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Contour detection in an infrared image using the modified snake algorithm

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Abstract. Infrared and thermal images have been used widely in the different forensics and security applications. Such images show the temperature difference between different objects and scene background. One of the drawbacks of such images is low contrast and noisy images which should be enhanced. This paper presents a new thermal image contour detection algorithm using the modified snake algorithm. The segmentation algorithm based on the image enhancement and the modified model of active contours based on regions, taking into account the calculation of the anisotropic gradient. Some presented experimental results illustrate the performance of the proposed cloud system on real thermal images in comparison with the traditional methods.

1 Introduction

At the present stage of the development of technical vision systems, thermal imaging technologies are becoming increasingly popular. Such systems allow to get rid of the main problems typical for the visible spectrum sensors: effect of lighting variability, dependence on background parameters and the appearance of the object of interest, and the presence of shadows. The variability of lighting includes the following conditions: night shooting and poor visibility, which is related to weather conditions (fog, mist, rain, snow) and other conditions [1]. Therefore, thermal images are widely used for video surveillance and security in controlled areas: detection and recognition of objects, their classification, analysis of crowd behavior, for identification (face recognition), for remote sensing for objects of critical infrastructure for manmade disasters and other hazards. Thermal images are formed based on information of thermal energy on radiated by the surface of an object, represented by the temperature gradation. In connection with the special properties of infrared rays, thermal images are characterized by a weak signal-to-noise ratio and contrast, and defects related to reflecting surfaces, various types of noise, depending on the temperature difference between the environment and objects, and on the observation distance [2]. Such features introduce additional complexity for the automatic selection of objects; therefore, in order to obtain accurate results of the analysis of infrared data, a preprocessing step is necessary.

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At the moment there are several types of preprocessing suitable for this type of data. One of them is a widely used method based on histogram equalization. Due to the global nature of the processing, the entire tone of the image changes as brighter or darker. Often, these methods lead to artifacts and a general tonal image change due to the expansion of the dynamic range of the image in local areas. Another type of processing is associated with the use of the frequency domain transformation by means of the values of the modification and change in the frequency content of the image. An example of the transformation used for these methods are DCT and Fourier transform. In some cases, the image properties such as low and high-frequency coefficient's histograms may be so tightly packed that distinguishing them from one another may be impossible. A solution for improving the difference between levels is found in [3], where a logarithmic transformation is used. Another group of image enhancement methods includes Adaptive histogram equalization (AHE) [4, 5]. However, such methods have the disadvantage of excessive increase of noises in the homogeneous regions of the image. Therefore, an algorithm called contrast limited adaptive histogram equalization (CLAHE) was proposed, which is most suitable for processing thermal and infrared images [5,6].

An important and indispensable step in the automatic detection, recognition and tracking of objects of interest is the segmentation stage. The existing methods of segmentation of infrared images can be classified as follows: based on the classification [7-9], the threshold value [10, 11], neural network model [12], based on the active contour model [13].

In general, segmentation methods based on active contours can be classified into the edge-based models and the region-based models [14]. There are several examined on infrared images among the edge-based methods [15,16]. In [17] for extract the contours of objects of infrared images with a complex background, the setting of the level of tensor diffusion is used; in [18], an edge map is used by calculating the guide filter and the gradient vector flow (GVF); in [15] the background subtraction technique is additionally used. The main known problems of edge-based methods are associated with skips at the boundaries due to the weak sharpness of the boundaries. An improvement in the function for stopping the evolution of the contour on weak boundaries is proposed in [19] using the method of intensity adjustment level set evolution.

Methods based on the region use some descriptor to control the evolution of the active contour. One of the widely used and many modifications and improvements is the Chan-Vese image segmentation model [13, 20], which is based on the algorithm developed by Mumford and Shah [21] and the assumption of uniformity of intensity. One of the improvements proposed by the Chan-Vese model is proposed in [22] using the region approximation method and solving the drift problem of the center of classes, typical for the traditional model and affecting the segmentation result.

For thermal images, the Chan-Vese model is an acceptable solution for extracting objects of interest, unlike other types of segmentation algorithms. As a result of processing by this method, the selected edges of objects are smooth and without discontinuities due to the achievement of the subpixel accuracy model of the object boundaries. Providing a closed and smooth contour is more favorable for recognition problems [22].

The classical model of the active contour [13] consists in the deformation of the curve, which is limited by the process of compensation of internal and external forces given around the segmentation region. The main disadvantages of the classical approach are the extreme sensitivity to the parameters and the initial position of the curve; the leakage of the curve evolution due to the weak boundaries of objects; edge smoothing in the presence of noise.

The purpose of the work is to develop a segmentation algorithm based on the image enhancement and the modified model of active contours based on regions, taking into account the calculation of the anisotropic gradient.

2 Proposed method

The developed method of segmentation of infrared images consists of three main stages: image enhancement, anisotropic gradient calculation based on LPA-ICI (Local Polynomial Approximation – Intersection of Confidence Intervals) [23] and image segmentation with using algorithm of active contour [14] (Fig.1).

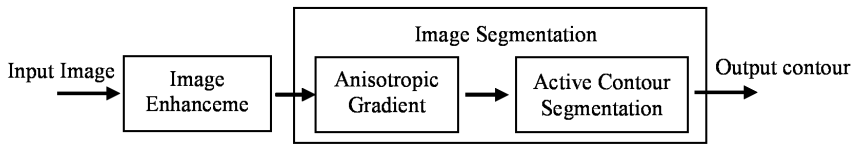


Fig. 1. Overall framework of the proposed algorithm.

The input thermal image is represented as a two-dimensional image, each pixel being attributed a grayscale, which is determined in correspondence with a conventional radiation scale.

First, the input image at the preprocessing stage, where the image had been subjected to a process of enhancement. The following steps describe a modified method of active contour segmentation thermal images using the LPA-ICI technique. The initial contour is determined by the manual selection of the object of interest. It is proposed to use an LPA-ICI anisotropic gradient to solve segmentation problems in the conditions of noise and inhomogeneity intensity in region of target object, and also weak target boundaries on a thermal image. This helps to eliminate the boundary leakage problem and the issue of the level set evolution prematurely stopping when the active contour segmentation is performed.

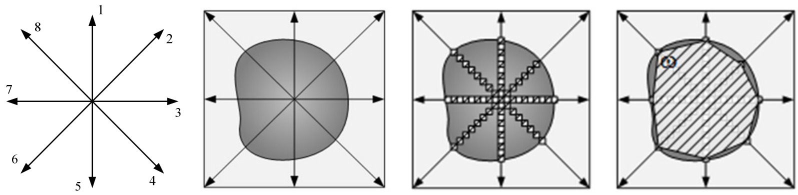
In [25] presents a new thermal image enhancement algorithm based on combined local and global image processing in the frequency domain. The basic idea is to apply logarithmic transform histogram matching with spatial equalization approach on different image blocks. The resulting image is a weighted mean of all processing blocks. The proposed image enhancement results for thermal images compare favourably against other state-of-the-art approaches.

In connection with the feature of generating thermal images, they are characterized by weak edges, a high degree of heterogeneity and low resolution. As a method of noise reduction, adaptive filtering based on local polynomial estimates using the ICI rule (LPA-ICI) is used [23].

The LPA-ICI technique combines two independent ideas [14]:

- Local polynomial approximation (LPA) to design a bank of linear filters of various bandwidth that perform pixel-wise polynomial fit on a certain neighbourhood.
- The intersection of confidence interval rule (ICI) is an adaptation algorithm, used to define the most suitable neighbourhood where the polynomial assumptions fit better the observations.

We use the LPA-ICI method to build the 'ideal' neighbourhood ω in the discrete image domain using LPA filters having directional supports for the image $f(x, y)$ (Fig.2).



a) b) c) d)

Fig. 2. Building neighborhoods using LPA-ICI method.

The anisotropic gradient concept allows the existence of a few neighborhoods V_i at the pixel p with the corresponding a few possible different vectors $(\nabla f(p))_l$ such that

$$f(p+v) - f(p) - v^T (\nabla f(p))_l = o(|v|),\ v \in V_l. \tag{1}$$

The ICI adaptive anisotropic differentiation is aimed at estimating simultaneously both the gradients $(\nabla f(p))_l$ and the neighborhoods V_l.

We used a modified segmentation algorithm based on active contour model to extract the boundaries of objects of interest on thermal image. After determining the anisotropic gradient in the previous stage, the energy of the function E was determined. Then, a curve was defined to minimize the energy. After all, the curves were propagated (gradient descent) to reach the minimum using level set, that easier to implement in reality.

The active contour or "snake" is a flexible curve consisting of n points in two-dimensional space:

$$V = \{v_i ..., v_n\}, \tag{2}$$

where $v_i = (x_i, y_i),\ i = \{1, ..., n\}$

The algorithm of the described segmentation method is presented in Algorithm 1.

Algorithm 1 Segmentation based on active contour model

Input: Original image $I_{x,y}$, Initial contour v_i, $i = \{1, ..., n\}$

for every pixels image $I_{x,y}$
  for every contour coordinates v_i (x_i, y_i)
    calculate $E_{internal}$ energy
    calculate E_{con} energy
    calculate ω – a weight functions
    calculate E_{image} energy (4)
  end
end
calculate $E_{edge} = |\nabla f(x, y)|^2$ energy

Output: Binary image or point list of output contours

The internal value of the elastic energy $E_{internal}$ depends on the shape of the contour and determines the type of deformation; the external value of energy $E_{external}$ controls the fit of the contour to the edges of the area of interest, that is, tends to minimize the difference between the active contour and the boundaries of the object under study. The first part of the external energy is the forces due to the image itself Eimage, the second part is the constraint forces introduced by the user Econ. The curve is calculated as the total energy of the three energy terms [24]:

$$E_{snake} = \int_0^1 E_{snake}\left(v(s)\right)ds =$$
$$= \int_0^1 \left(E_{internal}\left(v(s)\right) + E_{image}\left(v(s)\right) + E_{con}\left(v(s)\right)\right)ds \tag{3}$$

The image energy is calculated as

$$E_{image} = \omega_{line}E_{line} + \omega_{edge}E_{edge} + \omega_{term}E_{term} \tag{4}$$

where ω is a weight function.

The edge functional is defined by:

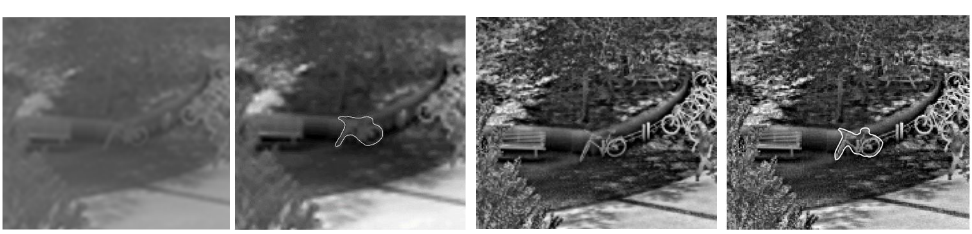
$$E_{edge} = \left|\nabla f\left(x,y\right)\right|^2 \tag{5}$$

3 Experimental results

Figures 3 and 4 demonstrate the thermal image enhancement results (LTIR dataset v1.0) obtained by the proposed algorithm respectively (a – original image; b - edge based active contour detection method without image enhancement, c – enhanced image; d - edge based active contour detection method with image enhancement). The results achieved by current proposed scheme have visually more contrast. The proposed method is useful if the user is interested in separating a selected object from the rest of the image background.

a) b) c) d)

Fig. 3. Thermal Image Enhancement.



a) b) c) d)

Fig. 4. Thermal Image Enhancement.

Conclusion

This paper presents a new thermal image contour detection algorithm using the modified snake algorithm. The algorithm based on the image enhancement and the modified the active contours model based on regions, taking into account using the anisotropic gradient.

The proposed approach has been proven to be valuable in applications in the contour detection in a thermal image.

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