I J C T A, 8(5), 2015, pp. 2145-2152

Recent Advances in Face Detection Techniques: A Survey

M. V. Ganeswara Rao*, Rajesh K. Panakala and A. Mallikarjuna Prasad*****

Abstract: Human face detection has been one of the important research areas in digital image processing for Human Computer Interface (HCI). The automation of various processes plays very vital role in addressing the security issues. These processes require a computer program which verifies the presence of human face in an image. Until the recent past power consumption and requirement of more computing power were the bottle necks to use image processing for automation, with development of FPGA and embedded processor technologies, researchers are developing advanced image processing algorithms for more efficient and high performance real time automation systems. Human face detection is a computational tool that finds the presence and location of a face in a given image. In the beginning face detection techniques are based on identification of anterior human face, however in recent times advanced techniques like feature invariant techniques are enabling us to detect face in the existence of pose, structural objects or facial expressions etc. In this paper we presented a survey of various face detection techniques with focus on face detection using skin tone, which is one of the invariant features of the human face.

Keywords: Human computer interaction; VLSI;Processor Technology; Face detection; Automation

I. INTRODUCTION

The human face detection plays a vital role in extensive range of applications in image processing such as, face recognition, personal identity, Content Base Image Retrieval (CBIR) etc. According to Keren, M. Osadchy, and C. Gotsmanthe aim of human face detection is to find whether an human face is present in the given image or not and if present, further find its location and size. [1]

The difficulties with the face detection are associated with pose, presence of structural objects, facial expressions, imaging conditions, Occlusion, and Image orientation. Figure 1(a)-(d) shows images with different poses, illumination, facial expression and occlusion respectively. According to Yang and

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

Figure 1: Images with (a) Different pose. (b) Different illumination. (c) Different facial expression. (d) Different Occlusions

* Research schelor JNUK, Kakinada,Andhra pradesh, India. *Email: mgr_ganesh@svecw.edu.in*

** PVP Siddhartha Institute of Technology,Vijayawada, AP, India. *Email: rkpanakala@gmail.com*

*** JNTU college of Engineering, Kakinada, AP, India. *Email: a_malli65@gmail.com*

Kriegman(2002) et. Al. single image face detection algorithms are classified into four distinct categories based on feature identified to detect human face [1]. These categories are as follows.

1.1. Knowledge Based methods

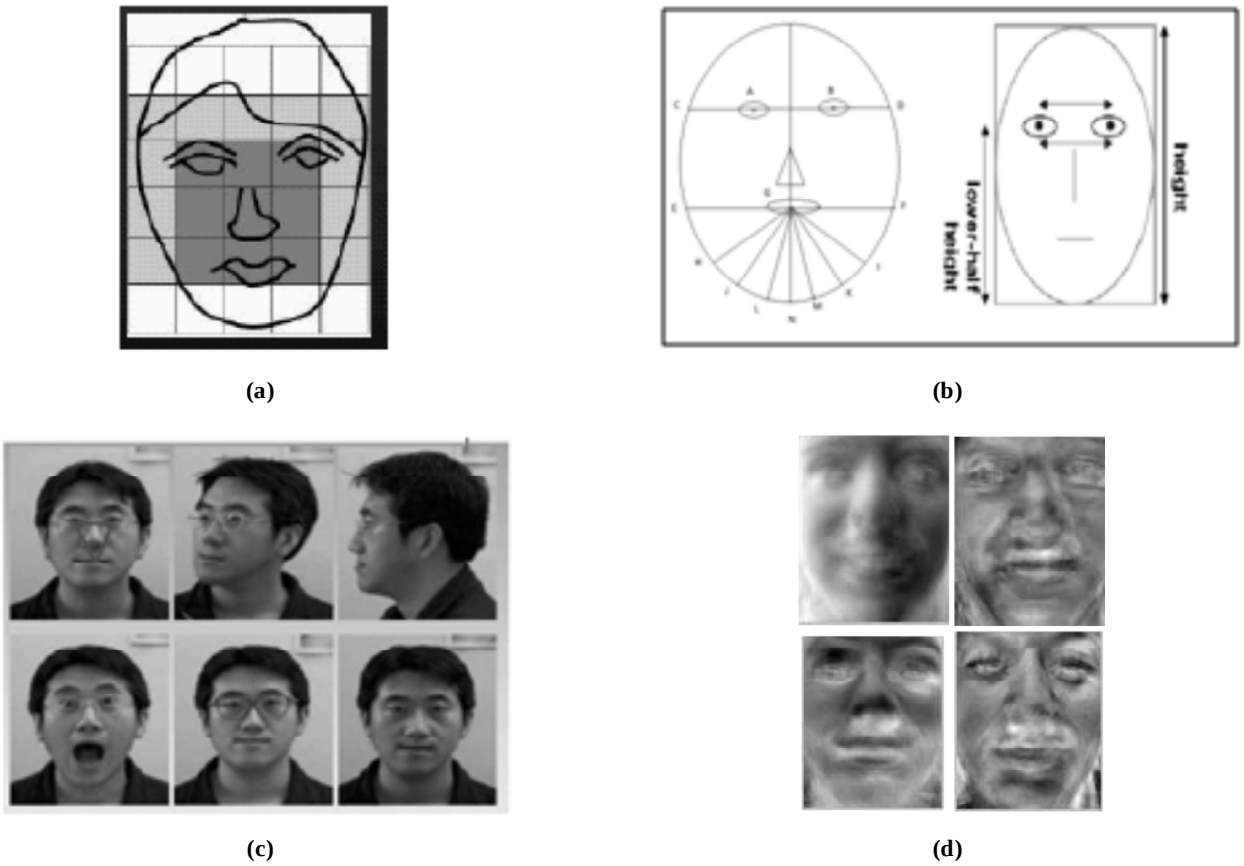
These methods make use of human awareness about the face and typically what a face comprise, which are used to form common rules to define the relation between facial features. There are two issues associated with this, first one is to find correct technique to convert human knowledge about face into well-defined rules, and second one is to identifying face candidates based on these rules. These techniques are not successful under varying head pose. A typical face, which is used in these methods is shown in Figure.2 (a).

1.2. Feature invarient methods

In these approaches structural feature are extracted from images, which are invariant even when view point, pose and diversify lighting conditions. The various structural features are facial local features, textures, shape and color. On the other hand local features such as mouth, nose, and eyes are extracted using various method such as edge detector derivative filters, multi resolution, etc. Figure.2 (b) shows some of the invariant features of human face. After feature extraction, statistical models are formed to determine relationships among facial features and finally decide the existence of face in an image.

1.3. Template matching method

In these methods numerousregular patterns of a face are stored in the data base and theses patterns are correlated with input image to detect the faces in the image. Figure.2(c) shows examples face patterns.



(a) **(b)**

(c) **(d)**

Figure 2: (a) Typical face for knowledge based methods (b) Invariant features of face (c) Example of templates used in template matching method (d) Eigen faces

These methods are sensitive to scale, pose and shape. To avoid these drawbacks deformable temple matching methods are proposed, in which feature of interest, for example nose, is described by deformable template. An energy function is formed, which links the valleys, hills and edges in the image based on the property of templates. The template then operated on image by changing parameter value to reduce energy function value to minimum, which leads to deformation of template to find the top fit.

1.4. APPEARANCE BASED METHODS

In contrast with previous template matching methods these methods are not based on predefined template,instead these appearance based methods use large image database, which consist of numerous images of faces with different variation. Most widely used methods to detect faces, under this category areLDA, eigenfaces, Support Vector Machine (SVM)and Neural Networks.Figure.2(d) shows the Eigen faces.

Table 1Categorize various the algorithms proposed by the researchers to detect the faces in images, under four categories

Table 1
Categeration of Methods for Human Face Detection in single Image (2010)

Method	*Contribution of Work*
Knowledge based	*Multi resolution rule based method*
Feature invariant	
• Facial features	Grouping of edge
• Texture	Space Gray –level Dependence matrix(SGLD) of face patterns
• Skin tone(colour)	Mixture of Gaussian
• Mixed Features(multiple Features)	Integration of skin colour, size and shape
Template matching	
• Predefined face templates	Shape template
• Deformable templates	Active shape model(ASM) Antiface
Appearance based methods	
• Eigen face	Eigen vector decomposition and clustering
• Distribution based	Gaussian distribution and multilayer perception
• Neural network	Ensembles of neural networks and arbitration Constrain generative Model
• Support Vector Machine(SVM)	SVM with polynomial kernel SVM speed up Resolution based SVM SVM Multi view face detection
• Naïve bayes Classifier	Joint statistics of local appearance and position
Hidden Markov Model (HMM)	High order statistics with HMM
• Information Theoretical Approach	Kullback relative information

2. ADVANCED FACE DETECTION TECHNIQUE

Several Face detection techniques proposed up to 2010 are summarized in the above section and several advanced techniques are proposed by the researchers to detect the face which are less sensitive to the illumination change, high speed performance and high accurate. In this section these advanced algorithms are summarized.

2.1. Face Detection based on Gradient Magnitude Images and a Geometrical Face Model

Kang-Seo Park, Rae-Hong Park, et. al. reported a human face detection algorithm, which is based on the 3 × 3 block rank patterns of gradient magnitude images and a geometrical face or not[2]. Finally, the face,

if any, is detected by using a geometrical face model. The 3 × 3 block rank patterns are used to approximately grade whether the detected face candidate area contains a human face or not.

2.2. PCA Based Human Face Detection

Padma PPaul and Marina G et. al. proposed a PCA (Principal Component Analysis) based automatic human face detection, which very important stage in autonomous systems. In this, geometric structures are modeled to detect face in images [3]. This approach enhances the face detection performance and reduces the search portion of the image. Several researches proved that, Skin colour modeling is most efficient method for detecting face clusters in images and video frames. However, selecting right feature is key to achieve good detection rate in any method.

2.3. Detection of Facial Features in Frontal Face Image

Anima Majumder and L. Behera and et. al. developed different approach to detect the facial features for fully Automatic detection [4]. In this technique the location of mouth, nose and eyes are estimated using basic concepts of facial geometry. This technique estimates the detection area for facial features like nose, eye and mouth to improve the detection precision and detection rate significantly. Proposed method uses Hue plane of the HSV color model to detecting eye pupil from the estimated eye region.

2.4. A hybrid face detection technique (Face Mask Pre-filtering and Adaboosting)

Jing-Ming Guo and Chen-Chi Lin et. al. reported "a two-stage hybrid face detection scheme using Probability-based Face Mask Pre-Filtering (PFMPF) and the Pixel- Based Hierarchical-Feature Adaboosting (PBHFA)[5]" The two stages hybrid technique shorten the training time than that of other face detection technique and accordingly decrease the computation density in face-detection systems. The authors also reported that, proposed algorithm successfully eliminated around 8 non-faces out of 10 faces in an image in first stage and the residual tiny number of face candidates are eliminated with a single strong PBHF Adaboost classifier in the second stage. In spite of hybrid two stage face detection algorithms are used for face-detection tasks, the computational demand is still lesser than that of the traditional Adaboosting method (using integral image).

2.5. Cascade Detector based on Haar feature

Ning Jiang and Wenxin Yu al. reported a new Cascade Detector to improve the performance based on Haar feature. In this firstly, a new feature called Separate Haar Feature for cascade detector is described. Next, they presented a new technique in cascade detection to enhance the detection performance of system. This approach adds important contributions to face detection. In this a don't–care space is added among the rectangles of Haar feature by defining new haar feature called "Separate Haar Feature". Subsequently the algorithm is proposed to find the best space for don't- care area [6]". This algorithm not only makes the face detection but also improve the detection rate

2.6. Face detection based on a mixtures of trees witha shared pool of parts

Xiangxin Zhu & Deva Ramanan proposed a novel unified method to detect to detect face, head pose assessment and landmark estimation in the wild (uncontrolled background)[7]. In this approach every facial landmark is modeled and used global mixtures to capture topological changes due to view point change. This approach proved that proposed tree structure modeling is very successful to confine global deformations in images under process.

2.7. Detection of feces using image reterival and discriminative learning.

Xiaohui Shen1and Zhe Lin2 et. al. Proposed tough prototype based face detector, which combine image retrieval as well as discriminative based learning [8]. In this approach huge database of images with faces

identified with rectangles and facial land mark positions are collected, after that a basic decision classifiers are trained with database collected. Later these classifiers allowed cast their vote on every face image in collected data base using efficient image retrieval technique. Consequently, faces in the images are detection effortlessly without complex window sliding technique. Proposed method not only detects face and also provides information about alignment of face in the image.

H. Joint Cascade Face Detection and Alignment

It observed that, combined detection of face detection and alignment, aligned face shapes in images provide effective features for face detection. Based on this observation Dong Chen and Shaoqing Ren et. Aal.Proposeda new technique to detect faces, which execute two tasks jointly in a single structure and this approach greatly enhance the detection rate and detection capability[9]. Authors also reported that this detector needs only 15MB memory space which is very low compared to other methods and it also suitable for real world applications such as mobile phones

3. FEATURE INVARIANT METHODS

Unlike other method, in this approach researchers are trying hard to discover invariant (unchanged) features of human face to detection face in images. The human can easily detect human faces in different head orientation, poses and lighting variations etc. therefore, certainly there must be a invariant feature or properties which are unaffected under these variables. Various approaches have been reported to detect these invariant features and after that to detect the presence of human face in the image. “Facial features such as eyebrows, eyes, nose, mouth, and hair line are commonly extracted using edge detectors[1]” apart from above features human skin tone (colour)is one of the most researched area in face detection and it has proven that colour is most effective invariant feature of human face in many applications.

H.P. Graf, T. Chenand E. Petajan et. Al. reported that “Many researcher studies showing that, even though humans have diversified skin color, major variation largely lies in their intensity instead of chrominance [10]”. Numerous color models have been used to classify a pixel as face or non face pixel which include RGB, Normalized RGB, YCrCb, YIQ,YES, CIE XYZ and CIE LUV.

4. Color spaces for face detection

All though many digital image acquisition devices uses RGB colour model to capture images and many display devices are using R, G, and B components to display images on monitor, the RGB colour space is converted into different colour spaces due to high correlation between colour components and based on application. Some researchers also reported that, RGB colour model is not efficient in face recognition systems. Therefore, it is necessary to find a colour space, which offers less correlation between its colour components. This intern accelerates the face classification performance [11].Here, we present efficient color spaces for face detection in digital images.

4.1. HSV colour space

HSV colour space is most familiar colour pace that explains human perception in real sense. The colours in this model are defined by Hue (H), Saturation (S), and Value (V). (see Fig. 3 (a) to (d)).

$$H = \begin{cases} \alpha & \text{if } B \le G \\ 360_{-\alpha} & \text{if } B > G \end{cases} \quad (1)$$

$$S = 1 - \frac{1}{(R+G+B)}\left[\min(R,G,B)\right] \quad (2)$$

$$V = max(R, G, B) \tag{3}$$

$$\alpha = \cos^{-1}\left\{\frac{0.5\left[(R-G)+(R-B)\right]}{\sqrt{\left[(R-G)^2\right]+(R-B)(G-B)}}\right\} \tag{4}$$

B. YCrCb Color Model

As discussed in the previous section several color space are utilized to represent color and many methods have been developed to build a human skin tone model. The simplest way is to define a region of skin tone pixel using Cr and Cb values [12], unlike RGB color space Y, Crand Cb components uncorrelated (see Fig. 3 (e) to (h)).

In this model *Y* represent luminance and *Cr* and *Cb* are non negation chrominance values, The chrominance values provides easy ways to segment skin fraction of image compared to RGB & HSV model. Equations (5) & (6) are used to extract skin fraction from image.

$$\left.\begin{array}{c} 140 \Leftarrow Cr \Leftarrow 165 \\ 140 \Leftarrow Cb \Leftarrow 195 \end{array}\right\} \tag{5}$$

$$\left.\begin{array}{c} [\text{Cr, Cb}] = \text{Skin tone pixel if. } Cr1 \le Cr \le Cr2 \\ \text{and} \\ Cb1 \le Cb \le Cb2 \\ = \text{Non skin tone pixel} \quad \text{Otherwise} \end{array}\right\} \tag{6}$$

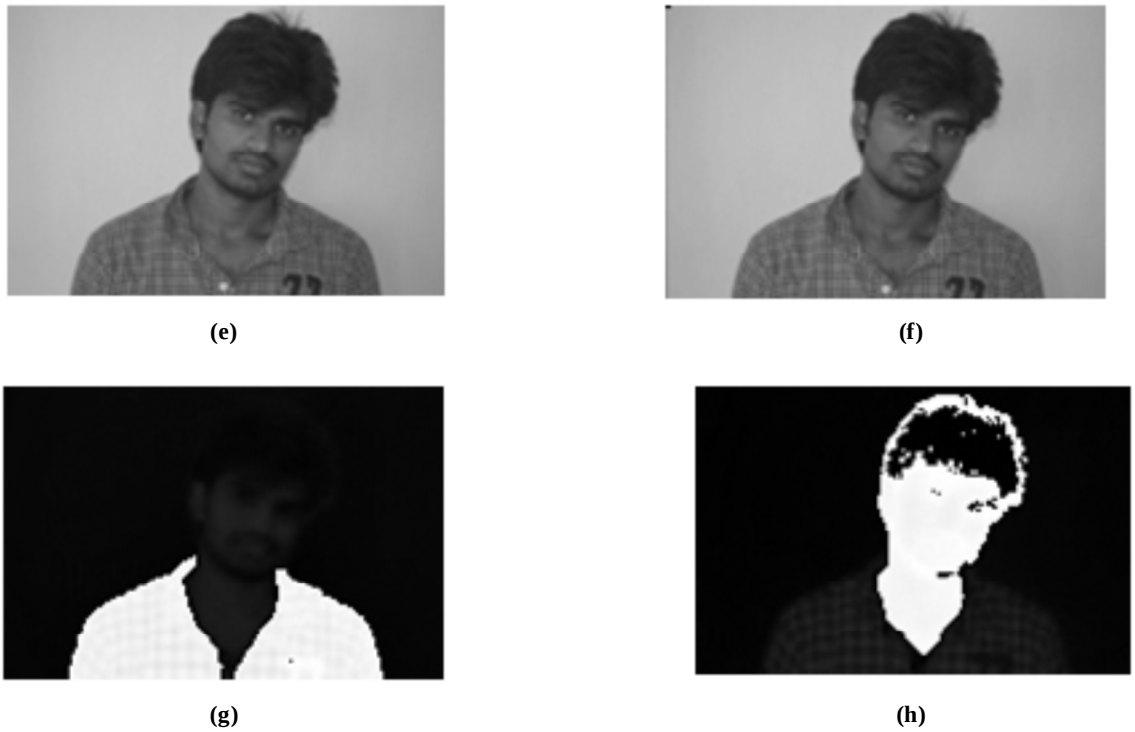
However, images are represented in RGB model, these RGB values are converted into YCrCb model using following questions

(a)

(b)

(c)

(d)



(e) **(f)**

(g) **(h)**

Figure3: a) RGB Image. b) Hue component (H) c) Saturation component (S) d) value component (V) e) RGB Image f) Luminance Component (Y). g) Red chrominance Component (Cr) h) Blue chrominance Component (Cb).

5. CONCLUSION

This paper provides a review on basic to advanced face detection technique and brief report on color models however, more emphasis on HSV and YCrCb color models. The face detection is the particular class of object detection which places important role in automation of process. We find that there no uniform and systematic performance evolution hence it is very difficult to judge the performance of algorithms in various platforms such as GPUs, DSPs and FPGAs. Although many face detection algorithms producing satisfactory result, still we need to develop more robust face detection systems to work under variation in illumination condition, orientation, pose, occlusion, and expression etc. It also identified that skin color is effective invariant feature of human face and very much useful in face detection. Instead of searching for entire image, first identify skin tone in the image and then detect the faces in these skin patches.

Performance of any face detection systems depends on face detection algorithms and platform on which these algorithms implemented. Many performance optimized face detection algorithms are proposed by the researchers. Human faces are most probably connected with other parts of the body and these parts can offer a strong indication of face. It is observed significant research has been going on context based object categorization [13] and visual tracking.

Finally during this survey we observed that researchers are working on to develop more accurate and high performance algorithms and it is also required to develop advanced platforms such as heterogeneous platforms instead of GPP and DSP based platforms.

References

[1] M H Yang, D.J. Kriegman, and N. Ahuja. " Detecting faces in images: A survey," IEEETrans.Pattern Analysis and Machine Intelligence,vol.24, no 1, pp:34-58, Jan 2002.

[2] Kang-Seo Park, Rae-Hong Park, and Young-Gon Kim,"Face Detection Using the 3×3 Block Rank Patterns of Gradient Magnitude Images and a Geometrical Face Model", in Proc. IEEE Inl. Conf. Consumer Electronics (ICCE), 2011. pp. 793-794.

[3] Padma Polash Paul and Marina Gavrilova, "PCABased Geometric Modeling for Automatic Face Detection", Int. Conf. Computational Science and Its Applications, 2011 pp. 33-38.

[4] Anima Majumder, L. Behera and Venkatesh K Subramanian, "Automatic and Robust Detection of Facial Features in Frontal Face Images", 13thInt. Conf. Modeling And Simulation,2011 pp. 331-336.

[5] Jing-Ming Guo, Chen-Chi Lin, Min-Feng Wu, Che-Hao Chang, and Hua Lee, " Face Detection Using Probability-Based Face Mask Pre-filtering and Pixel-Based Hierarchical-Feature Adaboosting", IEEE signal proc. letters, vol. 18, no. 8, pp. 447-450, August 2011.

[6] Ning Jiang, Wenxin Yu, Shaopeng Tang, Satoshi Goto,"Cascade Detector for Rapid Face Detection", IEEE 7th Int. Coll. on Sig. Processing and itsAppl., pp. 155-158, 2011.

[7] H.P. Graf, T. Chen, E. Petajan and E. Cosatto, &ldquo, " Locating Faces and Facial Parts, & rdquo", Proc. First Int. Workshop Automatic Face and Gesture Recognition, pp. 41-46, 1995.

[8] Xiaohui Shen, Zhe Lin, Jonathan Brandt, Ying Wu, "Detecting and aligning faces by image retrieval," in Proc. IEEE Conf. Computer Vision and Pattern Recognition (CVPR), 2013, pp. 3460-3467

[9] Dong Chen and Shaoqing Ren et.al. "Joint cascade face detection and alignment," Computer Vision – ECCV 2014, vol. 8694, no. 8, 2014, pp. 109-122.

[10] X Zhu and D Ramanan, "Face detection, pose estimation, and landmark localization in the wild," IEEE Proc. Computer Vision and Pattern Recognition (CVPR),2012 pp. 2879-2886.

[11] M. Yang, Y. Wu, and G. Hua, "Context-aware visual tracking," IEEE Trans. on Pattern Anal. Mach.Intell., vol. 31, no. 7, pp. 1195–1209, 2009.

[12] Seunghwan Yoo, Rae-Hong Park, Dong-Gyu Sim, "Investigation of Color Spaces for Face Recognition", in Proc. IAPR Conf. Machine Vision Applications, May 2007, pp. 106-109.

[13] C. Galleguillos and S. Belongie, "Context based object categorization: A critical survey", Computer Vision and Image Understanding (CVIU), 114:712–722, 2010.