International Journal for Modern Trends in Science and Technology, 6(11): 131-134, 2020

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST061124
Available online at: http://www.ijmtst.com/vol6issue11.html

Face Detection Using Viola Jones Algorithm

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To Cite this Article
Dherya Bengani and Prof. Vasudha Bahl, "Face Detection Using Viola Jones Algorithm", *International Journal for Modern Trends in Science and Technology*, 6(11): 131-134, 2020.

Article Info
Received on 26-October-2020, Revised on 10-November-2020, Accepted on 20-November-2020, Published on 23-November-2020.

ABSTRACT

Face detection is one of the most widely researched topics in recent times and is at the helm of the computer vision technology. This paper aims to review and study in detail the implementation of Viola Jones algorithm to detect faces in Realtime. Viola Jones algorithm is reviewed first followed by its main steps which include Haar features, integral image and cascading classifiers.

KEYWORDS: *Haar features, integral image, cascading classifiers*

I. Introduction

Computer vision has become one of the most worked upon and prominent technology of this decade and most people believe that it is going to continue to be so for a significant period of time. The popularity of this technology is validated by its applications in a wide number of fields and with time it is becoming more and more reliable and safe. It is a convenient tool through which digital systems can recognize a person and his traits easily and accurately.

At the heart of computer vision is face detection. It all started with detection of faces by machines at the first place. The technology then evolved to also identify the face.

The foundation of facial detection was laid by Dr W.W. Bledsoe in 1964 when he introduced a method for facial recognition for the first time in his paper titled – "The model method of facial recognition". But it was in 2001 when Paul Viola and Michael J. Jones came up with an effective real-time face detection solution in their paper titled – "Rapid Object Detection Using a Boosted Cascade of Simple Features". The results were very promising with their proposed system being quicker by at least 15 times than any other previous face detection systems.

In this paper we present a detailed study of face detection model proposed by Paul Viola and Michael J. Jones which is still very widely used today for the above stated purpose and has become the backbone of many further advancements in the field of computer vision.

The introduction to Viola Jones Model is followed by the study of its major features like integral image, selection of Haar like features and cascading classifiers.

II. THE VIOLA JONES MODEL FOR FACE DETECTION

Paul Viola and Michael J. Jones first presented their model for object detection in 2001 which was primarily motivated towards detecting full frontal faces of human beings. The model has three main steps in order to detect faces.

First step involves detecting Haar-like features in the image. Haar features are like small rectangular features calculated on pixel level to determine different facial features which are present on a face. Confirming these features makes sure that there is indeed a face present.

Second step involves creation of an integral image. An image comprises of a large number of pixels and detecting Haar-like features for such large number of pixels is not feasible, so to solve this problem an integral image is created which makes detection of Haar-like features easy.

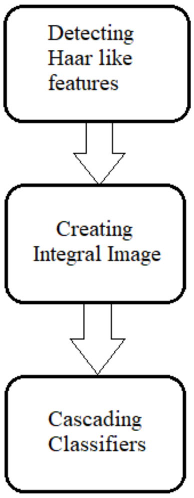

Fig.1. Major steps of Viola Jones Algorithm

Third and final step is cascading of the classifiers.It involves cascading a strong classifier which is made up of a number of weak classifiers where each stage represents a weak classifier. The main function of the cascade is to discard non-faces to save time.In the following sections of the paper we have discussed the above-mentioned steps in detail.

A. Detection of Haar-like Features

Our face has a number of unique features such as eyes, nose and lips. So, in order to detect a face, we try to detect these unique features which differentiates a face from other parts of the body. In a grayscale image of a face there are some regions

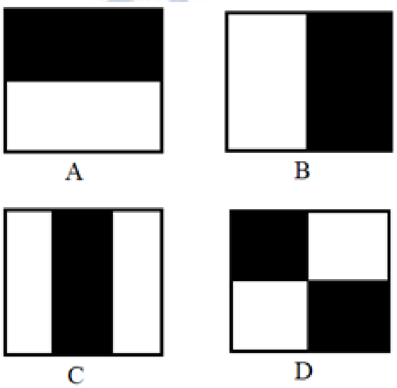

Fig.2. Some standard Haar features. A and B are used to detect edges whereas C is used for vertical lines and D for horizontal features.

of face which are lighter or darker than other parts of face. For example, eye region is darker than the bridge of the nose. This difference in intensity of some regions from other helps in detecting features of a face and this task is accomplished using Haar-like features. Haar features are rectangular clusters of pixels usually visualized as white and black where white denotes lighter region and black denotes darker region. These rectangular Haar features are applied on different parts of faces and the size of these boxes is also varied. Each pixel present in white or black region is given a value depending on its intensity, with the lightest being 255(white) and the darkest being 0(black).

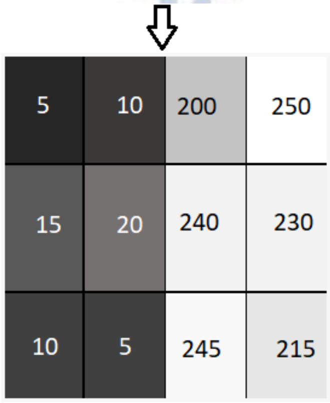

Fig.3. An example of 2 rectangle feature for edge detection applied on certain region of face.

Average value of all pixels in black region is subtracted from the average value of all pixels in white region. The equation is as follows:

$$\Delta = \frac{1}{n}\sum_{1}^{n} values\ in\ white\ region$$

$$- \frac{1}{n}\sum_{1}^{n} values\ in\ black\ region$$

A predetermined threshold value for Δ is set. If the value calculated for Δ using above equation meets the threshold then that region is accepted as a positive region or a regioncontaining a facial feature. This process is continued until all facial features are identified.

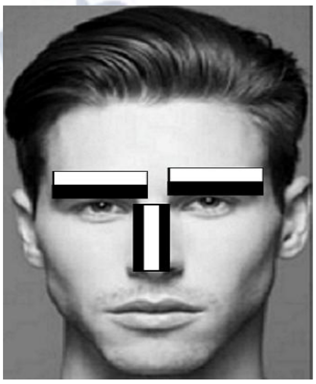

Fig.4. Different Haar features identified on a face.

The only problem is that computing these values for every set of rectangular features is not feasible. Just for instance a 24x24 image can have up to 180,000+ rectangular features, computing which takes a lot of time.

B. Integral Image

To compute the rectangular features rapidly an integral image is used which is an intermediate representation of the original image. The integral image at position (x, y) consists of the sum of all the pixels above and to the left of (x, y) including the point itself. It is given as:

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

Where ii(x,y) represents the integral image and i(x´,y´) represents the original image.

Original Image

1	7	4	2
7	2	3	8
1	8	7	9

Integral Image

1	8 (A)	12	14 (B)
8	17	24	34
9	26 (C)	40	59 (D)

Fig.5. Integral image derived from an original image

In the above Figure 5, the sum of pixels inside rectangle feature ABCD can be calculated as:

Sum (ABCD) = D – B – C + A

i.e., 59 – 14 – 26 + 8 which is equal to 27, which is same as 3 + 8 + 9 + 7 in the original image.

The integral image makes it easy to compute sum of pixels required to detect Haar features as the number of operations to compute a double rectangular feature will remain 4 irrespective of the number of pixels inside the rectangle feature. So instead of adding hundreds and thousands of pixels for each rectangular feature in the original image, the computer just performs 4 operations in the integral image.

C. Cascading Classifiers

A single classifier for Haar features is not accurate enough and is called a "weak classifier". So, to increase detection performance while also drastically reducing the computation time, these single weak classifiers are cascaded to form a strong classifier. This cascading of classifiers is done using AdaBoost which selects the best weak classifiers after trying out multiple weak classifiers over several stages and combining them to create a strong classifier. Each stage in the cascade is trained to reduce false positives by adding more features at every stage.

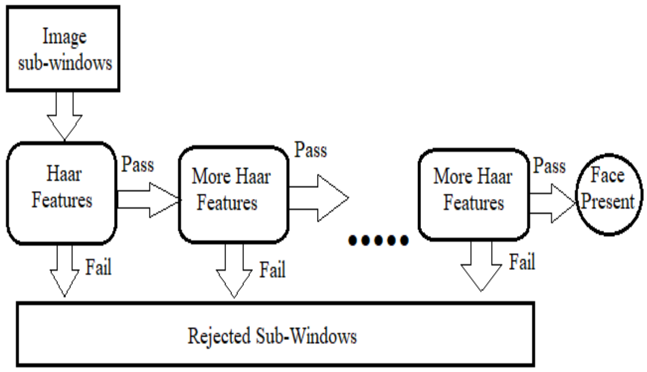

Fig.6. The process of face detection by passing all image sub-windows through a cascade of classifiers.

To detect faces an image is broken down into a number of sub-windows containing parts of the image. Each sub-window is then passed through this cascade of classifiers which detect Haar features, starting from the first classifier also known as stage 1. A positive result from stage 1 triggers the second classifier, which in turn on producing a positive result triggers the next classifier and so on. This process continues until the last stage is passed. Generation of a negative result at any stage results in that sub-window being rejected. Only a sub-window containing a face will be able to pass through all the classifiers. The initial stages are simple and reject most of the sub-windows not containing a positive. As the sub-window moves to higher stages, the classifiers become more complex, containing more features.

III. RESULT

The system takes the input using any web camera. The output of our face detection system based on viola jones algorithm is presented below:

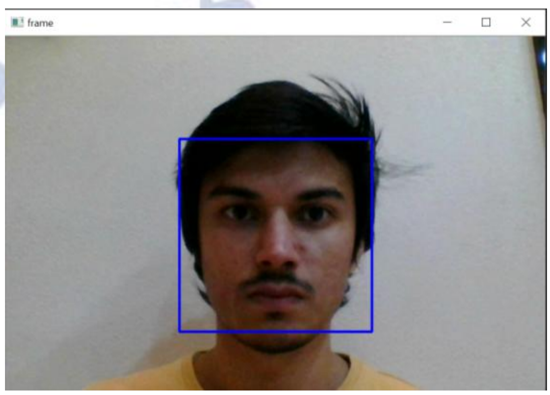

Fig.7. Face detected successfully.

IV. CONCLUSION

In this paper, we have presented a detailed study of Viola Jones algorithm and its major steps. We have successfully implemented Viola jones algorithm to detect faces in real-time. The input can be taken through any working camera given that it is connected to the system.

Even after evolution of a number of technologies for facial detection, this algorithm is still widely used at present to detect faces by a number of big companies, particularly because of how fast and simple it is.

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