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Hybrid active contour model based on edge gradients and regional multi-features for infrared image segmentation

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ABSTRACT

Infrared image segmentation is always a tough task due to blurred boundaries, low contrasts and noises. Active contour model (ACM) is an efficient tool which has been proved to be useful when applied to image segmentation, but still has lots of drawbacks. In this paper, a hybrid ACM for infrared image segmentation is presented via combing both edge gradients and regional multi-features which are seldom considered in previous researches, meaning that its level set formulation (LSF) is made up of an edge-based term, a region-related term and a regularization term. The first term steams from intensity gradients and promotes the contour to approach the object boundary. The second term is constructed by means of integrating a novel multi-feature signed pressure function (MSPF) with a traditional signed pressure function (SPF) through an adaptive weight coefficient. In this case, both local and global regional information are considered and challenges caused by inhomogeneity are thus overcome. Lastly, the third term provides a stable evolution for the contour. In addition, a Gaussian filter is introduced to avoid computationally expensive re-initializations of the LSF efficiently. Both qualitative and quantitative experiments demonstrate the effectiveness and robustness of the proposed method with the initial contour being set randomly.

1. Introduction

Infrared image segmentation plays an important role in military target detection and tracking. However, it is always a tough task due to the adverse characteristics of infrared imaging, such as the low target/background contrast, the weak boundary of target and the troublesome noise.

Recently, ACM has attracted much attention and has been designed for image segmentation [1–6]. This model can obtain sub-pixel accuracy and locate the target with a closed and smooth contour, which is almost impossible in conventional infrared detection methods [7–10]. Generally speaking, the existing ACMs can be classified into two main categories: edge-based methods and region-based methods. The former ones, the most representative model of which is geodesic active contour (GAC) [11], are designed to drive the evolution of object boundaries through intensity gradient and serves to stop the contour on the desired target boundary within a short time, but are sensitive to blurred edges and noises. The latter ones utilize the statistical information, rather than the edge information, to control the curve evolution. They usually outperform the edge-based ACMs in case of a low imaging quality and are relatively not sensitive to the initial contour. However, like the C-V model [12] and the selective local or global segmentation (SLGS) model [13], most region-based ACMs can only achieve

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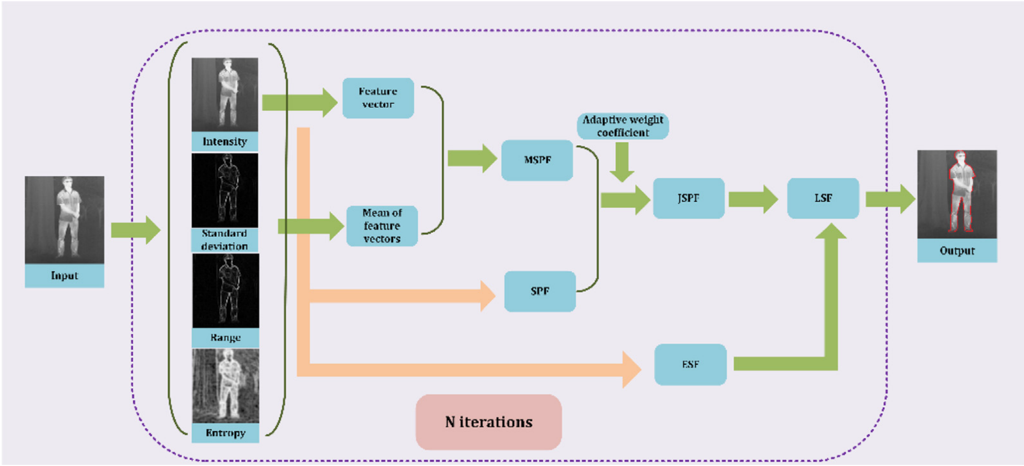

Fig. 1. Flow chart of the presented model.

good segmentation results on condition that intensity distribution inside of the target always maintains constant due to the lack of local statistical information. Another widely-used region-based ACM called local binary fitting (LBF) model [14] can handle images with intensity inhomogeneity, but only takes the local intensity feature into consideration, which results in the sensitivity to background elements. Recently, hybrid model [15] are designed to combine advantages of two categories and are proved to have good performances [16]. However, how to choose appropriate features and construct a robust LSF with suitable weights for each part still remain to be problems worthy of investigation.

Motivated by these aforementioned phenomena, this paper presents a novel hybrid ACM which integrates edge properties with regional multi-features for infrared image segmentation. The core task of this work is to form an LSF that consists of an edge-based term, a region-based term and a regularization term and drive the active contour to evolve towards the real boundary of infrared object. First, the edge-based term is brought forward based on the edge stopping function (ESF) that structured through gradient information. This term makes our model easily adjust to high-quality images, like high-resolution infrared images. Second, regional multi-features which are seldom considered in the previous ACMs, including standard deviation, range and entropy, are employed to form an MSPF which represents the local information. Further, the region-related term is instituted based on a joint signed pressure function(JSPF) that combines MSPF with a traditional SPF which represents the global information together via an adaptive coefficient. Third, a regularization term is developed to ensure the stable evolution of the contour. At the same time, a Gaussian filter is employed to smooth the LSF, through which the computationally expensive re-initialization can be avoided.

The reminder of this paper is organized as follows. Section 2 describes the theory of our model, especially for the construction of each term in the LSF. In Section 3, several real infrared images are used to make both qualitative and quantitative comparisons between typical methods and ours. And in Section 4, an overall conclusion is drawn for a summary of our work.

2. Theory

In this section, a detailed introduction of theories related to the hybrid ACM for infrared image segmentation is presented. The principle of our LSF is given first, and then a special discussion about the MSPF which is a key innovation of our work is made at length. Here, a complete flow chart of the model is given in Fig. 1 to show a clear skeleton.

2.1. Structure of level set formulation

First, let's define Ω as a boundary open subset of R^2 and I: $[0, m] \times [0, n] \rightarrow R^{+}$ as a given infrared image. Then let $C(p) : [0, 1] \rightarrow R^2$ be a parameterized curve in the Ω domain. Motivated by GAC model, an edge-based term of the energy functional is introduced to reflect the edge stopping information:

$$Edge(C(p)) = \int_0^1 g(|\nabla I(C(p))|)|C'(p)|dp \quad (1)$$

where, $\nabla[\cdot]$ represents a gradient operator; $g(|\nabla I|) = \frac{1}{1+(\nabla G_\sigma * I)^2}$ is the ESF; $G_\sigma * I$ denotes the convolution of image I and a Gaussian kernel whose standard deviation is σ.

Considering the shortcomings of SLGS model discussed in Section 1, we take regional multi-feature information, which is seldom considered in ACMs, into consideration to structure a JSPF. This function combines the conventional SPF with a