

# FACE CONTOUR TRACKING IN VIDEO USING ACTIVE CONTOUR MODEL

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## ABSTRACT

Face contour represents important information used for human face analysis in image and video. Here, we propose an improvement to the conventional active contour model, called Snake, to track complex face contour. We propose using Gradient Angular Difference (GAD) to constrain the Snake contour to the specific face region. The Snake method obtains the optimal contour by iteratively minimizing its energy function. The iteration process is time consuming. Therefore, we proposed a motion compensation method to accelerate the face contour tracking process using Snake method in image sequences. The technique is shown to greatly reduce the computation time needed to minimize Snake energy. The simulation results show that the accurate Snake contour can be detected with minimal computation.

## 1. INTRODUCTION

Face contour offers an important cue for human face analysis. It can be used for 3-Dimensional human face reconstruction, as well as feature vector for human face recognition [5]. Detection and tracking of face contour are an important processing for face detection [6][7]. In order to acquire the complex face contour, active contour model called Snake, proposed by Kass et al. in 1987, has been successfully applied for face area segmentation [3]. However, these methods are only suitable for still images where computation time is not of a big concern. When tracking the contour in image sequence, the computation time is limited. The iterative energy minimization processing needed for seeking the optimal contours is time consuming. Therefore, we propose a motion compensation to accelerate the computation of Snake. A new energy term called Gradient Angular Difference (GAD) is proposed to improve the human face contour tracking performance in image

sequences. The technique has shown to greatly reduce the computation time needed to minimize Snake energy.

## 2. FACE CONTOUR TRACKING

The active contour, *Snake*, was used to solve the problem of tracking the complex shape of human face. It has been reported to locate and extract head and face boundaries [2]. We propose a new energy term to improve the performance and propose applying motion estimation to speed up *Snake* contour tracking in image sequences.

### 2.1. Snake definition

*Snake* was first introduced by Kass *et al* [3]. *Snake* is a deformable contour. In its discrete representation, the active contour is defined as a set of snaxels (*Snake* contour points)  $v_i = (x_i, y_i)$ , for  $i = 0, \dots, N-1$ , where  $x_i$  and  $y_i$  are the x- and y-coordinates of the snaxels  $i$ . The energy, which is to be minimized, is defined as:

$$E_{snake}(v) = \sum_{i=1}^{N-1} (E_{int}(v_i) + E_{ext}(v_i)) \quad (1)$$

We can use a discrete approximation of the second derivative to compute  $E_{int}$ :

$$E_{int} \approx \alpha |v'_s(s)| + \beta |v''_{ss}(s)| = \alpha |v_i - v_{i-1}| + \beta |v_{i-1} - 2v_i + v_{i+1}| \quad (2)$$

By minimizing this internal energy, the curves are made smooth. Depending on the applications, the external energy term,  $E_{ext}$ , is defined by the user to achieve the desired properties [4][9][10]. For instance, one may use the gradient of the image  $I(x, y)$ .

The original external force proposed by Kass has a limited attraction range. Many methods, such as the dilation force introduced by Cohen and Cohen [8], was proposed to solve this problem. However, nearby strong edges may still affect the accuracy of Snake computation.

In our application, the desired contour, being the face region, has specific shape. We propose that the orientations of image gradient vectors provide useful information about the contour. We introduce a new term, Gradient Angular Difference (GAD), which is described in section 2.2.

## 2.2. Gradient angular difference (GAD)

In conventional Snake technique, only the image gradient amplitude is used for the external force. We propose that the orientations of image gradient vectors can be used to limit the contour to be a smooth contour. In our work, we use the orientation of the gradient vector as an internal force by introducing a function called Gradient Angular Difference (GAD) to constraint the Snake to be a smooth contour. In reference [11], gradient orientation has been used for initialization of Snake contour.

The image gradient, along the x direction,  $G_x$ , and y direction,  $G_y$ , are defined as partial derivatives:

$$\mathbf{G} = \nabla I = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \partial I / \partial x \\ \partial I / \partial y \end{bmatrix} \quad (3)$$

and

$$\theta(x, y) = \tan^{-1} (G_y / G_x) \quad (4)$$

where  $g(x,y)$  is the Gaussian function. Fig. 1 shows the result of gradient vector calculation using Eq. (5). The zoom-in portion showing the details in face area is shown in Figure 1 (c). Notice that the orientations of the gradient in the immediate neighboring portion along the face contour are similar.

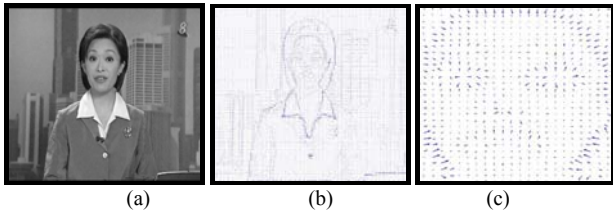


Fig. 1 Gradient vector of real image, (a) an input image, (b) the gradient vector, (c) the details in face area

In the weak portions of the contour, i.e. where the gradient amplitude is small, the orientation changes of the gradient vectors are continuous. Therefore, the orientation information can be used to attract the Snake contour to the valid region with small gradient.

We define GAD as the marginal orientation between two neighboring Snake points. For Snake point  $i$ , the GAD is defined as:

$$GAD(v_i) = \begin{cases} |\theta_i - \theta_{i-1}| & \text{if } |\theta_i - \theta_{i-1}| < \pi/2 \\ \pi - |\theta_i - \theta_{i-1}| & \text{if } \pi/2 < |\theta_i - \theta_{i-1}| < \pi \\ |\theta_i - \theta_{i-1}| - \pi & \text{if } \pi < |\theta_i - \theta_{i-1}| < 3\pi/2 \\ 2\pi - |\theta_i - \theta_{i-1}| & \text{if } 3\pi/2 < |\theta_i - \theta_{i-1}| < 2\pi \end{cases} \quad (6)$$

where  $\theta_i$  and  $\theta_{i-1}$  are the directions of the gradient vector at snake point  $i$ ,  $i-1$  respectively.

This term measures the difference of the orientations between two gradient vectors at neighboring Snaxels with respect to the tangent of the Snake contour. A smaller GAD implies a larger possibility for the snake point  $i$  to be on the same contour as snake point  $i-1$ . Therefore, minimizing this term will help to produce a smoother change in the Snake contour. Since the measurement of gradient vector orientation is usually accurate even in the region with low contrast, GAD containing this information acts as an efficient supplement to gradient amplitude. Moreover, identical to the essence of the active contour model (Snake), GAD integrates in one term the image feature (the gradient vector at Snaxels) and geometric information (the relationship between neighboring Snaxels). Combined with the robustness of the gradient vector orientations, this integral energy provides a comprehensive and reliable criterion to decide whether the concerned candidate points belong to a Snake contour.

We add GAD term into the Snake energy function with the dilation force:

$$E_{snake}(v) = \sum_{i=1}^{N-1} (E_{int}(v_i) + GAD(v_i) + E_{ext}(v_i)) \quad (7)$$

## 2.3. Motion-compensated Snake computation

The Snake method is often applied iteratively; a small neighborhood region around the previous snaxel is used as the search region. The algorithm is applied repeatedly until there is no change in the total Snake energy. The disadvantage of this method is that the computational time can be very high if the initialization is far from the actual minimum. We propose a motion compensation method for tracking the Snake in image sequences. The technique has shown to greatly reduce the total computation time needed.

This method utilizes the motion vectors obtained by proper motion estimation method such as described in [1] to reduce the search area for every snaxel. Besides reducing computation time, another advantage of this technique is that the detection may be implemented to avoid possible pseudo snaxels nearby. The concept of

reduced search region using motion information is shown in Figure 2. The solid line is the original Snake contour and the dotted line is the estimated contour (in the next image frame). Without using motion vector, the large search window,  $m_2$ -by- $m_2$ , is needed. If the motion vector,  $d = (dx, dy)$ , is used only the shadowed area on the top right corner,  $m_1$ -by- $m_1$ , is searched.

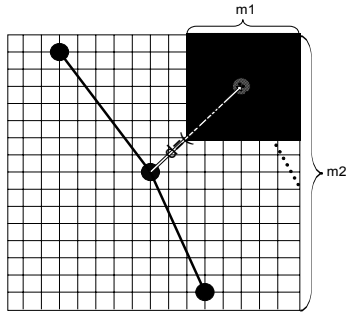


Fig 2. Modified search region using motion estimation.

Since the computational complexity is proportional to the number of snaxels and cube of the size of the search windows,  $m_3$ . That is, in each optimization step, the computation can be expressed in the form:

$$\text{Complexity} \propto O(nm^3) \quad (8)$$

where  $n$  is the number of snaxel and  $m$  is the size of the search window. Therefore, the overall computation can be greatly reduced if the accurate motion vector is available. For example in Figure 2; after the compensation, if the size of the search window is reduced with ratio  $m_1/m_2 = 1/2.5$ , the computation is reduced by ratio  $1/16$ .

### 3. EXPERIMENTAL RESULTS

In this section, we present some simulation results based on the methods described earlier.

The application of the proposed GAD energy term in face contour extraction is illustrated in Figure 3. We initialized a circle shaped contour inside the face region as shown in Figure 3(a). In Figure 3(b), the dilation force pushes the contour to the face boundary. The contour is pushed through the short edges of eyebrows and mouth to arrive at the face contour as expected. However, it also overstepped the face boundary near the ear because of the small gradient at this region. Employing the orientation information, the GAD energy term will enhance the ability of Snake to attract to this region. Figure 3(c) demonstrates the improved tracking performance using GAD. Combined with the dilation force, the GAD term guides the Snake to the exact face contour, excluding the ear region. This can be seen more clearly in Figure 3(d), which shows the zoom-in region around the right ear. For the purpose of demonstration, we superimposed the

tangent vector, which is perpendicular to the gradient vector. In the figure, since the gradient vectors at the ear part are distinct to the ones on the face boundary, the Snaxel stops to evolve into the ear region.

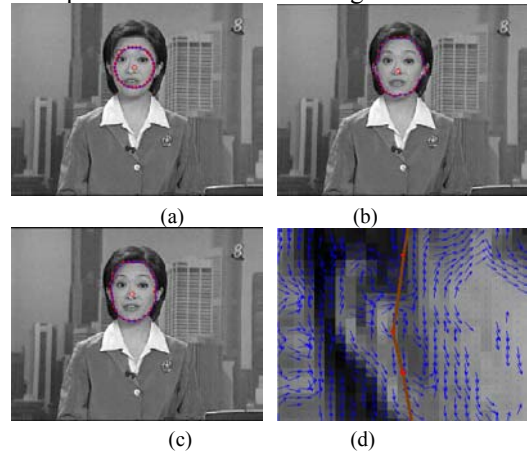


Fig. 3 Application of GAD term in *Snake* detection. (a) *Snake* initialization, (b) resulting contour without GAD, (c) the face contour using GAD, (d) the zoom-in region around the right ear



Fig 4. Examples of face contour tracking in practical image sequences. The first two rows are image sequences commonly used in motion analysis; the later two rows are the image sequences captured by the author

We have tested our techniques using the motion imagery database from Ohio state university. These sequences contain moving face with speech. We also performed the same tests on the image sequences captured by ourselves. The results on practical image sequences are shown in Figure 4. The first two rows show the result using the

image sequence from motion imagery database and the last three rows show the results using our image sequences. As can be seen that the proposed method can extract and track the face contours successfully. Since the GAD term includes not only the geometric information but also the image gradient information, it provides a smooth contour that matches the face area exactly even in the hair region where the contour converges properly.

Figure 5 compares the Snake energy progression; with and without using motion compensation. The dash red line shows the Snake energy progression without motion compensation whereas the cyan line is the Snake energy progression using motion compensation. Note that the energy of the Snake contour when using the motion compensation (cyan) is lower than that when motion vector is not used (red), especially for lower number of iterations. This is because of the fact that the motion vector allows a better initialization of Snake and therefore the Snake energy converges much faster.

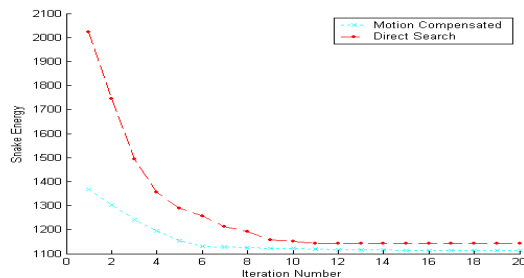


Fig 5. The energy changes comparison between direct search and using motion compensation

Table 1. Comparison of computation time of Snake, with- and without motion compensation

Iteration No.	1	2	3	4
Comput. time without motion (s)	16.2	15.6	14.9	15.5
Computat. time with motion (s)	0.48	0.52	0.52	0.48

Note: The system used is a Pentium III, 800 MHz, running Matlab 6.5

Table 1 shows the advantage of using motion compensated Snake tracking in image sequence of second row of Fig. 4. The Table shows the average computation time of every iteration using the same number of Snaxels, with and without motion compensation. The computation time needed in the motion compensated method is much less than that needed in the direct search method.

#### 4. CONCLUSION

In this paper, we presented a system for face contour tracking on successive frames from a video sequence using an improved Snake method. The Gradient Angular

Difference, or GAD, energy term is proposed to improve the traditional Snake algorithm. The GAD energy term can help to increase the attraction force in these regions with weak edges (with small values of gradient amplitude). In order to track the face contour in image sequence, a motion compensation method was introduced. The motion information can be used as compensation in tracking the face contour in the successive video frames. The motion compensated Snake searching method can greatly speed up the computation.

#### 5. REFERENCES

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