Tracking of Multiple Moving Objects Using Split-and-Merge Contour Models Based on Crossing Detection

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Abstract

The problem addressed in this paper is the automatic detection and tracking of multiple moving objects. Active contour models (snakes) are useful for detecting and tracking boundaries of deformable objects. However, Snakes can not track multiple objects correctly when they apparently overlap. This paper proposes a split-and-merge contour model based on detecting self- and mutual-crossings of the model. The proposed method can find occlusions of multiple objects by detecting mutual-crossing of different contour models which extract different objects. Multiple different contours which are mutually crossing are merged into a single contour. The merged contour model is split into multiple contour models when overlapping objects leave away from each other. We have implemented the method on DSP boards for real-time tracking of multiple moving objects in a dynamic image.

1 Introduction

Motion tracking is one of the most important problems in computer vision. Active contour models (Snakes)[1] provide a promising approach to the problem. Snake is a parameterized curve $\mathbf{v}(s) = (x(s), y(s))$ ($0 \leq s \leq 1$) on an image plane (x, y), which is deformed to detect object boundary by minimizing the following energy functional:

$$E_{Snakes} = E_{int}(\mathbf{v}) + E_{image}(\mathbf{v}) + E_{ext}(\mathbf{v}), \quad (1)$$

where E_{int} is an internal energy associated with splines, E_{image} is an image energy such as edge potential and E_{ext} is an external energy associated with external forces. Snakes are potentially useful for not only detecting target objects but also tracking them in noisy environments[1][2].

However, Snakes have the following two difficulties in their application to motion tracking in a time-varying image sequence:

1. Automatic extraction of multiple objects,
2. Tracking of apparently overlapping objects.

The first problem primarily concerns initial setting of contour models. In existing methods, initial contours for moving target objects have to be carefully set around the actual boundary of each object because snakes including multiple objects can not extract each of them individually. In most previous works, only semi-automatic motion tracking is realized since initial contours are set manually in such an application. Thus, it is essential to automatic tracking of multiple moving objects that they are automatically extracted in the first frame of an image sequence. The second problem in tracking multiple moving objects is that snakes can not track their boundaries correctly when they apparently overlap, since a contour model is attracted by edges which are extracted by another model.

In order to overcome these difficulties, we propose a split-and-merge contour model based on detecting self- and mutual-crossings of the model. Splitting contour models based on detecting their self-crossings [3] have recently been proposed by the authors for automatic extraction of multiple objects. The self-crossing is caused by employing the area term for energy function[4]. An initial single contour, for which an image frame can be simply selected, iteratively splits into multiple contours by cutting at crossing points for extracting each object individually. The splitting contour model can extract multiple moving objects by using optical flows. A contour is attracted by only pixels with motion cues by setting the image energy E_{image} such as edge potential to be zero when an optical flow calculated at each discrete point of the contour is small. By using the splitting contour model, multiple moving objects can be extracted as some groups of pixels with motion cues, which are smoothly connected.