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IMAGE SEGMENTATION AND MATTING BASED ON THE EXTENDED DISTANCE TRANSFORM

In this paper we present a novel semi-automatic method for image segmentation and matting that utilizes the newly proposed generalized distance transform to determine the hybrid distance between the foreground and background regions within the image. This distance values are then used to estimate the alpha matting coefficient needed for composing new image by blending the foreground objects into a new background image scene. The effectiveness of the proposed algorithm allows the user to work interactively and to obtain the desired results promptly after marking the regions by scribbling the image. In the paper we show, that the proposed method yields satisfactory results for gray scale and colour images.

1. INTRODUCTION

The aim of the *image matting* procedure is to extract the foreground objects from the image background and to blend them into a new image scene. This process is commonly used for photo editing operations and for the creation of special effects in video sequences.

The basic task of image matting is to extract the foreground element from the background by assigning to the image pixels the opacity level and to merge the desired object into a new background to create the final composite image. In this way the composite colour image C is a combination of the foreground F and background image B :

$$C = \alpha \cdot F + (1 - \alpha) \cdot B, \quad (1)$$

where α is the opacity, which controls the blending of foreground and new background.

The problem of image matting is severely ill posed as F , B and also the values of α are unknown. However, the strong correlations between neighbourhood pixels can be leveraged to alleviate to some extent the difficulties, [1].

Previous approaches can be generally divided into techniques based on the sampling to estimate the foreground and background colours of the image pixels and methods exploiting the concept of exploration of local neighbourhood under some assumptions about image statistics.

The sampling methods estimate the foreground and background pixels using the information provided by the user, who specifies groups of pixels that belongs definitely to the foreground and background. That information is used for the estimation of the α values of the remaining pixels. In [3] the authors used the Gaussian mixture model to estimate the distribution of the foreground and background pixels, in [6] the matting was accomplished by solving Poisson equation using boundary conditions provided by the user, while in [2,5,12] a Bayesian approach has been applied.

The methods based on propagation assume the smoothness of the foreground and background regions and the matting problem is usually solved using some optimization methods working on the distances between the regions defined by the operator as a foreground and background [4, 7-11].

Our approach belongs to the second group. We make use of the newly proposed generalized distance transform, which determines the hybrid distance of the unlabeled pixels to foreground and background regions determined by the user in form of colour scribbles, [13, 14]. The computed distances are then used to estimate the transparency values α , which are used to embed an image containing the object of interest into a new background. The proposed algorithm gives favourable results, is extremely fast and allows the user to interactively correct the results, so that a visually pleasing composite image can be obtained.

2. THE PROPOSED ALGORITHM

In this Section we present our novel algorithm for image segmentation and matting, that exploits the distance transformation and source image structures to determine the distance between background and foreground regions. This regions are marked by a user simply by scribbling the image, (see Fig. 1).

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Fig.1. Illustration of the proposed matting process: colour source image (a), image with marked regions (b), new background image (c) and our matting result (d).

2.1. STANDARD DISTANCE TRANSFORM

Since the regions are marked simply by scribbling the image, the first step of our algorithm, after the user inserts scribbles, is to isolate them and compute their distances [15] to all pixels of the source image. Within the provided scribbles, two kinds are distinguished: the first ones (marked red) for the background that is going to be erased or replaced with new background from another image, and the second ones (marked green) for the foreground objects that are going to remain in the image. Then, the distance transformation is applied to those two sets of scribbles separately.

Thus, let P be a binary image defined on the image domain G , where:

$$\langle P \rangle = \{p : P(p) = 1\}, \quad \langle \bar{P} \rangle = \{p : P(p) = 0\} \quad (2)$$

are proper subsets of G . For any metric, the distance transform of P associates with every pixel p of $\langle P \rangle$ the approximation of the Euclidean distance from p to $\langle \bar{P} \rangle$.

For any $p \in G$ let $B(p)$ (pixels in neighbourhood relation before scan) be the set of pixels adjacent to p that precedes q when G is scanned, and let $A(p)$ (after scan) be the remaining neighbours of p . Then during the first scan (in top-left to bottom-right direction) we compute:

$$f_1(p) = \begin{cases} 0 & : p \in \langle P \rangle, \\ \min \{f_1(q) + 1 : q \in B(p)\} & : p \in \langle \bar{P} \rangle, \end{cases} \quad (3)$$

After the first scan, we perform to the second one in the opposite direction (bottom-right to top-left), and compute the following:

$$f_2(p) = \min \{f_1(p), f_2(q) + 1 : q \in A(p)\}, \quad (4)$$

Thus, after the second scan we obtain the distance values that can be expressed as intensities of points within a gray scale image, (see Fig. 2).

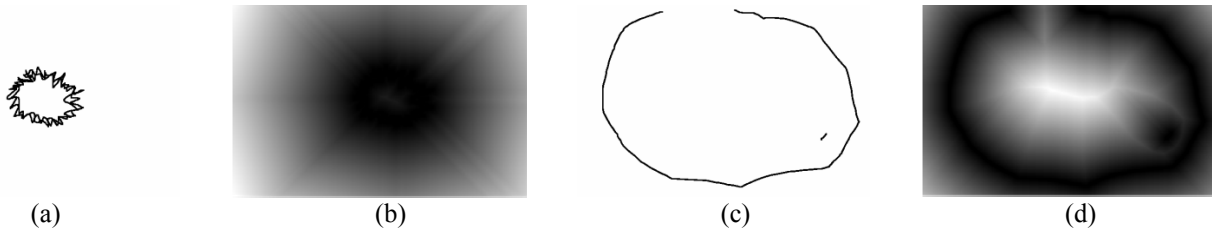


Fig.2. Isolated scribbles for the foreground (a) and background (c) objects from Fig. 1 and the image of the distance transform performed on those scribbles (b, d).

2.2. EXTENDED DISTANCE TRANSFORM

Considering the result of the distance transformation presented in the previous subsection, we conclude that this transform is not able to capture the information on image structures and other structural information contained in the source image. In order to detect boundaries between objects, we decide to utilize these information by computing the distance between colours of two neighbouring points p and q within the given colour space, assuming colour similarity between these

two points contained in the same object. Regarding the *RGB* colour space, the distance D_c between colours of two neighbouring pixels p and q can be defined as:

$$D_c(p, q) = \sqrt{(p_r - q_r)^2 + (p_g - q_g)^2 + (p_b - q_b)^2}, \quad (5)$$

Since the calculation of the topological distances (Eqs. 3, 4) as well as the computation of the distances between colours D_c , requires a sequence of local operations on the neighbouring

pixels within the image, these steps can be merged together resulting in the following equations that define the extended distance transform (EDT):

$$f_1(p) = \begin{cases} 0 & : p \in \langle P \rangle, \\ \min \{f_1(q) + D_c : q \in B(p)\} & : p \in \langle \bar{P} \rangle, \end{cases} \quad (6)$$

$$f_2(p) = \min \{f_1(p), f_2(q) + D_c : q \in A(p)\}, \quad (7)$$

The results of the EDT performed on the scribbles from the Fig. 2 are depicted in Fig. 3.

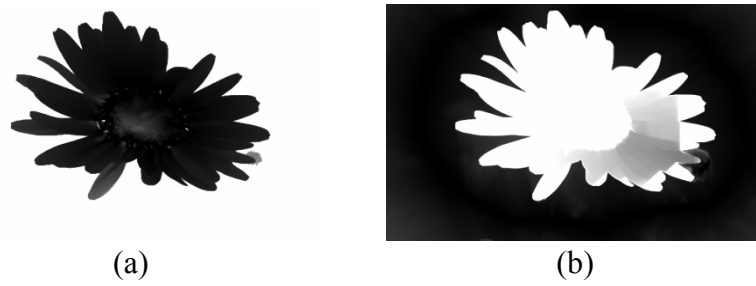


Fig.3. EDT performed on (a) foreground and (b) background scribbles from Fig. 2a, c.

The application of the EDT for the gray scale images has been proposed in [13], while the application of probabilistic distance transform based on Gibbs statistical distribution has been elaborated in [14]. All these approaches can be successfully used in the proposed image segmentation and matting algorithm.

2.3. SEGMENTATION AND MATTING

The distance values obtained with the EDT can be then used in the image segmentation or matting process. In order to extract the foreground object we have introduced the following cropping function:

$$f_{cro}(p, q) = \begin{cases} 0 & \text{if } M_b(p, q) \geq M_f(p, q), \\ 1 & \text{otherwise,} \end{cases}, \quad (8)$$

where M_f and M_b stand for the distance values obtained for a foreground and background scribbles using EDT. As a result we obtain a binary cropping mask (Fig. 4a), which applied to the source image (Fig. 1a) gives us the desired result (Fig. 4b).

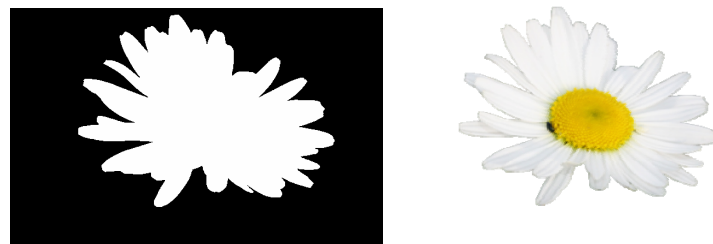


Fig.4. Illustration of the binary cropping mask and the result of its application to the source image from Fig. 1.

The image composition and matting procedure can be expressed with the following equation:

$$I(p, q) = \alpha \cdot F(p, q) + (1 - \alpha) \cdot B(p, q), \quad (9)$$

where $F(p, q)$ denotes the foreground image, $B(p, q)$ denotes the background image, and α denotes the alpha matting coefficient used to blend foreground and background. In our approach, the value of foreground F and background pixels B are computed during the segmentation process, while the value of α -mate is defined regarding the values of extended distance transform obtained for foreground and background objects:

$$\alpha = \exp \left\{ - \frac{|M_b - M_f|}{\beta} \right\}, \quad (10)$$

where β is the smoothing parameter defined by a user. The matting results obtained with the presented algorithm are presented in the following Section.

3. RESULTS

The result shown here were all obtained using the presented method that works utilizing the extended distance transformation.

In Fig. 5 we can see the natural image matting example. After the user marks the appropriate regions within the source colour image by providing the scribbles, distance values are calculated and used to estimate the alpha matting coefficient needed for composing new image by blending the foreground objects into a new background image scene. The result is shown in Fig. 5, the most right picture.

Fig. 6 depicts the image matting procedure and result in case of bio-medical images, where the foreground objects from the source image are blended into another bio-medical image, composing the final result (Fig. 7, at most right).

Presented method can also be successfully used in the image segmentation process. Segmentation results obtained with the presented method are shown in Fig. 7.

4. CONCLUSIONS

In the paper a new fast image matting technique based on the extension of the distance transform has been presented. The new distance transform has the ability to detect boundaries between two neighbouring objects within the image, assuming the colour similarity between the two neighbouring points belonging to the same object. The results of experiments performed on natural images as well as on the bio-medical ones show, that the proposed approach yields good results. The implementation of the algorithm works fast enough to allow the user for interactive work without noticeable delays and achieving real-time preview.

The future work will focus on the distance transformation in order to increase the accuracy of the edge detecting and quality of matting results, as well as on the optimization of the code of our application, which will further shorten the time of matting process in case of very large images.



Fig.5. Illustration of the natural image matting: From the left: source image, image with scribbles, new background image and our matting result.

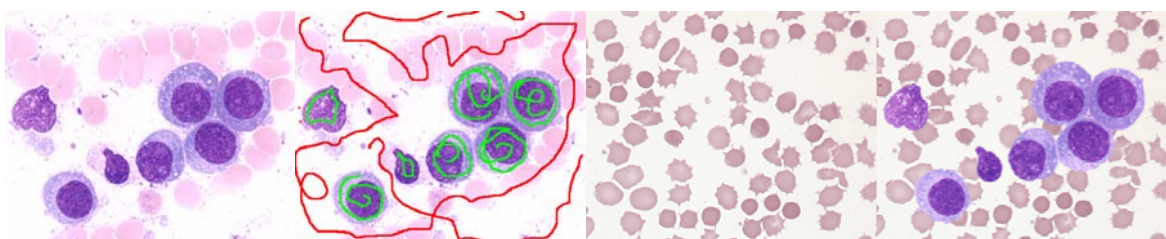


Fig.6. Bio-medical image matting examples. From the left: source images, images with scribbles, new background images and matting results.

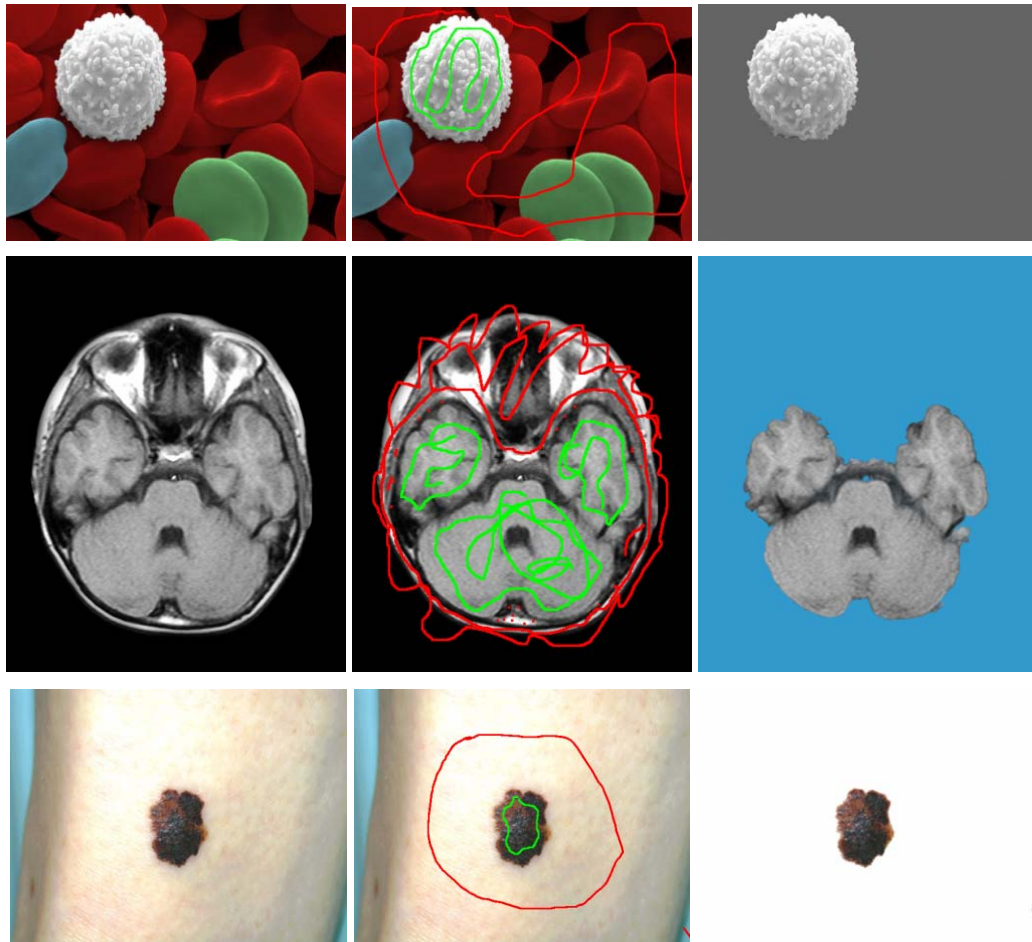


Fig.7. Bio-medical image segmentation examples. From the left: source images, images with scribbles, and segmentation results obtained with the presented method.

BIBLIOGRAPHY

- [1] WANG J., COHEN M. F., Optimized color sampling for robust matting. Proc. Computer Vision and Pattern Recognition, pp. 1–8, 2007.
- [2] CHUANG Y.-Y., AGARWALA A., CURLESS B., Video matting of complex scenes, ACM Transactions on Graphics, vol. 21, no. 3, pp. 243–248, 2002.
- [3] RUZON M. A., TOMASI C., Alpha estimation in natural images. Proc. Computer Vision and Pattern Recognition, pp. 259–268, 2000.
- [4] WANG J., COHEN M. F., An iterative optimization approach for unified image segmentation and matting. Proc. IEEE International Conference on Computer Vision, pp. 936-943, 2005.
- [5] CHUANG Y.-Y., CURLESS B., SALESIN D. H., A, SZELISKI R., Bayesian approach to digital matting. Proc. Computer Vision and Pattern Recognition, pp. 264–271, 2001.
- [6] SUN J., JIA J., TANG C.-K., Poisson matting. ACM Transactions on Graphics, vol. 23, no. 3, pp. 315–321, August 2004.
- [7] LEVIN A., LISCHINSKI D., WEISS Y., Colorization using optimization. ACM Transactions on Graphics, vol.23, no. 3, pp. 689–694, 2004.
- [8] GRADY L., SCHIWIETZ T., AHARON S., WESTERMANN R., Random walks for interactive alpha-matting. Proc. VIIP, pp. 423–429, 2005.
- [9] LEVIN A., LISCHINSKI D., WEISS Y., A Closed-form solution to natural image matting. IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 30, no. 2, pp. 228–242, 2008.
- [10] YATZIV L., SAPIRO G., Fast image video colorization using chrominance blending. IEEE Transactions on Image Processing, vol. 15, pp. 1120–1129, 2006.
- [11] BAI X., SAPIRO G., Distance cut: interactive segmentation and matting of images and video. Proc. ICIP, pp. 249–252, San Antonio, TX, 2007.

- [12] CHEN T., WANG Y., SCHILLINGS V., MEINEL C., Grayscale image matting and colorization. Proc. Asian Conference on Computer Vision, pp. 1164–1196, 2004.
- [13] LAGODZINSKI P., SMOLKA B., Fast digital image colorization technique. Proc. IEEE International Symposium on Signal Processing and Information Technology, pp. 813–818, December 2007.
- [14] LAGODZINSKI P., SMOLKA B., Digital image colorization based on probabilistic distance transform. Lecture Notes in Computer Science 5197, Springer-Verlag Berlin Heidelberg, pp. 626–634, 2008.
- [15] KLETTE R., ROSENFELD A., Digital geometry – geometric methods for digital picture analysis. MA: Morgan Kauffman, 2004.