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A REVIEW OF SKIN DETECTOR BASED DEEP LEARNING TECHNIQUES: COHERENT TAXONOMY, OPEN CHALLENGES, MOTIVATIONS, RECOMMENDATIONS AND STATISTICAL ANALYSIS, FUTURE DIRECTION

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ABSTRACT

This study review and analysis the literature on skin detector (SD), in order to establish the coherent taxonomy and figure out the gap on this pivotal research area. An extensive search is conducted to identify articles that deal with skin detection, skin segmentation, skin tone detector and skin recognition issues, related techniques are reviewed comprehensively and a coherent taxonomy of these articles is established. ScienceDirect, IEEE Xplore and Web of Science databases are checked for articles on skin detector. A total of 2803 papers are collected from 2007 to February 2018. The set comprised 173 articles. The largest portion of the papers *(n=158/173) = 91%* belong to Development and Design, that is aimed to develop an approach for skin classifier into skin and non-skin. A sum total of *(n=5/173)=3%* of the papers belong to Evaluation and Framework, *(n=10/173) = 6%* papers was categorized as Comparative Study. This study discusses the open challenges, motivations and recommendations of the related works. Furthermore, state-of-the-art is a step to demonstrate the novelty of the presented study by conducted a statistical analysis for previous studies such as (Dataset, Colour spaces, features, image type, and Classification techniques) as a future direction for other researchers who are interested in skin detector (SD).

Keywords: *Skin Detector, Detection, Segmentation, Skin Tone, Recognition. Skin Classification, Deep Learning.*

1.0 INTRODUCTION

This research is conducted in the area of skin detection. Skin detection is currently used in various applications especially that involved identification of human skin and to differentiate between skin and non-skin using computer technology and sets of techniques and datasets [1]. Many researches have been done to come with the best techniques especially skin detector and specific skin detection methods that can accurately identify the skin and non-skin [2], and at the same time reduce the computational cost, increase the processing speed and better in performance [3]. Skin detection researches being done to be applied in various applications [4]. Among the applications are human computer interaction, image filtering [5], computer vision, surveillance, medical diagnosis, military, anti-pornography and human tracking [6] [7]. The computer systems designed as detector will able to select skin regions from images being input and compare with the one in the databases, depending on a variety of applications that identifies them [8].

As for example for medical diagnosis [9], the affected skin of the actual patient will be captured using capture device. The specialist will use the detector machine to compare the image captured with the one in the databases to provide certain kind of diagnosis result that enable the medical specialist to determine the possible illness and prescribe specific medicine for that illness [10]. In most high end offices, biometric device is being used as authentication for entering restricted areas or even as attendance to the working place [11]. In new smartphone, skin detection and fingerprint recognition is used as password to access the phone for valid users [12]. In image filtering such as anti-pornography, skin detection is used to determine the websites that show illicit materials so the authority can block the websites from viewing especially for under age citizens [13]. Parents can use this application to filter what their children can access in the internet.

Various researches have been done in skin detection and among the specific area the researchers focus on are in the area of skin detection modelling and skin detection application [14]. Skin detection is a significant step for a wide range of research related to image processing and computer vision, several methods have already been proposed to come up with best accuracy of classification skin and non-skin [15].Skin detection is performed as an initial step in most human-related image processing applications [16]. The detected of the skin regions are usually processed based on the different application such as face detection, hand detection, gesture recognition, video surveillance applications, skin disease and web content filtering (e.g., pornographic filters) [17] [18].

The performance of these applications is significantly affected by the accuracy of the skin detection step. All these application relay on the process of finding skin region or skin pixels in images or video [19]. Detection of human skin and skin tone itself considering as main area of many researcher attention in recent years [17]. Skin tone has been chosen for many skin detection applications due to its high speed processing as well as good detection performance. Recent challenges faced by researchers in skin tone detection include choice of colour space and creating skin model to detect the skin regions effectively [20].

This study aimed to provides up to date an overview on the current skin detectors and highlight the efforts of the researcher in area of skin detection. In this review concentrated more on the systematic literature review than approaches, techniques and methods themselves, many review papers in skin detector techniques to compare with it. In [21] aimed to come up with best suitable colour space while the missed to reviewed the most relevant techniques and the dataset. In [22] the reviewed various approaches that use skin-colour and the most appropriate colour space but the missed the dataset. The author in [23] come up with evaluation and benchmarking skin detector in real time and provide some criteria for evaluation and benchmarking based on reliability , time complicity and the error rate with in dataset but missed to reviewed the colour spaces. While the author in [24] try to review the most known approaches in skin detector with 33 approaches and colour spaces as well but missed to explain how important the dataset, that's make it different from others reviews articles. The rest of this paper is organised as follows: section 1 introduction; Section 2 describe the systematic review protocols, Section 3 explaining the taxonomy part, Section 4 shows the statistical results of reviewed papers; Section 5 discusses which is includes (challenges, motivations and recommendations), Section 6 Methodological Aspects of Previous Research, Section 7 Features, Section 8 Image type, section 9 Conducted Country and flowed by Future work and finally is conclusion.

2.0 SYSTEMATIC REVIEW PROTOCOL

In these Systematic searches, three digital databases were chosen which are: Web of Science (WoS), Science Direct and IEEEXplore digital library. The reason of choosing these three electronic databases was made based on the quality of most

journals published in the respective online digital libraries in terms of accuracy, timeliness and relevancy. Furthermore, they allow for complex inquiry question and specifically track a substantial number of journals and conferences in computer science, software engineering, medical and social science. The search query is meant to cover all publication in regards of techniques and case studies on skin detections and relevant literature review. These exercises provide a broad and comprehensive look to the researchers, but relevant, range of disciplines.

2.1 INFORMATION SOURCE

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2.2 SEARCH STRATEGY

The search strategy starts with queries namely "skin detector" OR "skin detection" OR "skin segmentation" OR "skin tone detector" OR "skin recognition", typed in three different online libraries. Originally the author started with a total of 2835 and sorted down to173. This is based on the most accurate and relevant title and content that further research will be done.

2.3 STUDY SELECTION

The procedure of systematic study is comprised of searching the literature sources, taken after by two iterations of screening and filtering. The first step of iterations is filtering by excluding the irrelevant and duplicates papers, done by Analysing the titles and abstracts. While the second step of iterations is based on filtering the papers after a thorough full-text reading of the selected articles from the first step.

2.4 Eligibility criteria

In order to be included in this systematic search, a study was required to meet the criteria which should meet inclusion criteria as the following:

- Written in English and published paper from 2007-2018 and focus either on skin detection, skin recognition, skin segmentation or skin detector in human body.
- Revolve around development, comparative study, and evaluation and framework

2.5 DATA COLLECTION

Data collection started with all papers listed with matching categories which have been obtained from three sources in one Excel spreadsheet. The spreadsheet columns were divided to specific heading namely title and author, year of publication, country, index database, techniques, study case, data set, image type, colour space, application, and result that were obtained from full-text readings of selected publication. This followed by the process of summarization, Table and description of the main findings. All commentaries were saved based on the original texts and groups of significant information were saved in Microsoft word processor and Excel spreadsheet.

3.0 TAXONOMY

As in the taxonomy of skin detection in Figure 2.3 above, from the total of 173 papers, majority of the papers *(n=158/173) = 91%* belong to Development and Design. A sum total of *(n=5/173) = 3 %* of the papers belong to Evaluation and Framework, *(n=10/173) = 6 %* papers can be categorized as Comparative Study.

3.1 COMPARATIVE STUDY

In comparative study, in which there are 10 out of 173 papers, the authors mostly compare in between colour spaces that being used in segmentation and the illumination conditions of the images and three of them compared between the techniques, one of the author try to compare between the techniques at the same time with the best colour space. Different types of colour space mentioned are RGB (108 times in publication), Ycbcr (60), HSV (41) and Yuv/Luv (13) and others

In the study conducted in [26] twelve representative illuminations of pre-processing methods were compared, and they include; LT, HE, DGD, GIC,SSR, LoG, SQI, LTV, GHP, LN, LTV, TT. The comparison was performed based on two perspectives which are, small and large-scale feature bands, and holistic approach localization. Again in the study carried out by [15]], a comparison and identified the major techniques of skin detection in the extraction of feature as well as feature classification. For each of the skin maps, the use of two fit ellipses was employed, and these two include, fit ellipse of the largest region of skin and fit ellipses of all the regions of the skin. Both of them are referred to as Local and Global Fit Ellipses, respectively. Through the use of real-time system, the authors trained a multi-layer perceptron classifier for the features. Here, the input video is categorized into two, being non-adult and adult videos.

In order to ascertain the best colour spaces [27] used in colour, and colour texture colour feature separately. In the study, the use of a popular classifier known as Multilayer Perception artificial neural network (MLP) was used for comparative analysis. Results of the study experiments showed that the highest separability between non-skin and skin pixels among the various colour spaces was achieved by the YIQ colour space. The testing of the various colour spaces was done using colour features. In the study by [28] different colour components were integrated to provide representations of skin across different ethnics. The skin detection methods which were used are threshold-based. The combination of the colour components is done based on the performance of the different colour components combinations. The following combinations were made: a*, b* and g, a combination of U, V and g, a combination of H, r, g and b, a combination of H new, S new and g, and a combination of H new, S new, H and g, when integrated with RGB and morphological filters.

In paper [19] YCbCr colour space and human skin colour detection HSV were compared. The process of detecting the skin colour of humans involves separating the skin from non-skin pixels. The development of a homogeneous technique of detecting or segmenting human skin is a difficult task because of the great variation in the colour tone of humans; this varies from people of one region to another. In order to compare the detection of skin colour, the author in study [29] conducted an experiment using HSV, RGB and YCbCr colour spaces. An effective way of distinguishing between non-skin points and skin points in an image is to use the HSV colour space attributes for the detection of skin colour. In the study conducted by [30] a performance analysis was carried out using neural network based-YCbCr skin recognition technique. The results of the analysis

showed that the YCbCr colour space model outperforms RGB colour space model.

They are three research articles in the table above try to compared between the techniques of the skin detections to shows the best techniques and six research papers aimed to comparison the most popular colour space such as (RGB, YCbCr and HSV) to come up with the most appropriate colour spaces for skin detector and only one research paper try to comparison between the techniques and colour space at the same time.

3.2 DEVELOPMENT AND DESIGN

Majority of the published academic paper on skin detection fall under the category of development and design, with the exact total of 158 out of 173 papers. Most of the papers discussed on the improvement of methods and/or techniques. The papers under this category can be further divided to Skin Modelling, Methods based and Applications.

3.2.1 SKIN MODELLING

In skin modelling, a total of 45 research articles were identified out of total 158 articles in development and design. Under skin modelling there are three subcategories (i.e. Parametric, Non-parametric and Semi-parametric)

3.2.1.1 PARAMETRIC

A parametric model is a set of related mathematical equations that incorporates variable parameters. A case study or scenario is defined by selecting a value for each parameter. In skin detection, the scientist are deriving a parametric model from training set, as example Gaussian model and mixture of Gaussian. This parametric method have useful ability of interpolating and generalizing incomplete training data, they are expressed by a small number of parameters and require very little storage space. However their performance depends strongly on the skin distribution of the training image in the selected colour space [31].

A sum total of (*n=15/84*) of the skin modelling found 15 articles discuss parametric model skin detection. They are nine papers used Gaussian, Generalized Gaussian Distribution, Mixture Gaussian and single Gaussian in skin detection. The first article [32] used simple method to detect human skin region based on Mixture of Gaussian and used YIQ colour space to enhance back ground subtraction. While in [33] aimed to highlight an efficient model in human skin colour by using surrounding points for each pixel that involves Discrete Cosine Transform (DCT) and followed by Generalized Gaussian Distribution (GGD). In [34] used Gaussian mixture model in skin probability map for skin colour segmentation. In [35] article proposed a new approach based on Gaussian model and the projection process to eliminate the redundant training vectors. [36] paper used a number of Mixture Gaussian to skin and background in each model is determined by starting with a single Gaussian and then adding one mixture component up to the point before the converged model has an ill-conditioned covariance matrix. Gaussian, Sinc Function and Elliptic methods used in pixel based skin detection and some limitations of these methods reviewed in [37] . In [38] used Gaussian model to test new colour space the author came with based on popular existing colour spaces. Article [39], single Gaussian model used in skin detection system based on regional property of objects which is called; Lambertian reflection to detect skin like pixel in images. The last article [40] proposed approach human skin colour, the approach involves affecting a block average value in each pixel location by using surrounding point and follow by Generalized Gaussian Distribution (GGD).

They are five papers used Neural Networks in skin detection. Aimed to highlight neural network imperialist competitive algorithm [41] for skin colour segmentation. The article highlights determining effective of colour components for skin detection using a Clustered Neural Networking [22]. In [42, 43] used two methods High Performance Extreme Learning Machine (HP-ELM) and Big Data Self SOM (BD-SOM) efficient skin segmentation by neural networks. And the article in [44] explains enhancing skin detection technique by using block matching skin neural network.

In [45] proposed skin feature algorithm based on stacked Autoencoders, which is deep neural networks, to try to solve the problem of varying illumination conditions of encountered skin segmentation. deep learning algorithms, especially convolutional neural networks (CNNs), have achieved great success in [46] with pixel-wise labelling tasks ,The author integrate recurrent neural networks (RNNs) layers into the fully convolutional neural networks (FCNs), and develop an end-to-end network for human skin detection.

3.2.1.2 NON-PARAMETRIC

Non parametric method of modelling skin involves the estimation of distribution of skin colour from the training data without the need to derive a comprehensive skin model [47]. For instance employing the use of histogram model or look up table, and Bayes Skin Probability map. Non-parametric method of skin modelling is distinguished by the fact that an estimation of the distribution of skin colour can be done without the need to derive a comprehensive skin colour model.

The non-parametric Bayesian approach was used by [12] for skin detection, and based on a Dual-Threshold Bayesian method, the author developed multiple colour spaces. The use of Bayesian and YCbCr colour space approaches was employed in [12, 48] the detection of skin. Through the use of Bayesian Skin Detection Classifier, a large dataset was created by the author in [49] to enable the creation of colour probability. This author also provided a discussion on Bayes classifier for the segmentation of human skin.

The authors in [50],[51],[52] came with Region growing method implemented by an adaptive cost propagation and neighbourhood analysis scheme that used in first paper. The second paper used Region Growing based high brightness skin detection. And the last author discusses region growing method in Data-Mining based skin detection method in JPEG compressed domain.

The authors in [53] [54, 55] used Adaboost algorithm, the first article discuss skin segmentation based on a similarity classifier of skin-tone constructed by the real Adaboost algorithm, the second article used Adaboost and statistical luminance features in skin detection. And the third article based on a complete Adaboost algorithm which considers the different attributes of an arbitrary face such as rotation and occlusion.

They are six articles in this part used Histogram, the authors in [56] [57] [58] [47] [59] [60], the first article study colour constancy methods in skin detection by using Bhattacharyya Histogram. The second author used outliner removal techniques based on Histograms in human skin detection. The third author proposed skin detection method based on Histogram. The fourth one based on modelling skin detection Histogram, the fifth article presented colour images in two-dimensional Histogram. And the last one used basic detection method based on Histogram model. The last article discuss in this part non-parametric model which is Random forest approach used to investigate colour classification [61].

3.2.1.3 SEMI-PARAMETRIC

Semi parametric is a model can be mixed between two parametric and non-parametric components. Semi parametric could be one of the stronger models if compared with parametric and non-parametric models. A sum total of 100 papers presented on the skin modelling, and 12 of it used semi parametric components.

In the paper [62], the researcher came up with probabilistic skin detection approach with some of the most significant methods involve which are mixture of Gaussian, Multilayer Perceptron classifier and Bayesian for classification of skin and non-skin pixels

are used for probability distribution of colour pixel. While in paper [63] the author proposed fusion-based or Dempster-Shafer- based skin detection (DSSD). In the aim was to use neural network and block processing techniques in human skin detection [64]. The paper in [65] used a hybrid neural network and K-Mean clustering techniques for skin detection. The s proposed multi-agent learning method that combines the Bayesian method with a grouping histogram (GH) in image skin segmentation based on RGB and YCbCr colour spaces in [31]. In [66] presented the performance of skin segmentation in (qusai-skin region) digital images. Qusai-skin region is non-skin part which is categorized as a skin misclassification or error skin segmentation to overcome of this problem the author combine four classifier are cellular learning automaton, likehood, Gaussian and SVM.

Based on multi-seed propagation in study [67], the author highlighted the multilayer colour graph for colour and regional consistency. In the study, a simple Bayesian skin detection method was used in setting some of the nodes on the graph were set as background or foreground seeds. In [68] a used an adapted self-organizing mixture network was proposed for effectively and accurately developing colour models for skin and non-skin classes. Furthermore, in the study carried out by [69], a method for detection of skin in images that are coloured was proposed. For this reason, the author applied three kinds of kernel functions to the framework of the Generalized Discriminant Analysis (GDA) algorithm in the YCbCr colour space.

While the author in [70] the author focused on skin pixels detection in coloured images; the coloured images were made up of skins from various ethnic groups. Such images may be distorted by difference in illumination and the types of image capturing devices used. In the study, the authors combined linear classifiers scheme, in which a specific ethnic group is allocated one of the classifiers. Due to the performance of the kernel Bayesian logistic regression in comparison to other extant linear classifiers, the authors used it.

Based on the Graph cuts, a method of skins segmentation was proposed by [71] with the aim of segmenting random skin regions from images. In order to determine the background non-skin seed and the foreground skin seeds, the authors used the detected face. They represented the foreground's colour probability distributions through the use of single Gaussian model, while the background was represented using the Gaussian mixture model. A discussion on the segmentation of the skin image based on multi-agent learning Bayesian as well as neural network was provided in [31]. According to their discussion, these two approaches are used in sophisticated and robust image environments due factors such as the changes in reflection of glass or water and light conditions. With these factors, serious challenges can arise in the detection of skin using pixel based detectors when the use of colour feature is employed.

3.2.2 METHOD BASED

In this section reviewed the existing methods to detect skin regions in color image. It can be classify single image skin detection methods into four categories; Pixel-based, Region based, hybrid and others methods.

3.2.2.1 PIXEL BASED

In this section, we discuss pixel-based skin detection methods that classify each pixel as skin or non-skin individually without regard to surrounding pixels. *Fuzzy* is one of improvement in skin detection performance can be used to differentiate between the similarity between skin and background colour in image, the skin appearance of human under different lightning condition also enhances the complexity in skin detection increase the classification accuracy when distinguish between skin and non-skin pixels in human skin images. A sum total of (n=4/100) of the skin modeling used fuzzy logic, fuzzy rule base and fuzzy C-Means.

In [72] studied of the best fitting color space in skin detection as a case study for face detection by applying fuzzy logic concept in human skin modeling that can consider the light conditions and illumination. While in [73] used fuzzy rule model based system and skin likelihood, that can calculate pixel value. If it is exceeded threshold then it is considered as skin pixel. The proposed technique utilized multi-layer perceptron neural as skin classifier, based on HSV color space.

In [74] used Possiblistic Fuzzy C-Means (PFCM) clustering. The PFCM is employed to group the initially detected pixels into two clusters: a true-skin cluster and a false-skin cluster which showed that the proposed method can perform well when there is a color similarity between the skin colored foreground regions and the scene background. Furthermore in [75], a set of modified fuzzy rules has been introduced to deal with the skin-lie pixels problem. These modified fuzzy rules were integrated with skin modelling method in order to discriminate skin pixel and non-skin pixel. The experiment conducted in this paper is classification of human skin image and animal images in which the experimental result is then compared with explicitly defined skin region and fuzzy sugeno classification method.

Color space of one the most useful component in skin detection the are several color space used in skin detection techniques the most popular color spaces are (RGB, HSV and YCbCr). They are many techniques addressed in this literature review. A sum total of (n= 20/100) of the skin modeling found 20 articles came with different approaches for more reliability, lesser time and accurate skin detection.

The paper in [76] proposed a new color space and aimed to selecting an array within color components. The idea was to conduct a principle component analysis (PCS) with the aim of reducing the future space dimension. While the paper in [77] trying to improving performance and attempted the improvements on skin detection methods which is based on color based skin , in addition to establish it with low cost of calculation. The paper in skin color modeling [78] explain the investigations he made were focused on the environment and information illumination over the skin classification by exploring Bayesian approach.

In [79] came up with color space method which use CMYK color spacing, the method wasn't a popular selection among the ones in skin detection algorithms, however the results indicated that the performance good and it turned to be a good method. The paper [14] proposed a simple model was proposed in order to describe the compromise in skin detection by utilizing three level of rules. In [80] explored large number of hand samples using color space virtualization. While in [81] showing a skin detection for the color images with the use thresholding found in HUE component of HSV.

In [8] showing skin detection for the color images with the use thresholding found in HUE component of HSV. Proposed statistical fusion model in [82], the idea was to detect regions of skin in an arbitrary image by using conditional random field (CRF). In [83] an algorithm of skin detection was proposed based on the color of the

preprocessing mechanism, the algorithm was inspired by visual system farther more a neural network is proposed to identify skin area in an image. While [84] skin segmentation approach was introduced, the approach used made use of human illumination features in order to measure the position of the face and the image amount and later analyses every illumination feature of the face.

Paper in [85] came up with a model which can overcome the sensitivity in regards with the variations in the condition of lighting and also while complex backgrounds used Hue, Saturation, and Value color space and multi-level segmentation. Furthermore in [86] The author proposed a new method in skin region segmentation, his method utilize color distance map (CDM) and another algorithm which is based on water flow. Paper number fourteen [87] come up with framework was introduced, the content-based framework was aimed for detecting skins with grayscale images. And the fifteenth paper in this part [88] proposed an approach mixing two models of skin color for each pixel into a vector that contains color elements of H, S, Cb, and Cr.

In [89] described a method for skin detection based on RGB vector space, while paper in [90] used correlation rules between the YCb and YCr subspaces based on dynamic color clustering. In the next paper [91] , an algorithm to improve the recognition of skin pixels in given images. The authors proposed robust algorithm that not only considers individual ranges of the three color parameters (namely RGB (Red, Green, Blue), HSV (Hue, Saturation, Value) and YCbCr (Luminance, Chromi-nance)) but also takes into account combinational ranges which provide greater accuracy in recognizing the skin area in a given image.

Paper in [92] proposed integrative labeling based statistical color models and the last paper [93] showed that by adequately mixing color spaces, it is possible to segment the human skin, even if the images are collected from many different sources from different ethnics.

3.2.2.2 REGION BASED

The main idea of region-based segmentation techniques is to identify various regions in images. Spatial information is useful as most segments corresponding to real world objects consist of pixels, which are spatially connected.

Dynamic Region growing skin detection techniques is one of approaches is widely used [94] paper in dynamic skin detection present a dynamic threshold approach by applied fix threshold classification (fix decision boundaries) in skin to differentiate between skin pixels and non-skin pixels. The paper in [95] aimed to solve urgent issue for adaptive skin detection such as (accurate facial skin extraction and reliability) by used facial structure estimation to reduce the impact of non-skin factor in skin color. While the paper in [96] proposed method to allow skin region to grow dynamically which is Dynamic Region Growing (DRG). In dynamic skin detection model [97] present real time skin detection based on dynamic approach tracking and blobs detection. The paper in [34] used a dynamic region growing to improve the skin detection rate , Subsequently approaches used first local skin distribution model (LSDM) and its similarity with the global skin distribution model (GSDM) and finally, a fusion based skin model is obtained using both the GSDM and the LSDM. The paper in [98] used multicolor spaces to improve skin detection based on dynamic threshold. The paper in [90] is based on correlation rules between the YCb and YCr subspaces based on dynamic color clustering. While in [99] proposed an approach for detecting skin in a single image using a local skin model to shift a globally trained skin model to adapt to the final skin model for the current image.

spatial approaches the article in [100] used multi-step spatial method color –based skin segmentation in videos. While in paper [101] used spatial analysis and adaptive seed in skin detection. And the last paper [102] in this part came up with skin detection used discriminative skin presence feature based on spatial.

3.2.2.3 HYBRID

The paper in [103] presented a method in image segmentation based on conception of multi-scale scale stochastic regional texture appearance models. The paper in [104] focused on discrimination between textural feature vectors belonging to skin and non-skin segmentation based on multi-manifold-based skin classification. While the paper [105] came up in skin color and texture based graph cuts (SCTGC) to purchase the final skin detection. The fourth paper [106] proposed skin detection method based on texture, color and space information. In [107] presented a technique for improved skin detection, using a trainable color feature and a multi-scale texture feature for TV Image Enhancement and the paper in [108] presented a skin detection algorithm for TV applications, and investigates the feasibility of its real-time implementation on a Digital Signal Processing (DSP) and an field-programmable gate array (FPGA) platform, which combines a flexible histogram-based color feature, and a color-constrained texture feature suitable for skin detection.

3.2.2.3 OTHERS

The author in [109] proposed an approach based on Local Pixel Wise Skin Detection (LPWSD) to detect skin and taking 16 by 16 pixels in video, based on Field-Programmable Gate Array(FPGA). In [110] the author optimize the human model by reconstruction of naked body by using Kinect device based on skin classifier of RGB image. The author in [111] used rotation invariant ellipsoid projection for domain transfer in human skin detection. In [112] used statistics of small amount of training data in skin detection. In paper [113] , an approach for machine learning to solve the problem of classification and/or probability approximation has been developed for skin detection application. Paper as in [114] , proposed an automatic image grading method, which classifies an image into three levels, i.e., Normal, Revealing Attire and Nude. First, a region based skin detection method which incorporates the clues of color, shape, texture and neighbourhood is used to get the skin regions. Then a normalized mask is generated from the skin region image according to the scale and location of the face. Global and spatial features extracted based on this mask are used as the input of SVM to give the grade of an image. Researcher as in [115] proposed the skin detection model by ascertaining the threshold values of human skin color model and evaluate the skin detection model among ethnicities and to evaluate the accuracy of the model by comparing the model in human and animal skin. Paper [116] presented a motion-based skin Region of Interest (ROI) detection method using a real-time connected component labeling algorithm to provide real-time and adaptive skin ROI detection in video images. Paper [117] focused on the needs to have proper datasets for assessment and training of human skin classifiers. Another paper [118] presented a technique

for segmentation of skin lesion in Dermoscopic images based on wavelet transform along with morphological operations.

Paper [119] implemented and discussed on strategies for automatic recognition of Brazilian Sign Language (BSL) signs, which ultimately aims to simplify the communication between deaf signing in BSL and listeners who do not know this sign language, accomplished through the processing of digital videos of people communicating in BSL without the use of colored gloves or data gloves and sensors or the requirement of high quality recordings in laboratories with controlled backgrounds or lighting. In another development, a paper as in [120] proposed using a Multiband Camera for Early Pedestrian Detection. In this paper, two approaches are presented to detect human skin from spectral images in an outdoor environment. One is an analytical method based on visible color information and subtraction between the NIR spectral images. Another is a statistical method for learning the brightness distribution of human skin in the seven spectral images.

They are different techniques and many dataset had been used with the different color space for each model of skin detector. The table down below is shows the skin detection.

3.2.2 SKIN DETECTION APPLICATIONS

Skin detection is one of the important roles in numerous applications such as face detection, anti-pornography, hand detection, recognitions, chip real time skin detection, skin disease, and tracking app. A total number of articles in skin detection applications are 58 papers. Majority of the papers (*n=22/58*) aimed to highlight face detection applications. A sum total of (*n=7/58*) of the papers to descript anti-pornography, (*n=7/58*) papers can be categorized as hand detection, (*n=6/58*) categorized as recognitions. (*n=3/58*) categorized as chip real time skin detection. (*n=4/58*) categorized as skin disease and (*n=9/58*) categorized as tracking app. The following are type of applications identified in the literature.

3.2.2.1 ANTI- PORNOGRAPHY

The fast growing in the field of digital media and extensive Internet penetration. That leads to anyone and anywhere to access to the non-textual information such as video, audio and images. The rapid advancement in the field of digital media, as well as availability of internet allows people from different parts around the world to have access to non-textual information like images, videos and audio.

A multi-agent learning which is a mixture of a grouping histogram technique and Bayesian method was proposed by the author [13] , so as to enable the extraction of features from skin detection based on YCbCr colour space. Afterwards, they extracted shape features from skin detection using back propagation neural network method. Again, an approach which can be used in the detection of child exploitation material that is distributed over social networks was developed in study [17]. The algorithm for the proposed approach is based on a novel stochastic model that detects and identifies patches of child pornography on images. In order to compress domain based recognition of pornographic images, the researchers in [121] proposed the multi-cost decision tree method.

The researchers in study [122] proposed a method of filtering adult-content in real-time. The authors opined that the extant methods only majorly pixel-based and do not consider the fact the skin of humans is region-based. Based on this, they introduced an effective method of region detection known as MSER by considering the skin as region as the maximally stable external region (MSER).

3.2.2.2 FACE DETECTION

The role of human face detection in different biometric applications cannot be underestimated. Human face detection plays so many important roles in tracking, human computer interaction (HCI), automatic recognition of target, surveillance and several other security areas [123] . Despite the many benefits offered by face detection, it is accompanied by challenges like variations in pose, colour variation, variation in conditions of illumination and brightness variations.

From the total of 58 papers in skin detection applications. The majority of the papers discuss about face detection apps. In [124] [125] [126] [127] [128] [129] [123] face detection using skin colour modelling and analysis from colour images. In [11] [130] the authors focuses on pre-processing technique in face detection and facial feature. And the other papers focused on the techniques in like fuzzy rule-based [6], knowledge-based method for segmentation [131], artificial neural network classifier [132], by the Gaussian Mixture Model [133], Genetic Algorithms for finding optimal limits for colour components [134], using a straightforward and low complex skin percentage to enhanced weak detectors performance [135], and Using self-organizing fuzzy network with support vector learning [136]. Author in [137] employed combination of Skin based background removal.

In the study which was carried out [1] , a localized approach for the detection of face according to segmentation of skin colour and facial characteristics were proposed. In the approach facial characteristics like bounding box, ratio of eccentricity for segmentation of face and eye-mouth hole detection were used. In the same vein, the author in [138] proposed an approach that can enhance the verification of face using spectral signatures of material surfaces within the short wave infrared (SWIR) range. The method is capable of effectively differentiating real human skin from other materials, irrespective of the kind of skin.

3.2.2.3 HAND DETECTION

The detection and recognition of hand has emerged as an essential field in Human Computer Interfaces (HCI). This is evident from the number of researchers that have recently showed interest in the field. Out of 58 articles that were found in the area of skin detection applications, 7 of them focused on hand recognition and detection.

In the first paper, a novel method of hand detection in a complicated background was proposed [139]. In another paper, Hough Transform and skin detection were used for the detection of hand in a classroom [140]. In [141] occluded arms were detected in human bodies using skin segmentation. They further proposed a method of strengthening the security of the contactless hand detection in biometric devices through the use of skin detector [142].

A high level method of extracting hand features for the purpose of recognizing real-time gesture was presented in study [16] The process of developing a model of skin model based on ellipse clustering was presented in [143] [143], and image was detected using the model of skin colour. In the last paper, a scheme which includes two procedures for the calculation of generic threshold ranges of Cb-Cr colour, was proposed for the segmentation of skin [144].

3.2.2.4 RECOGNITION

Recognition of human skin is significant mission for computer vision and graphics. Skin recognition used in different applications for example biometric systems, pornographic filtering images, hand tracking and widely used in face recognitions.

A sum total of (*n=5/52*) of the papers to descript recognition. Discussed about skin recognition based on enhance colour images in [112]. Used recognition in video by using skin detection features with motion information [122]. In the paper aimed to discuss about recognition faces in images used fuzzy approach to extract skin region [145]. While in [146, 147] papers discuss about ear in face images one focus on the localize ear in face and the other one focus on the prepressing techniques. And the last paper [148] presented a system for automatic spectral signature acquisition and recognition of skin from hyper spectral face imagery.

3.2.2.5 TRACKING APPS

The use of face tracking is considered as the major step in several applications of computer vision like Human motion tracking (HMT) and human-computer interaction and human-computer interaction (HCI). This also regarded as the initial step in tracking applications. A sum total of (n=9/52) of the papers reviewed provide a description of tracking applications. The studies in In [149] [150] [151] focused on real time tracking, the first one the use of frontal person profile faces was employed in detections and tracking, while the second author focused on applying human tracking system in defence applications. The third author used statistical skin colour method was used with no colour changes in surveillance tracking system.

In a study carried by [152] a discussion about automatic segmentation of skin and tracking in the recognition of sign language. In study [153] the use of Convolutional Neural Network was employed in detecting patient and in the segmentation of skin in Non-contact Vital Sign Monitoring. The authors in these two studies focused on monitoring. The authors in [154, 155] the authors focused on skin detection through video monitoring. In the first paper, the author presented an approach that is capable of detecting skin by adapting its parameters to image data obtained from video monitoring with a medium field view. In the second paper, conventional skin colour models and colour space are analysed in order to generate double-models.

In order to facilitate the identification of humans in crime cases, the use of skin detection and segmentation was employed by the author in [156] This author used tattooed human body for the detection and segmentation of skin. Through the use of image negative method, the proposed approach has been applied in forensic science. In the last paper, And the last paper [157] provided a discussion on the reduction of motion estimation time with skin detection.

3.2.2.6 SKIN DISEASES

Skin is the largest organ in a human body, early detection of skin disease is more complex to the inexperienced dermatologist, that's why many researchers try to come with new system or methods in skin detector diseases. Over the total of the number found in skin detection apps (*n=4/52*), four articles discuss about skin detection and segmentation in skin diseases.

The author in [158] present a details comparison between segmentation techniques and pixel based in skin psoriasis images. The second article used an automatic segmentations and classifiers to extract skin lesions areas. Furthermore, SVM and k-NN used for classification [10].

The authors in [9, 159] discuss about the skin cancer the first author came with a fast and fully automatic algorithm for skin lesion segmentation in images, the second author explain automated skin segmentation in ultrasonic evaluation of skin toxicity in breast cancer radiotherapy.

3.3 EVALUATION AND FRAMEWORK

Total of *5* out *of 173* papers belong to Evaluation and Framework. In Evaluation and Framework, most researchers discussed about the accuracy of the methods used based on experiments of images in selected data sets. The authors usually reviewed different methods from previous researchers and test the techniques/ methods according to research motivation. After they managed to get results, the either build a framework or identify the best methods that they can suggest in regards of skin detection either in the aspect of skin segmentation, feature extraction, image classifier which includes discussion on colour space, datasets, classifiers, algorithms, images and features.

In [160], the study two region methods and five threshold based methods were evaluated. The implementation of threshold based method is simple because it is based on decision rules. More so, the threshold methods are effective in segmenting the skin and offer good processing time. The study in [161] is a case study which was carried out with the aim of improving TV image for reported texture-adaptive skin detection algorithm. The result of their study showed that their approach, which uses a texture-adaptive skin detector provides overall improvement of skin detection and skin-dependent enhancements.

In [162] a discriminative fusion framework in image pixels was proposed for the classification of skin and non-skin pixels. This was achieved through the use of conditional random fields (CRFs) to merge low and high level of information for decision making about classifying an image's pixels as non-skin and skin classes. In order to enhance the accuracy of skin region segmentation in real-life images, the authors in the fifth article proposed a robust framework of progressive learning. The framework is capable of automatically learning the information of skin colour on each real-time, and afterwards produce specific skin model (SSM) for the images. in this category, the authors in the last paper developed skin detection framework [163]. The use of fuzzy integral was employed in the proposed framework, and the framework focuses on a pre-processing operation, which is relevant in different applications and fields like prosecution of cyber-crime and surveillance.

4.0 DISCUSSION

In this part of discussion, three main part were reviewed the first one the challenges facing the skin detector itself, the second part which is the motivation for skin detection and the last part is the recommendations

4.1 CHALLENGES

There are some challenges identified in the publication that can be classified to illumination variation, diversity in colour tone and colour variation, challenges related to overlapping skin and non-skin pixels and the background, skin detection without colour information, human tracking and model estimation, skin segmentation and content filtering. One paper specifically discuss about evaluation and benchmarking with possible solutions [23]. In paper [21] mentioned that "The challenges for skin colour detection include: skin colour type, lighting conditions, camera sensors, complexity of the background and its similarity to skin colour." The following Figures 2.4 summarized the challenges that will be elaborated further in each sub headings below.

4.1.1 CHALLENGES RELATED TO ILLUMINATION VARIATION

There is a good number of publications that have highlighted and discussed the challenges that are associated with conditions of illumination. One of such publications is that noted that the accurate detection of skin pixels is only achievable when the information about the real condition of image's illumination is obtained from the image itself [110]. Adequate information about an image's real colour of skin pixels can be obtained using the distribution of pixels of an image. Some authors [111] [73] [52] [37] [134] [164] [42] [81] have noted that one of the challenges is that of varying conditions of illumination that can be adapted to the detection of human skin. Researcher also found that even after implementation of certain methods, the illumination still posed challenges in skin detection methods[12] [87] [144] [45] [165]. As for example, in [45] stated "Unlike traditional machine learning methods, instead of predicting each pixel individually, our algorithm utilizes blocks to learn the representations and detect the skin areas. However, the algorithm still suffers from some illumination-related problems."

4.1.2 CHALLENGES RELATED TO DIVERSITY IN COLOUR TONE AND COLOUR VARIATION

One of the widely discussed challenges is that associated with the difference in colour tone and variation in colour [145] . Papers in [165] [21] [129] [28] highlighted some challenges in terms of

exploring other colour components combinations which are the best representations of human skin from various ethnicities and can be utilized in several applications.

4.1.3 CHALLENGES RELATED OVERLAPPING SKIN AND/OR NON-SKIN PIXELS WITH THE BACKGROUND

In some cases, it is difficult for the detector to distinguish between the skin and background that looks like the skin [71]. This disables the accuracy of skin detection [39]. In [28], the proposed algorithm was able to identify some of the non-skin pixels in a complex background. The author in [28] [134] [128] suggested that in order to enhance the accuracy of detection, future studies should incorporate texture-based method into the algorithm. In [46], it was found that determining if a single skin pixel is non-skin or skin pixels without giving consideration to the context is a difficult task. For the development of an efficient traditional hand-crafted algorithm of skin detection, domain experts must engage in extensive work [34] [21].

4.1.4 CHALLENGES RELATED TO SKIN DETECTION WITHOUT COLOUR INFORMATION

There are situation that images captured in the wild comes without colour information. Paper [87] "many situations exist for which colour information is either not available or not reliable. Examples include images obtained under low-light conditions, legacy grayscale images and videos, and near-infrared images [87]. Furthermore, for human observers it is often the visual texture of skin that is prominent in an image in which many situations exist for which colour information is either not available or not reliable [79] [88] [27]. Examples include images obtained under low-light conditions, legacy grayscale images and videos, and near-infrared images.

4.1.5 CHALLENGES RELATED TO SKIN SEGMENTATION AND CONTENT FILTERING

Another challenges of skin detection is for the application that requires content filtering such as to block pornographic images. Papers in [94] [48] [103] [166] stated among the challenge posed is the difficulty to extract accurate skin regions form various input images. Object detection methods such as face detection or eye detection have been employed to estimate the colour model adjusted to the current input image [39] [132]. But these approaches increase the computation time and cannot be used for input images which do not include any faces [83]. Another segmentation problems highlighted by researchers [104] [84] such as there are still some problems with regard to the textural features extracted from the Bayesian skin probability map that need to be addressed to solve the skin segmentation problem.

4.1.6 CHALLENGES RELATED TO EVALUATION AND BENCHMARKING

In study [23] the researchers carried out a review of many methods of real-time skin detectors benchmarking and evaluation. Two major areas were identified by the authors based on the present evaluation criteria, which include extant techniques of benchmarking and highlighting of conflicting areas. The study also presented a discussion on shortcomings of the techniques, and other recommendations. In the [152] [23] [40] findings, emphasis was placed on general issues and problems associated with benchmarking and evaluation. More so, the author emphasised the importance of using different criteria in decision making within the framework of benchmarking and evaluation of real-time skin detectors. The author in study [23] highlighted the evaluation criteria as dataset error rate.

4.2 MOTIVATIONS

The selected academic publication on detection has been analysed in terms of motivation behind the research. The following are the summary of the motivation which can be classified into four main motivations. They are motivations related to skin detection classifiers, techniques and methods that found in majority of the papers. Other motivation is on the application of skin detection, colour space and performance.

4.2.1 MOTIVATION RELATED TO SKIN DETECTION CLASSIFIERS, TECHNIQUES AND METHODS

Majority of the research in skin detection are focusing on design and development of Skin Detection Classifiers, Techniques and Methods[167] [152] [104] [144] [100] [45] [95] [80] [34] [34] [79] [133] [62] [93] [157] [64] [66]. Therefore there is a need to properly formulate the skin detector, overcoming all the difficulties that arise in detecting skin in an image.

4.2.2 MOTIVATION RELATED TO APPLICATION

The application of skin detection is required in several applications such as surveillance [87], medical [45], forensics [135], authentication and security [150]. As noted by the researcher in [168], forensic investigation is key to the prohibition of pornographic video and image usage in media. In order to prevent the spread of pornographic images throughout the web, it is important to differentiate pornographic video and images from other media [123]. One of the initial steps involved in many applications like face recognition in image and video surveillance, is identifying region of skin colour in coloured images [127]. The approach used in the current study is basically concerned with the detection of such images by focusing on skin region [168]. Another application of skin detection is biometrics [49]. The use of biometrics in personal identification has a become common technique of enhancing security applications like access control [142]. However, this growing popularity of biometrics is threatened by successful spoofing attempts as seen in publications. The security of biometrics is compromised by such attacks [20]. Huge efforts are made in the academia and in the industry to increase the robustness of biometric devices so that countermeasures can be effective[58].

4.2.3 MOTIVATION RELATED TO COLOUR SPACE

The detection of skin colour of the key techniques often used in the detection of faces in videos or images [87]. Nonetheless, there is no conclusion on the most appropriate colour space for this task [165]. Thus, the researchers are motivated to carry out the study in order to identify the most appropriate method of building an efficient face detector that is can be concealed within a functional face recognition system [34]. In study [169], the researchers explored the multicolour space use. The reason why colour space is used in the detection of skin can be improved through the use of combined colour spaces as compared to using just one colour spaces [56]. The authors in the study carried out in [98] placed emphasis on choosing a colour space, in which segmentation algorithm is used, because its great value. In [28] [98] [25] recent times, YIQ, RGB, YUV, and HSV are widely used. The colour information for HSV colour system is carried by H (Hue) and Saturation (S) components [111]. The colour information of RGB is carried by R (Red), G (Green), B (Blue) components in RGB colour system [79]. Additionally, there are two kinds of colour components for YUV and YIQ colour spaces, and they are Q (quadrature) and I (in-phase), and (blue chroma) and (red chroma); U and V, [25].

4.2.4 MOTIVATION RELATED TO PERFORMANCE

Higher detection rate of the proposed method is reflective of an improved capability of skin segmentation, and as such can be used in applications of skin detection [144] . The importance of improving the rate of detection by enhancing performance of techniques and methods has been highlighted by [126]. The researchers in the current study[46] [87] [95] [135] propose the combination of colour spaces for skin detection so as to enhance detection. The research is motivated by the fact that the existing skin detectors are slow in terms of processing the captured image [31]. In study [14] , the

author noted that no perfect solution for skin detection exists, since the process is slow, complex and lacks precision. Achieving the three aspects at the same time has been found to be impossible. It may be fast, simple but lacking in precision with higher numbers of false positive detections [13]. Again, it may be precise but lacking in simplicity, or even it may even be complicated and slow [84]. In majority of applications, a particular level of accuracy and speed is adequate, and the complexity of a model is determined by this[86].

4.3 RECOMMENDATIONS

The following are recommendations which are identified in selected papers. Overall can classify them into four main categories namely, improvement of segmentation features, new model and framework proposal, measurement of accuracy of skin segmentation classifiers and the choice of suitable colour space.

4.3.1 IMPROVEMENT OF CLASSIFICATION SCHEMES/ ALGORITHMS

A paper [124] suggested on improving the algorithm in combination with other face detection algorithm to achieve better performance and further reduce the false detecting rate in dealing with images with more complex background.

4.3.2 PROPOSING NEW MACHINE LEARNING FRAMEWORK

Currently, many schemes of detection and classification that can be used the problem of skin detection exist. In one research, a framework of incremental learning was proposed; the use of the framework can be employed in segmentation of region in arbitrary objects like mountain, vegetation, sky etc. in image retrieval systems [170]. The focus of the proposed framework is integrity and precision of the derived skin map, and therefore, being appropriate for use in recognition of gesture and filtering of objectionable image [170]. The researcher in [113] introduced a new machine learning approach that can be used in solving the probability estimations and/or classification problem. The contribution of these researchers is related to the Optimal-Spanning-Tree distributions that are commonly applied in several areas of optimization.

The frameworks discussed in this section are flexible, and as such can be easily extended to deal with particular issues that have not been handled by the extant image sets. More so, it is easy to use these frameworks for the introduction and embedding of appropriate knowledge (expert system rules) for the segmentation of new images.

4.3.3 ACCURACY OF SKIN SEGMENTATION AND CLASSIFIERS

More computation is required for the generation of a local skin colour model than in the original method [155]. More so, two enhancements are made with the aim of increasing the speed of processing. The two improvements involve the use of Intel Integrated Performance Primitives (IPP) function and down sampling skin pixel samples. In the study in [99], improvements in the processing time by 54% was achieved without hampering on the accuracy.

4.3.4 THE CHOICE OF COLOUR SPACE

Another major step involved in the classification/detection of skin is colour space choice [126]. The most widely used colour space for the majority of the extant image formats is the RGB colour space. Nonetheless, there is a strong relationship between the channels of RGB and the integration of luminance and chrominance information together, which reduces colour space usage in particular applications. More so, the researcher in study [30] noted that the performance of ANN-based YCbCr is better in the detection of possible skin pixels than that of other techniques which they evaluated in their study.

4.3.5 CONSIDERATION ON ILLUMINATION CONDITIONS AND REFLECTIONS

The author in [110] suggested future work in the area of skin region detection under different conditions of illumination and skin-like background conditions. Many authors [33] [45] [28] have suggested that techniques of skin detection under conditions of illumination and complex be improved, since the quality of detection can be serious affected by these conditions.

5.0 METHODOLOGICAL ASPECTS OF PREVIOUS RESEARCH

In this part have a five sup category start from dataset have been used in the previous systematic literature review, colour space how many frequent time have been used, There are many classification techniques used in skin detection . Which listed the classification techniques identified from the selected literatures in next part, also features, they are three type of features shape, colour and texture. And finally the conducted country about the publication of the paper over author's country is listed in the next part.

5.1 DATASET

The following is the summary of the dataset and frequency of used in the experiments as mentioned by the publication.

5.2 COLOUR SPACE

There is numerous colour spaces as used in skin detection. Among the popular one for the image is RGB (Red, Green, and Blue). Another popular colour space is YCbCr that includes Luminance and Chrominance in which it represents colours in terms of one luminance component/luma (Y), and two chrominance components/chroma (Cb and Cr). . HSV is named as such for three values: hue, saturation, and value. This colour space describes colours (hue or tint) in terms of their shade (saturation or amount of gray) and their brightness value.

Majority of the papers discussed on RGB colour space in which the frequency percentage is 36% followed by YCbCr (23.3%) and HSV (15.5%). The remaining were YUV, CIE Lab and others as can be viewed in Figure 2.7 above and Table 2.7 below. Others represent some variations of RGB such as i1i2i3 and NTSC.

5.3 CLASSIFICATION TECHNIQUES

In order to classify the skin, the use of different techniques has been employed in the literature. Through the use of a skin classifier, which is a one-class classifier, a decision boundary of the class of skin colour within a feature space is defined. With regards to the detection of skin, the feature space is regarded as the selected colour space. Any the colour of any pixel that falls within the class boundary of skin colour is labelled as skin. Thus, the shape of skin class within the colour space selected by a skin detector can have a direct influence on the selection of skin classifier. The classifier becomes simple when the shape of skin colour class is more regular and compact.

There are many classification techniques used in skin detection as identified in Figure 2.11 which listed the classification techniques identified from the selected literatures. There are many techniques and classification techniques being mentioned in the journals. The most popular techniques were Neural network, Bayesian and Gaussian followed by Threshold, Histogram, Adaboost, Region Growing, Graph Cut, Fuzzy rule, fuzzy logic, deep learning, DSSD, SVM and Random Forest. Some amount of 32 times is others as for example block matching technique and K-Means Clustering Technique. The following Figure 2.11 shows the classification techniques and the frequency of the techniques used in the literature

5.4 FEATURES

The feature is defined as a function of one or more measurements, each of which specifies some quantifiable property of an object, and

is computed such that it quantifies some significant characteristics of the object [41]. Feature extraction in image processing can be divided in to three type of feature extraction which is colour, shape and texture.

5.4.1 COLOUR FEATURES

colour feature is one of the most widely used visual features in image retrieval [78] . Images characterized by colour features have many advantages: Robustness. The colour histogram is invariant to rotation of the image on the view axis, and changes in small steps when rotated otherwise or scaled. It is also insensitive to changes in image and histogram resolution and occlusion. Effectiveness. There is high percentage of relevance between the query image and the extracted matching images [61]. Implementation simplicity. The construction of the colour histogram is a straightforward process, including scanning the image, assigning colour values to the resolution of the histogram, and building the histogram using colour components as indices and Low storage requirements. The colour histogram size is significantly smaller than the image itself, assuming colour quantization.

5.4.2 SHAPE FEATURE

Shape based image retrieval is the measuring of similarity between shapes represented by their features [73]. Shape is an important visual feature and it is one of the primitive features for image content description [10]. Shape content description is difficult to define because measuring the similarity between shapes is difficult. Therefore, two steps are essential in shape based image retrieval, they are: feature extraction and similarity measurement between the extracted features [114]. Shape descriptors can be divided into two main categories: region-based and contour-based methods. Region-based methods use the whole area of an object for shape description, while contour-based methods use only the information present in the contour of an object.

5.4.3 TEXTURE FEATURE

Texture is another important property of images. Texture is a powerful regional descriptor that helps in the retrieval process [106]. Texture, on its own does not have the capability of finding similar images, but it can be used to classify textured images from non-textured ones and then be combined with another visual attribute like colour to make the retrieval more effective. Texture has been one of the most important characteristic which has been used to classify and recognize objects and have been used in finding similarities between images in multimedia databases [104]. Basically, texture representation methods can be classified into two categories: structural; and statistical. Statistical methods, including Fourier power spectra, co-occurrence matrices, shift-invariant principal component analysis (SPCA), Tamura features, Wold decomposition, [17] Markov random field, fractal model, and multi-resolution filtering techniques such as Gabor and wavelet transform, characterize texture by the statistical distribution of the image intensity [171].

5.5 IMAGE TYPE

They are three type of image in image processing start with Binary image which the simple one, followed by Gray-scale image and the last type which is colour images[172].

5.5.1 BINARY IMAGE

This is the simplest type of image with two gray-values, 0 and 1 or black and white [173]. Each pixel is represented by a single bit. These types of images are useful in computer vision applications where only information about images or outlines are required [137]. It can be created from gray-scale image that uses 0 for pixels with gray levels below the threshold and 1 for other pixel but this way of creation is not useful because most of the information is lost and the image result are smaller.

5.5.2 GRAY-SCALE IMAGE

These images contain the brightness information [87]. The number of bits that are used to represent each pixel, are related to the number of different brightness levels available[174]. The typical image contains 8 bits per pixel so there are 256 different possible gray-tones (Ng) or intensity values from 0 to 255.

5.5.3 COLOUR IMAGE

Normally, images are represented as RGB (Red, Green, Blue) models, and each pixel has 24 bits [22] . The brightness information and colour information are coupled and represented in many applications [136]. These two information are separated by transferring RGB information to the mathematical.

6.0 CONDUCTED COUNTRY

The following figure 2.14 down below is shows the Relationship between number of articles in each data base within the years of their publication. And Figures 2.15 depicts the country of origin of the published papers. Majority of research on the topic has been done in China, Malaysia India, Iran and USA followed by UK, Spain, Australia and Italy. The rest are as listed in the figure which considered very little from 1 to 3 numbers of papers from each country.

7.0 FUTURE WORK

There are many direction for the future work. One of most important point which is deep learning. Deep learning allows computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction. Deep learning techniques could be improve skin detection result as recommended by [175] [46]. Deep learning methods are new techniques in learning that have shown improved classification power compared to neural network [45]. However, none of the previous deep learning skin detection studies attempt to standardize a dataset and categorized based on skin colour tone considering the range.

8.0 CONCLUSION

This study attempt to provide an over view on skin detector up-to-date, the survey of the research on skin detection were described in over 173 research articles. This paper aimed to understanding and insights by surveying and classifying relevant research efforts. The first category of our taxonomy, namely comparative study, which there are (*n=10* out of *173= 6%*). Three of them tried to compare between the most appropriate skin detector techniques and six of paper came up with the most suitable colour spaces such as (RGB, YCbCr and HSV) furthermore, one of these paper aimed to comparison between the techniques and colour space at the same time. The second category of our taxonomy, namely Development and Design which there are (*n=158* out of *173= 91%*) obviously the papers focus on design and development which is the biggest number of papers in the taxonomy. Development and Design divided into category skin modelling and skin applications. In the skin modelling there are (*n=100* papers), these papers can be categorized as (Parametric *n= 13/100 = 13%*, Non-Parametric *n=18/100 = 18%*, Semi-Parametric *n= 13/100 = 13%*, Deep learning *n= 2/100 = 2%*, Dynamic *n= 8/100= 8%*, Colour space *n= 20/100 = 20%*, Fuzzy *n= 4/100 = 4%*, Texture *n= 6/100 = 6%*, Spatial *n= 4/100 = 4%*, and the last one in this category others *n= 13/100 = 13%)* clearly shows the biggest numbers of skin modelling based on colour space model and followed by Non-parametric. The second part of the development and design is skin applications (*n=58* out of *158*), these papers can be categorized based on applications skin detection (Anti-Pornography *n= 7/58= 12%*, Hand Detection *n= 7/58= 12%*, Recognition *n= 6/58= 10%*, Skin Disease *n= 4/58= 7%*, Tracking *n= 9/58= 15%*,

chip real time n= 3/58= 5%, and face detection *n= 22/58= 38%)* based on the categorized on skin detection application the majority of papers discuss about the face detection and followed by tracking apps based on skin detector techniques. The third category of our taxonomy, namely Evaluation and Framework total of *(n=5/173) = 3 %* In Evaluation and Framework, most researchers discussed about the accuracy of the methods used based on experiments of images in selected data sets. In discussion, had reviewed the challenges facing the skin detection such as illuminations, complex background, skin like and the reflection. And the motivation for example motivation to improve the classifier and accuracy and the recommendation like improvement of classification schemes/ algorithms and the choice of the colour spaces. Also reviewed the previous studies on the Dataset of the previous studies found the used different data as using camera scanner and internet source is the 33 time followed by the ECU and Compaq dataset. Colour space numerous colour spaces as used in skin detection. Among the popular one for the image is RGB, YCbCr and HSV. There are many classification techniques used in skin detection such as Neural network, Bayesian and Gaussian. Feature extraction in image processing can be divided in to three type of feature extraction which is colour, shape and texture. They are three type of image in image processing start with Binary image which the simple one, followed by Gray-scale image and the last type which is colour images. Relationship between numbers of articles in each data base within the years of their publication with in the years.

REFERENCES

[1] S. Yadav and N. Nain, "A novel approach for face detection using hybrid skin color model," *Journal of Reliable Intelligent Environments*, vol. 2, pp. 145-158, 2016.

[2] A. Zaidan, H. A. Karim, N. Ahmad, G. M. Alam, and B. Zaidan, "A new hybrid module for skin detector using fuzzy inference system structure and explicit rules," *International Journal of Physical Sciences*, vol. 5, pp. 2084-2097, 2010.

[3] D. Jensch, D. Mohr, and G. Zachmann, "A Comparative Evaluation of Three Skin Color Detection Approaches," *Journal of Virtual Reality and Broadcasting*, vol. 12, 2015.

[4] A. Zaidan, H. A. Karim, N. Ahmad, G. M. Alam, and B. Zaidan, "A novel hybrid module of skin detector using grouping histogram technique for Bayesian method and segment adjacent-nested technique for neural network," *International Journal of Physical Sciences*, vol. 5, pp. 2471-2492, 2010.

[5] A. Zaidan, H. A. Karim, N. Ahmad, B. Zaidan, and M. M. Kiah, "Robust pornography classification solving the image size variation problem based on multi-agent learning," *Journal of Circuits, Systems and Computers*, vol. 24, p. 1550023, 2015.

[6] P. Moallem, B. S. Mousavi, and S. A. Monadjemi, "A novel fuzzy rule base system for pose independent faces detection," *Applied Soft Computing*, vol. 11, pp. 1801-1810, 2011.

[7] A. Zaidan, H. A. Karim, N. Ahmad, B. Zaidan, and A. Sali, "An automated anti-pornography system using a skin detector based on artificial intelligence: A review," *International Journal of Pattern Recognition and Artificial Intelligence*, vol. 27, p. 1350012, 2013.

[8] L. Zhengming, Z. Tong, and Z. Jin, "Skin detection in color images," in *Computer Engineering and Technology (ICCET), 2010 2nd International Conference on*, 2010, pp. V1-156-V1-159.

[9] Y. Gao, A. Tannenbaum, H. Chen, M. Torres, E. Yoshida, X. Yang, *et al.*, "Automated skin segmentation in ultrasonic evaluation of skin toxicity in breast cancer radiotherapy," *Ultrasound in medicine & biology*, vol. 39, pp. 2166-2175, 2013.

[10] R. Sumithra, M. Suhil, and D. Guru, "Segmentation and classification of skin lesions for disease diagnosis," *Procedia Computer Science*, vol. 45, pp. 76-85, 2015.

[11] S. Bodhi and S. Naveen, "Face Detection, Registration and Feature Localization Experiments with RGB-D Face Database," *Procedia Computer Science*, vol. 46, pp. 1778-1785, 2015.

[12] F. Chen, Z. Hu, K. Li, and W. Liu, "A hybrid skin detection model from multiple color spaces based on a dual-threshold Bayesian algorithm," *International Journal of Pattern Recognition and Artificial Intelligence*, vol. 30, p. 1655018, 2016.

[13] A. Zaidan, N. N. Ahmad, H. A. Karim, M. Larbani, B. Zaidan, and A. Sali, "On the multi-agent learning neural and Bayesian methods in skin detector and pornography classifier: An automated anti-pornography system," *Neurocomputing*, vol. 131, pp. 397-418, 2014.

[14] S. Omanovic, E. Buza, and I. Besic, "RGB ratios based skin detection," in *Information and Communication Technology, Electronics and Microelectronics (MIPRO), 2014 37th International Convention on*, 2014, pp. 1348-1353.

[15] H. Bouirouga, S. El Fkihi, A. Jilbab, and M. h. Bakrim, "A comparison of skin detection techniques for objectionable videos," in *I/V Communications and Mobile Network (ISVC), 2010 5th International Symposium on*, 2010, pp. 1-4.

[16] Y. Zhou, G. Jiang, and Y. Lin, "A novel finger and hand pose estimation technique for real-time hand gesture recognition," *Pattern Recognition*, vol. 49, pp. 102-114, 2016.

[17] M. Islam, P. A. Watters, and J. Yearwood, "Real-time detection of children's skin on social networking sites using Markov random field modelling," *Information Security Technical Report*, vol. 16, pp. 51-58, 2011.

[18] A. Zaidan, H. Abdul Karim, N. N. Ahmad, B. Zaidan, and A. Sali, "A four-phases methodology to propose anti-pornography system based on neural and Bayesian methods of artificial intelligence," *International Journal of Pattern Recognition and Artificial Intelligence*, vol. 28, p. 1459001, 2014.

[19] K. B. Shaik, P. Ganesan, V. Kalist, B. Sathish, and J. M. M. Jenitha, "Comparative study of skin color detection and segmentation in HSV and YCbCr color space," *Procedia Computer Science*, vol. 57, pp. 41-48, 2015.

[20] K. Nallaperumal, S. Ravi, C. N. K. Babu, R. Selvakumar, A. L. Fred, S. Christopher, *et al.*, "Skin detection using color pixel classification with application to face detection: A comparative study," in *iccima*, 2007, pp. 436-441.

[21] A.-S. Ungureanu, H. Javidnia, C. Costache, and P. Corcoran, "A review and comparative study of skin

segmentation techniques for handheld imaging devices," in *Consumer Electronics (ICCE), 2016 IEEE International Conference on*, 2016, pp. 530-531.

[22] P. Kakumanu, S. Makrogiannis, and N. Bourbakis, "A survey of skin-color modeling and detection methods," *Pattern recognition*, vol. 40, pp. 1106-1122, 2007.

[23] Q. M. Yas, A. Zaidan, B. Zaidan, B. Rahmatullah, and H. A. Karim, "Comprehensive insights into evaluation and benchmarking of real-time skin detectors: Review, open issues & challenges, and recommended solutions," *Measurement*, 2017.

[24] W. Kelly, A. Donnellan, and D. Molloy, "Screening for objectionable images: a review of skin detection techniques," in *Machine Vision and Image Processing Conference, 2008. IMVIP'08. International*, 2008, pp. 151-158.

[25] S. Ketenci and B. Gencturk, "Performance analysis in common color spaces of 2D Gaussian Color Model for skin segmentation," in *EUROCON, 2013 IEEE*, 2013, pp. 1653-1657.

[26] H. Han, S. Shan, X. Chen, and W. Gao, "A comparative study on illumination preprocessing in face recognition," *Pattern Recognition*, vol. 46, pp. 1691-1699, 2013.

[27] H. K. Al-Mohair, J. Mohamad-Saleh, and S. A. Suandi, "Color space selection for human skin detection using color-texture features and neural networks," in *Computer and Information Sciences (ICCOINS), 2014 International Conference on*, 2014, pp. 1-6.

[28] K. Klevan, M. Hanafi, and A. Ramli, "Optimal Combination of Color Components for Skin Detection," in *Artificial Intelligence with Applications in Engineering and Technology (ICAIET), 2014 4th International Conference on*, 2014, pp. 171-176.

[29] Y. Lei, W. Xiaoyu, L. Hui, Z. Dewei, and Z. Jun, "An algorithm of skin detection based on texture," in *Image and Signal Processing (CISP), 2011 4th International Congress on*, 2011, pp. 1822-1825.

[30] A. M. Aibinu, A. A. Shafie, and M. J. E. Salami, "Performance analysis of ANN based YCbCr skin detection algorithm," *Procedia Engineering*, vol. 41, pp. 1183-1189, 2012.

[31] A. Zaidan, N. N. Ahmad, H. A. Karim, M. Larbani, B. Zaidan, and A. Sali, "Image skin segmentation based on multi-agent learning Bayesian and neural network," *Engineering Applications of Artificial Intelligence*, vol. 32, pp. 136-150, 2014.

[32] Z. Musa, K. Jumari, and N. Zainal, "A method of human skin detection base on background subtraction and color enhancement," in *Business, Engineering and Industrial Applications (ISBEIA), 2011 IEEE Symposium on*, 2011, pp. 498-502.

[33] S. Ghouzali, S. Hemami, M. Rziza, D. Aboutajdine, and E. M. Mouaddib, "A skin detection algorithm based on discrete cosine transform and generalized gaussian density," in *Image Processing, 2008. ICIP 2008. 15th IEEE International Conference on*, 2008, pp. 605-608.

[34] B. K. Chakraborty, M. Bhuyan, and S. Kumar, "A Weighted Skin Probability Map for skin color segmentation," in *Wireless Communications, Signal Processing and Networking (WiSPNET), International Conference on*, 2016, pp. 2133-2136.

[35] Z. Yu, "Fast Gaussian mixture clustering for skin detection," in *Image Processing, 2006 IEEE International Conference on*, 2006, pp. 2997-3000.

[36] M. J. Mendenhall, A. S. Nunez, and R. K. Martin, "Human skin detection in the visible and near infrared," *Applied optics*, vol. 54, pp. 10559-10570, 2015.

[37] A. Nadian and A. Talebpour, "Pixel-based skin detection using sinc function," in *Computers & Informatics (ISCI), 2011 IEEE Symposium on*, 2011, pp. 317-321.

[38] K. Chenaoua and A. Bouridane, "Information theoretical based feature selection approach for human skin detection," in *Acoustics Speech and Signal Processing (ICASSP), 2010 IEEE International Conference on*, 2010, pp. 1122-1125.

[39] A. N. Ghomsheh, A. Talebpour, and M. Basseri, "Regional skin detection based on eliminating skin-like Lambertian surfaces," in *Computers & Informatics (ISCI), 2011 IEEE Symposium on*, 2011, pp. 307-312.

[40] S. Ghouzali, M. El Aroussi, M. El Hassouni, M. Rziza, and D. Aboutajdine, "Statistical block-based skin detection," in *I/V Communications and Mobile Network (ISVC), 2010 5th International Symposium on*, 2010, pp. 1-4.

[41] N. Razmjooy, B. S. Mousavi, and F. Soleymani, "A hybrid neural network Imperialist Competitive Algorithm for skin color segmentation," *Mathematical and Computer Modelling*, vol. 57, pp. 848-856, 2013.

[42] S. Araban, F. Farokhi, and K. Kangarloo, "Determining effective colour components for skin detection using a clustered neural network," in *Signal and Image Processing Applications (ICSIPA), 2011 IEEE International Conference on*, 2011, pp. 547-552.

[43] C. Swaney, A. Akusok, K.-M. Björk, Y. Miche, and A. Lendasse, "Efficient skin segmentation via neural networks: HP-ELM and BD-SOM," *Procedia Computer Science*, vol. 53, pp. 400-409, 2015.

[44] K. Kaabneh, E. Abu-Hammad, and F. Hamd, "Enhanced Skin Detection Technique Using Block Matching," in *Signal Processing and Communications, 2007. ICSPC 2007. IEEE International Conference on*, 2007, pp. 21-24.

[45] Y. Lei, W. Yuan, H. Wang, Y. Wenhu, and W. Bo, "A skin segmentation algorithm based on stacked autoencoders," *IEEE Transactions on Multimedia*, vol. 19, pp. 740-749, 2017.

[46] H. Zuo, H. Fan, E. Blasch, and H. Ling, "Combining convolutional and recurrent neural networks for human skin detection," *IEEE Signal Processing Letters*, vol. 24, pp. 289-293, 2017.

[47] M. Shruthi and B. Harsha, "Non-parametric histogram based skin modeling for skin detection," in *Computational Intelligence and Computing Research (ICCIC), 2013 IEEE International Conference on*, 2013, pp. 1-6.

[48] L. Yun and W. Chuan-xu, "An improved algorithm of human skin detection in video image based on linear combination of 2-order Markov and Wiener predictor," in *Computer Science and Computational Technology, 2008. ISCSCT'08. International Symposium on*, 2008, pp. 665-668.

[49] S. Shirali-Shahreza and M. Mousavi, "A new Bayesian classifier for skin detection," in *Innovative Computing Information and Control, 2008. ICICIC'08. 3rd International Conference on*, 2008, pp. 172-172.

[50] S. Zhao, L. Zhuo, Z. Xiao, and L. Shen, "A data-mining based skin detection method in JPEG compressed domain," in *2009 Sixth International Conference on Fuzzy Systems and Knowledge Discovery*, 2009, pp. 297-301.

[51] B. K. Chakraborty, M. Bhuyan, and S. Kumar, "Adaptive propagation-based skin segmentation method for color images," in *Communication (NCC), 2016 Twenty Second National Conference on*, 2016, pp. 1-6.

[52] J.-q. Zhu and C.-h. Cai, "Region growing based high brightness skin detection," in *Signals, Circuits and Systems (ISSCS), 2011 10th International Symposium on*, 2011, pp. 1-4.

[53] T.-h. Huang, Y.-m. Yu, and X.-g. Qin, "A High-Performance Skin Segmentation Method," *Procedia Engineering*, vol. 15, pp. 608-612, 2011.

[54] P. Tavallali and M. Yazdi, "Robust skin detector based on AdaBoost and statistical luminance features," in *Technology, Communication and Knowledge (ICTCK), 2015 International Congress on*, 2015, pp. 98-103.

[55] M. R. Mahmoodi and S. M. Sayedi, "Boosting performance of face detection by using an efficient skin segmentation algorithm," in *Information Technology and Electrical Engineering (ICITEE), 2014 6th International Conference on*, 2014, pp. 1-6.

[56] A. A. Mustafa, A. A. Elbashir, and S. F. Babikir, "A study of color constancy methods for skin detection," in *Computing, Control, Networking, Electronics and Embedded Systems Engineering (ICCNEEE), 2015 International Conference on*, 2015, pp. 342-347.

[57] K. Chenaoua, F. Kurugollu, and A. Bouridane, "Data cleaning and outlier removal: application in human skin detection," in *Visual Information Processing (EUVIP), 2014 5th European Workshop on*, 2014, pp. 1-6.

[58] M. Ghaziasgar, J. Connan, and A. B. Bagula, "Enhanced adaptive skin detection with contextual tracking feedback," in *Pattern Recognition Association of South Africa and Robotics and Mechatronics International Conference (PRASA-RobMech), 2016*, 2016, pp. 1-6.

[59] B. Moradi and M. Ezoji, "Skin detection based on contextual information," in *Pattern Recognition and Image Analysis (IPRIA), 2015 2nd International Conference on*, 2015, pp. 1-6.

[60] J. Geng, Z. Miao, and C. Zhong, "Skin detection with illumination adaptation in single image," in *Multimedia and Expo (ICME), 2011 IEEE International Conference on*, 2011, pp. 1-6.

[61] R. Khan, A. Hanbury, and J. Stoettinger, "Skin detection: A random forest approach," in *Image Processing (ICIP), 2010 17th IEEE International Conference on*, 2010, pp. 4613-4616.

[62] S. Mitra, "A probabilistic method of skin detection," in *Image Information Processing (ICIIP), 2013 IEEE Second International Conference on*, 2013, pp. 73-77.

[63] M. Shoyaib, M. Abdullah-Al-Wadud, and O. Chae, "A skin detection approach based on the Dempster–Shafer theory of evidence," *International Journal of Approximate Reasoning*, vol. 53, pp. 636-659, 2012.

[64] C. M. DUMITRESCU and I. Dumitrache, "HUMAN SKIN DETECTION USING NEURAL NETWORKS AND BLOCK PROCESSING TECHNIQUES," *UNIVERSITY POLITEHNICA OF BUCHAREST SCIENTIFIC BULLETIN SERIES C-ELECTRICAL ENGINEERING AND COMPUTER SCIENCE*, vol. 78, pp. 87-102, 2016.

[65] H. K. Al-Mohair, J. M. Saleh, and S. A. Suandi, "Hybrid human skin detection using neural network and k-means clustering technique," *Applied Soft Computing*, vol. 33, pp. 337-347, 2015.

[66] M. Fatahi, M. Nadjafi, and S. V. A.-D. Makki, "Improving the performance of skin segmentation in quasi-skin regions via multiple classifier system," in *Machine Vision and Image Processing (MVIP), 2013 8th Iranian Conference on*, 2013, pp. 333-338.

[67] I. Hwang, Y. Kim, and N. I. Cho, "Skin detection based on multi-seed propagation in a multi-layer graph for regional and color consistency," in *Acoustics, Speech and Signal Processing (ICASSP), 2017 IEEE International Conference on*, 2017, pp. 1273-1277.

[68] L. Chang, L. Jun-min, and Y. Chong-xiu, "Skin detection using a modified self-organizing mixture network," in *Automatic Face and Gesture Recognition (FG), 2013 10th IEEE International Conference and Workshops on*, 2013, pp. 1-6.

[69] F. Salimi, H. Farzin, and F. Ebrahimi, "A novel skin detection method using Generalized Discriminant Analysis," in *Computer Systems and Industrial Informatics (ICCSII), 2012 International Conference on*, 2012, pp. 1-5.

[70] I. Filali, D. Ziou, and N. Benblidia, "Multinomial bayesian kernel logistic discriminant based method for skin detection," in *Signal Image Technology and Internet Based Systems (SITIS), 2012 Eighth International Conference on*, 2012, pp. 420-425.

[71] Z. Hu, G. Wang, X. Lin, and H. Yan, "Skin segmentation based on graph cuts," *Tsinghua Science and Technology*, vol. 14, pp. 478-486, 2009.

[72] A. Kumar, "An empirical study of selection of the appropriate color space for skin detection: A case of face detection in color images," in *Issues and Challenges in Intelligent Computing Techniques (ICICT), 2014 International Conference on*, 2014, pp. 725-730.

[73] M. Shemshaki and R. Amjadifard, "Skin detection using fuzzy rule base system," in *Automation, Robotics and Applications (ICARA), 2011 5th International Conference on*, 2011, pp. 250-254.

[74] B. K. Chakraborty and M. Bhuyan, "Skin segmentation using possibilistic fuzzy c-means clustering in presence of skin-colored background," in *Intelligent Computational Systems (RAICS), 2015 IEEE Recent Advances in*, 2015, pp. 246-250.

[75] A. Selamat, M. A. Maarof, and T. Y. Chin, "Fuzzy Mamdani Inference System Skin Detection," in *Hybrid Intelligent Systems, 2009. HIS'09. Ninth International Conference on*, 2009, pp. 57-62.

[76] Z. Yong-jia, D. Shu-ling, and X. Xiao, "A Mumford-Shah level-set approach for skin segmentation using a new color space," in *System Simulation and Scientific Computing, 2008. ICSC 2008. Asia Simulation Conference-7th International Conference on*, 2008, pp. 307-310.

[77] M. M. Aznaveh, H. Mirzaei, E. Roshan, and M. Saraee, "A new and improves skin detection method using RGB vector space," in *Systems, Signals and Devices, 2008. IEEE SSD 2008. 5th International Multi-Conference on*, 2008, pp. 1-5.

[78] D. Kuiaski, H. V. Neto, G. Borba, and H. Gamba, "A study of the effect of illumination conditions and color spaces on skin segmentation," in *Computer Graphics and Image Processing (SIBGRAPI), 2009 XXII Brazilian Symposium on*, 2009, pp. 245-252.

[79] D. J. Sawicki and W. Miziolek, "Human colour skin detection in CMYK colour space," *IET Image Processing*, vol. 9, pp. 751-757, 2015.

[80] F. E. Sandnes, L. Neyse, and Y.-P. Huang, "Simple and practical skin detection with static RGB-color lookup tables: A visualization-based study," in *Systems, Man, and Cybernetics (SMC), 2016 IEEE International Conference on*, 2016, pp. 002370-002375.

[81] R. M. Jusoh, N. Hamzah, M. H. Marhaban, and N. M. A. Alias, "Skin detection based on thresholding in RGB and hue component," in *Industrial Electronics & Applications (ISIEA), 2010 IEEE Symposium on*, 2010, pp. 515-517.

[82] N. Nadimi, Z. Azimifar, and E. Ahmadi, "Skin detection using a statistical color spaces fusion model," in *Machine Vision and Image Processing (MVIP), 2013 8th Iranian Conference on*, 2013, pp. 270-274.

[83] Q. Wu, R. Cai, L. Fan, C. Ruan, and G. Leng, "Skin detection using color processing mechanism inspired by the visual system," 2012.

[84] P. Ng and C.-M. Pun, "Skin segmentation based on human face illumination feature," in *Proceedings of the The 2012 IEEE/WIC/ACM International Joint Conferences on Web Intelligence and Intelligent Agent Technology-Volume 03*, 2012, pp. 373-377.

[85] S. A. Naji, R. Zainuddin, and H. A. Jalab, "Skin segmentation based on multi pixel color clustering models," *Digital Signal Processing*, vol. 22, pp. 933-940, 2012.

[86] M. Abdullah-Al-Wadud and O. Chae, "Skin segmentation using color distance map and water-flow property," in *Information Assurance and Security, 2008. ISIAS'08. Fourth International Conference on*, 2008, pp. 83-88.

[87] A. Sarkar, A. L. Abbott, and Z. Doerzaph, "Universal Skin Detection Without Color Information," in *Applications of Computer Vision (WACV), 2017 IEEE Winter Conference on*, 2017, pp. 20-28.

[88] M. A. Rahman, I. K. E. Purnama, and M. H. Purnomo, "Simple method of human skin detection using HSV and YCbCr color spaces," in *Intelligent Autonomous Agents, Networks and Systems (INAGENTSYS), 2014 IEEE International Conference on*, 2014, pp. 58-61.

[89] M. M. Aznaveh, H. Mirzaei, E. Roshan, and M. Saraee, "A new color based method for skin detection using RGB vector space," in *Human System Interactions, 2008 Conference on*, 2008, pp. 932-935.

[90] N. Brancati, G. De Pietro, M. Frucci, and L. Gallo, "Human skin detection through correlation rules between the YCb and YCr subspaces based on dynamic color clustering," *Computer Vision and Image Understanding*, vol. 155, pp. 33-42, 2017.

[91] S. Kolkur, D. Kalbande, P. Shimpi, C. Bapat, and J. Jatakia, "Human skin detection using RGB, HSV and YCbCr color models," *arXiv preprint arXiv:1708.02694*, 2017.

[92] M. Dong, L. Yin, J. Guo, W. Deng, and W. Xu, "Integrative labeling based statistical color models with application to skin detection," in *Image Processing (ICIP), 2012 19th IEEE International Conference on*, 2012, pp. 2369-2372.

[93] J. A. Tomaschitz and J. Facon, "Skin detection applied to multi-racial images," in *Systems, Signals and Image Processing, 2009. IWSSIP 2009. 16th International Conference on*, 2009, pp. 1-3.

[94] P. Yogarajah, J. Condell, K. Curran, P. McKevitt, and A. Cheddad, "A dynamic threshold approach for skin tone detection in colour images," *International Journal of Biometrics*, vol. 4, pp. 38-55, 2011.

[95] Y. Luo and Y.-P. Guan, "Adaptive skin detection using face location and facial structure estimation," *IET Computer Vision*, vol. 11, pp. 550-559, 2017.

[96] B. K. Chakraborty, M. Bhuyan, and S. Kumar, "Combining image and global pixel distribution model for skin colour segmentation," *Pattern Recognition Letters*, vol. 88, pp. 33-40, 2017.

[97] S. Bilal, R. Akmeliawati, M. J. E. Salami, and A. A. Shafie, "Dynamic approach for real-time skin detection," *Journal of Real-Time Image Processing*, vol. 10, pp. 371-385, 2015.

[98] M. Z. Osman, M. A. Maarof, and M. F. Rohani, "Improved skin detection based on dynamic threshold using multi-colour space," in *Biometrics and Security Technologies (ISBAST), 2014 International Symposium on*, 2014, pp. 29-34.

[99] H.-M. Sun, "Skin detection for single images using dynamic skin color modeling," *Pattern recognition*, vol. 43, pp. 1413-1420, 2010.

[100] M. R. Mahmoodi, S. M. Sayedi, and F. Karimi, "Color-based skin segmentation in videos using a multi-step spatial method," *Multimedia Tools and Applications*, vol. 76, pp. 9785-9801, 2017.

[101] M. Kawulok, J. Kawulok, J. Nalepa, and M. Papiez, "Skin detection using spatial analysis with adaptive seed," in *Image Processing (ICIP), 2013 20th IEEE International Conference on*, 2013, pp. 3720-3724.

[102] M. Kawulok, J. Kawulok, and J. Nalepa, "Spatial-based skin detection using discriminative skin-presence features," *Pattern Recognition Letters*, vol. 41, pp. 3-13, 2014.

[103] R. Medeiros, J. Scharcanski, and A. Wong, "Image segmentation via multi-scale stochastic regional texture appearance models," *Computer Vision and Image Understanding*, vol. 142, pp. 23-36, 2016.

[104] R. Hettiarachchi and J. F. Peters, "Multi-manifold-based skin classifier on feature space Voronoï regions for skin segmentation," *Journal of Visual Communication and Image Representation*, vol. 41, pp. 123-139, 2016.

[105] L. Huang, W. Ji, Z. Wei, B.-W. Chen, C. C. Yan, J. Nie, *et al.*, "Robust skin detection in real-world images," *Journal of Visual Communication and Image Representation*, vol. 29, pp. 147-152, 2015.

[106] Z. Jiang, M. Yao, and W. Jiang, "Skin detection using color, texture and space information," in *Fuzzy Systems and Knowledge Discovery, 2007. FSKD 2007. Fourth International Conference on*, 2007, pp. 366-370.

[107] B. Zafarifar, A. Martinière, and P. H. de With, "Improved skin segmentation for TV image enhancement, using color and texture features," in *Consumer Electronics (ICCE), 2010 Digest of Technical Papers International Conference on*, 2010, pp. 373-374.

[108] B. Zafarifar and T. Van Den Kerkhof, "Texture-adaptive skin detection for TV and its real-time implementation on DSP and FPGA," *IEEE Transactions on Consumer Electronics*, vol. 58, 2012.

[109] J. Zhang, Z. Zhuang, and W. Geng, "Local pixel wise skin detection algorithm based on FPGA," in *Information Technology and Artificial Intelligence Conference (ITAIC), 2014 IEEE 7th Joint International*, 2014, pp. 262-265.

[110] G. Chen, J. Li, J. Zeng, B. Wang, and G. Lu, "Optimizing human model reconstruction from RGB-D images based on skin detection," *Virtual Reality*, vol. 20, pp. 159-172, 2016.

[111] J. Geng, Z. Miao, Q. Liang, and S. Wang, "Rotation invariant ellipsoid projection for domain transfer in human skin detection," in *Multimedia Signal Processing (MMSP), 2015 IEEE 17th International Workshop on*, 2015, pp. 1-5.

[112] T. Hao-Kui and F. Zhi-Quan, "Skin Recognition Based on Color Image Enhance Algorithm," in *Computer Science & Service System (CSSS), 2012 International Conference on*, 2012, pp. 2281-2284.

[113] S. El Fkihi, M. Daoudi, and D. Aboutajdine, "The mixture of K-Optimal-Spanning-Trees based probability approximation: Application to skin detection," *Image and Vision Computing*, vol. 26, pp. 1574-1590, 2008.

[114] P. Cheng, M. Zhang, and J. Zhou, "Automatic Image Grading Based on Skin Segmentation," in *Intelligent Human-Machine Systems and Cybernetics (IHMSC), 2011 International Conference on*, 2011, pp. 39-42.

[115] H. Jati and D. D. Dominic, "Human skin detection using defined skin region," in *Information Technology, 2008. ITSim 2008. International Symposium on*, 2008, pp. 1-4.

[116] W. Song, D. Wu, Y. Xi, Y. W. Park, and K. Cho, "Motion-based skin region of interest detection with a real-time connected component labeling algorithm," *Multimedia Tools and Applications*, vol. 76, pp. 11199-11214, 2017.

[117] M. R. Mahmoodi, S. M. Sayedi, F. Karimi, Z. Fahimi, V. Rezai, and Z. Mannani, "SDD: A skin detection dataset for training and assessment of human skin classifiers," in *Knowledge-Based Engineering and Innovation (KBEI), 2015 2nd International Conference on*, 2015, pp. 71-77.

[118] S. Khalid, U. Jamil, K. Saleem, M. U. Akram, W. Manzoor, W. Ahmed, *et al.*, "Segmentation of skin lesion using Cohen–Daubechies–Feauveau biorthogonal wavelet," *SpringerPlus*, vol. 5, p. 1603, 2016.

[119] B. T. Teodoro, J. Bernardes, and L. A. Digiampietri, "Skin Color Segmentation and Levenshtein Distance Recognition of BSL Signs in Video," in *2017 30th SIBGRAPI Conference on Graphics, Patterns and Images (SIBGRAPI)*, 2017, pp. 95-102.

[120] K. Kidono, Y. Kanzawa, T. Tagawa, Y. Kojima, and T. Naito, "Skin segmentation using a multiband camera for early pedestrian detection," in *Intelligent Vehicles Symposium (IV), 2013 IEEE*, 2013, pp. 346-351.

[121] S. Bobbia, R. Macwan, Y. Benezeth, A. Mansouri, and J. Dubois, "Unsupervised skin tissue segmentation for remote photoplethysmography," *Pattern Recognition Letters*, 2017.

[122] H. Bouirouga, S. E. Lrit, A. Jilbab, and D. Aboutajdine, "Recognition of adult video by combining skin detection features with motion information," in *Multimedia Computing and Systems (ICMCS), 2011 International Conference on*, 2011, pp. 1-5.

[123] S. Yadav and N. Nain, "Fast face detection based on skin segmentation and facial features," in *Signal-Image Technology & Internet-Based Systems (SITIS), 2015 11th International Conference on*, 2015, pp. 663-668.

[124] K. H. B. Ghazali, J. Ma, and R. Xiao, "An innovative face detection based on YCgCr color space," *Physics Procedia*, vol. 25, pp. 2116-2124, 2012.

[125] Y. Jie, L. Xufeng, Z. Yitan, and Z. Zhonglong, "A face detection and recognition system in color image series," *Mathematics and Computers in Simulation*, vol. 77, pp. 531-539, 2008.

[126] B. Muhammad and S. A. R. Abu-Bakar, "A hybrid skin color detection using HSV and YCgCr color space for face detection," in *Signal and Image Processing Applications (ICSIPA), 2015 IEEE International Conference on*, 2015, pp. 95-98.

[127] M. Heshmat, M. Girgis, W. M. Abd-Elhafiez, and S. Elaw, "An efficient scheme for face detection based on contours and feature skin recognition," in *Computer Engineering & Systems (ICCES), 2015 Tenth International Conference on*, 2015, pp. 255-260.

[128] G. Liu and Z. Shi, "Embedded implementation of real-time skin detection system," in *Transportation, Mechanical, and Electrical Engineering (TMEE), 2011 International Conference on*, 2011, pp. 2463-2466.

[129] F. Z. Chelali, N. Cherabit, and A. Djeradi, "Face recognition system using skin detection in RGB and YCbCr color space," in *Web Applications and Networking (WSWAN), 2015 2nd World Symposium on*, 2015, pp. 1-7.

[130] Y. Ban, S.-K. Kim, S. Kim, K.-A. Toh, and S. Lee, "Face detection based on skin color likelihood," *Pattern Recognition*, vol. 47, pp. 1573-1585, 2014.

[131] M. Subasic, S. Loncaric, and J. Birchbauer, "Expert system segmentation of face images," *Expert Systems with Applications*, vol. 36, pp. 4497-4507, 2009.

[132] S. D. F. Hilado, E. P. Dadios, and R. C. Gustilo, "Face detection using neural networks with skin segmentation," in *Cybernetics and Intelligent Systems (CIS), 2011 IEEE 5th International Conference on*, 2011, pp. 261-265.

[133] Y. C. See, N. M. Noor, and A. C. Lai, "Hybrid face detection with skin segmentation and edge detection," in *Signal and Image Processing Applications (ICSIPA), 2013 IEEE International Conference on*, 2013, pp. 406-411.

[134] T. R. Babu, K. Mahalakshmi, and S. Subrahmanya, "Optimal skin detection for face localization using genetic algorithms," in *Hybrid Intelligent Systems (HIS), 2011 11th International Conference on*, 2011, pp. 668-673.

[135] O. Lucena, Í. d. P. Oliveira, L. Veloso, and E. Pereira, "Improving Face Detection Performance by Skin Detection Post-Processing," in *Graphics, Patterns and Images (SIBGRAPI), 2017 30th SIBGRAPI Conference on*, 2017, pp. 300-307.

[136] C.-F. Juang and S.-J. Shiu, "Using self-organizing fuzzy network with support vector learning for face detection in color images," *Neurocomputing*, vol. 71, pp. 3409-3420, 2008.

[137] M. Sattiraju, M. V. Manikandan, K. Manikantan, and S. Ramachandran, "Adaptive BPSO based feature selection and skin detection based background removal for enhanced face recognition," in *Computer Vision, Pattern Recognition, Image Processing and Graphics (NCVPRIPG), 2013 Fourth National Conference on*, 2013, pp. 1-4.

[138] H. Steiner, S. Sporrer, A. Kolb, and N. Jung, "Design of an active multispectral SWIR camera system for skin detection and face verification," *Journal of Sensors*, vol. 2016, 2016.

[139] E. Stergiopoulou, K. Sgouropoulos, N. Nikolaou, N. Papamarkos, and N. Mitianoudis, "Real time hand detection in a complex background," *Engineering Applications of Artificial Intelligence*, vol. 35, pp. 54-70, 2014.

[140] H. Ham, F. Jingga, D. Suryani, and I. A. Siswanto, "Unsupervised Hand Detection in Class Room Using Combination of Skin Detection and Hough Transform," *Procedia Computer Science*, vol. 116, pp. 516-522, 2017.

[141] R. R. Porle, A. Chekima, F. Wong, and G. Sainarayanan, "Wavelet-based skin segmentation for detecting occluded arms in human body pose modelling system," in *Intelligent and Advanced Systems, 2007. ICIAS 2007. International Conference on*, 2007, pp. 764-769.

[142] M. Ferrer, A. Morales, C. Travieso, and J. Alonso, "Wide band spectroscopic skin detection for contactless hand biometrics," *IET computer vision*, vol. 6, pp. 415-424, 2012.

[143] H.-k. Tang and Z.-q. Feng, "Hand's skin detection based on ellipse clustering," in *Computer Science and Computational Technology, 2008. ISCSCT'08. International Symposium on*, 2008, pp. 758-761.

[144] E. Thabet, F. Khalid, P. Suhaiza Sulaiman, and R. Yaakob, "Low Cost Skin Segmentation Scheme in Videos Using Two Alternative Methods for Dynamic Hand Gesture Detection Method," *Advances in Multimedia*, vol. 2017, 2017.

[145] A. Chowdhury and S. S. Tripathy, "Human skin detection and face recognition using fuzzy logic and eigenface," in *Green Computing Communication and Electrical Engineering (ICGCCEE), 2014 International Conference on*, 2014, pp. 1-4.

[146] M. R. Ganesh, R. Krishna, K. Manikantan, and S. Ramachandran, "Entropy based Binary Particle Swarm Optimization and classification for ear detection," *Engineering Applications of Artificial Intelligence*, vol. 27, pp. 115-128, 2014.

[147] P. L. Galdámez, A. G. Arrieta, and M. R. Ramón, "A small look at the ear recognition process using a hybrid

approach," *Journal of Applied Logic*, vol. 17, pp. 4-13, 2016.

[148] C. P. Huynh and A. Robles-Kelly, "Hyperspectral imaging for skin recognition and biometrics," in *Image Processing (ICIP), 2010 17th IEEE International Conference on*, 2010, pp. 2325-2328.

[149] B. M. Nair, J. Foytik, R. Tompkins, Y. Diskin, T. Aspiras, and V. Asari, "Multi-pose face recognition and tracking system," *Procedia Computer Science*, vol. 6, pp. 381-386, 2011.

[150] M. R. Nair, D. Deepa, and R. Aneesh, "Real time human tracking system for defense application," in *Next Generation Intelligent Systems (ICNGIS), International Conference on*, 2016, pp. 1-6.

[151] Y.-H. Chen, K.-T. Hu, and S.-J. Ruan, "Statistical skin color detection method without color transformation for real-time surveillance systems," *Engineering Applications of Artificial Intelligence*, vol. 25, pp. 1331-1337, 2012.

[152] S. Chaichulee, M. Villarroel, J. Jorge, C. Arteta, G. Green, K. McCormick, *et al.*, "Multi-task convolutional neural network for patient detection and skin segmentation in continuous non-contact vital sign monitoring," in *Automatic Face & Gesture Recognition (FG 2017), 2017 12th IEEE International Conference on*, 2017, pp. 266-272.

[153] J. Han, G. Awad, and A. Sutherland, "Automatic skin segmentation and tracking in sign language recognition," *IET Computer Vision*, vol. 3, pp. 24-35, 2009.

[154] J. C. Sanmiguel and S. Suja, "Skin detection by dual maximization of detectors agreement for video monitoring," *Pattern Recognition Letters*, vol. 34, pp. 2102-2109, 2013.

[155] H.-k. Tang and Z.-q. Feng, "Skin segmentation based on double-models," in *Intelligent Information Technology and Security Informatics (IITSI), 2010 Third International Symposium on*, 2010, pp. 3-7.

[156] P. Duangphasuk and W. Kurutach, "Tattoo skin detection and segmentation using image negative method," in *Communications and Information Technologies (ISCIT), 2013 13th International Symposium on*, 2013, pp. 354-359.

[157] M. H. Shirali-Shahreza and S. Shirali-Shahreza, "Reducing Motion Estimation Time with Skin Detection," in *Imaging Systems and Techniques, 2009. IST'09. IEEE International Workshop on*, 2009, pp. 67-70.

[158] Y. George, M. Aldeen, and R. Garnavi, "Pixel-based skin segmentation in psoriasis images," in *Engineering in Medicine and Biology Society (EMBC), 2016 IEEE 38th Annual International Conference of the*, 2016, pp. 1352-1356.

[159] A. Pennisi, D. D. Bloisi, D. Nardi, A. R. Giampetruzzi, C. Mondino, and A. Facchiano, "Skin lesion image segmentation using Delaunay Triangulation for melanoma detection," *Computerized Medical Imaging and Graphics*, vol. 52, pp. 89-103, 2016.

[160] F. Saxen and A. Al-Hamadi, "Color-based skin segmentation: An evaluation of the state of the art," in *ICIP*, 2014, pp. 4467-4471.

[161] B. Zafarifar and E. B. Bellers, "Application and evaluation of texture-adaptive skin detection in TV image enhancement," in *Consumer Electronics (ICCE), 2013 IEEE International Conference on*, 2013, pp. 88-91.

[162] E. Ahmadi, F. Garmsirian, and Z. Azimifar, "A discriminative fusion framework for skin detection," in *Artificial Intelligence and Signal Processing (AISP), 2012 16th CSI International Symposium on*, 2012, pp. 542-545.

[163] A. Soria-Frisch, R. Verschae, and A. Olano, "Fuzzy fusion for skin detection," *Fuzzy Sets and Systems*, vol. 158, pp. 325-336, 2007.

[164] L. Huang, T. Xia, Y. Zhang, and S. Lin, "Human skin detection in images by MSER analysis," in *Image Processing (ICIP), 2011 18th IEEE International Conference on*, 2011, pp. 1257-1260.

[165] M. M. Oghaz, M. A. Maarof, A. Zainal, M. F. Rohani, and S. H. Yaghoubyan, "A hybrid color space for skin detection using genetic algorithm heuristic search and principal component analysis technique," *PloS one*, vol. 10, p. e0134828, 2015.

[166] J.-J. Yu and S.-W. Han, "Skin detection for adult image identification," in *Advanced Communication Technology (ICACT), 2014 16th International Conference on*, 2014, pp. 645-648.

[167] B. K. Chakraborty, M. Bhuyan, and S. Kumar, "Fusion-based skin detection using image distribution model," in *Proceedings of the Tenth Indian Conference on Computer Vision, Graphics and Image Processing*, 2016, p. 67.

[168] V. Powar, A. Kulkami, R. Lokare, and A. Lonkar, "Skin detection for forensic investigation," in *Computer Communication and Informatics (ICCCI), 2013 International Conference on*, 2013, pp. 1-4.

[169] J. M. Chaves-González, M. A. Vega-Rodríguez, J. A. Gómez-Pulido, and J. M. Sánchez-Pérez, "Detecting skin in face recognition systems: A colour spaces study," *Digital Signal Processing*, vol. 20, pp. 806-823, 2010.

[170] B. Li, X. Xue, and J. Fan, "A robust incremental learning framework for accurate skin region segmentation in color images," *Pattern Recognition*, vol. 40, pp. 3621-3632, 2007.

[171] N. K. Al Abbadi, N. S. Dahir, M. A. Al-Dhalimi, and H. Restom, "Psoriasis Detection Using Skin Color and Texture Features 1," 2010.

[172] O. Marques, *Practical image and video processing using MATLAB*: John Wiley & Sons, 2011.

[173] Y. Zhang, B. Du, and L. Zhang, "A sparse representation-based binary hypothesis model for target detection in hyperspectral images," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 53, pp. 1346-1354, 2015.

[174] P. Corcoran, I. Barcovschi, E. Steinberg, Y. Prilutsky, and P. Bigioi, "Digital image processing using face detection and skin tone information," ed: Google Patents, 2010.

[175] S. Naji, H. A. Jalab, and S. A. Kareem, "A survey on skin detection in colored images," *Artificial Intelligence Review*, November 17 2018.