OPTIMAL SELECTION OF IMAGE SEGMENTATION ALGORITHM FOR HEAT-EMITTING OBJECTS

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Abstract

In this paper problem of image segmentation quality is delibered. Especially, issue of segmentation method selection for images presenting heat-emitting objects is discussed. Particular attention is paid to thresholding method and edge-based image segmentation. Results of applying these methods to exemplary images are presented and discussed.

Key words: image processing, image segmentation, image quantitative analysis, heat-emitting objects.

1 Introduction

Nowadays computer vision systems model the real world or recognize objects from digital images. These images can be acquired using video, digital cameras, radars or specialized sensors. However, visual representation of information contained in an image is characterized by high level of redundancy. Therefore, after converting an image into its digital representation, a stage of detailed image analysis is carried out, to separate information significant to user or process from entire information reaching to observer or detector. In order to extract interesting information for further processing (such as description or recognition) image segmentation algorithms are applied.

Segmentation process is then one of the most important part of every image processing and analysis system. In many applications its quality and effectiveness is the most important criterion to be considered during vision system design process.

In this paper problem of segmentation algorithm selection for images of heat-emitting objects has been regarded. These considerations can be especially useful in case of industrial applications (metallurgy, welding, glass making) where sources emitting intense non-visible radiation (for example white-hot metal or glass) have to be monitored.

2 Problem Definition

Images considered in this paper present heat-emitting specimens of metals. They were acquired from computerized system for high-temperature measurements of superficial properties. The system calculates contact angles and surface tension of metals and alloys. However, other materials (for example glass) can be also investigated. Measurements are based on images of specimens of investigated materials. More detailed description of the system and the measurement process can be found in [1, 2, 3, 4]. Exemplary images acquired while the measurement process are shown on the Figure 1. Types of material and specimen temperature are indicated on each image. It can be easily seen, that the images present bright objects characterized by homogenous surfaces seen on the contrasting background. Edges of the specimens are blurred by "aura" i.e. phenomenon of borders illumination, caused by specimen high-temperature radiation. Moreover, object reflection on the base plate appears. The accurate determination of specimen shape is of crucial significance from the point of view of considered application, because superficial

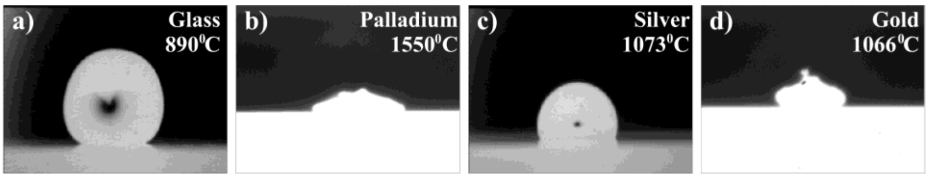

Figure 1. Exemplary images of heat-emitting objects; type of material and its temperature is indicated on each image.

parameters determination is carried out based on specimen shape analysis. In order to extract object and base from the background, image segmentation process is carried out. The result of image segmentation should enable to determine geometric features of objects placed in a scene as accurate as possible.

3 Image Segmentation

The aim of image segmentation process is to distinguish objects of interest from the background. It is equivalent with finding in analyzed images cohesive areas, characterized by similar values of certain attribute (for example graylevel) or set of features (for example texture) [5, 6, 7].

3.1 Mathematical Preliminaries of Image Segmentation

Each digital image $L(x; y)$ of the scene D consists of objects placed in this scene and the background in accordance with equation [8],[9]:

$$L_s(x,y) = H_1(x,y) + H_2(x,y) + \cdots + H_s(x,y) + H_\phi(x,y) \tag{1}$$

where:
x, y - pixel cordinates;
s - number of objects in the scene;
$H_k(x,y)$ - k-th object image, $k = \{1; 2;...; s\}$;
$H_\phi(x,y)$ - image of the background.
Moreover, conditions given by equation:

$$\left.\begin{array}{l} H_k(x,y) = 0 \quad for \quad (x,y) \notin D_k \\ H_\phi(x,y) = 0 \quad for \quad (x,y) \notin D_\phi \end{array}\right\} \tag{2}$$

are fulfilled, where: $D_k \subset D$ denotes area of k - th object and $D_\phi \subset D$ is the background area. The relationship between areas D_k and D_ϕ is given by equations (3) and (4).

$$D_1 \cup \ ... \cup \ D_s \cup \ D_\phi = D \tag{3}$$

$$D_i \cap \ D_j = 0 \quad for \quad i \neq j \tag{4}$$

Image segmentation process can be then defined as image $L_s(x,y)$ decomposition into images of:

- objects $H_k(x,y)$ placed in the scene, $k = \{1; 2;...; s\}$;
- the background $H_\phi(x,y)$.

The decomposition can be made by labeling each pixel of the image $((x,y) \in D)$ with the label π[10], in accordance with transformation given by equation:

$$\pi: D \rightarrow \{1,2,\dots,s\} \tag{5}$$

Labels $\pi(x,y)$ define each pixel's affinity to the certain image component. Different labels are assigned to separate objects. Background is usually assigned value of "0" (see eq. (6)).

$$\pi(x,y) = \begin{cases} l & for \quad (x,y) \in D_l \\ 0 & for \quad (x,y) \in D_\phi \end{cases} \quad where\ l \in \{1,2,\dots,s\} \tag{6}$$

The result of image segmentation is decompostion of the scene D into areas of objects D_l and the background D_ϕ.

3.2 A Short Reviev on Popular Methods of Image Segmentation

Nevertheless a variety of different segmentation techniques exists [5, 6, 7, 11, 12, 13] there is no general theory of it. Mostly, segmentation algorithms are developed for given application. However, following general-purpose techniques have been developed for image segmentation [5]:

- thresholding;
- edge-based image segmentation;
- region-based segmentation (growing, merging and splitting);
- segmentation by morphological watersheds.

These techniques often have to be combined with domain knowledge, in order to effectively solve an image segmentation problem for a given domain.

Due to the nature of images considered in this paper (bright object seen on contrasting background) usage of thresholding and edge-based image segmentation for specimen shape determination seems to be relevant.

In the following part of this section two mentioned above techniques of image segmentation are described as the most important ones in the area of problems being regarded.

Tresholding is a basic method of image segmentation. It is defined as follows:

$$\pi : D \rightarrow \{0,1\} \tag{7}$$

where

$$\pi(x,y) = \begin{cases} 1 & for \quad (x,y) \in D_l \\ 0 & for \quad (x,y) \in D_\phi \end{cases} \quad where\ l \in \{1,2,\dots,s\} \tag{8}$$

Objects' pixels are labelled "1", to the background pixels label "0" is assigned.

The labelling process is usually determined by parameter T known as a threshold, which is a result of analysis of the attribute $Y(x;\ y)$ (the most commonly gray levels of pixels are considered) [5, 6, 7]. Each pixel of the image is compared with the threshold. If the pixel's value of the attribute is lower than the threshold, the pixel is qualified to the background, otherwise the pixel is marked as object's pixel (see eq. (9))

$$\pi(x,y) = \begin{cases} 1 & for \quad Y(x,y) \geq T \\ 0 & for \quad Y(x,y) < T \end{cases} \tag{9}$$

Edge-based image segmentation can be defined as follows:

$$\pi : D \rightarrow \{1,2,\dots,s\} \tag{10}$$

at the condition:

$$\pi(x,y) = \begin{cases} l & for \quad (x,y) \in \partial D_l \\ 0 & for \quad (x,y) \notin \partial D_1 \cup \ldots \cup \partial D_s \end{cases} \quad where\ l \in \{1,2,\ldots,s\} \tag{11}$$

where ∂D_l is a set of border points (the edge) of cohesive area D_l

Because edges are connected with abrupt changes in image gray-level, the goal of edge detection is to mark all those points in a digital image at which the gray-levels change sharply. Methods of edge detection are then based on image gray-level function analysis and can be grouped into two categories:

– search-based (looking for extreme in the first derivative - gradient);
– zero-crossing based (detecting zero crossings in the second derivative).

In order to approximate spatial derivatives and generate a vector derivative processed image is filtered with gradient masks. More detailed information about gradient detection can be found in [5, 6, 7].

4 Comparison of Segmentation Results

In this section results of segmentation using different methods are presented. Particular attention is paid to tresholding and edge based segmentation. 8-bit monochromatic images presenting heat-emitting specimens of palladium and glass are used as an example.

Figure 2 presents results of image segmentation using thresholding method. Different techniques of threshold selection were tested. Each technique is indicated in figure caption. For iterative (local and global) threshold selection isodata algorithm [14] was used. More detailed information about algorithm of local threshold selection can be found in [15] and [16]. Figure 3 presents results of edge-based image segmentation applied to exemplary images of heatemitting objects. Images of palladium and glass are used to present achieved results. Types of masks used are indicated in figure caption.

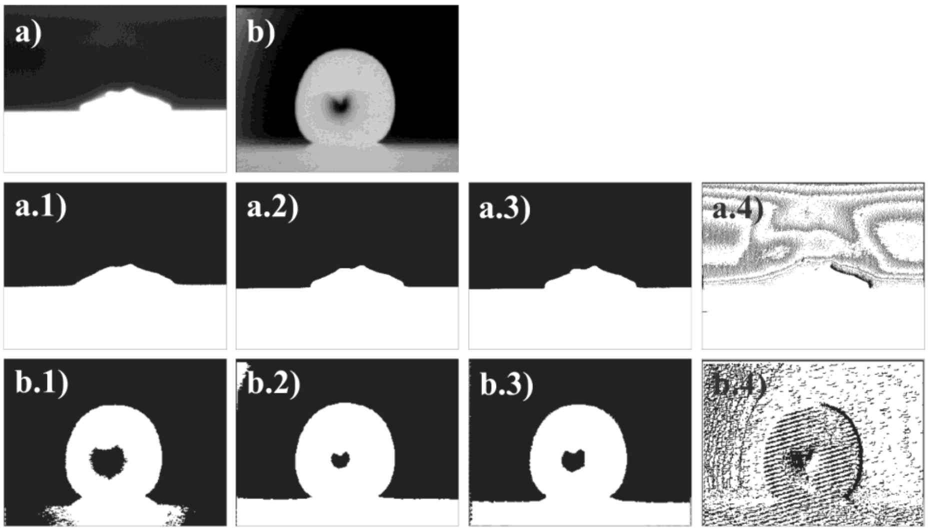

Figure 2. Results of image thresholding; a) image of palladium, 15500C; b) image of glass, 8900C; 1) global thresholding, T = 170; 2) global thresholding with iterative threshold selection; 3) local thresholding with iterative threshold selection; 4) local thresholding with threshold set to median.

5 Discussion

Results presented on Figure 3 show that edge-based image segmentation applied to images of heat-emitting objects fails. Obtained results do not match the specimen shape accurate enough for further quantitative analysis. Specimen profile is incomplete and not continuous, upper edge of base plate is not determined properly. Moreover, the border of specimen profile is relatively wide, what hinders proper edge localization. Profile round-offs at the base (especially important from the point of view of wetting angle determination) are strongly deformed.

Significanlty better results are achieved using thresholding method (Fig. 2). However segmentation of images presenting heat-emitting specimens is more challenging and can not be done with the simple thresholding. The global threshold selection effects with low accuracy of the segmentation results, especially if threshold is selected without image properties analysis (Fig. 2a1 and 2b1). Only threshold selection based on gray-levels analysis guarantees highquality image segmentation. Therefore for analyzed images, algorithm with local threshold selection was developed. The algorithm computes threshold locally using isodata algorithm [14]. Achieved results (Fig. 2a3 and 2b3) are characterized by high quality. Contours of the objects after segmentation are well presented. They are continuous, smooth, and free from defects.

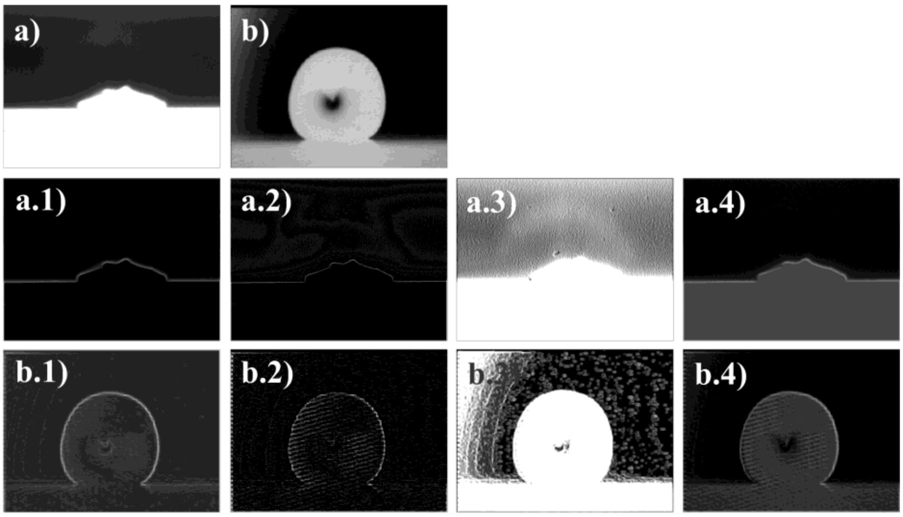

Figure 3. Results of edge-based image segmentation; a) image of palladium, 1550^0C; b) image of glass, 890^0C; 1) Sobel's masks; 2) Laplace's operator; 3) Frei-Chen's masks; 4) Krish's masks.

Moreover, non-uniform background, which is not satisfyingly segmented with a basic threshold, is well segmented with the presented iterative method. Obtained results present proper shapes from the original images and can be successfully used for further specimen shape analysis.

It should be emphasized that replacing iterative threshold selection with statistical values (i.e. median, mean, minimum or maximum) significantly decreases quality of achieved results (Fig. 2a4 and 2b4).

6 Final Remarks

In this paper problem of image segmentation algorithm selection was considered. Images of heat-emitting objects were used as an example. Presented analysis of results achieved using different methods allowed to select segmentation technique optimal for analysed class of images.

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