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Visual Tracking Using Snake Algorithm Based on Optical Flow Information

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Abstract

An active contour model, Snake, was developed as a useful segmenting and tracking tool for rigid or non-rigid (i.e. deformable) objects by Kass in 1987. In this research, Snake is newly designed to cover this large moving case. Image flow energy is proposed to give Snake the motion information of the target object. By this image flow energy Snake's nodes can move uniformly along the direction of the target motion in spite of the existences of local minima. Furthermore, when the motion is too large to apply image flow energy to tracking, a jump mode is proposed for solving the problem. The vector used to make Snake's nodes jump to the new location can be obtained by processing the image flow. The effectiveness of the proposed Snake is confirmed by some simulations.

1. Introduction

Automatic controls in various fields have affected the world in which we are living in recent years. Automation has been carried out in factories, military defense, services in hospitals and so on. Controllers for high performance need large amounts of integrated information about systems and the environment for feedback information. A vision system is a sensor that can give this kind of information. Visual sensors are necessary equipment for sensing obstacles or targets in complex automation systems like mobile robots, AICC (Active Intelligent Cruise Controls) and so on. In a vision system, some processing such as segmentation and tracking are important procedures.

Active contour models have been developed as useful tools for segmenting and tracking rigid or non-rigid (i.e. deformable) objects. *Snake*, one of the active contour models(ACMs), was introduced by Kass et al.[1] in 1987. They defined Snake energies such as internal energy, image energy and external energy. Segmentation and tracking can be done by this energy minimization process. They tried to solve optimization problem for energy minimization by a variational approach. Amini[2] presented dynamic programming for finding minimum points. Point Snake algorithm was developed for discrete contours. Snake forces were introduced for finding the direction of local minimum points on the boundary of objects[3]. Leymarie[4] tried to segment and track deformable objects like amebas and proved the convergence of Snake's motion. Yang[5] tried to track the contours of a human face for the recognition of human's intentions and emotions by the computer vision technique, and Kim[6] tracked the hand motion of humans for the recognition of gestures. Xu[7] used the Snake for modeling three dimensional objects.

2. Problem Statement

When the variance between successive images is small Kass' snake operates well by the variational solution or dynamic programming method. But in the case of large variance between successive image streams the convergence of Snake motion can not be ensured because the assumptions of variational approach can not be effective in this case. This is a major problem of Snake in tracking objects, which may have discrete motions in image streams due to the abrupt increase of object's speed or the low performance of the vision system. Three kinds of problems are discussed in this chapter : a tracking problem, a contraction problem and an image force problem

2.1 Tracking Problem

Snake can find an object's boundary by the process of energy minimization in the energy space defined on the basis of the object's geometry and the intensity information of the image. In Fig. 1 the segmentation process is explained conceptually.

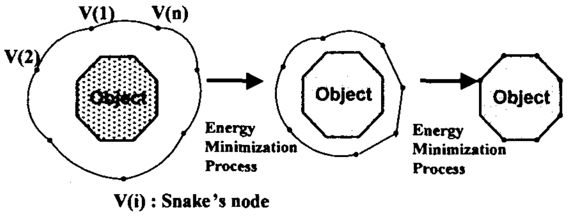


Fig. 1. The concept of segmentation process

Snake contour may contract into the boundary of the target object from the initial location along the gradient of the energy related to the object's geometry. Snake's contour may be expressed by the set of node vectors in discrete cases. Snake can find the exact boundary of the object by searching the maximum gradient points. Kass defined image energy as a function of the gradient of image intensity.[1], [4].

$$E_{\text{image}}(x, y) = -\gamma|\nabla I(x, y)|^2 \quad (1)$$

Fig. 2 is a representation of image energy. In Fig. 2 (a) an original image is presented. There is a ball on green grass. By the gradient process of equation (1) the original image can be expressed as energy value sets. In Fig. 2 (b) we can know the points that exist within the boundaries of the object which have minimum values in the image energy space. Therefore Snake can make segmentation of the object from an image by the minimization of the energy level.

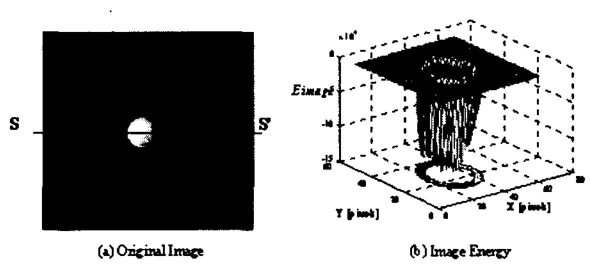


Fig. 2. The profile of image energy.

When the next image is grabbed by the image-grabbing unit of the vision system, a tracking concept is needed to find the object's boundary image in spite of the variation of the object's location from the previous image. If the variation is small, the solutions gained from the variational approach are effective with the next image and Snake can find the object's boundary by the gradient of the image energy. But if not, the effectiveness of solutions on the Snake's motion is not ensured.

2.2 Contraction force problem

Kass proposed internal energy to make the contour of Snake have smooth geometry. Snake's internal energy is composed of two terms. The first term is the first derivative of the contour along spline 's', and the second one is the second derivative of the contour along spline 's'. Internal energy, E_{int}, can be expressed as the equation (2) at the i-th node.

$$E_{\text{int}} = \alpha_i\,|\vec{v}_i - \vec{v}_{i-1}|^2 + \beta_i\,|\vec{v}_{i-1} - 2\vec{v}_i + \vec{v}_{i+1}|^2 \quad (2)$$

In initial segmentation mode, contraction forces need to be generated into the center of the object. The contraction forces are related with the second term in the equation (2).

If we introduce $\vec{u}_i$, $\vec{u}_{i+1}$ such as

$$\vec{u}_i = \vec{v}_i - \vec{v}_{i-1} \quad (3)$$

$$\vec{u}_{i+1} = \vec{v}_{i+1} - \vec{v}_i \quad (4)$$

then $\vec{u}_{i+1} - \vec{u}_i$ can be expressed as follows :

$$\vec{u}_{i+1} - \vec{u}_i = \vec{v}_{i-1} - 2\vec{v}_i + \vec{v}_{i+1} \quad (5)$$

From the equation (5) we can know the direction of minimization of $\boldsymbol{E_{int}}$ is the same as vector, $\vec{u}_{i+1} - \vec{u}_i$. The contraction forces are generated by the second term of $\boldsymbol{E_{int}}$.

If objects have rectangular forms like cars or some kinds of robots, the $\boldsymbol{E_{int}}$ may have larger values at corners than at the others. Moreover if the objects have non-convex forms, then the contraction forces may not be generated into the center of the target object at the points in the vicinity of the non-convex region. New energy has to be designed not to be affected by the form of the object to be tracked.

2.3 Image force problem

After Snake's nodes move to the vicinity of the target objects by the contraction forces, they are mainly moved by the image forces generated by the gradient of the image intensity. Image forces are affected by the quality of the image but most raw images have noisy components. First, a preprocessing of image is needed to gain stable image forces for rejecting noisy components. But preprocessing needs additional processing time. Second, the gradient descent method for deciding the position of Snake's nodes at the next time step has difficulty with this kind of energy profile because the changes of image gradient are very abrupt in the vicinity of the edges. This difficulty also needs a preprocessing like smoothing.

3. Design of active contour model

In this chapter a new Snake's model, proposed energies, operation modes for Snake, the application of image flow, and a search method using Snake's force will be explained.

3.1 Design of Energy

3.1.1 Image Energy

image energy is the same as Kass' as expressed in equation (1). Gradient operation for calculating image energy can be executed by the convolution of image with a Sobel operator [8]. A Sobel mask is composed of two orthogonal operators.

3.1.2 Contraction Energy

As explained in Chapter 2, the equation (2) of E_{int} is related to the geometry of the object. In equation (2) the second term makes the contraction forces generate. But this kind of internal energy has some problems explained in Section 2.2. A new kind of internal energy must be proposed to overcome these problems. Therefore contraction energy, E_{cont}, is proposed on the basis of quadratic function in (6). This function has parabolic characteristics of which the center point is the one calculated by the initial Snake contour. The estimated center point can be calculated by using the first moment and the area of initial Snake.

$$E_{cont}(i) = \beta_i \cdot K_{cont}\{(x_i - \hat{x}_c)^2 + (y_i - \hat{y}_c)^2\} \quad (6)$$

where β is a constant for E_{cont} , K_{cont}, is a energy constant.

and ($\hat{x}_c$, $\hat{y}_c$) is the center point estimated from initial Snake.

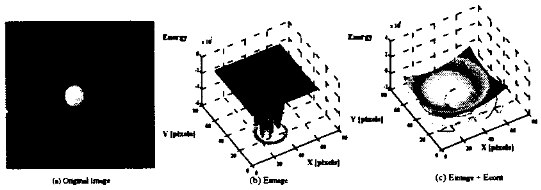


Fig. 3. The concept of contraction energy

The concept of contraction energy, E_{cont}, is explained in Fig. 3. The original image can be converted into image energy, E_{image}. E_{image} + E_{cont} are expressed in Fig. 3 (c). The resulting energy has a form that contracts the Snake's nodes into the estimated center of the target object by the gradient. Initial Snake's nodes may be contracted by the contraction energy, E_{cont}, and in the boundary of the object to be segmented nodes can fall into the valley of the image energy, E_{image}. Through this process objects can be segmented successfully.

3.1.3 Image Flow Energy

Image flow energy is designed for making nodes roll along the direction of the image flow in the tracking mode.

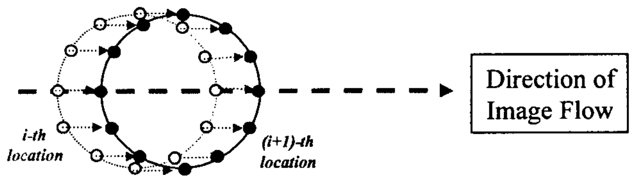


Fig. 4. The concept of tracking based on optical flow

The tracking based on image flow information is conceptually explained in Fig. 4. An object expressed as the dotted circle is being segmented by Snake's nodes at ***i-th*** frame. At ***(i+1)-th*** frame an object expressed as a thick line moves to the right, and the forces to make the nodes move to right are also needed to track this motion. If the direction of the image flow is obtained, then a certain energy such as E_{flow} can be designed to make the nodes move in the direction of the object's motion.

Image flow energy can be proposed in the next equation at node i.

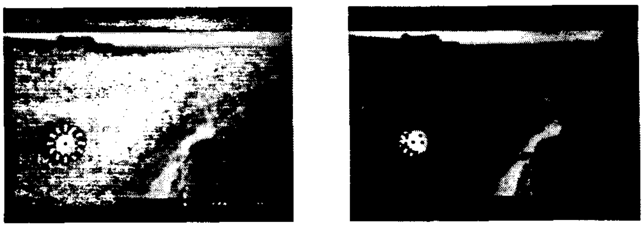
$$E_{flow}(x'_i, y'_i) = K_{flow1} \cdot \exp(-x'_i/3r_{obj}) - K_{flow2} \cdot \exp(-(y'_i/1.25r_{obj})^2) \quad (7)$$

where K_{flow1}, K_{flow2} are energy constants, x', y' are the axes of frame for image flow and r_{obj} is the radius of a object.

The direction of the image flow is dependent on the motion of the object. So image flow energy, E_{flow}, has to be defined in the frame of the image flow and transformation between the original image frame and the image flow frame is needed to be defined. x' axis is aligned in the image flow direction and the exponential function is assigned to this axis. Considering the accuracy of the calculation result of the image flow, Gaussian function is assigned to y' axis. Because of this Gaussian function along the y' axis the nodes can be gathered into the object's boundary.

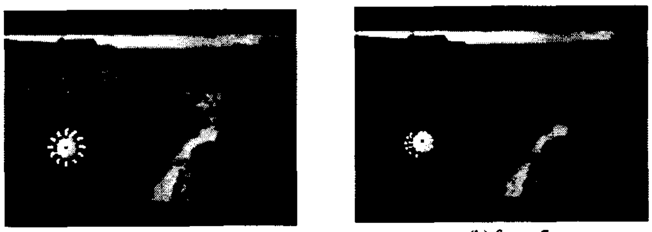
4. Simulation Result

In this section simulation results comparing Kass' Snake and the proposed Snake are explained. First, the simuation results of Kass' Snake are expressed in Fig. 5. There is a ball on the grass in the picture of Fig. 5 (a). In this initial state segmentation is needed to know the boundary of the target object(the ball). So segmentation mode has been executed. Snake is roughly placed around the object in the initial state, and that contracts into the boundary of the target object by the gradient of Snake's energy in the first frame. In Fig. 5 (a) segmentation of the target object is successfully done in several iteration steps by the segmentation mode. For simulating large differences between two images the 7-th picture was selected as the next input picture because the difference of location of the object is large. The simulation result of the proposed Snake on tracking a ball is expressed in Fig. 6. In this case image flow information about the target's motion is obtained by the process of image flow.Therefore tracking a ball is successful as seen in Fig. 6 (b).



(a) frame 1 (b) frame 7

Fig. 5. The tracking of Kass' snake



(a) frame 1 (b) frame 7

Fig. 6. The tracking of the proposed snake

5. Conclusions

The original Snake can be applied to case, where there are the changes between two images because the solutions are based on the variational approach. In this research the image flow energy, E_{flow}, is newly designed to make Snake's nodes roll along the direction of motion by using the image flow information.

6. References

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