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Face Tracking Techniques in Color Images : A Study and Review

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Abstract — Face tracking has become an increasingly important research topic in the computer vision field, mainly due to its large amount of real-world applications and situations where such methods can be applied, such as Video Surveillance, Criminal Identification, Terrorist Identification, Border Intrusion. It is very difficult to come up with a robust solution due to variations in illumination, pose, appearance, etc. This paper presents a comparative study and analysis of face tracking techniques. Of the face tracking methods used till now, Memory-based Particle Filter method and Stereo methods and Kanade–Lucas–Tomasi and Scale-invariant Feature Transform of Model Based used for face tracking algorithm produces almost 100% results.

***Index Terms*—Kalman Filters, Gabor Wavelets, Active Contour Model, Bayesian Network.**

I. INTRODUCTION

In order to analyse and recognize faces people in realistically unconstrained environments, robust tracking and segmentation is a prerequisite. This provides a sequence of face images normalized with respect to scale and image plane translation. Robust tracking and segmentation of faces is a prerequisite for face analysis and recognition. Robust real-time tracking and segmentation of a moving face in image sequences is a fundamental step in many computer vision systems including automated visual surveillance, human machine interface, and very low-bandwidth telecommunications. An advanced surveillance interface may use face tracking and detection techniques to direct the attention of the computer to a human being and maintain the face in the camera's field of view and in consequence reduce the communication bandwidth as well as a memory space by transmitting/storing only the fraction of a video frame which contains the area of interest (the tracked face). Monitoring the human face continuously may be necessary to accomplish tasks such as recognizing the user's face [14]. Nowadays intelligent service robots are providing services for human beings. They operate in dynamic and unstructured environment and interact with people using user-friendly interface in natural end efficient way. The mobile agents can aid the surveillance tasks and provide useful information about human activity [15].

II. FACE TRACKING SYSTEMS

Face tracking is one of the challenging research area in recent years. It is a very challenging problem due to the large appearance variability of a face. A human can track the human face because we already know where the face is in the previous frame and how it looks like. Particular scenarios where face tracking can be used are face modelling, this is done using an interpolation which takes too long in high resolution images regarding the good points of this tracker, and the more important one is its ability to keep tracking a face even when small occlusions occur. An algorithm is developed by Claudio A.Perez, Alvaro Palma, Carlos A.Holzmann and Christian Pena [9] for face detection and eye tracking on frontal faces with no restrictions on the background. The questionable observer detection problem is introduced and defined by Jeremiah R. Barr, Kevin W. Bowyer and Patrick J. Flynn [48] as: Given a collection of videos of crowds, determine which individuals appear unusually often across the set of videos.

An efficient foreground/background video coding algorithm was proposed by Kwok-Wai Wong, Kin-Man Lam, Wan-Chi Siu and Kai-Ming Tse [10]. A vision system that performs tracking a human face in 3D was presented by Bogdan Kwolek [13]. He combined color and stereo cues to find likely image regions where face may exist. A greedy search algorithm was used that checked for a face candidate focusing the action around the position of the face. A novel object tracking algorithm was proposed by Mohand Said Allili and Djemel Ziou [24] for video sequences. The formulation of their tracking model is based on variational calculus, where region and boundary information cooperate for object boundary localization by using active contours. A real-time system called "DRUIDE", for "Detection-Recognition-Unification-Interpretation-Decision-Evolution" was proposed by Jean-Christophe Terrillon, Arnaud Pilpré, Yoshinori Niwa and Kazuhiko Yamamoto [21] and that is intended for the robust simultaneous face detection or face tracking and for the recognition of multiple hand postures of the Japanese Sign Language (JSL) in color video sequences. A method that merge face detection and face tracking into a single probabilistic framework was proposed by Sachin Gangaputra, and Sachin Gangaputra [27].

A 3-tier framework for hardware implementation of Dynamic Face Tracking System (DFTS) based on Gabor Wavelets was presented by Eustace Painkras and Charayaphan

Charoensak [28]. Amine Iraqui.H, Yohan Dupuis, Rémi Boutteau, Jean-Yves Ertaud and Xavier Savatier [50] have described a dual camera vision system, capable of automatically detecting and tracking regions of interest at a higher zoom level. A unified system for segmentation and tracking of face and hands in a sign language recognition using a single camera was presented by George Awad, Junwei Han and Alistair Sutherland [30]. Unlike much related work that uses color gloves, they detect skin by combining three useful features: color, motion and position. A multiple-stage face detection and tracking system that is designed for implementation on the NICTA high resolution (5 MP) smart camera was presented by Y. M. Mustafah, T. Shan, A. W. Azman, A. Bigdeli, and B. C. Lovell [41].

A spatial-temporal mutual feedback scheme was proposed by Xuchao Li, Xiaofang Zhou [8] [42] that aimed at face detection and tracking in video sequences. The beauty of the algorithm is its ability to form the close-looped negative feedback contributions from spatial detection and temporal tracking, which decreases the error of detection and tracking. A novel particle filter, called M-PF was proposed by Dan Mikami, Kazuhiro Otsuka, And Junji Yamato [45], for the visual tracking of human face pose. The omni-directional cameras have an obvious drawback; that is, only low-resolution images are captured. Therefore, the objects are not able to be correctly identified if they are far from the omni-directional cameras. To overcome this problem, Chin-Shyurng Fahn and Chin-Sung Lo [46] proposed a high-definition human face tracking system using the fusion of omni-directional and pan-tilt-zoom (PTZ) cameras. Based on the research of the existing digital image processing algorithms Zhao Wenge and He Huiming [49] has a reasonable hardware and software division for the realization of the face tracking functions.

An image tracking stratagem was developed to perform different facial emotions on the robot skull by Ching-Kuo Wang, Yuan-Chang Chang and Cheng-Hang Shieh [51] to analyze the neck dynamics. A visual tracking and servoing of human face are implemented through image processing by A. A. Shafie, A. Iqbal and M. R. Khan [52]. Zdenek Kalal, Krystian Mikolaj, Jiri Matas [56] designed a novel system for long-term tracking of a human face in unconstrained videos on Tracking-Learning-Detection (TLD) approach.

Two broad approaches to the representation and tracking of moving objects are motion-based and model-based. Both methods have their relative strengths and weaknesses and seem to be complementary [3]. Motion-based approaches depend on a robust method for grouping visual motions consistently over time [4]. They tend to be fast but do not guarantee that the tracked regions have any meaning. Model based approaches, on the other hand, can impose high-level semantic knowledge more readily but suffer from being computationally expensive due to the need to cope with scaling, translation, rotation and deformation [1]. Di Xie et al proposed a novel system that acquires clear human face or head in video stream from a single surveillance camera and applies several state-of-the-art computer vision algorithms to generate real-time human head detection and tracking results.

A. Motion Based Face Tracking Systems

i. Kalman Filters

Stephen McKenna and Shaogang Gong [1] implemented a real-time multi-motion tracker using Kalman filters to track objects as groups of temporal zero crossings. A new near-real time technique for 3D face pose tracking from a monocular image sequence obtained from an uncalibrated camera was proposed by Zhiwei Zhu, Qiang Ji [19]. The basic idea behind their approach is that instead of treating 2D face detection and 3D face pose estimation separately, they performed simultaneous 2D face detection and 3D face pose tracking. 3D face pose at a time instant is constrained by the face dynamics using Kalman Filtering and by the face appearance in the image.

ii. Active Contour Models

An improvement to the conventional active contour model, called Snuke was proposed by Xiong Bing, Yu Wei, and Charuyaphan Chareonsak [20], and applied it in the application of face biometric; i.e. automatic detection and tracking of complex face contour. Fast and efficient motion detection and estimation methods are introduced. The obtained motion information is used to reduce the number of sub-images to search.

iii. Particle Filter

A system was developed by Lukasz Stasiak and Andrzej Pacut [40] to detect and track individuals and groups of people in real-time, designed as a first screening of the iris-based access control. The particle filtering was used in the Conditional Density Propagation framework of Isard and Blake, and the face detection was carried out by using the skin color in HSV color space. An automatic approach was described by Tie Yun and Ling Guan [54] to track fiducial points for various facial expressions. This approach combines color based kernel correlation technique for the observation likelihood with DE-MC particle filtering distribution for multiple points tracking. An efficient face detection and tracking system for mobile interaction was proposed by Yeong Nam Chae, Jaewon Ha, and Hyun S. Yang [55]. To detect face rapidly, the proposed system adopts color filtering based efficient region selection method.

iv. Dynamic sound beam Algorithm

A method of visually steerable sound beam forming was presented by Kensuke Shinoda et. al. [18]. The method is a combination of face detection and tracking by motion image processing and sound beam forming by speaker array.

v. Stereo methods

Stephen J. Krotosky, Shinko Y. Cheng, Mohan M. Trivedi [22] reviews both a stereo-based and long wave infrared-based system for “smart” airbag deployment as vision based systems for “smart” airbag systems is aimed to give precise information about occupant pose and location. This information can be used to make intelligent airbag deployment decisions *vi. Wavelet Transform*

An efficient algorithm was presented by Bardia Mohabbati and Shohreh Kasaei [31] to detect and track faces in color image sequences in wavelet domain. The algorithm first utilizes a nonlinear skin color model and face model to extract face candidate regions.

vii. De-Identification

Prachi Agrawal and P. J. Narayanan [59] presented an approach to de-identify individuals from videos.

B. Model Based Face Tracking Systems

i. Kalman Filtering

A novel algorithm for detecting facial features and an implementation of a real-time system for tracking multiple faces and facial features was presented by Antonio Colmenarez et. al. [5]. E.Loutas, C.Nikou and I.Pitas [11] proposed an information theoretic approach to joint probabilitistic face detection and face tracking. Likelihood information is performed by using set of automatically generated feature points, while the priority probability estimation is based on mutual information tracking cue and a Gaussian temporal model. A trainable system for face detection and tracking was described by Augusto Destrero et. al. [37]. The structure of the system is based on multiple cues that discard non face areas as soon as possible. They combine motion, skin, and face detection. Vincent Girondel et. al. [25] have presented a fast and efficient algorithm based on the combination of partial Kalman filtering and faces pursuit to track multiple persons even under occlusions. This method can be used for indoor video sequences.

ii. Continuously Adaptive Mean Shift Tracking

A novel probabilistic approach to unify face detection and tracking was presented by Ji Tao and Yap-Peng Tan [26]. Using preliminarily detected FOR's, a hypothesis sequence can be constructed to recover the missing faces by maximizing the probability score of a graphical chain model. A system for multiple objects tracking and multi-view faces detection and recognition was proposed by Han-Pang Huang', and Chun-Ting Lin [32] using a novel method called Multi-CAMSHIFT.

Prahlad Vadakkepat et. al. [44] addressed a scenario where a robot tracks and follows a human. A neural network was utilized to learn the skin and nonskin colors. The skin-color probability map is utilized for skin classification and morphology-based preprocessing. Heuristic rule is used for face-ratio analysis and Bayesian cost analysis for label classification.

iii. Condensation Algorithm

XIA Siyu LI Jiuxian XIA Liangzheng [35] addressed the problem of human face tracking in color image sequences. A method using human skin color feature integrated with Condensation algorithm is proposed. Vincent Girondel et. al. [25] proposed the Boosted Adaptive Particle Filter (BAPF) algorithm for face detection and tracking in video sequences. The APF algorithm is proposed to obtain more accurate estimates of the proposal distribution and the posterior distribution for improving the tracking accuracy in the input video sequences. Therefore, Frank Wallhoff et. al. [36] presented a multi-modal approach for finding and tracking a face and estimating the head's gaze as well as the eyes' view direction.

iv. Active Contour Model

A new approach for automatically segmenting and tracking of faces in color images was presented by Karin Sobottka Ioannis Pitas [2]. The segmentation of faces is done based on color and shape information. By searching for facial features, face hypotheses are verified.

v. Top-Down Algorithm

Shinjiro Kawato and Jun Ohya [6] proposed a method that automatically extract a skin color distribution model for face detection systems. They applied this method to their face detection and tracking system.

vi. Dynamic Programming

Zhu Liu and Yao Wang [7] proposed a new face detection method based on template matching. Recognizing that the actual face in the test image can be stretched non-uniformly compared to the face template, they developed an algorithm that uses dynamic programming to test stretching in both horizontal and vertical directions and search for the best matching region.

vii. Bayesian Network

A joint probabilistic face detection and face tracing algorithm was proposed by E.Loutas, C.Nikou, I.Pitas [11]. Face tracking is achieved by a Bayesian network. The likelihood estimation is based on statistical training of set of automatically generated feature points.

viii. Gaussian Temporal Model

Wcimin Huang et. al.[12] presented a novel algorithm to detect face eyes in a reliable manner with a stereo camera. Joint probabilistic face detection and tracking algorithm combining likelihood estimation and a prior probability is proposed by Evangelos Loutas, Ioannis Pitas, and Christophoros Nikou [23]. The likelihood estimation scheme is based on the statistical training of sets of automatically generated feature points and a mutual information tracking cue, while the prior probability estimation is based on a Gaussian temporal model. Usman Qayyum and Dr. Muhammad Younus Javed [33] dealt with the real time implementation of face detection, tracking and facial feature localization in video sequence that is invariant to scale, translation, and (±45) rotation transformation. The proposed system contains two parts, visual guidance and face/non-face classification.

ix. Adaboost Classifiers

Tilo Burghardt and Janko Calic [34] presented A real-time method for extracting information about the locomotive activity of animals in wildlife videos by detecting and tracking the animals' faces. As an example application, the system is trained on lions. The underlying detection strategy is based on the concepts used in the Viola-Jones detector, an algorithm that was originally used for human face detection utilising Haar-like features and AdaBoost classifiers.

x. Hierarchical Multi-Resolution LP Model

Eng-Jon Ong and Richard Bowden [38] proposed a learnt data-driven approach for accurate, real-time tracking of facial features using only intensity information. The task of automatic facial feature tracking is non-trivial since the face is a highly deformable object with large textural variations and motion in certain regions.

xi. Scale-Invariant Feature Transform

Michail Krinidis, Nikos Nikolaidis, and Ioannis Pitas [39] presented a novel approach for selecting and tracking feature points in video sequences. In this approach, the image intensity is represented by a 3-D deformable surface model. The proposed approach relies on selecting and tracking feature points by exploiting the so-called generalized displacement vector that appears in the explicit surface deformation governing equations.

xii. Color Histograms

Soufiane Ammouri and Guillaume-Alexandre Bilodeau [43] presented detection and tracking methods for user's body parts in video sequences. They used a technique based on color and shape to detect the body parts and the medication bottles. A systematic discussion of both pros and cons of two well-known traditional approaches for image contrast enhancement is conducted by K. Kyamakya, J. C. Chedjou, M. A. Latif and U. A. Khan [47]. The first approach is based on the CNN paradigm and the second one is based on the coupled nonlinear oscillators' paradigm for image processing.

xiii. Nonintrusive System

A nonintrusive system which can detect fatigue of the driver and issue a timely warning was developed by Hardeep Singh, Mr. J.S Bhatia and Mrs. Jasbir Kaur [57]. Since a large number of road accidents occur due to the driver drowsiness.

xiv. Hybrid Fourier-Based Facial Feature

A robust face recognition system for large-scale data sets taken under uncontrolled illumination variations was proposed by Wonjun Hwang, Haitao Wang, Hyunwoo Kim, Seok-Cheol Kee, and Junmo Kim [58]. The proposed face recognition system consists of a novel illumination-insensitive preprocessing method, a hybrid Fourier-based facial feature extraction, and a score fusion scheme.

xv. Statistical Skin Color Model

De-Jiao Niu, Yongzhao Zhan, Shun-Ling Song [16] presented a method for face detection, tracking and privacy protection. According to skin-color distribution in the color space, they developed a statistical skin color model through interactive sample training.

xvi. Probabilistic Method

A new probabilistic method for detecting and tracking multiple faces in a video sequence was presented by Ragini Choudhury Verma, Cordelia Schmid, and Krystian Mikolajczyk [17]. The proposed method integrates the information of face probabilities provided by the detector and the temporal information provided by the tracker to produce a method superior to the available detection and tracking methods.

III. DISCUSSION

Robust real-time tracking and segmentation of a moving face in image sequences is a fundamental step in many vision systems including automated visual surveillance, human machine interface, and very low-bandwidth telecommunications. An advanced surveillance interface may use face tracking and detection techniques to direct the attention of the computer to a human being and maintain the face in the camera's field of view and in consequence reduce the communication bandwidth as well as a memory space by transmitting/ storing only the fraction of a video frame which contains the area of interest (the tracked face).

The results obtained by all the researchers are shown in the table I and II. There are two types of face tracking systems namely, motion based face tracking and model based face tracking system. In the motion based face tracking, Kalman filters, Dynamic sound beam, Active Contour Model, Stereo methods, Wavelet Transform, Differential Evolution Markov Chain (DE-MC) particle filters, Particle Filter, De-Identification, Feature Point Tracking, Principle Component Analysis, Mean-Shift, Genetic Algorithm and Principle Component Analysis, Markov Model, Gabor Wavelets, Boosted Adaptive Particle Filter(BAPF), Kalman Filtering, Memory-based Particle Filter, Particle Filter, Hierarchical Agglomerative Clustering, Real-time Image Processing System, Adaboost, Pen-Tilt Zoom, Visual Tracking, Online boosting OC, Tracking-Learning-Detection and Digital Image Processing. All the methods specified produce better face tracking results. But the methods, Stereo methods, Digital Image Processing and Memory-based Particle Filter produce 100% face tracking results. The model based face tracking systems are: Kalman filters, Active Contour Model, Information-Based Maximum Discrimination (IBMD) classifiers, Top-down algorithm., Clustering Method, Bayesian network, Stereo Tracking, Continuously Adaptive Mean Shift, Multi-Continuously Adaptive Mean Shift, Wavelet Transform, Adaboost, Condensation algorithm, Biased-Linear Predictor, Kanade–Lucas–Tomasi and Scale-invariant Feature Transform, Modified X-Means algorithm, Color Histograms and their Second Order Hu Moments., Continuously Adaptive Mean Shift Tracking, Coupled Nonlinear Oscillator and Hybrid Fourier features. Kanade–Lucas–Tomasi and Scale-invariant Feature Transform produce the best face tracking results with 99%.

IV. CONCLUSION

Most of the time, a video sequence of the scene is available using which a person may have to be recognized. Hence, a robust system that detects and tracks a face is necessary. Face detection and tracking becomes an important task with the growing demand for content-based image functionality. This paper provides a comparative analysis on face detection and face tacking. Of the face tracking methods used till now, Memory-based Particle Filter method and Stereo methods and Kanade–Lucas–Tomasiand Scale-invariant Feature Transform of Model Based used for face tracking algorithm produces almost 100% results.

TABLE I. MOTION BASED FACE TRACKING SYSTEMS

Authors Name	Face Tracking Method Used	Detection Rates
Stephen McKenna et.al. [1]	Kalman filters	----
Kensuke Shinoda et.al.[18]	Dynamic sound beam	----
XiongBing, Yu Wei et. al.[20]	Active Contour Model	90%
Stephen J. Krotosky et. al.[22]	Stereo methods	100%
Bardiaet. al. [31]	Wavelet Transform	85%
Tie Yun et. al. [54]	Differential Evolution Markov Chain (DE-MC) particle filters	88%
Yeong Nam Chaeet. al.[55]	Particle Filter	88%
PrachiAgrawal et. al.[59]	De-Identification	90%
Claudio A.Perezet.al. [9]	Digital Image Procesing	100%
Kwok- Wai Wong, et.al. [10]	Feature Point Tracking	----
BogdanKwolek [13]	Principle Component Analysis	----
Jean-Christophe Terrillon et. al[21]	Mean-Shift	96%
Kwok-Wai Wong et. al. [24]	Genetic Algorithm and Principle Component Analysis	----
SachinGangaputra et. al. [27]	Markov Model	----
Eustace Painkraset. al. [28]	Gabor Wavelets	----
Vincent Girondel et. al. [29]	Boosted Adaptive Particle Filter(BAPF)	----
George Awad et. al. [30]	Kalman Filtering	----
Y. M. Mustafah et. al. [41]	Background Subtraction	----
Xuchao Li et. al. [42]	Kalman Filtering	----
Dan Mikami et. al. [45]	Memory-based Particle Filter	100 %
Chin-ShyurngFahn et. al.[46]	Particle Filter	----
Jeremiah R. Barr et. al. [48]	Hierarchical Agglomerative Clustering	----
Zhao Wenge et. al. [49]	Real-time Image Processing System	----
Amine Iraqui et.al. [50].	Adaboost	----
Ching-Kuo Wang et. al. [51]	Pen-Tilt Zoom	----
A. A. Shafieet. al. [52]	Visual Tracking	----
HongwenHuoet. al. [53]	Online boosting OC	
ZdenekKalal et. al. [56]	Tracking-Learning-Detection	99%

TABLE II MODEL BASED FACE TRACKING SYSTEMS

Authors Name	Face Tracking Method Used	Detection Rates
Stephen McKenna et.al. [1]	Kalman filters	----
Karin Sobottkaet.al. [2]	Active Contour Model	----
Antonio Colmenarezet.al. [5]	Information-Based Maximum Discrimination (IBMD) classifiers	98%
ShinjiroKawatoet.al. [6]	Top-down algorithm.	----
Zhu Liu et.al. [7]	Clustering Method	82%
E.Loutas, et.al. [11]	Bayesian network	----
Wcimin Huang et.al. [12]	Sterio Tracking	96%
Ji Tao et. al. [26]	Continuously Adaptive Mean Shift	94%
Han-Pang Huang' et. al. [32]	Multi-Continuously Adaptive Mean Shift	91%
UsmanQayyumet. al. [33]	Wavelet Transform	90%
TiloBurghardtet. al. [34]	Adaboost	----
XIA Siyuet. al.[35]	Condensation algorithm	----
Frank Wallhoff et. al. [36]	Condensation algorithm	90%
Augusto Destrero[37]	Kalman Filtering	94%
Eng-Jon Onget. al.[38]	Biased-Linear Predictor	----
MichailKrinidis et. al. [39]	Kanade–Lucas–Tomasiand Scale-invariant Feature Transform	99%
Lukasz Stasiaket. al. [40]	Modified X-Means algorithm.	----
SoufianeAmmouri et. al. [43]	Color Histograms and their Second Order Hu Moments.	97%
PrahladVadakkepat et. al. [44]	Continuously Adaptive Mean Shift Tracking	----
K. Kyamakya et. al. [47]	Coupled Nonlinear Oscillator	----
HardeepSinghet. al.[57]	Eye tracking system	----
WonjunHwanget. al. [58]	Hybrid Fourier features	95%

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