Nudity Detection Using Face-Body Ratio

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Abstract:

On the Internet, it is inevitable to view images containing nudity whether voluntarily or not. Some people find this offensive and more importantly children must be protected from such images. This work aims to increase accuracy of capturing nude images. For this purpose, after obtaining faces in an image, corresponding bodies are estimated according to general face-body ratio. Body areas are individually checked for nudity using three different color spaces together for the best skin pixel detection – YCrCb, HSV, and NormRGB. In this method, total number of skin pixels and total pixels are respectively calculated for each body area and compared with a threshold that is relative to face-body ratio of current body area. For testing, randomly chosen images where at least one face can be detected are categorized by human eye and evaluated. 86% accuracy is obtained by the generated algorithm while classic method that evaluates a whole image has 74% accuracy for the same test images. The reason of using face-based nudity detection is to decrease inaccurate results caused by skin pixels that are on faces and normally not considered as nude. And the reason of using face-body ratio is not to waste resources for whole image and as a result gaining considerable efficiency.

Key words: image classification, face detection, nudity detection, face-body ratio, color spaces.

1. Introduction

Filtering images containing nudity needs to be thoroughly taken into consideration. The main motivation that ignited this workshop is all about protecting children from accidentally viewing nude images because of their physical or psychological development, meanwhile some people find seeing them offensive too [1]. It is also intended to filter images that are partially nude according to the classification model suggested in this work. Discarding consideration of speed and resource limitations, the question of to what extent nude images can be filtered appears. Currently some parental programs that are text-based and some programs or tools that disable all of images flowing from the internet perform filtering which is not preferable.

In recent years, there has been an amount of research on this subject – they are mainly based on body structure, image retrieval, and skin color region [1]. In [2] and [3], firstly skin color regions are detected and then the identified regions converted into a body based on the prior body structure in order to classify an image as nude or not.

In [4], the features of an image such as color or texture are obtained and then the pattern classifier resolves the recognition results.

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In [5], a pre-classified database to match an image is used. Here, a single image is not analyzed directly. When the number of pre-classified images from the database reaches to a threshold for an image, then it is labeled as a nude image.

While detecting nudity in methods using skin color, the nudity ratio is calculated through dividing skin regions by whole image. The most apparent disadvantage of those methods is that they do not properly classify images containing large amount of skin color but do not contain nudity – e.g. frames that show only faces have skin color with high ratio but it is clear that those methods mistakenly consider such an image as nude. In addition to that inaccuracy, an additional feature is needed to distinguish skins whether they belong to a human or not. To overcome these issues, in this work, human faces of an image are detected and separately computed from the image they belong to by cropping related body area of an individual face.

In the previous work [6], it was achieved that a ratio gained through dividing total number of nude pixels by the number of faces on an image can help to make decision about nudity. However, in this study, it is intended to go further by considering only the body areas that is taken from whole image and belong to a face. Such areas can be estimated after face detection according to the ratios of different parts of body described in [7]. Also, it must be pointed that these estimated areas are calculated vertically and any other body positions can be miscalculated – this can be considered as disadvantage though it increases accuracy. Rather than using a pre-classified database or a classifier, skin color methods described below are used in this study.

2. Background

2.1. Skin Color

In image segmentation, color as the most important feature of an image has exhaustively been used. Objects can be identified based on color variation in images [8].

Throughout this work, nudity means that sexual organs or most part of the body is open to public. Using skin color as the base feature, it is evident to measure nudity of an image [8], [9]. Although nudity is subjective, changing the threshold value can make it tunable.

There are many researches applying to color-based image classification in literature. Before proceeding, it must be pointed skin colors in grey-scale images cannot be detected – this can be ignored. The main reason of detecting skin colors is to construct a means in the classification of pixels whether they belong to skin. Many methods have been proposed in order to predict skin color in literature. The classification done by evaluating pixels according to pre-determined ranges is one of the simplest and fastest methods in addition to complex methods such as ANN, Bayesian classifications. Since range classification is easy to deploy and produces instant results, it has widespread use. Image pixels are classified as skin or not in different color spaces – NormRGB, HSV, and YCbCr color spaces are used in this work rather than pure RGB. So, the color spaces are briefly described below.

2.1.1 NormRGB Color Space

To detect skin color, NormRGB is one of the most widely used methods. After R, G, and B values of each pixel are summed and each component is divided by this summation, new r, g, and b values are generated (Equation 1). Afterwards, using those r,g, and b values, the ranges that belong to skin colors containing nudity are given as in Equation 2. The equations proposed by Gomez and Morales [10] can be obtained as below:

$$\left.\begin{aligned} Base &= R+G+B \\ r &= \frac{R}{Base} \\ g &= \frac{G}{Base} \\ b &= \frac{B}{Base} \end{aligned}\right\} (1) \qquad \left.\begin{aligned} \frac{r}{g} &> 1.185 \\ \frac{R.G}{Base^2} &> 0.107 \\ \frac{R.B}{Base^2} &> 0.107 \end{aligned}\right\} (2)$$

Since sum of the normalized values are 1, the last component b can be omitted for simplicity and the space dimensionality can be reduced [11].

2.1.2. YCbCr Color Space

In this color space, the components Y, Cb, and Cr stand for the luminance, the chrominance and the red components of a pixel respectively – showing how much each component deviate from gray. The following equations related to YCbCr color space are taken from the algorithms developed by Chai and Ngan [12].

$$\left.\begin{aligned} Y &= 0.299R + 0.587G + 0.114B \\ Cb &= B - Y \\ Cr &= R - Y \end{aligned}\right\} (3)$$

In YCbCr color space, any pixel that satisfies the condition shown in the Equation 4 is considered as a skin pixel

$$\left.\begin{aligned} Y &> 80 \\ 77 < Cb &< 127 \\ 133 < Cr &< 173 \end{aligned}\right\} (4)$$

2.1.3. HSV Color Space

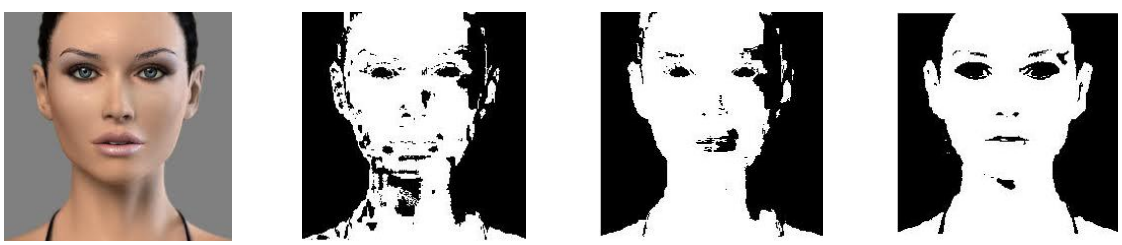
The three subdivision components of HSV color space are hue, saturation, and value. Hue is the color type ranging from 0 to 360, saturation is the vibrancy of the color ranging from 0 to 100%, and finally value is the brightness of the color ranging from 0 to 100% [13].

$$\left.\begin{array}{l} H = \begin{cases} undefined & , if \max = min \\ 60x\frac{G-B}{\max - min} + 0 & , if \max = R \; and \; G \geq B \\ 60x\frac{G-B}{\max - min} + 360 & , if \max = R \; and \; G < B \\ 60x\frac{B-R}{\max - min} + 120 & , if \max = G \\ 60x\frac{R-G}{\max - min} + 240 & , if \max = B \end{cases} \\ S = \begin{cases} 0 & , \max = 0 \\ 1 - \frac{min}{max} & , otherwise \end{cases} \\ V = \max \end{array}\right\} \quad (5)$$

The Equation 5 illustrates the pseudo-code for the transform from RGB color space into HSV color space [14]. For HSV color space, skin pixels are in the range shown below:

$$\left.\begin{array}{r} 0 \leq \mathrm{H} \leq 50 \\ 0.23 \leq S \leq 0.69 \end{array}\right\} \quad (6)$$

As an example of capturing skin pixels in the color spaces mentioned, the image shown in Figure-1 (a) is examined for each color space. In Figure-1 (b), (c), and (d), a white pixel represents skin for the image. It is clear that the best skin detection for the image is gained by YCbCr color space.



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

Figure – 1 (a) Original Image, (b) NormRGB, (c) HSV, (d) YCbCr

2.2. Face-Body Ratio

Since skin pixels can easily be detected, it is needed to go further and detect nudity through gaining help from face recognition techniques. Once a face detected in an image, a body area can be allocated for the face according to face-body ratio defined in [7]. The face-body ratios used in this work are illuminated in Figure-2.

In the algorithm, all the images are considered as vertical images. Even if real world images are not always vertical, this body area estimation increases accuracy in detecting nudity over classic methods that only find nude pixels of a whole image.

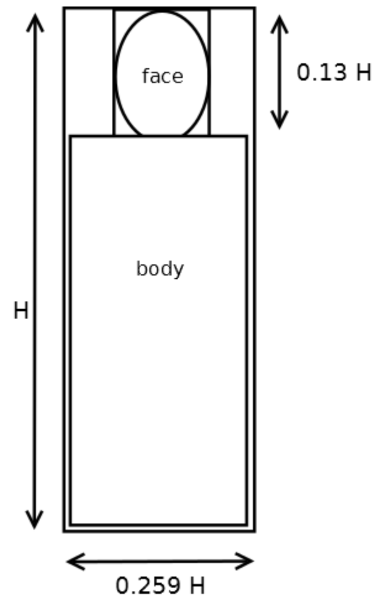


Figure-2 Face-Body ratios taken from [7]

3. Nudity Detection

Having explained required and related background for nudity detection, it is time to explain the algorithm in detail. There are three stages that are used in this work as summarized in Figure-3. For the stages, after detecting skin pixels, some morphologic processes are applied to image and small areas are eliminated.

In the first stage, all faces of an image are detected by general face detection tools. If there are not any faces detected in an image, then classic methods will be applied.

If there is any face found in the first stage, then algorithm goes into the second stage where body areas of these faces are calculated as explained in 2.2. Although people in images are not always aligned as vertical, some body parts will be included in these estimated areas except those images where people are exactly aligned as horizontal. As a result, nudity can be captured depending on to what extent bodies are vertical.

In the last stage, each body area that is calculated for a face will be taken into account individually. Here, skin pixels are calculated firstly and subtracting these pixels from pixels that belong to face. This subtraction eliminates inaccurate results for images that are mostly covered by faces such as a passport photo. Afterwards the nudity ratio is taken through dividing this total number of non-face skin pixels by total number of pixels. At the end, the ratio is compared with a predefined threshold. If the ratio reaches to the threshold then the image is nude and vice versa. This process is applied for each face in an image, until reaching the last face. There must be a logical order for those faces to be taken. Vertically lower faces have priority over faces appearing on the upper part of an image. This process is applied until all the faces are taken into consideration. If any partial estimated area says the image is nude, then the algorithm stops working and the result is positive indicating nudity.

Also, to decrease inaccurate results, subsequent estimated body areas do not include previous body areas – meaning that a body area is completely cropped from an image and the whole image is changed after a body area is estimated.

In the meantime, the threshold can be optionally determined according to audience – it is clear that threshold must be lower for a system that is mostly used by children.

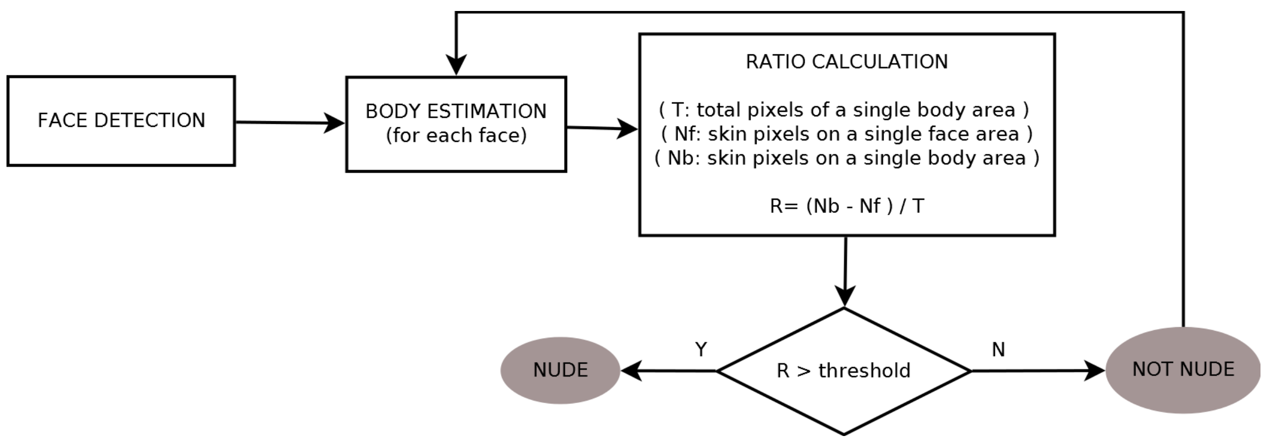


Figure – 3 The algorithm for the suggested method

In the previous work [6], it is shown that when face pixels are discarded for the ratio calculation, the accuracy will be higher. In this work, the notion is improved by taking faces individually independent from whole image – this gives more accurate and speedy results.

4. Testing and Results

To monitor success of the algorithm in this work, 100 arbitrarily chosen images with varying resolution and context are used. By human eye, 75 of them are tagged as nude with decreasing nudity rate and 25 are not nude. All of the images contain people and they all have at least a recognized face so that body areas can be estimated. Also, the three color spaces NormRGB, HSV, and YCbCr are used to together in order to increase accuracy while obtaining skin pixels.

In order to see accuracy of the suggested method over classic method which never considers faces, the test images seen in Figure-4 are used. The threshold is chosen as 0.17 for both classic nudity detection method and the suggested method after exhausted experiments during implementation.

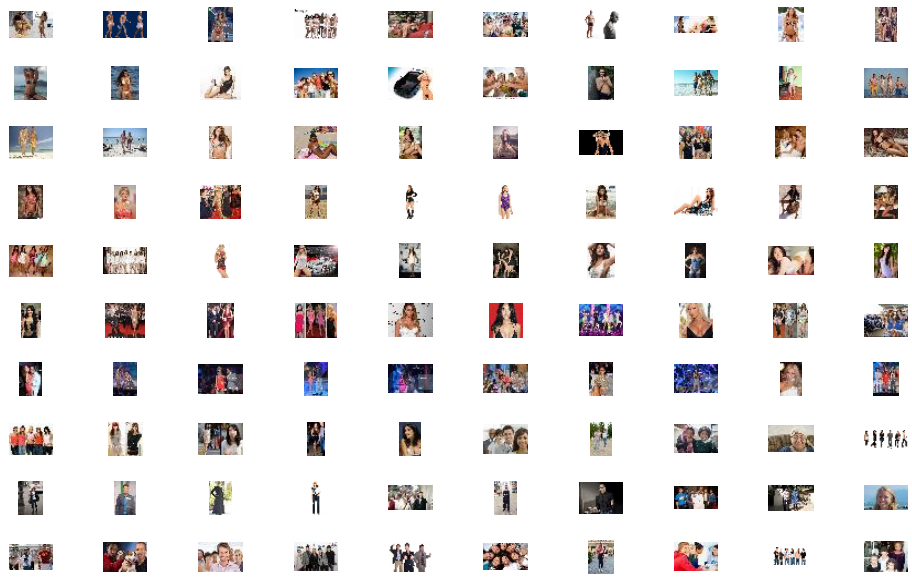


Figure – 4 Collective view of the test images

Table-1 and Table-2 shows how the images are classified for both classic nudity detection and the face-based nudity detection methods in the order. The number of True Positive (TP) and False Negative (FN) are almost the same for methods. The main goal in the suggested method is to stop images that are not nude from being classified as nude. Hence, TP and FN values will be the same. However, when looked at the number of False Positive (FP) and True Negative (TN) images, it can be concluded that the suggested classification method is more successful that the classic method. More specifically, 19 of the 25 non-nude images are classified as nude by the classic method, while the suggested method lowers it to only 6.

Table – 1 Classic Nudity Detection Results

	Nude	Not Nude
Test Nude	68 (TP)	19 (FP)
Test Not Nude	7 (FN)	6 (TN)

Table – 2 Face-Based Nudity Detection Results

	Nude	Not Nude
Test Nude	67 (TP)	6 (FP)
Test Not Nude	8 (FN)	19 (TN)

In addition to these results, the test images are given as an input into the algorithm which is suggested in the previous work [6] and the results are illustrated in Table-3. The threshold value of 0.17 is chosen again. The number of TP images is decreased and the number of TN images is increased when compared with classic method seen in Table-1. However, according to Table-3, in the end there is no significant change over classic methods for the test images while the new method considerably increases accuracy.

Table – 3 Nudity Detection Results for the Previous Work [6]

	Nude	Not Nude
Test Nude	63 (TP)	15 (FP)
Test Not Nude	12 (FN)	10 (TN)

The overall accuracy results are 74 and 86 for classic and suggested methods respectively. As a result, the significant improvement by 12% can be seen for the test images and the threshold value.

5. Conclusion

The aim of this work is to eliminate the error rate of classic nudity detection method which misclassifies nude images because of facial skin pixels. For this purpose, face areas which are never considered nude are detected and subtracted when calculating nudity ratio. According to the obtained results, the method is successful. Also, this method gives speedy results in contrast with classic methods because this method never checks nudity for whole image – only estimated body areas will be cropped and checked.

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