A Pornographic Image and Video Filtering Application Using Optimized Nudity Recognition and Detection Algorithm

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Abstract*—The combination of multimedia technology and Internet provides an amiss channel for pornographic contents accessible by certain sensitive groups of people. Furthermore, the same channel provides the easiest medium to distribute illicit images and videos without an autonomous content supervision process. In this study, an application was developed grounded from a pixel-based approach and a skin tone detection filter to identify images and videos with a large skin color count and considered as pornographic in nature. With nudity detection algorithm as the foundation of the system, all multimedia files were preprocessed, segmented, and filtered to analyze skin-colored pixels by processing in YCbCr space and then classifying it as skin or non-skin pixels. Afterwards, the percentage of skin pixels relative to the size of the frames is calculated to be part of the mean baseline for nudity and non-nudity materials. Lastly, the application classifies the files as nude or not, and then filter it. The application was evaluated by supplying a dataset of 1,239 multimedia files (Images = 986; Videos = 253) collected from the Web. On the final testing set, the application obtained a precision of 90.33% and accuracy of 80.23% using the supplied dataset.

***Keywords*—pornography, nudity detection algorithm, image and video filtering**

I. Introduction

Unlike at any other time in history, pornography has been consumed in greater quantities making it ubiquitous, due in large part to the Internet. Since then, pornography and its impact to people has long become one of the fastest growing concerns of the society. In the advancement of technology, Internet and computers serves as the most universal channel and instrument, respectively, from recording to distributing pornographic files and contents. More often than not, internet pornography can cause particular harm even to youngsters. A review of numerous researches about impact of internet pornography on adolescents [1] corroborate the deformation of healthy sexual development of these young viewers as pornography already has infected modern childhood.

In the computer vision community, plenty of detecting strategies, skin color models and scientific foundations have been proposed and researched for years to detect and recognize the pornographic nature of multimedia files. The first attempt [2] of screening pornographic images used skin-colored region segmentation as a pre-processing step before finding elongated regions for possible limbs. Albeit the method exhibited high recognition accuracy, it cannot satisfy the time-efficiency requirements since a single input image will be screened more than six minutes [2]. Another skin detection technique [3] was focused on using statistical methods by working in RGB color space rather than YCbCr or HSV which was measured by ROCgraphs. As discussed on the key findings, the skin color is a very good indication when classifying nudity. Following the skin as a determinant, another method that may be a follow-up is the approach [4] that detect skin by building a Maximum Entropy Model for the skin distribution. Combining the Bethe Tree and Belief Propagation, the model used the color gradient constraints of adjacent pixels in order to produce a skin map in grayscale format where the still brightness is equal to the probability of skin. A true positive rate at about 80% and false positive rate at about 10% was visually interpreted in the ROC-graph. In a practical content filtering application, in sum, color theories, preprocessing, segmentation, texture filter, and skin detection are all part of the process to identify pornographic content.

The emergence of pornography as a societal issue has created a strong demand for specialized tools, including mechanisms that integrate the aforementioned key processes to filter nudity in multimedia files. In order to provide a solution to the problem, the researchers developed an application based from nudity detection algorithm [5] to recognize, detect, and then filter nudity in multimedia files by using skin-colored pixels as primary determinant whether the multimedia material represents a possible nudity that corresponds to human skin color. The nudity detection algorithm consists of the following steps: (1) detect skin-colored pixels in the image; (2) locate skin regions based on the detected skin pixels; (3) analyze the skin regions for clues of nudity or non-nudity; and (4) classify the image as nude or not. The application was then tested for accuracy by supplying a dataset of 1,239 multimedia files (images = 986; videos = 253) collected from the Web and other stock photo and video library. Since the testing stage of the application is computationally heavy, the images were less than 100kb in size and videos were less than a minute in duration.

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II. METHODS

In order to accurately filter the nude parts of any image or video, the multimedia files are initially extracted and then analyzed by using common features that reveal clues such as color, texture, filenames, image dimensions, object shapes, and the number of relevant objects found in the images which are all based from the nudity detection algorithm [5]. As documented in the previous section, key processes including preprocessing, segmentation, texture filter, and skin detection are all important aspects if a nudity content filtering application is to be successful. Therefore, it is only intelligible to incorporate these processes in the application.

A. Preprocessing

To accurately detect the nudity part of a multimedia file, all images and videos must undergo preprocessing first. This will help to restore color illumination and bring out details in otherwise blurry images or videos. During the preprocessing stage, each file undergoes histogram equalization, lighting correction, noise reduction, and sharpening. The histogram equalization is in charge of enhancing the contrast of the files by redistributing their intensities to bring out more details. On the other hand, lighting correction remove shadows or adjust dark areas to compensate with files taken on a poor lightning conditions. Moreover, noise reduction removes unwanted pixels by using smoothing filters to make sure that the details are recognizable. To accomplish the mentioned intended outcome, the blurriness from an error capturing the file by sharpening was also enhanced using contrast.

B. Segmentation

The segmentation stage of the system extracts the parts of the multimedia files that satisfy the mean baseline of the skin-colored region. As mentioned, pixel-wise segmentation was employed instead of region-based segmentation as nudity requires the analysis of one pixel at a time for a more accurate result. Static threshold, the simplest segmentation, was the main foundation concept of the segmentation stage in the proposed application. By decomposing the images and video frames into pixels, locating the targeted colored-skin pixels was easier and computationally inexpensive. Using the mean baseline of the skin color relative to the image or video frame as the threshold value, the static threshold checks if the next pixel of the file is larger than, or in some cases smaller than the threshold value – the skin color.

C. Texture Filter

To strengthen pixel-wise classification for easy detection of human skin in an image, texture-filter was employed by calculating standard statistical measures, such as range, standard deviation, and entropy in all adjacent pixels. The main purpose of applying the texture filter is to remove pixels that were falsely classified as skin-pixels. Any texels (texture pixels) that are out of place in the skin regions should have peaks and valleys if it is to be represented in a graph. Therefore, it's easier to notice the texels that do not belong in the skin segment. To achieve texture filtering, there are several smoothing filters that are possible to use in nudity filtering application; for instance, Gaussian low-pass filters which is separable and given by in the [6, eq. (1)]

$$h_G(n) = \frac{1}{\sqrt{2\pi}\sigma_s} e^{-\frac{1}{2}\frac{n^2}{\sigma_s^2}} \quad (1)$$

D. Skin Detection

While RGB color space has been successfully used to detect skin in a still frame [3] for nudity classification, a more updated research used YCbCr [7] because redundancy of its channels is much lower compared to RGB. Statistically speaking, YCbCr is more superior to any other color spaces [8] and can be obtained via a linear transformation from RGB format. Grounded on these results, the goal of the skin detection stage is to eliminate other regions of the image and still frame that are not considered human skin. As discussed in [7], using the traditional idea of spatial analysis such as generation of seed and propagation will be very vital in the skin detection. Since their proposed algorithm outperformed other methods, their framework was used as the inspiration when building the system architecture of this study.

Fig. 1. Sample visualization of the colored-skin detection.

III. PROPOSED SYSTEM

The pornographic filtering application aims to classify images and video frames that may contain nudity. To do this, the key is to be able to detect skin with different skin color in different lighting conditions to avoid delimiting the accuracy.

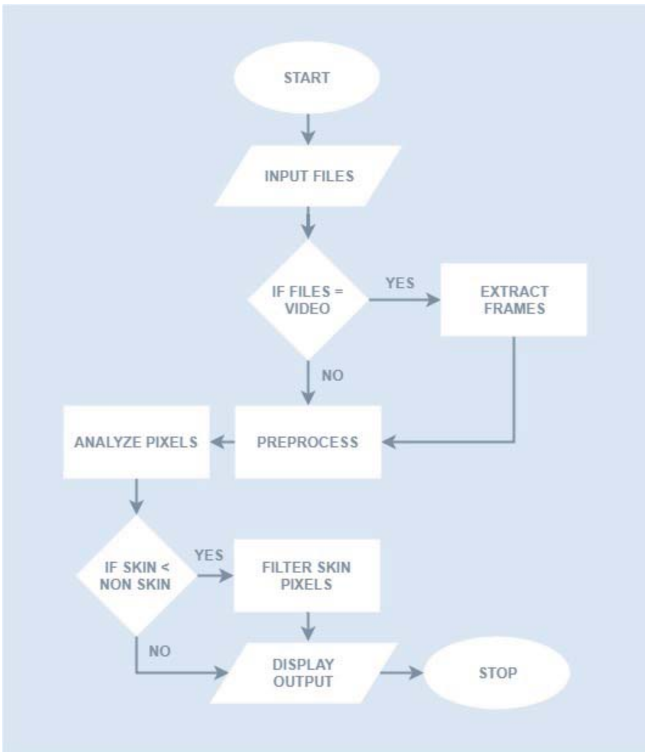

Fig. 2. Nudity Filtering Process Flowchart.

As can be seen on the nudity filtering process flowchart, the pornographic filtering application focuses on two media files: images and videos. Since video scenes are made up of still images, it's very important to extract all of the images in a single file. Therefore, all of the media files are screened first to identify whether the file is an image or video. For video files, PHP video toolkit was used as it can provide a convenient object-oriented wrapper on all things related to video manipulation such as extracting frames from a video, splitting video files into multiple parts, combining images to form a video, extracting the audio or a segment of that audio from a video, and a lot more. Upon the classification of the media file, images and video frames will be preprocess using histogram equalization, lighting correction, noise reduction, and sharpening as discussed in the previous section. Preprocessing will help restoring the color illumination and bring out details in otherwise blurry images or video frames. When the stage is finished and the preprocessed version is clearer than the raw files, the skin [eq. 2] and non-skin [eq. 3] percentage relative to the frame size will be computed by using pixel-wise segmentation. As contented in [7], pixels should be classified into three defined sets such as T_1 pixels as white (255), T_2 pixels as gray (128), and T_3 pixels as black (0) which will result to the creation of ternary conversion.

$$\text{skin \%} = \text{skin pixels} / \text{total number of pixels} \quad (2)$$

$$\text{non-skin \%} = \text{non-skin pixels} / \text{total number of pixels} \quad (3)$$

The technique to allow the system to intelligently detect and classify pixels as skin or non-skin pixels is by adding a skin color distribution model. Based on illumination level, images will be partitioned into three different subsets: light, brown, and dark. Based from the experiments of the nudity detection algorithm [5], there was a 96.29% recall and a 6.76% false positive rate on the training set for the skin filter. Aside from the pixel color, the percentage of the skin relative to the image size affects the probability of classifying a file as nude or not. Technically, the larger the percentages of skin pixels are, the higher the probability of a nude image. It is very important to disclaim that using the total number of skin pixels result to many false positives. For instance, a headshot might be classified as nude if the human face almost covers the entire portrait image (skin pixels > non-skin pixels).

In the most basic sense, the nudity filtering application will assume the possibility of having nudity and classify the file as nude if it meets the conditions of the algorithm [5]:

1. If the skin pixel is more than 15% in relation to the image size, then there is a possibility that it is nude.
2. If the skin pixel in the largest skin region is more than 35%, the second largest region is more than 30%, and the third largest region is more than 30%, then there is a possibility that it is nude.
3. If the skin pixel in the largest skin region is more than 45%, then there is a possibility that it is nude.
4. If the number of skin regions, however, is more than 60% and the average intensity within the polygon is less than 0.25, the image is not nude.

In a programming perspective, these rules will be part of the conditional expressions to allow the application to decide on its own whether certain media files (images and video frames) contain nudity or not. If the conditions of nudity are met, then the multimedia file will be classified as such.

Fig. 3. Presentation of the skin detection process through the use of pixel-wise segmentation and YCbCr color space. Screenshots shown: (A) Sample input image uploaded on the application; (B) the detected colored-skin extracted by the application behind the scene; and (C) the sample output of filtered image.

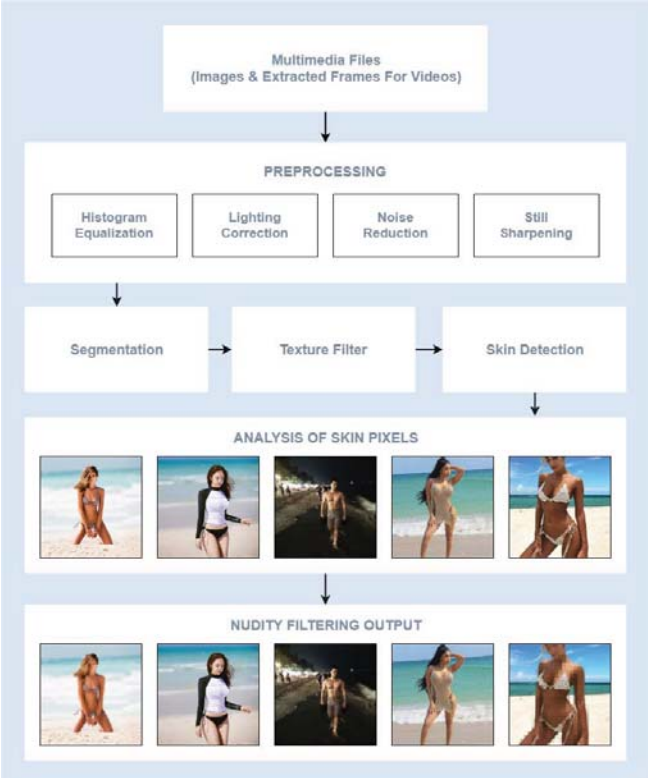

Fig. 4. System Architecture of Pornographic Filtering Application.

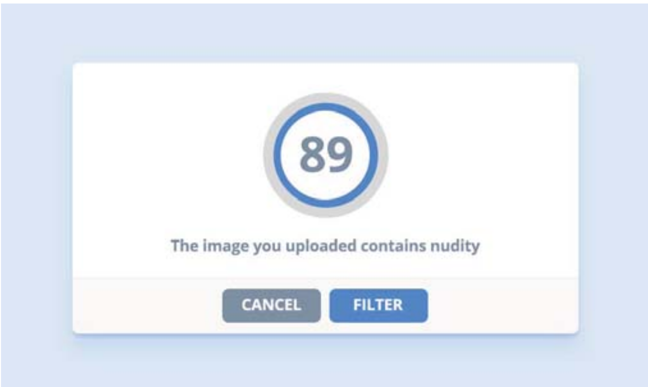

Fig. 5. Notification modal showing the nudity probability.

IV. Experimental Analysis and Results

Using a dataset of 1,239 multimedia files (images = 986; videos = 253) manually collected from the Web, the application was tested for its precision and accuracy. In the confusion matrix (table 1), the term "pornographic" means the files are being classified as contents with nudity; hence, it doesn't mean that literal pornographic materials were used. Examples of the files used were images like beach photos with women wearing bikinis and videos with intimate scenes between a boy and a girl. As expected, percentage of images and videos are not that far from each other since videos are extracted first into images. Nonetheless, the percentage difference may be for the reason that a video has different images wherein some of it has nudity while others don't.

TABLE I. Average Confusion Matrix

Media File	File Labeled as		
		Pornographic	*Non-Pornographic*
Image	Pornographic	89.6%	10.4%
	Non-Pornographic	25.5%	74.5%
Video	Pornographic	71.2%	28.8%
	Non-Pornographic	37.3%	62.7%

$$\text{Precision} = TP / TP + FP \quad (4)$$

$$\text{Accuracy} = TP + TN / TP + TN + FP + FN \quad (5)$$

Aside from the confusion matrix, precision and accuracy were also computed using the equations [eq. 4; eq.5] using True Positive (TP), False Positive (FP), True Negative (TN), and False Negative (FN). TP represents the number of skin pixels correctly identified as such, TN is the number of non-skin pixel correctly identified as such, FP is the number of non-skin pixel incorrectly identified as skin and FN is the number of skin pixel incorrectly identified as non-skin. Upon calculation, precision of 90.33% and accuracy of 80.23% were obtained on this dataset by getting the precision mean and accuracy mean of all the images and video frames tested using the pornographic filtering application.

TABLE II. Sample Image Precision and Accuracy Results

File	Total Pixels	Skin Pixels	Non-Skin Pixels	True Positive	False Positive	True Negative	False Negative	Precision	Accuracy
Image 001	165461	148333	17128	130942	17391	8764	8364	88.3	84.4
Image 002	186664	81527	105137	75810	5717	96774	8363	93.0	92.5
Image 003	176051	135043	41008	125555	9488	35400	5608	93.0	91.4
Image 004	208491	71831	136660	65605	6226	113812	22848	91.3	86.1
Image 005	146068	67754	78314	56891	10863	67979	10335	84.0	85.5
Frame 001	173153	32142	141011	22628	9514	117405	23606	70.4	80.9
Frame 002	186546	103672	82874	95322	8350	75225	7649	91.9	91.4
Frame 003	178833	148655	30178	136481	12174	18652	11526	91.8	86.7
Frame 004	216857	166197	50660	160297	5900	27236	23424	96.4	86.5
Frame 005	156762	104123	52639	93696	10427	30021	22618	90.0	78.9

V. CONCLUSION

In this study, a pornographic filtering application for the detection of pictures and videos with nudity was presented. Grounded from an existing nudity detection algorithm [5], the preliminary results of the evaluation indicate a promising outcome at least based from the dataset supplied. With pixel-wise skin detection with image processing techniques such as preprocessing, segmentation, texture filtering, and colored-skin detection for pornography filtering, precision of 90.33% and accuracy of 80.23% were obtained. To mathematically describe the colors in the multimedia files, YCbCr color model was used. This serves as a mathematical model that represents color information. Y channel is the luma or the brightness of the image which is based from the weighted sum of the gamma-compressed corrected RGB image [11]. Cb and Cr, on the other hand, are the color channels for blue chroma component and red component, respectively. Aside from the fact that YCbCr is a more superior color spaces [8] compared to others, it also initiates natural human vision as it exploits the properties of human eye, i.e., high sensitivity to light rather than sensitivity to hue. It is also widely used in digital encoding of color information and image compression [13]. The YCbCr color space has also to be effective and helpful in making the application flexible in terms of luminance overlap between image segmentation even under various illumination conditions as also established in [14].

As encouraging as it may be, the performance results would have been more meaningful and validated in some sense if there was a comparison with other similar nudity detection systems using the same dataset. Since the nudity filtering application is highly dependent on the skin color count, the accuracy of the results can be restricted by images with large skin color count regardless if these are nude or non-nude photos. For this, machine learning models [12] can be used for a more accurate detection of inappropriate content, like nudity, in images. To gain more insights in the valuation, several training cases and datasets should be tested again. In future research, the proposed system, may be used as intelligence in a larger system like a realtime image and video moderation but it must be developed again to make it more intelligent. For starters, employing machine learning [9] and other computer vision techniques such as object and face detection, and motion tracking for videos will warrant meta-cognitive analysis for astute nudity detection. Given the success of deep learning algorithms [10] in computer vision applications, harnessing the power of these two fields will arm the application the intelligence it needs to ensure that it is ready to face many challenges such as constriction of bodies and unlimited variations in clothing and accessories. After this, another set of testing should be conducted on extended datasets with tricky data.

The era of social media has led the revolution of heavy content generation on a day to day basis on the internet. This, in turn, creates an amiss channel that provides a quantum leap in distributing illicit images and videos without an autonomous content supervision process or centralized governance in technological implementation or policies for usage and access. With no safeguard installed in moderating inappropriate contents uploaded by millions of users, sensitive groups of people like children [15] and/or students who adopted e-learning technologies [16] are left with no defense or whatsoever in traversing the digital world now that there is a high probability of encountering and consuming sexually explicit material. Online computer exploration surely opens a world of possibilities for everyone where the emergence of an ugly trend of pornographic contents dissemination is just a normal phenomenon – even if it should not be. Hence, computer applications like this nudity detection with automatic filtering can play an important role as a prevention measure in halting exposure to such inappropriate contents. Online predators and their criminal nature will be restricted by the avoidance skills provided by the nudity filtering application. Because of Internet's power to deliver unending stimulation through internet activities and its contents, a revolutionary paradigm shift is needed to nullify pathological pursuit most especially of younger audience. With such application embedded in the core of a larger content-based system, everyone can safely surf without stumbling upon materials with nudity.

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