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APPLYING AN ADJUSTABLE IMAGE COLOR SYSTEM TO TRACK MULTIPLE CROSSING OBJECTS

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Abstract. *This paper proposes a new scheme of image technology to extract the color feature of objects and reduce the impact of environmental interference caused by the shadows and ambient illumination changes. This preliminary process is important for the further tracking by the particle filter. This paper designs a series of procedures for the moving objects tracking. The first step is the foreground segmentation to separate the moving objects from the background after color system transformation. The next part uses the closing and opening algorithm of morphology processing to deal properly with the noise and intensify the object shape. The final part applies the particle filter which is used properly in non-linear and no noises restriction system to tracking multiple crossing objects. According to the experimental analysis, the proposed method can track multiple crossing targets accurately.*

Keywords: Color system transformation, Particle filter, Multiple crossing objects

1. **Introduction.** To track the multiple crossing objects is more difficult because it is hard to determinate respective objects during and after crossing, and therefore, it needs clearer objects recognition for the further tracking using the particle filter. Many researchers study the intruder detection and object tracking who always use the object features such as contour, color and other characters to recognize objects. The tracked object profile changes continually when they move and need to spend more computation cost to extract them from images. The object color feature is an effective method as objects recognition. The RGB color system is easily affected by illumination change and shadows that influence the color feature extraction.

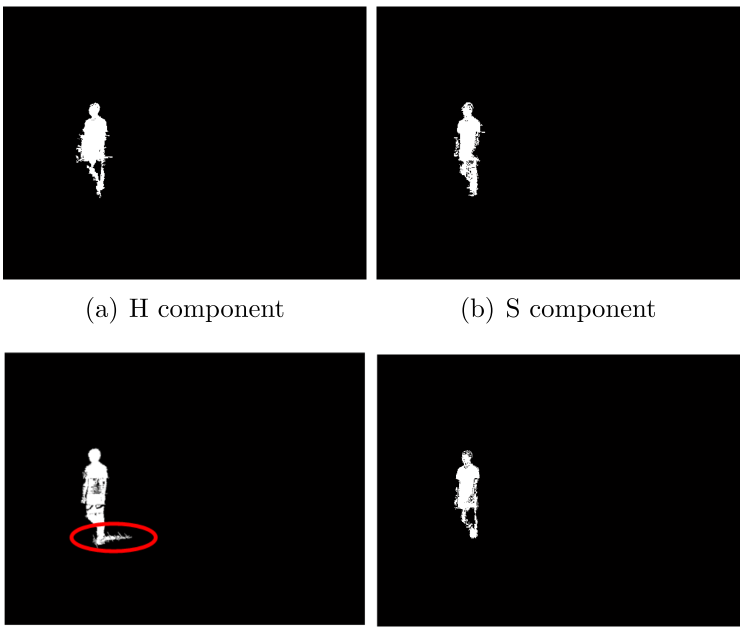
It proposes an adjustable image technology to find out and track the moving objects based on their color feature which has the advantage of lower computation and is easy to extract moving object in this paper. It can overcome these two disadvantages, shadows and ambient illumination changes, to convert the color space to the HSV color system [1]. The HSV represents hue, saturation, and color value, respectively, can protect the original color feature of moving objects by three color components to avoid noise influence.

In order to track the moving objects, the system must apply many preliminary image processing and tracking techniques. Many researchers usually use the optical flow, temporal differencing and the background subtraction methods to filter out the interest moving object for the further processing. The optical flow method suffers from higher computational cost and fails due to the ambient illumination changes of the environment [2,3]. The temporal differencing method is used properly in the variable background and needlessly updates the reference background frequently [4]. This method also has lower computational time but is hard to extract the color feature of moving objects. The background subtraction method is easy to implement and has satisfactory low computational cost. This method can be simple to capture object color feature for future tracking although it needs to update the reference background regularly [5,6].

The rest of this paper is organized as follows. Section 2 explains the image processing and segmentation, which show the color space transformation, morphological processing and object feature extraction. Using the particle filter to tack the multiple crossing objects is introduced in Section 3. Section 4 details the experimental results and comparisons with other algorithms. Finally, the conclusions are presented in Section 5. The designed tracking system framework has four parts in this system, which has image segmentation, morphological processing, color feature extraction and object tracking using particle filter.

2. **Image Segmentation.** In order to identify objects, an important job for object tracking preprocessing is applied when they enter the detection area. That needs to separate the moving objects from the input images when targets present in the region of interest. This paper proposes to use the background subtraction to extract the foreground objects which can keep the object's color feature for the further particle filter tracking [7,8]. In general, all the surveillance system show the images by the RGB color system, but that is easily influenced by shadow or ambient illumination changes. To transform the color system from RGB to HSV system, it can be easy to separate the influence factors and then use processing technology to reduce these interferences.

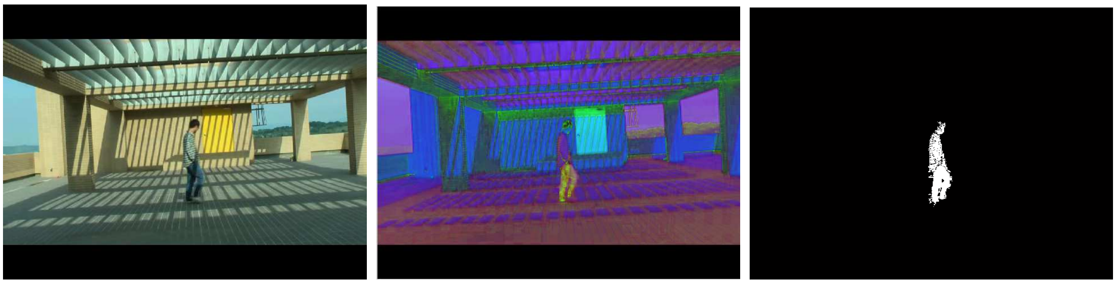
The HSV system uses the lightness value to present the object hue, so it can weaken the influence of shadow and ambient light change. Transforming the original image of figure to HSV color space, the color domain presents differently from RGB system because the color components are in the scope between 0 and 1 after transferring to the HSV system. That can obtain three different gray level images according to its three different color components as Figure 1. Through the binary process, the shadow influence can be more obvious. As Figure 1 shows, it displays the three components of HSV image with shadow.



(a) H component (b) S component

(c) V component (d) The intersection of H and S

FIGURE 1. The color components of HSV image with shadow effect



(a) The original image (b) The HSV image (c) The binary image

Figure 2. The image in the situation of ambient illumination changes

(a) The binary image (b) The image after operation

Figure 3. The relative image after the morphological processing

That can be easy to find out only the V component has the shadow following the object, so do the operation of intersection of H and S components and get purer object profile.

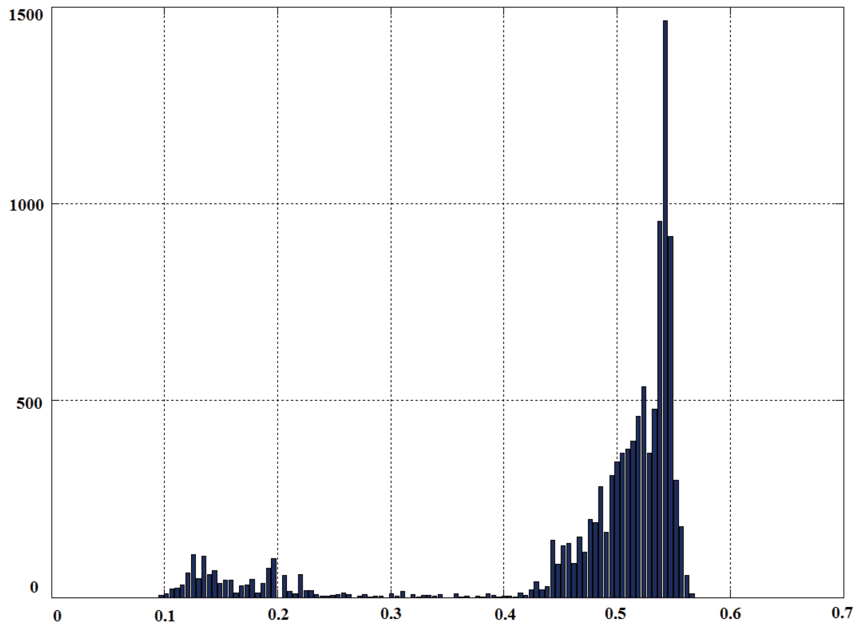
The influence of ambient illumination change is another comparison between the HSV and RGB system. The original RGB image is the composite of three primary colors, so it fluctuates violently following the light change. The area which light shines gets higher pixel value, namely too bright, that affects the color feature extraction of objects because the observed color does not match with the true color. Figures 2(a) shows the original image. Figure 2(b) is the HSV image transformed and finds out the color of pants kept the same, which reveals the object color feature just has a little reaction to the illumination change that can extract the true color without distortion for future tracking. These two kinds of interferences are usual for the most part of image processing defect for object tracking. To extract the hue and saturation components of image and execute the binary processing, and then get the intersection of these two components, obtain the foreground object as Figure 2(c) without the shadow component and lower the interference of ambient light change.

This paper only uses the morphological processing to reduce image noises that do not apply additional elimination algorithms for simplifying the process. The closing and opening algorithm of morphological processing based on dilation and erosion are useful to fill up the vacancies of segmented foreground object and eliminate some noises. These two algorithms can let the detected objects be more intact and be easier to trace. As Figure 3 shows, this paper applies these two algorithms properly and alternately calculates the foreground objects that can remove some small noises and fill up the vacant areas to get more complete outlines for the tracked objects.

The moving object tracking needs to have the tracing targets for the tracking system. That may use the profile, color, motion or appearance features of objects. This paper proposes to adopt the maximum color of objects for the tracing targets because they are easy to extract and the features are quite obvious after preceding process. That can obtain the foreground moving object shown as Figure 4(b) through the preceding

(a) The original image (b) The foreground object (c) The object hue component

FIGURE 4. The process of hue component extraction from the foreground object



(a) The hue color histogram

(b) The locations of maximum hue

FIGURE 5. The color histogram and the locations of the maximum hue

preliminary work after objects enter the ROI region. Figure 4(c) is the hue component of moving object. To gather the statistics of moving object hue components uses the color histogram which accumulates the gray level value of the whole object and shows each level by bars in the transverse axle as Figure 5(a).

That uses these hue levels which are between the maximum gray level values ± 0.01 to become the most hue level and obtain the locations of the maximum hue of object as

Figure 5(b). The object color feature is determined by this operation and is used to trace. The system can get the saturation and color value level for the same relative locations and calculate the mean value to become the other two color features. These three object color features are the maximum hue values and the gray level average of saturation and color value in the relative position. This paper uses these object color features to trace and that is easy to recognize the moving objects during the objects crossing, hiding or ambient light change conditions.

3. **Multiple Crossing Objects Tracking.** Dynamic object tracking is a difficult job, however, target tracing based on the particle filter has proven to work well in recent years. Particle filter of recursive computing to update the random discrete probability density function offers a probabilistic framework for dynamic state estimation. This paper proposes to use the particle filter for object tracking. Particle filter uses a set of weighted samples or particles to exhibit this distribution. So, each particle represents a forecast which is one possible location of the traced object. The set of particles has more weight in the location where the traced object is possible to be there. This weighted distribution is propagated through time change by using the Bayesian filtering equations, hence, it can determine the object trajectory by taking the particles with the highest weight during the tracking process.

At initial state, first create a group of particles $\left\{x_0^i\right\}_{i=1}^{N_s}$ from the prior probability $P(x_0)$ and $\{\omega_k^i, i = 0, \ldots, N_s\}$ is associated weights for $\{x_{0:k}^i, i = 0, \ldots, N_s\}$. $x_{0:k}^i = \{x_j, j = 0, \ldots, k\}$ is a set of state from time 0 to k and all the particle weights are set to $1/N_s$. The particle weights update to current state and posterior probability of object state at time k can be discretely weighted.

$$p(x_{0:k}\,|z_{1:k}\,) \approx \sum_{i=1}^{N_s} \omega_k^i \delta(x_{0:k} - x_{0:k}^i) \tag{1}$$

The posterior probability density function can be represented by

$$\begin{aligned} p(x_{0:k}\,|z_{1:k}\,) &= \frac{p(z_k\,|x_{0:k}\,, z_{1:k-1})p(x_{0:k-1}\,|z_{1:k-1}\,)}{p(z_k\,|z_{1:k-1}\,)} \\ &= \frac{p(z_k\,|x_k\,)p(x_k\,|x_{k-1}\,)}{p(z_k\,|z_{1:k-1}\,)} p(x_{0:k-1}\,|z_{1:k-1}\,) \\ &\propto p(z_k\,|x_k\,)p(x_k\,|x_{k-1}\,)p(x_{0:k-1}\,|z_{1:k-1}\,) \end{aligned} \tag{2}$$

The set of particles can be obtained from the importance density function $q(x_{0:k}|z_{1:k})$, and then the weights equation is $\omega_k^i \propto p(x_{0:k}^i\,|z_{1:k}\,)/q(x_{0:k}^i\,|z_{1:k}\,)$.

Then the formula of importance weights is

$$\omega_k^i \propto \frac{p(z_k\,|x_k^i\,)p(x_k^i\,|x_{k-1}^i\,)p(x_{0:k-1}^i\,|z_{1:k-1}\,)}{q(x_k^i\,|x_{0:k-1}^i, z_{1:k}\,)q(x_{0:k-1}^i\,|z_{1:k-1}\,)} = \omega_{k-1}^i \frac{p(z_k\,|x_k^i\,)p(x_k^i\,|x_{k-1}^i\,)}{q(x_k^i\,|x_{0:k-1}^i, z_{1:k}\,)} \tag{3}$$

where $q(x_{0:k}\,|z_{1:k}\,) = q(x_k\,|x_{0:k-1}, z_{1:k}\,)q(x_{0:k-1}\,|z_{1:k}\,)$. After obtaining the importance density function $q(x_{0:k}\,|z_{1:k}\,)$ and normalizing the weights, then that can figure out the estimation below and trace the object trajectory.

The estimation of state: $\hat{x}_x = \sum\limits_{i=1}^{N} \omega_k^i x_k^i$.

The estimation of square error: $P_k = \sum\limits_{i=1}^{N} \omega_k^i (x_k^i - \hat{x}_k)(x_k^i - \hat{x}_k)^T$.

The scheme should go back to keep on the recursive computing and object tracing if the tracked object is still in the image. That needs to stop the particle computing and cease the tracking if the tracked object leaves the image or disappears which determined no objects existed in the input image, and therefore need not waste computing resource to estimate in the environment without objects.

4. **Experimental Results.** In the experiment, there are two objects existing in the detected area shown as Figure 6. The system uses the color feature extraction to obtain these two object color features and set as the tracking target value. Then, the particle filter is used to create two groups of particles and trace objects individually.

FIGURE 6. The tracking process for multiple objects

The particle filter uses the white particles to trace the light white object and the white particles to trace the black object in this scenario. For simulating the actual state, this scenario lets two objects walk overlapped twice to verify how the tracking process interworks during the multiple objects overlap.

Table 1 shows that comparisons of the relative error for applying different color space system to tracing. It seems to have no discrepancies between two color system in the indoor and outdoor environment because that has no shadow or illumination change interferences. The situations with interferences cause the relative errors to show larger fluctuation as shown in the two bottom rows of Table 1. It causes to have the relative error of 10.4% and 6.1% by the shadow and light change influences which present the RGB color system is disturbed by this type of interferences and has poor tracking when extracting object color feature under this color space. However, applying the HSV color system to extracting the color feature as the particle filter tracing targets can prove to achieve better tracking result.

5. **Conclusions.** The object tracking is a series of image processing needed to solve a lot of interferences. In order to reduce the additional processes and simplify the tracking procedures, this paper proposes an object tracking method based on applying the color space adjustable technology combined with the particle filter tracing. The HSV color space system used to transform the original RGB images can obtain the moving objects profile more purely without the environmental changes accompanist. It is easy to obtain the maximum hue of objects from color feature extraction used for the tracking targets after this transformation and morphology processing. For tracing the moving objects, this paper makes good use of the particle filter to track objects. The particle filter is usually proposed to study recently which can be applied in the non-linear system and without any restrictions for system noises. As the above experimental results show, that

Table 1. Likelihood errors comparison table

Situation	Color System	Mean Likelihood Value	Mean Likelihood Error	Relative Error Percentage %
Indoor	HSV	0.946	0.054	2.5%
	RGB	0.921	0.079	
Outdoor (clear)	HSV	0.923	0.077	−0.8%
	RGB	0.931	0.069	
Outdoor (shadows)	HSV	0.832	0.168	10.4%
	RGB	0.728	0.272	
Outdoor (illumination change)	HSV	0.924	0.076	6.1%
	RGB	0.863	0.137	

has higher likelihood values and proves to have better object tracking. The experimental analysis indicates obviously these two technologies can improve the tracking accuracy in outdoor environment especially.

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