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Space Object Tracking Method Based on a Snake Model[†] [⋆]

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Abstract In this paper, aiming at the problem of unstable tracking of low-orbit variable and bright space objects, adopting an active contour model, a kind of improved GVF (Gradient Vector Flow) - Snake algorithm is proposed to realize the real-time search of the real object contour on the CCD image. Combined with the Kalman filter for prediction, a new adaptive tracking method is proposed for space objects. Experiments show that this method can overcome the tracking error caused by the fixed window, and improve the tracking robustness.

Key words space vehicles—telescopes—techniques: image processing

1. INTRODUCTION

Optical observation is an important measure for monitoring space objects, and the automatic tracking of space objects is a key-important technique of space object monitoring. The robustness of tracking relates directly with the automatic recognition, the positioning and cataloging accuracy of space objects, and the operation efficiency of the telescope. The purpose of automatic tracking of space objects is that as soon as the initial trajectory of a space object is acquired, the telescope is guided to perform an automatic tracking of the succeeding arc segments according to the object position predicted by using the real-time sampling data, and the tracking process includes the prediction and real-time sampling two continuously repeated interactive procedures.

Because of the quick motion of space objects, the sampling frame-frequency is rather high, to make processing on the whole frame of each sampled image will cost a very long

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time, generally, a window is defined around the predicted position of the space object, and the window's barycenter is taken as the object's barycenter. Because of the attitude variation of the space object or the shelter of cloud layer, the visual brightness of the space object may be apparently varied, this is exhibited as the variation of image size on the CCD image. When a fixed window is adopted, the variation of image size may cause the window failed to contain the object, or cause the window to contain other objects, so that increase the difference between the window barycenter and the object barycenter, even further lead to miss tracking[1]. And for the extremely bright objects, such as the international space station, the imaging area on the CCD image is very large, the fixed window may cover only a small part of the imaging area, and therefore leading to an unsatisfactory tracking effect.

References [2-3] proposed a method to adaptively change the window size according to the image size, to a certain extent it has solved the problem of the unstable tracking caused by the variation of object image size, but when a strong interference occurs in the window, the window can hardly enclose the object, so that affecting the tracking effect. References [4-5] introduced the mean-shift method into the object tracking, which can realize the position adjustment of the fixed window, but cannot correct the tracking error caused by interferences, as an adaptation, it cannot help giving up the sampling, and therefore affects the sampling efficiency.

Instead of a fixed rectangular window, this paper searches the real contour of a space object by using an active contour model. Based on the improved GVF (Gradient Vector Flow) - Snake algorithm, combining with the Kalman filter, this paper has proposed a kind of linear adaptive tracking method of space objects, and solved effectively the tracking problem of space objects with light variations or large-sized images.

2. ACQUISITION OF IMAGE CONTOURS

2.1 Snake Model

Snake model is a kind of active contour model proposed by Kass et al. in 1988 for tracking the contour of mouth on man's face[6], because of its excellent performance in both image noise and image contrast, and of its ability to obtain the closed contours of objects, it has been widely applied to the field of image processing. The snake model takes the object contour as a continuous elastic curve, and defines its corresponding energy function to make the curve deform according to the criterion of minimal energy, and therefore to make this elastic curve approach to the real contour of the object, the place of minimum energy function is just the object's real contour. The snake model mixes effectively the local image characteristics in the deep layer and the global information about the contour of the object image together, so that to realize the image division and recognition. The parametrization equation of the parameterized contour line v is defined as:

$$v(s) = [x(s), y(s)], \quad s \in [0, 1] \tag{1}$$

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