AUTOMATION OF SEGMENTATION OF TOMOGRAPHIC IMAGES

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Introduction

Today computer vision technology is used in many areas of modern industry. As a scientific discipline, computer vision is concerned with the theory and technology of artificial intelligent systems that obtain information from images. Applying of systems with computer vision can be divided into several groups [1]:

- Controlling processes (e.g., an industrial robot);
- Interacting (e.g., as an input to a device for computer-human interaction);
- Detecting events (e.g., for visual surveillance or people counting);
- Organizing information (e.g., for indexing databases of images and image sequences);
- Modeling objects or environments (e.g., medical image analysis or topographical modeling);
- Navigating (e.g., by an autonomous vehicle or mobile robot);
- Automatic inspecting (e.g., in manufacturing applications).

This paper is concerned with processing tomographic images received from the Institute for Photon Science and Synchrotron Radiation (IPS) of Karlsruhe Institute of Technology (KIT) in Karlsruhe, Germany. The main task given by partners from KIT was developing of an algorithm capable of identifying an object in a given image and determining its position in relation to the center of that image.

Segmentation algorithm

There are many algorithms for image segmentation. To solve the problem, the following algorithms have been considered:

> Heapsort segmentation;
> Segmentation based on graphs;
> Hough transform;
> Wave algorithm;
> Threshold filtering;
> Cluster analysis;
> Canny algorithm.

The Canny algorithm was chosen as optimal to achieve the goal with regards to the following criteria: detection, localization, number of responses. These criteria are the most significant issues to consider for the given task. With Canny's mathematical formulation of these criteria, the Canny Edge Detector is optimal for a certain class of edges (known as step edges) [1].

Segmentation using the Canny algorithm refers to a process of partitioning a digital image into regions (subsets of pixels) using defined characteristics. The result of image segmentation is a set of segments that together cover the entire image, or a set of contours allocated from the image. Implementation of this algorithm can be divided into five basic steps [2, 3]:

1) Smoothing the image with a Gaussian filter to reduce noise and unwanted details and textures;
2) Computing gradients using any of the gradient operators (Roberts, Sobel, Prewitt, etc.);
3) Suppressing non-maxima pixels in the edges to thin the edge ridges;
4) Thresholding the previous result by two different thresholds and obtaining two binary images;
5) Linking edges' segments to form continuous edges; tracing each segment to its end and then searching its neighbors to find any edge segment to bridge the gap until reaching another edge segment.

Preprocessing

To automate the process of segmentation and exclude a human factor from this process a special approach is required. This approach should determine characteristics of an image and threshold limits before using the main algorithm. Different values of threshold limits are needed due to sensitivity of the Canny algorithm to even small changes between a large quantity of images. Difference in limits is caused by a great variety of intensity and the number of pixels of certain brightness across the image.

A preliminary estimation can include histogram normalization in order to set necessary values of threshold limits. To make a histogram it is necessary to translate the image into a gray scale. Then goes obtaining of distribution of image gray tones, where a horizontal axis shows brightness and a vertical axis shows a relative number of pixels for a given brightness. Behavior of the histogram specifies the image type.

In addition, a histogram can be normalized to avoid inaccuracy. Coefficients for the threshold are chosen according to a normalized histogram. After preliminary estimation, the main algorithm can be executed with received coefficients [4].

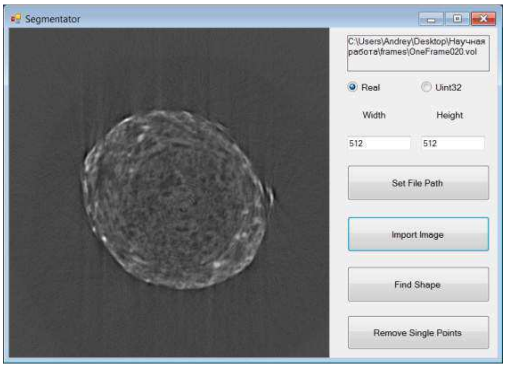
Image processing

The special software program, which is based on the Canny algorithm of segmentation, was developed for working with the given images. Researches were carried out by using that software with the given set of tomographic images of a match and other objects. These ones represent slices of that match from bottom to top.

Various convolution masks had being tried for smoothing the set of given images: the Gaussian matrix, an identity matrix and a matrix with central coefficients increased relatively to the entire matrix. Convolution mask is a small matrix that moves across an image and changes a value of underlying pixels according to the defined rule. The Gaussian mask of 3x3 was chosen with the best combination of size, smoothing effect and speed of image processing [5].

The results of image processing are shown in the following pictures. The basic image before processing is shown in picture 1 to enable comparison with the result of applying a small (3x3) Gaussian mask that is demonstrated in picture 2. An additional layer contains yellow dots indicating the found differences in brightness between pixels in the base image. The shape of the object is rather clear and there are no extra dots around.

The chosen algorithm yields good results, but is time-consuming. If an image source is a digital camera and it supplies images in real time, the time of image processing will exceed the time of existence of an image stream frame. The time of processing should be reduced.

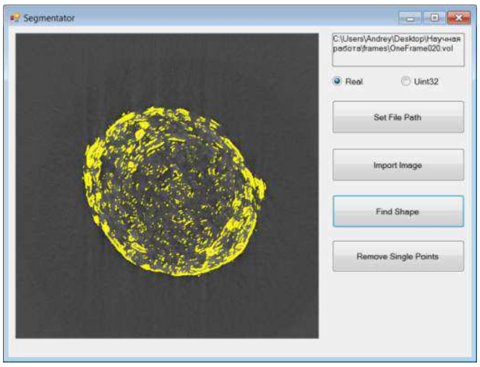


Picture. 1. Basic image (match slice)

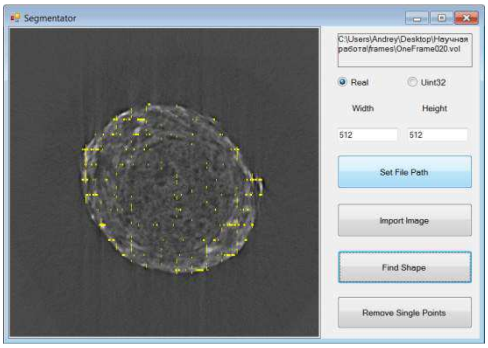
To reduce the processing time the Canny algorithm can be used with a grid-pass image processing type. Due to skipping some rows and columns of pixels while passing the image, the time of segmenting is greatly reduced. In comparison with the full-pass type of algorithm, the grid-pass type is performed almost 5 times faster for big objects. The result of using the grid-pass algorithm is shown in picture 3.

The algorithm acceleration depends on the grid-pass's step. The larger the step, the more acceleration it will give, but a step with a value larger than an object dimensions may cause its omission. If an object is predictably big, the step can be set to a quarter of the object's width or height. If the object has irregular shape the steps in horizontal and vertical directions can be different.

Approximate object positioning can narrow the searching area. The modified Canny algorithm allows quick and accurate determination of the position of an object relative to the image boundaries, so the grid-pass algorithm is applied to the whole image on the first search and only after that the full-pass algorithm is applied to the chosen area that is a small part of the whole image. Such combination requires less time than the basic Canny algorithm.



Picture. *2. Image with the additional layer after using the modified Canny algorithm*



Picture. *3. Result of using a grid-pass algorithm*

Conclusion

Canny algorithm with a Gaussian mask (size 3x3) assures a very high accuracy of finding borders of an object in an image. If border currency is not obligatory and only a position and dimensions of an object are needed, a grid-pass type of the algorithm is very effective. In this case the time of processing is reduced up to 1 second. This time allows real-time processing of images taken from a camera situated in a tomograph. If an object moves aside, its position in the camera will change and the tomograph can automatically readjust and center the object. Automated tomograph adjusting is also appropriate for changing target objects without human intervention.

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