Color Contour Extraction with Adaptive Color Model: Color Snake

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Abstract

Snake is an energy-minimizing deformable contour that can track the edges or lines of object we are interested in. In snake algorithm the external constraint force invoked by the edges and lines of object makes snake to converge on object's boundary. However the convergence of snake is difficult problem on image with complex background features because a lot of unexpected lines and edges affect snake as external constraint force.

In this paper we propose a novel approach to eliminate background features that disturb convergence of snake using the color information of an object. The color information of an object is considered as the key information that represents object's property. In color snake the color information is used to make probability image that represents how much the pixel of an image belongs to the color of a tracked object. Color snake applies snake algorithm to probability image, where background features is eliminated by the color information. Experimental results show the validation of color snake.

1. Introduction

Snake as known active contour model is deformable contour guided by the external and internal constraint forces [1]. In many applications such as visual tracking, motion analysis, object recognition the snake has been studied by a lot of researcher as an effective tool for modeling object shape, which varies over time[2][3]. But snake cannot work well in image that has complex background features because snake is forced by the external constraint energy invoked by the lines or edges. In an image with a lot of background features snake tends to be locked at bad features we do not want to track.

In this paper we use the color information of an object in order to overcome these problems. The color information as the native property of an object gives a lot of useful helps for finding and tracking object[4]. But the appearance of color is influenced by object's environment as ambient light, geometry of the scene or the object itself such as reflection properties, object shape and etc. So it is very difficult to model the color distribution of an object over time effectively. In our work, the color distribution of an object is modeled by normal distribution that has a shape like ellipsoid in color space. In real environment it is effective to model the color distribution of an object as ellipsoid because the color distribution influenced by the environment of an object has shape such as ellipsoid.

With normal distribution modeled as ellipsoid we can translate RGB image which elements are represented as a 3D vector to probability image which elements are represented as 1 dimensional vector. The probability image represents that how much the pixel of an image belongs to the color of a tracked object. So a color strongly related with the color of an object that we want to find has high value and a color weakly related with the color of an object we want to find has low value in probability image. In many tacking and segmentation algorithm using the color information a probability image is used to detect an object by the threshold method usually. However, it is very difficult problem to find a proper a threshold value because the color distribution of an image continuously changes over time.

In this paper the proposed color snake applies snake algorithm to probability image. As a result the problems of snake with complex background image and the decision of threshold value in probability image are overcome effectively.

2. Snake; Active Contour Model

Snake is an energy-minimizing spline guided by external (image) constraint forces and internal constraint force. In snake algorithm proposed by Kass et al [1], the external force makes snake move toward image features such as the lines and edges and the internal force makes it act like a membrane and thin plate. These constraining forces are represented as a combined expression of the total energy for minimization. The total energy of snake in a parametric representation $v(s)=(x(s),y(s))$ is defined as:

$$E_{total}=\int(E_{\text{int}}(v(s))+E_{image}(v(s)))ds \qquad (1)$$

The internal energy term of total energy is represented as

$$E_{\text{int}}(v(s))=\frac{\alpha|v_s(s)|^2+\beta|v_{ss}(s)|^2}{2} \qquad (2)$$

,where $v_s(s),v_{ss}(s)$ are the first and the second order partial derivatives of $v(s)$ respectively and α,β are the parameters to control sensitivity to the first and the second derivative. In internal energy E_{int}, the first-order term makes the snake act like a membrane and the second-order term makes it act like a thin plate. Adjusting the weights, α and β control the relative importance of the membrane and thin-plate terms

The external energy term, sometimes called as an image force term, is defined as

$$E_{image}=w_{line}*E_{line}+w_{edge}*E_{edge} \qquad (3)$$

,where $E_{line}=I(x,y)$, $E_{edge}=\|\nabla I(x,y)\|^2$, w_{line} and w_{edge} are the parameters to control the weight of E_{line} and E_{edge} respectively. E_{edge} term makes snake converge to the boundary of the object which snake is initialized nearby and E_{line} term makes snake converge to object line itself. Because these external energy terms allow snake to converge on the boundary of an object from nearby it, snake can track the lines and edges in image even though object moves somewhat. But convergence is a difficult problem in an image that has complex background features because the external constraint force terms are related with the lines or edges in image. A lot of objects in complex scene confuse snake to converge on the lines or edges. Therefore, it is a hard work to separate to object's edges or lines we want to track from the background edges or lines shown in Fig.2

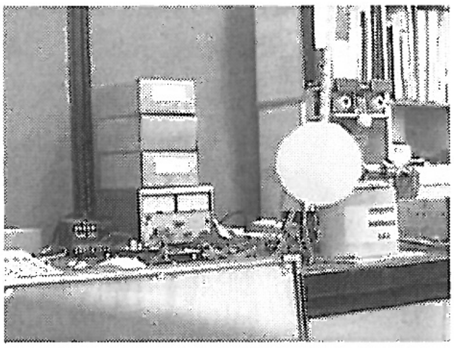


Fig. 1: We want find circular object with pink color

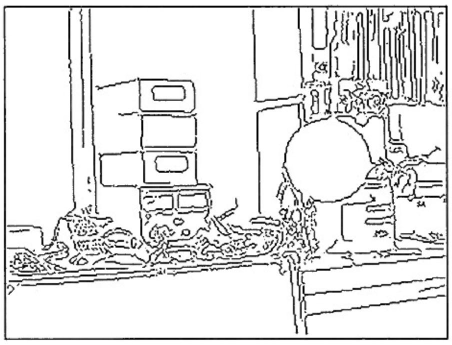


Fig. 2: Complex edge image of Fig. 1 image

In Fig.1, we want to find a circular object with pink color. However, if there are many edges in the image as in Fig. 2 that is the edge image of Fig. 1, it is hard shown to separate the edge of an object and track it. Our work is related with the elimination of background edges for finding and tracking object by snake algorithm. For the purpose of eliminating background edge we use color information of the object.

3. Color Modeling and Probability Image

In object tracking the color of an object is one of the most importance cues. Because the color is the native property of an object the color provides important information to detect and recognize the object in the image. But the color information of the object is influenced by object environment as ambient light, geometry of the scene or the object itself such as reflection properties, object shape and etc. Additionally in real environment most of the parameters are time dependent, where neither their parameters nor time variations are known also. Hence it can be a very complex task to model object color distribution over time.

A lot of work has been done on analyzing and modeling color distribution of an object in the image. In our work we use an ellipsoid to model the distribution of an object's color [4]. The ellipsoid models the color distribution of the object that we are interested in as shape of ellipsoid in color space. In real environment the color distribution of the object has similar shape to ellipsoid in color space as Fig. 3. Therefore ellipsoid can represent the color distribution of object effectively.

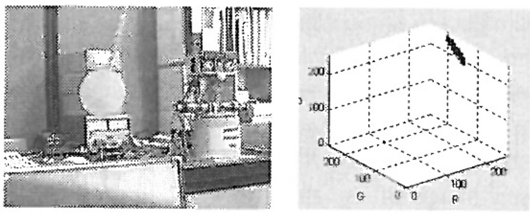


Fig. 3: Color distribution of object

Ellipsoid-model is based on the multivariate normal distribution.

$$n(v) = \frac{1}{\sqrt{(2\pi)^N \det \Sigma}} \exp\left(-\frac{1}{2}(v-\overline{\mu})^T \Sigma^{-1} (v-\overline{\mu}) \right) \quad (4)$$

where $v = (R,G,B)^T$ denotes the vector of pixel element in image and $\overline{\mu}$ is the mean of the color distribution of object and Σ is the covariance matrix.

$$\Sigma = \begin{bmatrix} \sigma_R^2 & Cov(R,G) & Cov(R,B) \\ Cov(G,R) & \sigma_G^2 & Cov(G,B) \\ Cov(B,R) & Cov(B,G) & \sigma_B^2 \end{bmatrix} \quad (5)$$

In covariance matrix σ^2 is variance and $Cov(x,y)$ is the covariance of variable x, y. In color space the equation (4) has probability distribution that has a shape as like ellipsoid which center is μ and covariance matrix is Σ. With equation (4) we can translate RGB image to the probability image which element represents degree of belonging to the color of the tracked object. Hence, the color nearby μ in color space has high value and the color far from μ in color space has low value in probability image. Fig. 4 shows the probability image translated from the original RGB image by equation (4), where μ and Σ are known initially. We can see that the circular region in the original image has a high value and another region except the circular region has a low value in probability image. (The darker is the higher value in probability image)

Therefore if there are pixels related with the color of tracked object, these pixels have values of near 1. Otherwise, these pixels have values of near 0 in probability image.

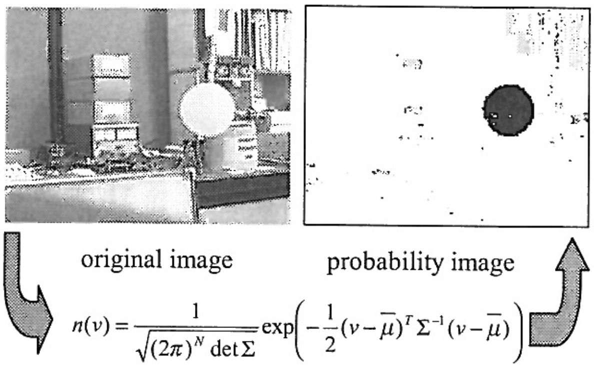
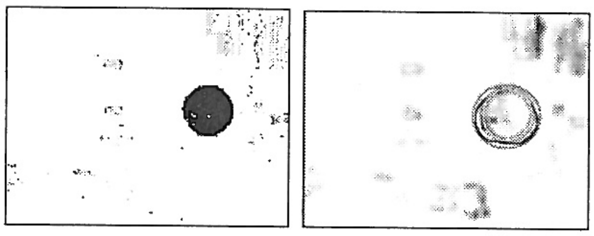


Fig. 4: Probability image using normal distribution

4. Snake Algorithm in Probability Image

Probability image represents the degree of belonging of the pixel of image to the color of tracked object. In probability image the element (pixel) of the image has a range from 0 to 1 by normalization. Color snake considers the probability image as gray level image for applying snake algorithm. Hence we can apply edge and smoothing operation in probability image and find object boundary. Because background features such as edges in RGB image can almost be eliminated in probability image by equation (4), a snake algorithm can be applied in probability image without any difficulty.



probability image and apply snake to it

Fig. 5: Apply snake algorithm to probability image

Fig. 5 is an edge image of the probability image applied the snake algorithm. Due to the elimination of background features snake can converge on the boundary of the object easily. In probability image, the pixels of the color of the tracked object have higher values than other pixels have. Also, the edge of the boundary of the traced object has stronger than any other edges beside the object. The reason why edge we want to find has strongest intensity makes tracking with snake be accomplished effectively in Fig. 5.

5. Experiments

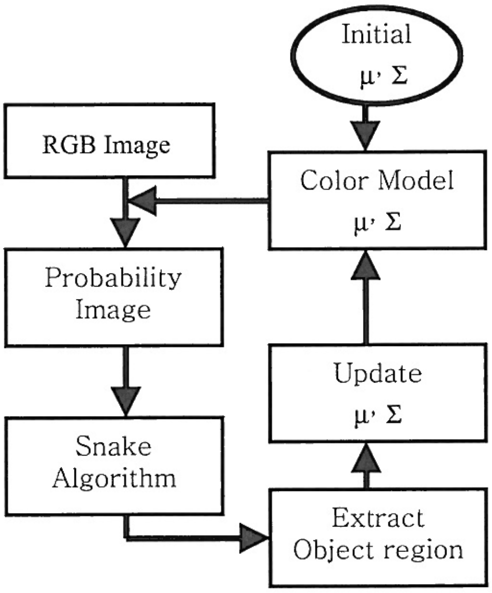


Fig. 6: Block diagram for color snake

Fig. 6 shows block diagram for color snake. Initially the mean μ and the covariance matrix Σ of color distribution are calculated from pixels in object's region that is selected manually and the initial position of snake is set also. By equation (4) with the initial μ and Σ we can make the probability image from the original RGB image. In next step the snake algorithm is applied to the probability image in order to track the object. When the snake is locked on the boundary of the object, the pixels inside active contour are extracted for updating the next μ and Σ. Then the next μ and Σ are calculated from selected pixels. Hence, new μ and Σ calculated from active contour become a start point for repetitive process. Because μ and Σ of color distribution are updated according to the color distribution of object tracked by active contour in each turn, the adaptation of color distribution can be achieved even though environment of object is changed.

Fig. 7 shows the results of experiments. The first row images in Fig. 7 are images sampled from the original image sequence. The numbers of the first row images in image sequence are 10, 15, 20, 25 and 30 in turn. The second row figures are the color distributions of the object to correspond to the same column of the first row images. They show that the color distributions in color space are changed according to position and orientation of the object in original images.

The third row figures represent probability images corresponding to the same column image in the first row. In the first column image of the third row, the object is segmented from background definitely. But in the last column image of the third row, the object cannot be segmented from background definitely because the color distribution of the tracked object is similar to the color distribution of some background features, where tracking algorithm with only color information cannot work well. However, even in that case a lot of background features are eliminated to compare with the original image and the edge of the tracked object is stronger than any other edges. Therefore, the tracking task is accomplished with snake algorithm successfully.

The final row images show the results of images applied snake algorithm. In these images a gray circle around the object represents active contour locked on the boundary of the object.

6. Conclusion

In this paper we proposed a novel approach to eliminate background features for sake of applying snake algorithm in image with complex background features. The snake algorithm using color information gives advantage to overcome problems caused by both snake algorithm with only edge or tracking algorithm with only color. Consequently, the color snake combines shape information and color information successfully for object tracking

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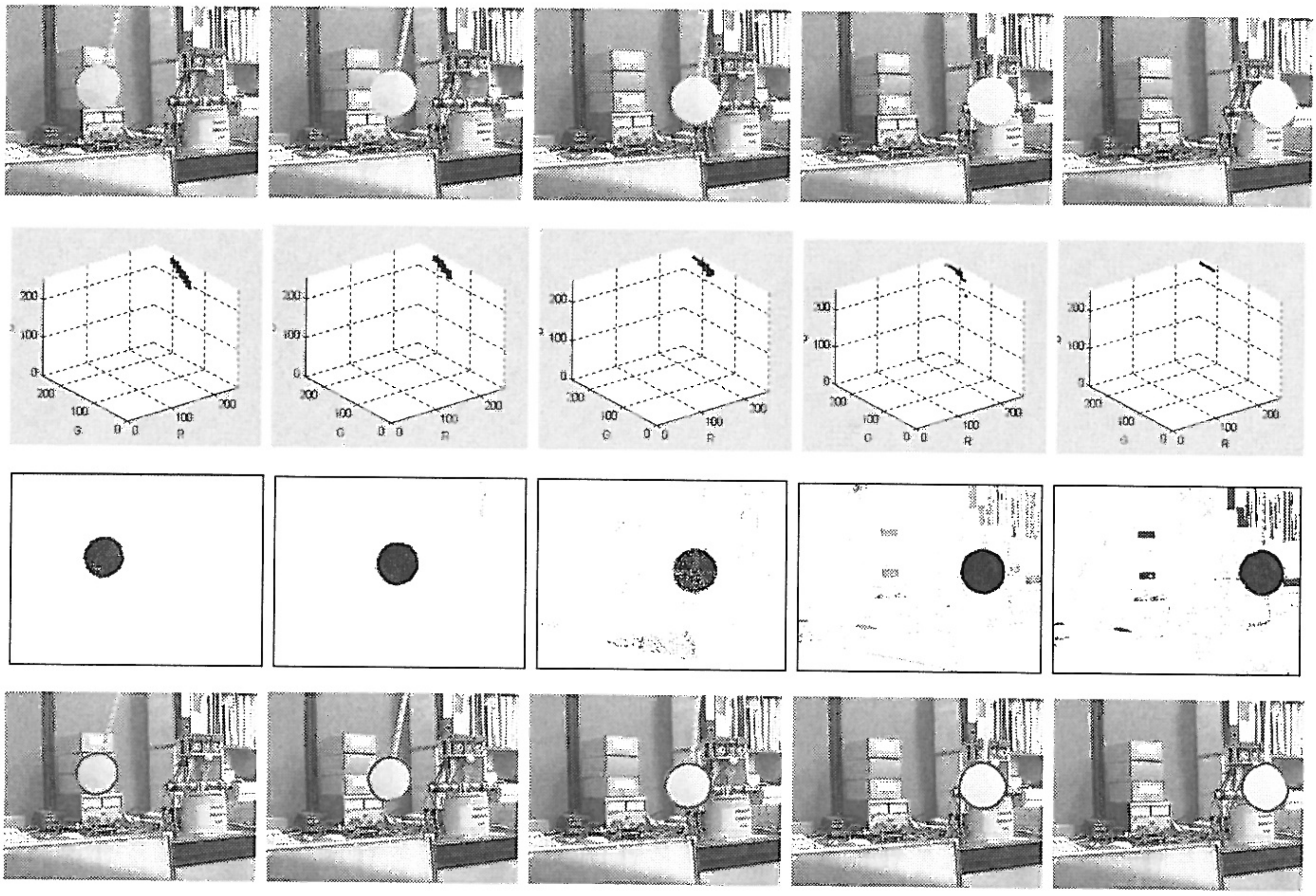

Fig. 7: Experimental results –original images, color distribution, probability images, images applied snake

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