# Face tracking using particle filer in the complex background

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**ABSTRACT**

*We present a novel method of tracking a face using color transformation, particle filter and the Motion Adaptive Weighted Unmatched Pixel Count algorithm that makes more effective combination of color and motion information in complex background and face occluded environment. The proposed algorithm of tracking the face has advantages in rejecting static background objects of similar color without background training and subtraction which is done only by color and motion information. We tested our algorithm at the PETS-ICVS 2003 Data. Tracked facial information can be used at the video surveillance and user position detection at the virtual reality.*

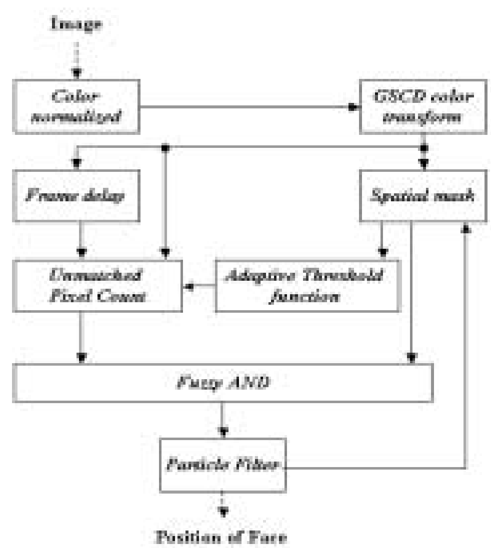
## 1. Introduction

Face tracking has attracted much attention from researchers in computer vision since face can be used as important means of Human-Computer interface, video surveillance, and user's position in virtual reality, etc.

General tracking methods use some low level features such as color, motion, contour, and depth information to track the object, including faces [1][2]. Color information provides an important clue for detecting human face in various images. However, if skin color is used, there would be some difficulties because of illumination variation and camera model. Head shapes are modeled as oval geometry, but the shape varies as head moves. Motion is an important capability in a vision system designed in order to operate in an uncontrolled environment for detecting moving objects. To track the face robustly and overcome the problem of each cue, and multi-modal based face tracking methods are popularly used. Motion Adaptive Weighted Unmatched Pixel Count (MAWUPC) algorithm that incorporates multiple cues to track the face in the complex background and face occluded environment is proposes in this paper proposes.

Numerous approaches have been proposed to track objects in image sequence. Among them, particle filter has been successfully applied to track moving objects in cluttered environment. The traditional tool for solving the estimation problem has been the Kalman filter and also its extended form. Kalman filter is derived from the assumption of linearity of model and Gaussianity of the dynamic and measurement noise. Unfortunately, many of the state estimation are nonlinear and non-Gaussian. Particle filter is the one of the popular tools to solve the tracking problems.

In section 2, we develop a method to extract the features using color and motion information, then we present the key algorithm, MAWUPC that fuses the motion and color information efficiently. We tracked the face using particle filter in section 3. By walking through to track face information, we can describe the experimental results and conclusion remarks in section 4 and section 5. Figure 1 depicts the total flowchart of our proposed algorithm.




Fg.1. Total flowchart of proposed system

## 2. Feature extraction using motion and color

Object tracking system has to identify and segment objects of interest from images. There are many features to use; color and motion are widely used features. Since color and motion are independent from object shape, they are appropriate features to track objects that have dynamic shape change, such as face and hands. The research on color and motion has been developed individually. However, we cannot be able to make a robust and efficient system with only one cue. Thus this section is focused on the combination of color and motion feature efficiency.

### 2.1 Color Transform

Skin color based human candidates detection is relatively robust to changes in illumination, in viewpoint, in scale, in shading and partial occlusion. Robustness of segmentation is generally achieved by separating the chrominance from the luminance in the original RGB color image, and by using only the chrominance of segmentation.

Generally the RGB color model has color information as well as brightness. Then object's RGB value in the RGB model varies according to light conditions which have no concerns with object's color information. In this paper, we adapt the normalized RGB color space that removes image dependency on the righting geometry and illuminant color. Many researchers used RGB normalization procedure to get pure color components and it is represented as

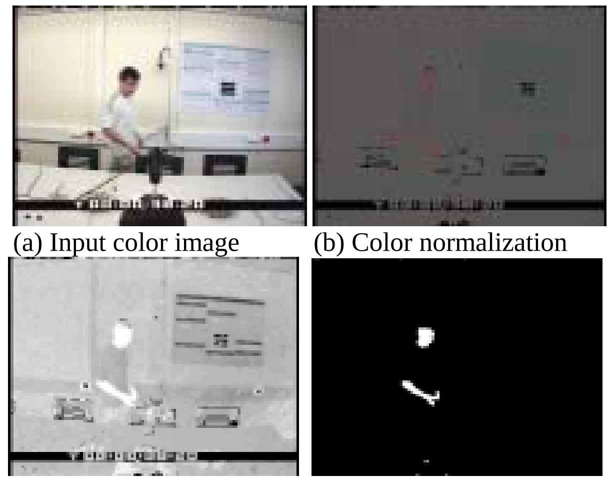
$$r = \frac{R}{R+G+B}, g = \frac{G}{R+G+B}, b = \frac{B}{R+G+B} \quad (1)$$

where $r + g + b = 1$.

Color transform is defined as a gray image that emphasizes a specific color region with Gaussian distribution from normalized color image. Transformed image has a high intensity as the color of normalized input pixel is close to the center of the Gaussian distribution. The color transform is represented as follows [3].

$$\begin{aligned} Z(x,y) &= G(r(x,y), g(x,y)) \\ &= \frac{1}{2\pi\sigma_r\sigma_g}\exp[-\frac{1}{2}\{(\frac{r(x,y)-m_r}{\sigma_r})^2 + (\frac{g(x,y)-m_g}{\sigma_g})^2\}]\} \end{aligned} \quad (2)$$

where $(x,y)$ is a coordinate of a pixel, $g(x,y)$ and $r(x,y)$ are the normalized color values of red and green components, respectively. $G(\cdot)$ is 2D Gaussian function. $\sigma_r$, $\sigma_g$ are standard deviations of red and green components, respectively. Skin color based face candidates' detection method has many regions including face and hands, but this method can reduce more processing time than image full searching method. Figure 2 shows the process of input image, color normalized image, and color transformed image of human candidates. Skin color based human candidates detection method has many regions including face and hands, but we can reduce the more processing time than image full searching method.



(a) Input color image (b) Color normalization

(c) Color transform (d) Skin color candidates

Figure 2. Skin color region detection process.

### 2.2 MAWUPC

In this section, we incorporate the color transformed features and motion features that were extracted from the frame delay. The effectively combinational algorithm of color and motion is the MAWUPC algorithm [4]. Originally the MAWUPC provides the method to track multiple objects. Because of proposed method of tracking the face from this paper, we simplify the MAWUPC without using the limited UPC operation.

The first method is introduction of a weighted search window around an object position that is estimated by the particle filter, using the spatial mask. The specific description of particle filter will be followed at section 3. After next position is estimated by particle filter, a search window is placed at the estimated position, and the following process is restricted within the window. Moreover, 2D Gaussian spatial mask is overlaid at the position of a color transform image to get a weighted result such as

$$Z_S(x,y) = S(x,y)Z(x,y) \quad (3)$$

$$S(x,y) = N(p_t, \sum_p^2 \quad (4)$$

where $S(x, y)$ represents the spatial mask with mean and the covariance. The mean is estimated position by particle filter at time *t*. The operation improves background objects rejection by having similar color targets.

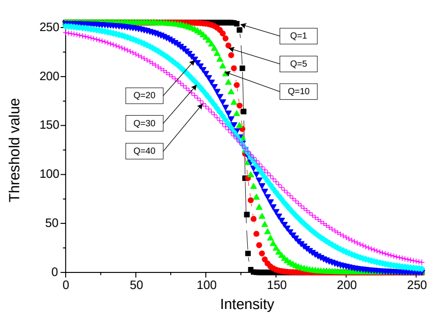
The second method is to introduce a limiter function for the Unmatched Pixel Count motion detection, according to relative magnitude of motions. If a target object has a small motion and other closely located objects have a large motion, the target object is likely to have small result of the UPC operation. This gives bad result of center obtaining process for the target object. This results a poor measurement for the particle filter. Therefore the estimation of particle filter gets worse and worse as frames go on. To overcome this problem, we limit results of the UPC operation using relative magnitude of motion vectors that are estimated by particle filter when we can expect another object to appear within the search window in a way that target object appears within search window for target face. Finally the MAWUPC formulated by the following equations.

$$sMAWUPC(x,y,t) = Z_S(x,y,t) \otimes UPC(x,y,t), \quad (5)$$

$$UPC(x,y,t) = \sum_{i=x-N}^{x+N} \sum_{j=y-N}^{y+N} U(i,j,t), \quad (6)$$

$$U(x,y,t) = \begin{cases} 1, & if\ |Z(x,y,t) - Z(x,y,t-1)| > Th(Z_S(x,y,t)) \\ 0, & otherwise \end{cases}, \quad (7)$$

$$Th(Z_S(x,y,t)) = \frac{255}{1+\exp\{\frac{Z_S(x,y,t)-255/2}{Q}\}}. \quad (8)$$




Fg.3. Sigmoid function for adaptive UPC threshold

where $\otimes$ represents fuzzy AND operation, which can be replaced by a product, and $Z_S(x, y, t)$ is a weighted search window around an object position that is estimated. In Eq.(4), $(2N+1)\times(2N+1)$ is the size of the window for UPC operation. The UPC operation is based on the color transformed image of Eq.(2). The UPC operation in Eq.(4) is a kind of matching process. In this case, the threshold is adjusted by pixel to pixel using a sigmoid function, Eq. (6) and Fig.3. The characteristics of sigmoid function play a role of a kind of sensitivity function and increase the sensitivity of specific colored and located objects while this reduces objects without any concern. $Q$ is a characteristic parameter of the sigmoid function in order to determine the threshold. Search window is made of particle filter using the spatial mask. After the next position is estimated by particle filter, a search window is placed at the estimated position. In the next chapter, we will explain more detail about the particle filter.

## 3. Tracking using particle filter

Particle filtering was developed to track object in clutter, in which the posterior density $p(X_t | U_{s,t})$ and the observation density $p(U_{s,t} | X_t)$ are often non-Gaussian [5]. The quantities of a tracked human are described in the state vector $X_t$ while the vector $U_{s,t}$ denotes all the observations $\{U_{s,1},...,U_{s,t}\}$ up to time $t$.

The key idea of particle filter is to approximate the probability distribution by a weighted sample set $S = \{(s^{(n)}, \pi^{(n)}) | n = 1,..., N\}$. Each sample consists of an element $s$ which represents the hypothetical state of an object and a corresponding discrete sampling probability $\pi$ where $\sum_{n=1}^{N} \pi^{(n)} = 1$. As weighing method factors samples, spatial mask is used. Particle filter provides a robust tracking framework although the model is uncertain or motion of target face is fast. Since less likely object sates have a chance of temporary remaining in the tracking process, particle filters can deal with short lived occlusion. The estimated position information using particle filter helps the system to track the face more robust and efficient search region. The result position of the target face is the weighted mean of each particle.

We can apply a particle filter in a MAWUPC contents. The current image after the MAWUPC algorithm has a probabilistic distribution with color and motion.

## 4. Experiment

As the experiments, we tested our algorithms in online and offline. First, we applied the MAWUPC and particle filter to color images sequences of PETS-ICVS 2003 DB for face tracking. PETS-ICVS 2003 DB is composed with many scenarios with various camera positions. In Scenario

1, we sampled 10 image sequences per second from Cam1 DB. We normalize the image sequence with 320*240 resolution. Figure 4 shows one of the experiments results. In the figure, red position of each image shows the weighted mean of the each particle. The red point of each image is the average point of weighted particles. The speed of our face tracking algorithm is measured by averaging the processing time of PETS DB and we obtain less than 100 ms at the Pentium 4 1 GHz IBM PC.

## 5. Conclusion

We have proposed the MAWUPC to solve the face tracking at the complex background which has similar skin color and occluded environment. The MAWUPC incorporates color transform, particle filter, and UCP operation to make more effective combination of color and motion features. The proposed algorithm has advantages in rejecting static background objects of similar color without background subtraction, and solving the problem of occlusion among target object at the same time. Experiment results showed that the proposed algorithm is successfully applied to face tracking and can be applicable to video surveillance, automatic human motion analysis.

It is expected that MAWUPC algorithm can be used in hand or face tracking in many vision-based applications. For further studies, as a first step for intelligent Human Computer Interaction for multiple target objects will be more investigated.

## 6. Reference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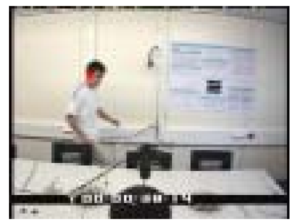
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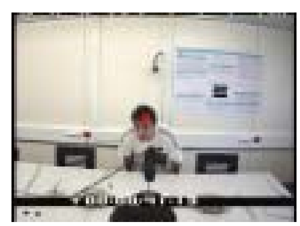
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Figure 4. Experiment results of PETS-ICVS 2003 DB.