. Due to the performance limit on the mobile devices, complex face detection process must be avoided in order to generate a fast detection. Most proposed face detection algorithms are highly rotational variant, which means only upright face can be detected in the image, and those existed rotational invariant face detection algorithms are too complicated to be suitable for the mobile devices. Our algorithm can detect non-upright face in the image with an efficient process implemented on the mobile device (Google Nexus 7 tablet), and has different detection ranges adapting to different user choices. The experiment results reveal the validity of our proposed algorithm. Meanwhile, our algorithm can be easily implemented on other mobile systems, such as Windows Phone, iPhone and so on.

Keywords: face detection, mobile platforms, opencv, rotation invariant, android.

1. Introduction

The mobile communication and hardware technology has given the mobile phones much computing power and interactive capability in recent years, so many computer vision algorithms can be implemented on the mobile device. Face detection[1] is one of the fundamental techniques which enable human-computer interaction in a natural way. It is a very complicated topic which involves face alignment, face modeling, face relighting, face recognition, face verification/authentication, head pose tracking, facial expression tracking/recognition, gender/age recognition and so on. Face detection is also a core research topic in human-computer interaction areas. Only when the face is accurately detected, the computers can truly understand people's thoughts and intentions. For human beings, they can easily detect people's human faces without hesitation. But for computers, face detection is a very complicated process which involved many aspects. Face detection methods can be divided into four categories[2]: knowledge-based methods, feature invariant methods, template matching methods, and appearance-based methods. Rowley et al.[3] have presented a neural network based face detection system, which can detect faces at any degree of rotation in the image plane. Their detector belongs to the template-based face detection category. Appearance-based methods which use less data storage and the rapid growing computation power have been widely adopted in various application areas. One of the most classical and famous appearance-based methods is Viola-Jones face detector, which utilizes the machine learning algorithm Adaboost in the classifier training phase presented by Viola-Jones[9]. Many approaches have been proposed to achieve a rotation invariant detection based on Viola-Jones face detection's framework. Du et al.[4] adopt new rotated Haar-like features to train the classifier. In order to use the new features, they divide the image into 12 orientations. As they have 12-times as much features than the original face detector system, their algorithm can not be used in the resource-limited mobile device. According to variant appearance produced by different view points, Wu et al.[5] propose rotational invariant multi-view face detection which is based on a variant of Adabost and Haar-like features. Because their algorithm cannot run in real-time on the ordinary PC, it is not applicable for the mobile device. Ren et al.[6] have proposed several optimization for Viola-Jones algorithm which include data reduction, search reduction and numerical reduction. But their optimization method also leads to a smaller face detection rate than Viola-Jones's method. By using inertial measurement unit on Apple's iPhone 4, Scheuerman et al.[7] proposed the fusion of inertial sensors and the boosting based face detection by Viola and Jones. They use the virtual upright image to detect the face on the image, and their method makes some performance improvement when the phone is rotated. However, when the face in the image is not upright, their method cannot detect it correctly. For the mobile device

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without inertial measurement unit, their algorithm cannot be used at all.

OpenCV library has the improved implementation of Viola-Jones face detector, implemented by Lienhart et al.[8]. Our proposed model is based on Viola-Jones face detection framework. As considering the performance of the face detector, OpenCV face detector have been trained solely onupright faces. So Viola-Jones face detector are highly rotational variant, i.e., it cannot detect correctly when the faces in the images are not upright. In order to solve this problem, we propose a new rotational invariant face detection algorithm. Our proposed method can detect face correctly even if the face is not upright in the image. At the same time, our face detection algorithm has been implemented on the mobile device.

2. Viola-Jones Face Detection Algorithm

There are mainly four face detection methods[2]: knowledgebased methods, feature invariant approaches, template matching methods and appearance-based methods. According to the knowledge of a typical human face, knowledge-based methods use pre-defined rules to detect a face. Feature invariant approaches aim to find structural features when the pose and lighting are changed. Template matching methods use defined templates to detect face on images. By learning face models from a set of representative training face images, appearance-based methods judge whether faces exist in the detected image. In general, appearance-based methods have superior performance to other face detection methods, such as higher performance and less data storage. Viola-Jones face detection algorithm[9] is the most famous appearance-based face detection algorithm. Many face detection methods based on Viola-Jones algorithm have been proposed, and some of them have been widely used in digital camera and related face detection areas. In ordinary PCs, Viola-Jones algorithm can run in real time, which includes three main components: the integral image, classifier learning with Ada Boost and attentional cascade structure.

2.1. Integral Image and Adaboost Learning

Integral image[10] is an intermediate representation of the image which can compute rectangle features efficiently. Viola and Jones directly use Haar-like features rather than pixels, as the feature-based operation are much faster than the pixel-based operation. Harr-like features can be divided into two-rectangle features, three-rectangle features and four-rectangle features.

The integral image at location (x, y) is constructed as follows:

$$ii(x, y) = \sum_{x' \le x, y' \le y} i(x', y')$$

where $ii(x, y)$ is the integral image at pixel location (x, y), and $i(x, y)$ is the pixel value of the detected image. We can effectively compute the sum pixel value of the green area in Figure 1 by using the integral image.

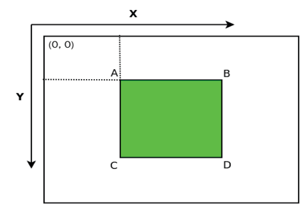


Figure 1. Compute rectangle ABCD by integral image

Although Harr-like features can be computed efficiently by the algorithm, there are still thousands of features for a 24×24 sub-window. Harr-like features include good features and bad features, and Viola and Jones have used machine learning approach to learn a classification function.Adaptive Boosting is machine learning algorithm, which is considered as the first step towards more practical boosting machine learning algorithm. By combining a set of weak classification functions to form a stronger classifier, the Ada Boost learning algorithm is used to boost the performance of the feature classifier. In the first round of the training phase, the examples selected incorrectly by the previous weak classifier are emphasized through the re-weighting process. So the final strong classifier is formed to a weighted combination of the weak classifiers. Then they associate a large weight with each good classification function and a smaller weight with each bad functions.

3. Rotational Invariant Face Detector

An improved version of Viola-Jones face detector has been implemented in OpenCV library. Because training all kinds of face pose needs a large training data and occupies long processing time, the OpenCV face detector have been trained solely on upright faces, which can reduce the complexity of the classification problem. As the development of the computation power of the mobile device, it can runs this face detector in real time. But the OpenCV face detector is rotation variant and non-upright faces are out of its detection range. Many rotational invariant face detectors have been proposed to solve the problem. But these face detector algorithm have complex detection process, which are difficult to be implemented in the mobile device.

We propose a simple and efficient detection algorithm which achieves a high detection rate and can be easily realized in the mobile device. Mobile devices are resource-limit appliances, so we just consider the frontal face in the video camera. In addition, our face detector does not need hardware support, so it can be applied in many mobile devices. Our face detector includes three main steps. Firstly we capture the image from the video camera on the mobile device, then we detect the top priority orientation which is produced by the latest detection result. If we do not detect the face in the top priority orientation which is upright initially, we detect the secondary priority orientation. Finally, we draw labeled rectangles in the image according to the detection position. When the face orientation is not upright in the image, matrix rotational transformation is the critical step in order to rotate the face orientation to a proper position.

3.1. Ordered Priority Algorithm

In order to reduce the computation time, we divide the image into several different parts. At the first detection stage of our detector, we give the upright direction to the top priority. And the nearer part of the top priority are given the secondary priority, and so on. According to the face orientation in the detected image, each part of the divided image have different priority. In the next frame, the top priority orientation are used to detect the face. If we do not detect the face in the top priority orientation, we detect the secondary priority and so forth. For video sequences, our order priority algorithm can save many unnecessary computation time and achieve good detection rates. Figure 2 shows the state that different priorities are given to different parts of the image, according to the face orientation. Each color in the chart represents different detection priority, and the red color chart is the top priority in the detection process. At the initial stage, we choose upright orientation as the highest priority.

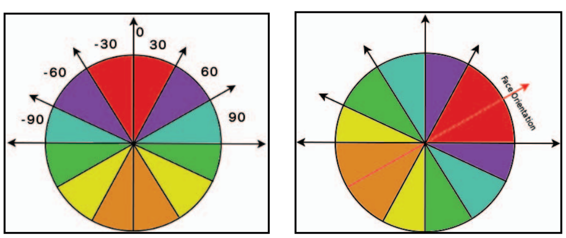


Figure. 2 The priority of the face orientation

3.2. Algorithm Flow Diagram

Figure 3 is the flowchart of our proposed rotational invariant face detection algorithm. At fist, we capture the image from the video camera. For some low resolution video camera image, we use related image processing algorithm to reduce image noise. Then we detect the first priority orientation in the captured image, according to the user's priority. If we do not find the face in the image, the second priority orientation is used to detect. This process continues until the detection process is over. In order to reduce the computation time, we just use three priority in our face detector. Based on different computation power of the mobile device, different priority can be used to detect the face in the image. So this process can reduce the processing time dramatically and have a better detection rates.

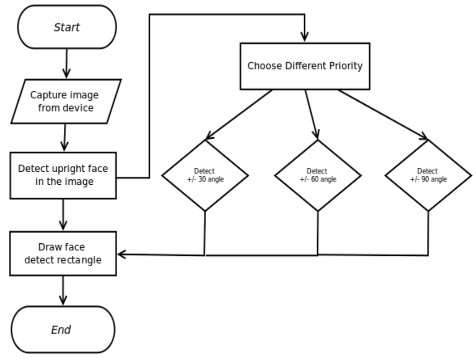


Figure 3. The Algorithm Flow Diagram

4. Experiment Results

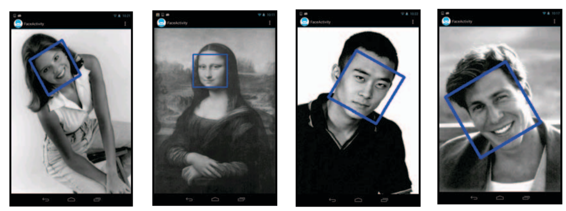


Figure 4. The face detection effects on the tablet

The mobile development platform that we use is Google Nexus 7 with the operating system is Android 4.1.2 edition. In order to reduce the algorithm complexity of the classification problem, OpenCV face detection algorithm have been trained solely on upright faces, so that can not detect faces which are not upright in the detected image. But our face detection algorithm which is based on OpenCV development library can detect non-upright face in the image.Different detection priority numbers will lead to different detection ranges of the our system.The larger the detection range is, the longer time the algorithm needs. Figure 4 shows the picture effects of our face detection algorithm on the mobile device. From the result picture, we can see that our face detector can detect non-upright faces in the image or the camera video.

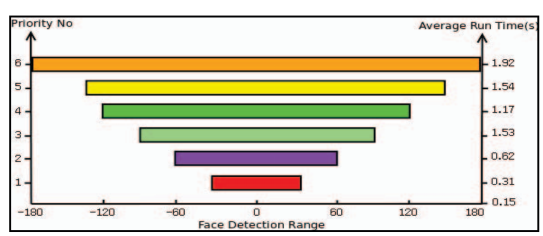
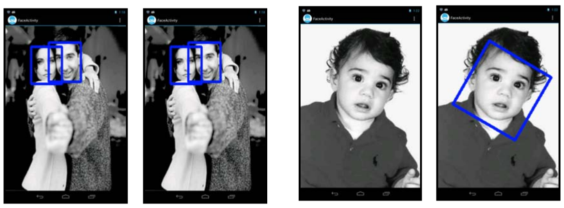


Figure 5. The running time refers to different priority

Figure 5 shows the running time of our face detector, according to the different priority. The left axis is the priority number, and the user can choose different detection priority which equals to different detection range. And the right axis show the detection time in the mobile device, which also refers to the number of priority. The horizontal axis shows the detection angle, in which different color bars are related with different detection ranges.



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

Figure 6. Comparation with OpenCV face detector

Figure 6 shows the comparation results between the OpenCV and our proposed face detector. (a) and (c) are the OpenCV face detector results, while (b) and (d) are our proposed method results. When the face-orientated is upright, the same detect results can be achieved by the two face detectors. But when the face-orientation is not upright, our face detector has better detection results than the OpenCV face detector.

Table 1 shows the comparation of detection rates between OpenCV and our proposed face detector. Our proposed method has high detection rates than OpenCV as we can dectect the non-upright faces of the images. The test image database is from the Vision and Autonomous Systems Center(VASC) at Carnegie Mellon.

Table 1. Comparation with OpenCV face detector

	OpenCV Detector	Proposed Detector
Sequence 1	≈79	≈80
Sequence 2	≈48	≈85

5. Conclusion

We propose a novel face detection algorithm for the mobile device, which can enhance the detection rates and reduce the running time. Experiments show that our proposed rotational invariant face detection algorithm not only can detect the upright face, but also for non-upright face of the image or video in real time. Specially, our face detector algorithm does not use any dedicated hardware coprocessor, so it can be applied in most mobile devices, such as smart phones, tablets and so on. Although our face detector system is implemented in the Android operating system, it can be also easily transplanted in other mobile operating systems, such as iPhone, Windows Phone and so on.

In the future, we will develop our methods on the mobile devices for other objects recognition, such as fingerprints or the iris. On the other hand, with the development of the mobile hardware, maybe we can extend our algorithm to the 3D space, and detect faces of 3D human models in real time using the mobile device.

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