Detecting and tracking moving objects using a new snake-based approach

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Abstract

Snakes, or active contours, are used extensively in computer vision and image processing applications. In this paper, a robust approach is proposed for detecting and tracking moving objects, exploiting both effective contour extraction algorithms and active contour models. We use a snake balloon for scanning each image in order to find moving objects. These can improve robustness against the presence of occlusion and object's motion complexity. Examples on simulated sequences of images and one real sequence of images are presented.

Keywords: Active contour, active contour balloon, contour extraction, moving objects, tracking.

1. Introduction

Computer vision tries to give computers capacity for understanding world from images. Eyesight is one of the most important senses for human beings, which explain that efforts in research in computer vision are growing. There are numerous scopes of application like robotics, virtual reality, sports, medical applications, etc., and applications which have importance for human security like vision-based system for traffic surveillance or driver assistance system which can detect and track obstacles.

Active contours models are studied a lot for image segmentation. There are two general types of active contour models in the literature: parametric active contours and geometric active contours [1-3]. In this paper, we focus on parametric active contours.

The use of parametric deformable models to extract features of interest in images has been first introduced by Kass *et al* [4] in 1987 and is knew as *"snakes"* or energy-minimising spline.

A snake is an active spline reacting with image features. The active contour is initialized near a known edge, and then the contour is subject to "internal forces" and "external forces" which move and deform it from its initial position to the edges in the image.

The active contour can be represented by a continuous curve $v(s) = (x(s), y(s))$ where s is a parameter representing the arc length. The active contour behavior is energy functional defined by:

$$E_{snake} = \int_0^1 [E_{internal}(v(s)) + E_{external}(v(s)) + E_{constraint}(v(s))]\, ds$$

Thus the curve is controlled by three forces:

- *Internal forces*, which control the regularity of the curve, i.e. his elasticity and rigidity. The internal curve energy is commonly written as:

$$E_{interne}(v(s)) = \frac{1}{2}(\alpha(s)\left|v'(s)\right|^2 + \beta(s)\left|v''(s)\right|^2)$$

where v' and v'' are respectively first and second derivative with respect to s; α(s) corresponds to the elasticity (or stretching) and β(s) the rigidity (or flexion).

- *External forces*, or image forces, push the contour to the significant edges. Image forces is commonly written as :

$$E_{externe}(x, y) = -\left|\nabla(G_\sigma(x, y) * I(x, y))\right|^2$$

where ∇ is the gradient operator, I(x, y) the gray level image, and G_σ a smooth operator with an experimentally decided σ.

A robust external force has been introduced by Xu [5], called *Gradient Vector Flow* (GVF). This force is computed as a diffusion of the gradient vectors of a gray-level edge map derived from the image. GVF largely solves problems associated with initialization and poor convergence to boundary concavities, but is computationally expensive.

- *Constraint forces* correspond to other high level constraints which improve the segmentation process.

Active contours are largely used in numerous scopes of application like medical images segmentation [6-7], lip edges extractions [8], or for traffic surveillance: contour extraction for moving vehicles tracking [9-10] and lanes detection [11].

In this paper a new snake-based approach is presented for detecting multiple moving objects in sequences of images.

2 Related works

In his thesis, Selsis [12] proposes to use an active contour based on the balloon model [13] and the Kalman filter [14] for detecting and tracking multiple moving objects in a sequence of images.

The balloon model, introduced by Cohen, solves some of the problems encountered with the initial active contour model, especially the initialization problem. Indeed, initial active contour needs to be initialized close to his final solution, if not it may not be attracted by object edges and the curve shrinks on itself and vanishes to a point. The balloon model introduces a pressure force pushing curve outside as if air was introduced inside. The pressure force can be defined by $k.\vec{n}(s)$ where $\vec{n}(s)$ is the normal unity vector to the curve at point v(s) and k is the amplitude of this force. Thus we can initialize the snake inside an object and he inflates until to be stopped by the object edges, as in figure 1 where this model allows detecting lane boundaries.

(a) (b)

Figure 1: Active contour model and balloon. (a). Initial curve. (b). The lane is detected.

For detecting and tracking multiple objects in a sequence of images, Selsis proposes the process below:

- Seeing that objects penetrate in the scene from image sides, a snake balloon is initialized with the image periphery, delimiting a monitoring zone. His function is to detect and capture moving objects entering the scene.
- A penetrating object pushes the snake balloon gradually. For each image, the snake balloon is initialized according to edges detected in the previous image, thus the snake can detect again this object in the current image. Once the object is completely entered in the scene, the snake balloon surrounds this object and a scission process intervenes to capture it. A traditional snake is then created, modelling this object during its crossing.
- Tracking is assumed by Kalman predictions, which allow initializing traditional snakes in the current image according to their preceding positions.

Figure 2 shows an example with two objects entering the scene.

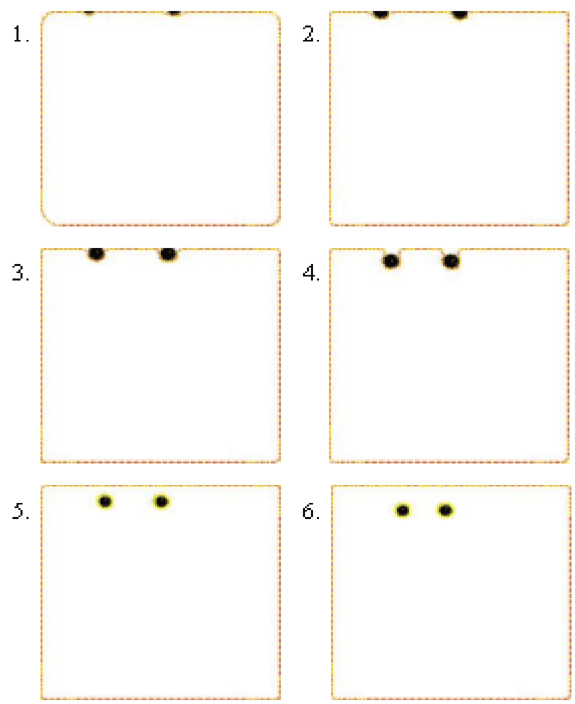

Figure 2: Selsis's approach for detecting and tracking moving objects.

Advantages

- All snakes are initialized automatically for each image without human intervention. The procedure is entirely computerized.
- All objects entering the scene are detected and tracked whatever their number, their size and their shape.
- The tracking scheme is robust against perspective effects (as an object moving towards the camera).

Drawbacks

- If objects motions are not with constant speed or with constant acceleration, or if objects abruptly modify their direction, tracking is likely to fail.
- This approach is not robust against occlusions. For example when two objects pass each other, the two classical active contours cannot model each object during occlusion.

In the next chapter, we propose a new approach which largely solves both drawbacks.

3 Our approach

We are interested here in images acquired by a static camera. Consequently, objects of interest can be put in a prominent simply with a difference (pixel by pixel) between background (the first image of the sequence) and the current image. The first image of the sequence must be free from any mobile object, and all images are acquired under same lighting conditions.

Once the image difference is computed, a contour extraction process is applied, and then we use a snake balloon to localize moving objects.

3.1 Contour extraction

We use a contour extraction algorithm, similar to the Canny-Deriche approach, resumed by figure 3. Figure 4 shows the successive stages on a real image.

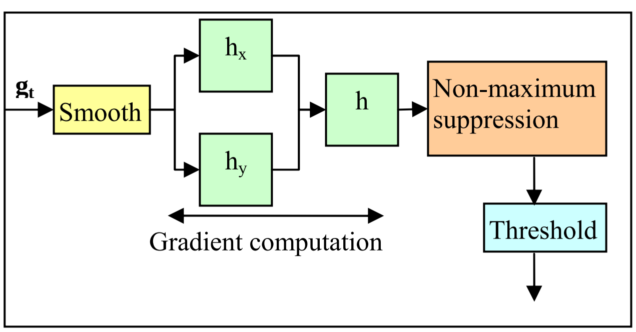

Figure 3: Contour extraction

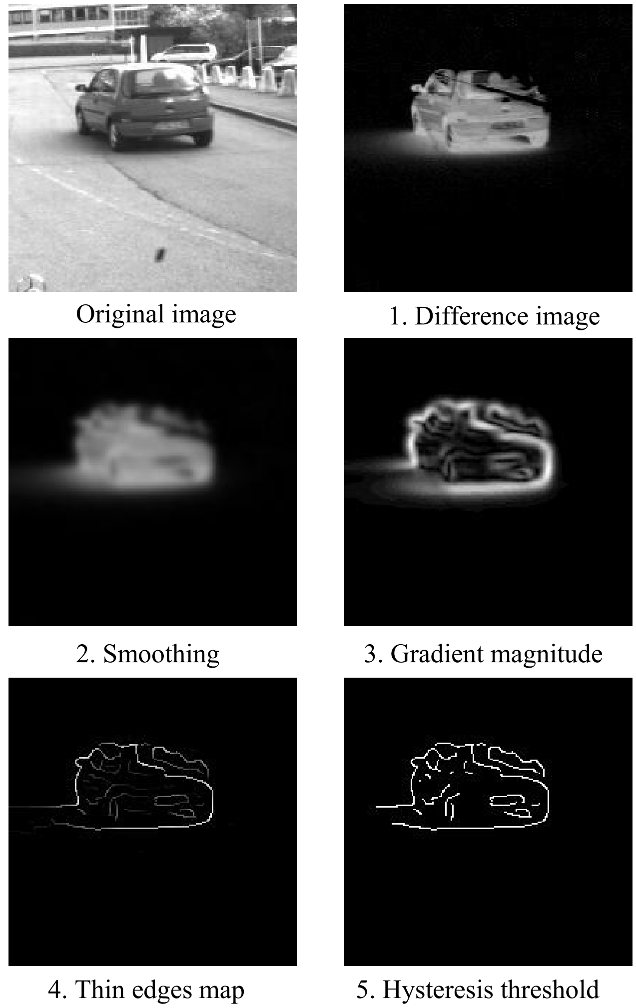

Figure 4: Contour extraction. The successive stages.

3.2 Objects detection

Once the edge map is computed, we use a snake balloon to localize moving objects. We propose the process below:

- Instead of initializing the snake balloon with the image periphery, the snake is initialized as a line at the bottom of the image. For each image, the snake is initialized in the same way. Like the previous approach, initialization process is automatic, not requiring human intervention.
- Then the snake balloon inflates to detect objects of interest. Visually, a line scans the image upwards. The line progression is blocked by objects contours, then like in the previous approach, the line surround objects of interest and a scission process intervenes to capture them. For each object, a traditional snake is then created, with for role modelling the object. Figure 5 shows an example with three simples object in one image.

- Objects detection is computed for each image. Consequently, we do not need to predict objects positions in the current image. In addition, this approach is robust against occlusions. For example, when two objects pass each other (see figure 6), the snake balloon detects one object during occlusion, then he detects the two objects when occlusion is finished.

Figure 7 shows an example on a sequence of real images where a vehicle is entering in the image from the right side.

4 Conclusion

This paper presents a new snake-based approach for detecting multiple moving objects in sequences of images. It exploits both effective contour extraction algorithm and the active contour balloon model. This approach has many advantages:

- Snakes are initialized automatically, without human intervention.
- All objects entering the scene are detected and tracked whatever their number, their size and their shape.
- Robust even if objects motions are not with constant speed or with constant acceleration, or if objects abruptly modify their direction.
- Robust against occlusions.

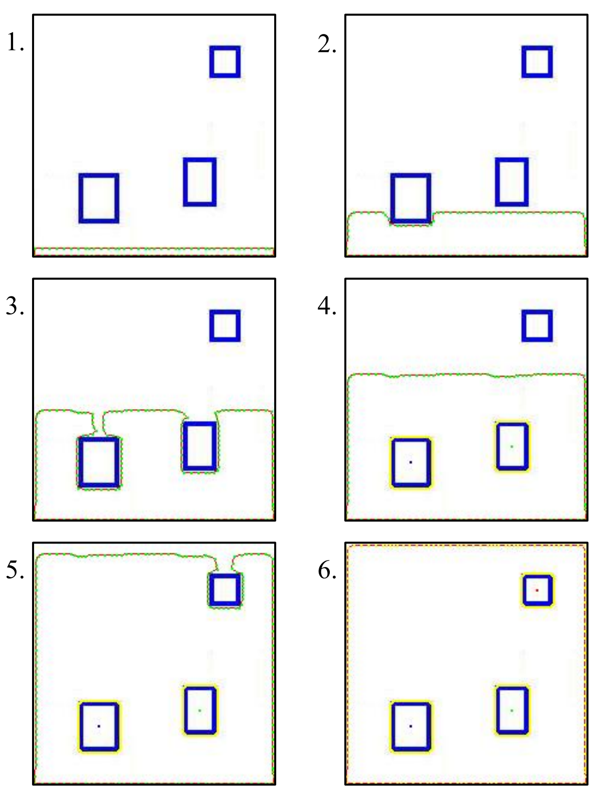

Figure 5: Detection process

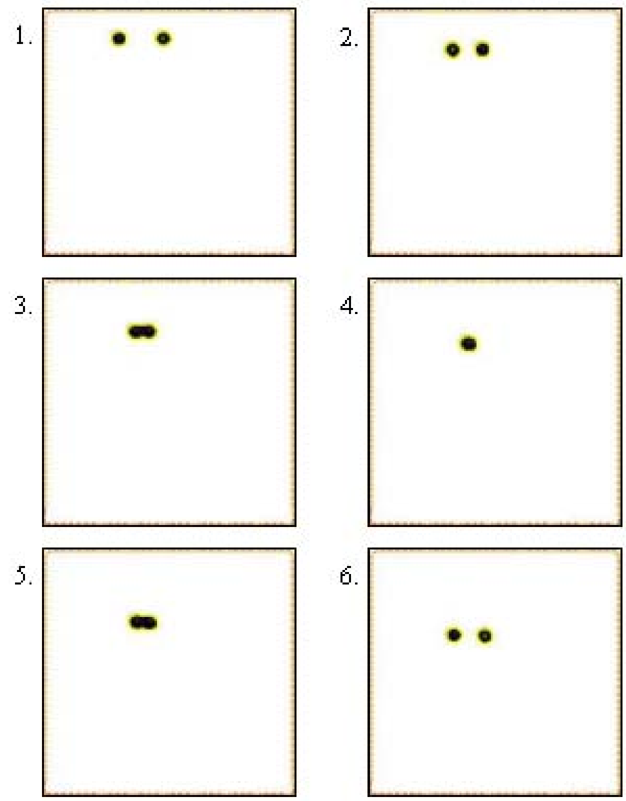

Figure 6: Detection robust against occlusions.

5 Future work

We plan to extend this approach for sequences of images acquired by a moving camera in a stereoscopic environment using snakes as high level primitives.

6 References

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Figure 7: Object detection and tracking