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Evolution of Face Detection: An Explorational Study

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Abstract: Face Detection is one of the most studied, basic, important and challenging topic in computer vision literature. There has been very considerable developments in the field of detection of faces in various directions since its inception early in the area of image processing and computer vision. Initially the work intended to be focused on detecting faces from still images. With the dawn of digital videos, the interest of researcher's have shifted to detection and extraction of faces from videos. In neoteric age of CCTV's, camera phones, surveillance and supervision, a lot of work has been done in the detection and extraction of faces from digital Images and Video data. The main challenges of face detection and extraction are accuracy and speed. The main problems in fulfilment of the challenges mentioned above are low resolution, small sizes of faces, lightning, shadows, background noise in the Images and Videos, due to these factorsaccuracy is greatly affected. Additionally, also the processing of video requires working on high fps (frames per second) visual data. Which combined with the lengthy and complex detection methods affects the speed of operation.So in this paper, we haveconducted an explorational study of the evolution of face detection in the field of computer vision literature.

Index Terms: Face Detection, Principal Component Analysis (PCA), Support Vector Machines (SVMs), Surveillance Video.

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I. INTRODUCTION

Face Detection is a process of finding and locating human faces in digital visual data (Images/Videos).In 1960's government agencies in U.S.A. made a contract with Woodrow W. Bledsoe of Panoramic Research Inc. for the development of first semi-automatic face recognition system. Although the detection of face was manual as this system relied solely on the administrator to locate features such as eyes, ears, nose and mouth on the photographs. It calculated distances and ratios to a common reference point that was compared to the reference data. As it can be observed that for a large set of visual data the above process become humanly impossible, unreliable and extremely difficult so it led to the need of a system which can detect human faces with more accuracy and speed. Face detection is not a straightforward problem as it involves various challenges such as face definition, pose and scale variation, image orientation, facial expressions, facial deformities, illumination conditions, occlusions and background noises. Face detection techniques can be mainly classified into four categories: Knowledge based methods, Feature-Invariant approaches, Appearance based methods and Template matching methods [1]. Knowledge based methods use the face knowledge to encode rules based on face structure and symmetrical positions of different parts of face like eyes, nose and mouth. Now in this approach challenge is that, it is difficult to translate human knowledge into well define rule set. Feature-invariant approaches uses features such as edges, geometric shapes, facial features such as eyes, nose, ears, mouth, hairline to build a statistical model which describes their relationships. Main challenges in this approach is face deformities, illumination conditions, pose variations, facial expressions and occlusions. Appearance based methods uses features based upon appearance such as Eigenfaces – PCA, Neural Network, SVMs, and AdaBoost. Here challenges are illumination conditions, facial deformities and speed and accuracy of operation. In template matching based methods pre-defined templates

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have to be stored and correlation values with the standard patterns are computed e.g.: for the face contour, eyes, nose and mouth independently. Limitation so far is that it cannot effectively deal with variations in scale, pose and shape. Challenges are how to represent the template, how to model deformations, and efficient matching algorithms.

In video surveillance systems where task is to detect-track and recognize people as well as analyze people activities, detection and extraction of human faces is of paramount importance. It is very important to attach the identity to person being detected and tracked in the video. From the fact that human faces are used as biometric entity, human faces are generally use to attach identity to a detected human in the surveillance video. Detection of human faces in surveillance video is a challenging task on account of various factors such as illumination, low resolution of surveillance cameras, pose variations, facial expressions and face occlusions. The facial images extracted from surveillance videos are of very low resolution and not suitable to be processed by face recognition system. Therefore there is also the need to estimate and enhance the quality of extracted facial images to bridge the gap between face detection and face recognition systems.

To resolve the challenges in the area of detecting and extracting facial images from videos, many approaches have been suggested such as incorporating the motion and skin color cues [2] [3], mainly to reduce the search area. Video based techniques work on motion estimation, video object segmentation, background subtraction, skin color detection, object tracking based methods. A recent trend in face detection is to combine multiple information such as color, motion contour etc. More the number of information channels, more will be the accuracy of system but at the cost of increased detection time.

Inter frame difference technique is simple and efficient one, equation given (Eq. 1).

$$\Delta(n)_{(x,y)} = I(n)_{(x,y)} - I(n-1)_{(x,y)} \qquad \text{(Eq. 1)}$$

Where ‘n’ represents time and (x, y) the pixel location. The current frame difference $\Delta(n)_{(x,y)}$ is compared with a threshold value, in case it is more than threshold value the corresponding pixel location is set to 1 otherwise 0. In case of color image, the calculation has to be performed in each color space separately and then aggregated to create final binary image showing the moving parts. Challenges in this are noise removal, threshold estimation, fast changing background, cluttered environment etc.

Another category of techniques in motion estimation are optical flow based methods. The biggest advantage of optical flow based techniques is that they can be used even if camera is moving or background is changing too fast. As in case of cluttered environment, where background is complex and changing fast, background subtraction technique cannot be used. However optical flow technique can be used in such situations. Optical flow technique has its shortcomings as it is more complex, time consuming and has poor anti-noise performance.

Skin color based methods has also been used in color images to reduce the search area. Different efficiencies has been achieved with various color formats for skin color extraction. RGB format has been found to be best for human vision but not for skin color detection. YCbCr format has been found to give best performance for the skin color detection, as it concentrates the skin colored pixels in small intensity range. Another challenge in this area is that different cameras produce different colors of same object in scene. So there is also the need of color correction techniques to fix different color of same object in images from different sources.

II. LITRATURE SURVEY

Face detection is as old as vision in humans and as far as we could trace the automation of face detection ability started in 1964 when government agencies in U.S.A. made a contract with Woodrow W. Bledsoe of Panoramic Research Inc. (PRI) for the first semi-automatic face recognition system. During 1964 and 1965, Bledsoe along with Helen Chan and Charles Bission, worked on using the computer to recognize human faces. This project was labeled Man-Machine because the detection of face was manual as this system relied solely on the administrator to locate features such as eyes, ears, nose and mouth using agraphics tablets (GRAFACON or RAND Tablet) on the photographs. It calculated distances and ratios to a common reference point that was stored to reference data. In the recognition phase, the set of distances and ratios was compared with the corresponding distances and ratios for each photograph, yielding a relation between the photograph and the database record of reference data set. The closest records are returned. Because it is unlikely that any two pictures would match in head rotation, lean, tilt and scale (distance from the

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camera), each set of distances is normalized to represent the face in a frontal orientation. To accomplish this normalization, the program first tries to determine the tilt, the lean, and the rotation. Then using these angles, the computer undoes the effects of these transformations on the computed distances. To compute these angles, the computer must know the 3-dimensional geometry of the head, Bledsoe used a standard head derived from measurements of seven heads. But this method becomes extremely difficult and inefficient for a large set of visual data, so it led to the need of a system which can detect and recognize human faces with more accuracy and speed independently without constant human supervision. In 1970's face recognition takes another step towards automation, in 1971, A. J. Goldstein, L. D. Harmon, and A. B. Lesk used 21 specific subjective markers such as hair color and lip thickness to automate face recognition [4]. The problem with both of these early solution was that the measurements and locations were manually completed. In 1977 L. Wiskott, J. M. Fellous, N. Kruger, and Christoph Von Der Malsburg, developed a system for recognizing human faces from single images out of a large database containing one image per person [5]. Faces were represented by labeled graphs, based on a gabor wavelet transform. Image graphs of new faces were extracted by an elastic graph matching process and could be compared by a simple similarity function. In this phase information was used for accurate node positioning, object-adapted graphs were used to handle large rotations in depth, image graph extraction was based on a novel data structure, the bunch graph, which was constructed from a small set of sample image graphs. But this system also needed manual selection of fiducial points. Moving to 1980's, in year 1987 Eigenfaces technique was developed by M. Kirby and L. Sirovich [6], they showed that principle component analysis could be used on a collection of face images to form a basic set of features. These basic images, known as Eigen-pictures, could be linearly combined to reconstruct images in the original training set. In 1991, Matthew A. Turk and Alex P. Pentland expanded the results of M. Kirby and L. Sirovich, they discovered that while using the Eigenfaces technique, the residual error could be used to detect Faces in images [7]. They presented an approach to the detection and recognition of human faces and made a near-real-time face recognition system. Acquiring of training set of images and calculating the Eigenfaces to define a face space, it was a first system to define a face to machine for detection purpose with help of face space. Once they defined a face they used it to detect the face as well as recognize it in a given image. But this system had its limitations it was only able to process frontal faces. This system was not able to handle noise, occlusions, tilt, and pose variations. The result of this discovery meant that reliable real time automated face recognition was possible. Although this method was somewhat constrained by environmental factors, but the discovery caused a large spark of interest in face detection and recognition development. In !993 the FacERecognition Technology (FERET) Evaluation was sponsored from 1993 to 1997 by the Defense Advance Research Products Agency (DARPA) and the DoDCounterdrug Technology development program office in an effort to encourage the development of face detection and recognition algorithms and technology. This evaluation assessed the prototypes of face detection and recognition systems and propelled the technology from its infancy to a market of commercial products. In 2000, multiple US government agencies sponsored the face recognition vendor test (FRVT). FRVT 2000 served as the first open, large-scale technology evaluation platform for multiple available systems. Additional FRVT's have been held in 2002 and 2006. FRVT's primary purpose is to evaluate performance on large scale datasets. This brought revolution in field in of the face detection and recognition. Afterwards there were many methods developed and improved with time the most popular of them are: 1. Viola-Jones Face Detection Algorithm (2004) [8] and 2. Hausdorff Distance-Based Face Localization (June, 2002) [9]. The breakthrough in face detection happened with Viola-Jones Face Detection Algorithm. It consists of two phases of development: 1. Trainingand 2. Evaluation. In Training it used haar-features based geometrical models to obtain a set of weak classifiers by training haar-features on a data set of face and non-face images with help of ada-boosting using the concept of integral image. Then they cascade the weak classifier set obtained from training to make a strong classifier cascade which is backbone of phase two evaluation in this the strong classifier cascade is fed with the input images for face detection and extraction.With this the era of face detection opened to all sort of possibilities and advances. A lot of work has been done to develop and use hybrid features in boosting based face detection algorithm in recent years. Jun, Bongjinet al [10] proposed two novel local transform features: local Gradient Patterns (LGP), modified version of LBP (Local Binary Patterns) and Binary Histogram of Oriented Gradients (BHOG),

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modified version of HOG (Histogram of Oriented Graphics), which were proved to be faster in computation as compared to LBP and HOG. They proposed hybrid feature that combines various local transform features including LBP, LGP and BHOG by means of AdaBoost method for face and human detection, Hybridization results in improvement of detection performance on account of LBP's robustness to global illumination variations, LGP's robustness to local intensity changes and BHOG's to local pose changes. The proposed local transform features and its hybrid feature have been found to be effective for face and human detection in terms of performance and operating speed.

Some work in recent years has been done to use holistic representation of features for detection, enhancement and recognition of faces. The idea is that the main aim of extracting faces from surveillance videos is to identify the person by applying face recognition. So system efficiency is expected to improve if holistic features are used instead of using separate features for each task such as detection, enhancement and recognition of faces. Bharadwaj, S. et al., [11] have studied the possibility of using Holistic descriptors Gist and HOG to use in biometric quality assessment of facial images. The spatial properties are preserved in representation, called as Gist. The promising results were obtained in use of above features for quality assessment in face biometrics.

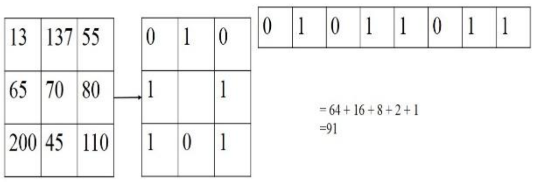

Fig. 1 Calculation of 2-D LBP Features

Another dimension in which the work of extracting faces from videos has been addressed is the use of volumetric features i.e., 3-D version of 2-D featuressuch as HAAR, LBP (see Fig. 1), HOG features. The recent work by Martinez-Diaz, Yoanna, et al., [12] hasbeen done in the use of spatio-temporal based features EVLBP (Extended Volumetric Local Binary Patterns)(see Fig. 2) for detecting the faces from videos. The motivation behind this work was enhancement ofefficiency of the system by using 3-D features, which can encode N number of frames in its generation. The main challenge in this area is to select the number of frames, which have to be processed at a time to encode the features. More the value of N, more will be the speed of processing, but accuracy may reduce as it may encode the non-facial information while feature encoding. The selection of value of N depends upon how fast the contents of scene in video are changing or how fast the object is moving. Use of EVLBP has been found to give better performance than spatial LBP.

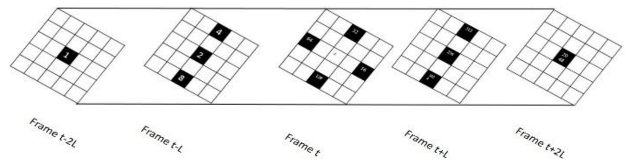

Fig. 2 A 3-D LBP Features (EVLBP)

Another dimension in which the work of face detection has leapt is the use of parallel and GPU computing [13] [14] [15] [16] [17] [18] to enhance the speed of operation at various stages. The GPU computing has been explored in accelerating the training of boosting based face classifiers. Oro, David, et al. [17] presented techniques to increase the performance of the cascade evaluation kernel, which is the most resource-intensive part of the face detection pipeline. Worked on handling problem of GPU underutilization, and achieved a 5X speedup in 1080p videos on average over the fastest known implementations, while slightly improving the accuracy. Also studied the parallelization of the cascade training process and its scalability under SMP platforms. The proposed parallelization strategy exploits both task and data-level parallelism and achieves a 3.5x speedup over single-threaded implementations.

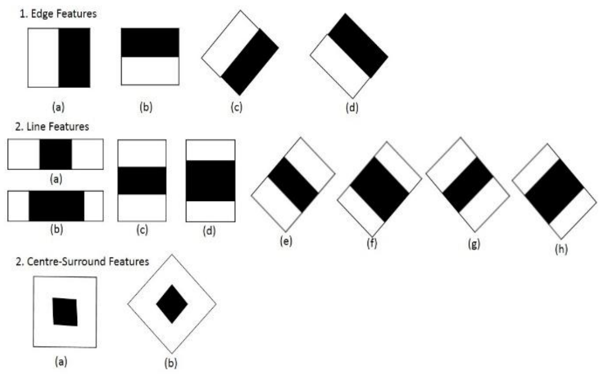

Fig. 3 HAAR Features (Basic & Extended)

The recent work by Jiaminwu et al. [19] have proposed new methodology, with the name C^4 for object detection, which has performed very well on face detection too. They have been able to achieve

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the 20 fps speed and state of the art detection efficiency. They have used and applied the conjecture that contours and signs of comparisons with the neighboring pixels are key information for object detection. The C^4 means, Contour, Cascade Classifier and CENTRIST visual descriptor [20]. Authors have proposed the future scope of work in accelerating the speed of operation of C^4. They have used new visual descriptor CENTRIST [20] which has been found to be suitable match for contour based object detection. CENTRIST visual descriptor encodes the signs of neighboring comparisons. It has been derived from Census Transform (CT) which was originally designed to establish correspondence between neighboring patches [21]. Please see Fig. 4, it shows the calculation of CT value for the center pixel. The CT image C of an input image I is generated by replacing a pixel with its CT value. The CENTRIST descriptor is a histogram with 256 bins, which is a histogram of these CT values in an entire image or a rectangular region in an image.

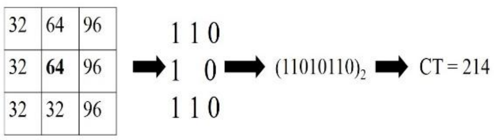

Fig.4 Census Transform

El-Sayed et al. [22] have used mean of medians of CbCr color correction approach to enhance the combined SMQT (Successive Mean Quantization transform) features and SNoW (Sparse Network of Winnow) classifiers (SFSC). The proposed method has been found to be more efficient and accurate as compared to original SFSC method.

Viola Jones et al., [8] did seminal work in face detection, implemented state-of-the-art face detector. This algorithm is still continuing to be leader in modern face detection implementations such as in mobile devices, also inbuilt in OPENCV and MATLAB. Key contributions of their work were: Scale invariance, New image representation called integral image to facilitate faster calculation of Haar features, Uses Machine learning, Adaboost learning algorithm for combining the weak classifier to obtain strong classifiers, Cascade of haar classifiers (see Fig. 3) for faster computation. It was 15 times faster than previous work, can be generalized to detect any type of object. There were some limitations such as the training set of negative examples has to be small to make training feasible, the process of creating the detector cascade is based on trial and error process, training process is lengthy (may take few days, depends upon speed of machine), can handle up to limited rotation angle of faces (± 15 degrees in plane, ±45 degrees out of plane), fails in face occlusions and low brightness of faces. See Fig. 5, how Haar features are able to search for various face features such as eyes, nose, lips etc.

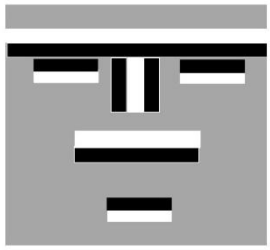

Fig. 5 Applying Haar features on Face

Nasrollahi, K. et al., [23] did excellent work on generating good quality frontal face image from low resolution video sequence, used viola and jones [2] face detector, face quality is estimated based upon facial features: sharpness, brightness, resolution, head Pose. They used auto associative memories for the head pose estimation. Further generated high resolution frontal face image using reconstruction and learning based super resolution techniques in cascade.

Bagdanov, A. et al. [24] worked on multi-face detection, tracking, facial image quality analysis and face-log generation. They developed multipose face detector, based on Adaboost face detector, used lateral and frontal face detectors. System has been evaluated on 10 hours of realistic surveillance videos, with both quantitative and qualitative analysis. However it reported to have limitations such as the proposed face logging system is appropriate for situations in which face size is bounded, illumination conditions are consistent with the images used to train the Adaboost detectors in their multipose face detectors.

Chen, Tse-Wei et al. [25] combined the spirit of image based face detection and essence of video object segmentation to filter out face candidates. Developed a face scoring technique, using eight scoring functions based on feature extraction technique, used a single layer neural network training system to obtain an optimal linear combination to select high quality faces. The face detector was based on skin color detection and video object segmentation. Scoring functions used eight functions: Skin color coverage, Luminance variation, Circularity measurement, Eye-pixel

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Histogram, Ratio, Angle, Symmetry and Hair. All eight functions were combined using fuzzy logic to calculate the final score.

Chang-yeon, Jo. et al. [26] worked on LBP, face images are divided into M small non-overlapping regions, LBP histogram are extracted from each sub region, All such histograms are combined together into a single spatially enhanced feature histogram, Extracted feature describes local as well as global shape of the face images, a variant of AdaBoost, Gentle AdaBoost has been used to select the features and train the classifier. Cascade of classifiers is used for enhancing the performance. The developed algorithm has been found to computationally efficient and tested on Mobile platform.

III. CONCLUSION

There is no doubt that lot of research work has been done in the area of face detection but the goal is still far from achieved: To mimic the human vision of detecting and identifying the human faces. So to meet that goal, still a lot of work has to be done in this area. As per literature survey, following directions for future work in this area are being proposed:

1. The training of Haar features in seminar viola jones' face detector takes a long time, which may be couple of days if used serial processing. There is scope of work to apply the parallel computing to enhance the speed of features training. Till date not much work has addressed the performance.
2. Comparisons of various software platforms such as MATLAB, use of GPU in C/C++ environment, use of GPU in MATLAB environment. So there is scope of using optimization work to address the issue of speed of training of features.
3. In the use of volumetric features, there is open research area in: a) Integrating the descriptor with the scanning strategy, b) Setting criteria for selecting the optimal number of frames to encode the descriptor, c) Investigating in using same feature space for face detection & recognition.
4. Use of holistic features for performing various tasks in the process of face extraction from video such as face detection, face quality estimation, face quality enhancement and face recognition instead of using separate feature for each task.
5. Using motion information in creating face-logs from the video.

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