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# Bilateral Intensity Fitting Energy for Image Segmentation

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**Abstract.** We introduce a bilateral intensity fitting active contour model, which takes into consideration both the space distance and local intensity variation. It demonstrates flexible contour initialisation in handing intensity inhomogeneity, efficient segmentation, robustness to high noise, and ability to work with weak boundaries and complex background. Experiments with synthetic and real images show high efficiency of the model.

**AMS subject classifications**: 65M10, 78A48

**Key words**: Image segmentation, active contour, level set method, bilateral filtering, intensity inhomogeneity.

## 1. Introduction

Active contour models have been vigorously studied and successfully used in image segmentation [4, 6, 22]. The basic idea is to educe a contour along with a specified constrains which would allow to extract a desired object. According to the nature of constraints, the existing active contour models can be classified as the edge-based [1, 2, 11, 12] and the region-based [3, 8, 10, 14, 18, 19, 23] models.

In this work, we focus on the region-based models with the aim to identify each region of interest by a region descriptor guiding the motion of the active contour. The region-based models generally perform well in the presence of image noise and are robust with respect to the location and size variations of the initial contour. One of the most popular region-based models is the Chan-Vese (CV) model [3], which can automatically detect all contours regardless of where they start. Nevertheless, the CV and other subsequent models [18, 19]

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require global information to control the contour evolution and that is why they are not so effective in segmentation of images with intensity inhomogeneity.

To overcome this problem, localised region-based models were introduced in [8–10, 14, 20]. Thus Li *et al.* [10] defined a region-scalable fitting (RSF) energy in neighbourhoods of each image pixel and deformed the active contour to minimise the integration of the RSF energy over the whole image. More exactly, the energy is a distance-weighted mean square error of the approximation of image intensities outside and inside the contour. However, this model turned out to be too sensitive to the contour initialisation and has difficulties when dealing with segmentation of multiple objects in the presence of high noise.

In order to improve the RSF model, Wang *et al.* [21] proposed a local and global intensity fitting (LGIF) model in a variational level set formulation. It is defined by a linear combination of a local intensity fitting (LIF) energy [9] and a global intensity fitting (GIF) energy [3] — i.e.

$$F^{LGIF} = (1-\omega)F^{LIF} + \omega F^{GIF}.$$

The LGIF model can handle intensity inhomogeneity and is robust with respect to initialisation and noise but it requires to use different parameters $\omega$ for different initial contours. In the earlier authors' work [7], the Gaussian kernel in the RSF energy was replaced by a "mollifying" kernel and the total RSF energy was defined as a weighted energy integral. This improved the robustness of RSF model with respect to initialisation and high noise. The intensity of a given point was approximated by the weighted average of intensities of all points around. This can preserve certain isolated points and influence the segmentation.

In this study, we introduce a bilateral intensity fitting active contour model for image segmentation combining the advantages of the RSF model [10] and bilateral filtering [17]. More precisely, defining the local energy of each image pixel, we also take into account the local intensity variation. This idea enables us to get rid of the complications caused by isolated points. Thus, in contrast to [7], the RSF and LGIF models, our new approach allows a more flexible contour initialisation. Besides, in the same figure the LGIF model uses different parameters $\omega$ for different initial contours, whereas the model proposed here can work with one and the same parameter — cf. Figs. 2-3. On the other hand, this model performs better than the RSF model or the model in [7] in such aspects as robustness to high noise, intensity inhomogeneity, weak boundary and complex background — cf. Figs. 4-6.

This paper is organised as follows. Section 2 briefly reviews the RSF model and bilateral filtering. In Section 3 we describe the idea of bilateral intensity fitting energy. Experimental results with synthetic and real images are presented in Section 4, where we also compare different models. Section 5 contains some ideas about the parameters and entropy and Section 6 contains our conclusions.

## 2. Related Works

### 2.1. The RSF model

The RSF model [10] was proposed for segmentation of images with intensity inhomogeneity. Let $I(\mathbf{x}) : \Omega \to R$ be an input image and $C$ be a closed contour. Similar to [10], one