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RESEARCH ARTICLE

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Active contour model based on force field analysis

Abstract The traditional snake initial contour should be close to the true boundary of an object of interest in an image; otherwise, an incorrect result will be obtained. Next, active contours have difficulties progressing into boundary concavities. Moreover, the traditional snake as well as almost all of its improved methods can be easily obtained from the local minimum because snake models are nonconvex. An active contour model based on force field analysis (FFA), namely, FFA snake model, is presented in this paper. Based on analyzing force distribution rules of the distance potential force field, a standard is introduced here to distinguish the false one from contour points. The result is not considered as the final solution when the snake energy is minimal. Furthermore, estimation and calculation should be made according to the established standard; only then can the result be considered final. Thus, the snake is prevented from running into the local minimum. The simulation results show that the FFA snake model has a large capture range and can move a snake into the boundary concavities, and that it is able to obtain the object of interest's contour precisely. Compared with the gradient vector flow snake, this new model has a low computational cost.

Keywords Active contour models, Snakes, Force field analysis, Aradient vector flow, Edge detection, Image segmentation

1 Introduction

Snakes, or active contour models, are presented by Kass et al.[1] in 1987. The problem of extracting the image contours is transformed into the problem of minimizing the energy by this method. A curve that is constrained by a set of parameters and is moved actively toward the image contours under internal, external, and constrained forces is defined. The curve is the image contours when its energy is minimal. This method uses the global information of the image contours to get a close curve and does not need any a priori knowledge about the image; having said this, it has a broad application in many image areas, such as edge detection, image segmentation, visual tracking, and so on. However, the traditional snakes have two weaknesses. Firstly, the initial contours must be close to the real image contours; otherwise, it would get an incorrect result. Secondly, it is very difficult to move a part of the snake into the boundary concavity. Aimed at these defects, many improvement methods have been presented. In general, each of these methods builds a new external force. These methods include pressure forces [2], distance potentials [3], gradient vector flow (GVF) snakes [4], etc. All of these methods have a large capture range; hence, the initial contours do not need to be near the real image contours anymore. However, additional defects were seen for these methods: pressure forces must be initialized to push out or push in, and pressure forces can push an active contour into boundary concavities but need not be too strong as "weak" edges will be overwhelmed. Distance potentials enlarge the capture range, but the second weakness of the traditional snakes still exists in this method. The GVF snake has a broad application that it has a large capture range and can easily move a part of the snake into the boundary concavity. However, the GVF snake has an obvious weakness that it has a high computational cost when calculating the GVF force field.

Because the snake model is nonconvex, the results could be at the local minimum when the curve energy is minimal. All the abovementioned methods consider that the curves are the image contours when the curve's energy is minimal; these methods do not make additional calculation and estimation to decide whether the results are the real image contours or not. Therefore, all these methods will get incorrect results if the results are at the local minimum.

Aimed at the weaknesses of the traditional snake and the defects of the above improvement methods, an active

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