Matching aspect ratio of digital photo via complementing

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Abstract

In this paper a new approach for matching aspect ratio of a digital photo for borderless printing by complementing it with fragments extracted from the same photo is proposed. This approach comprises analysis of side strips of the source photo in order to estimate the possibility to complement it without visible artifacts; complementing one or both opposite sides of the photo, matching the desired aspect ratio; additional processing of complements to make resulting photo look more natural.

Keywords: *Matching aspect ratio, borderless printing, complementing.*

1. INTRODUCTION

Digital photo and photo printing market grows very quickly, and usually user preferences fall to borderless printing. However, aspect ratio of digital images and photo paper very often do not match. The most common aspect ratio of a digital image produced by a cheap consumer Digital Still Cameras (DSC) or a cameraphone is 3:4, whereas most popular photo print size is 10 by 15 cm (4 by 6 inches). Paper size also does not match image size when printing image with aspect ratio 2:3 (prosumer and professional DSCs) onto 15 by 22 cm paper. In case of borderless printing, some cropping or trimming of the image borders is necessary, i. e. it is necessary to discard (not to print) parts of the image. In some cases it can deteriorate composition or/and loose some important details, some parts of human body or face can be lost. For example, Figure 1 demonstrates conventional trimming of photo for printing where man's face is damaged.

During last years many efforts are made to develop intellectual algorithms for image cropping. For example, in [1] authors consider a method for automatic image cropping by first segmenting an image, and then determining a ROI (region of interest). In this case ROI can be set up to have desired aspect ratio, and resulted cropped image will have the same desired aspect ratio. In [2] authors describe an algorithm for automatic photo image trimming. First they segment an image and then determine optimal widths of the strips to be trimmed. However, this method results in loss of some parts of the image. For example, it is not possible to crop an image from Figure 1, to change its aspect ratio 4:3 to 3:2 without clipping some parts of the head.

In this paper we propose an alternative way for matching aspect ratio, which is based on complementing of an image by fragments, extracted from itself. The proposed approach is not applicable for all cases but there are situations when the way gives the best results in comparison with alternatives.

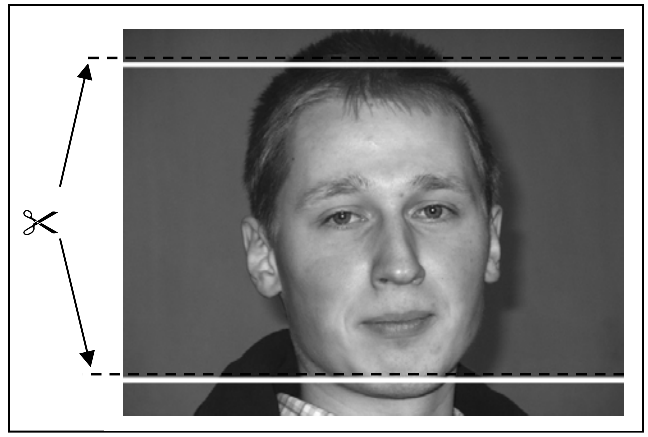

Figure 1. Conventional trimming of photo on printing.

For example, in [3] authors describe method for completing missing parts of an image, resulting from removal of foreground or background elements from the image. Visible parts of the image serve as a training set to infer the unknown parts, and the method iteratively approximates the unknown regions and composites adaptive image fragments into the image. Inpainting techniques restore and fix small scale flaws in an image, like scratches or stains and mainly oriented on filling lost parts of the image inside some bounded area, [4] [5]. These methods work inside bounded areas.

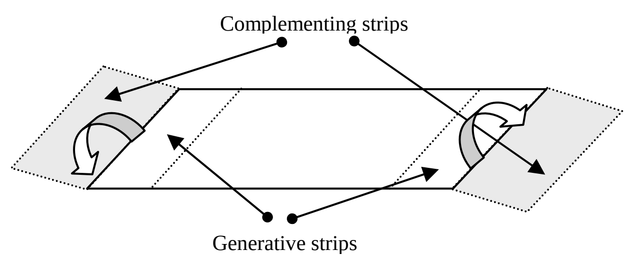

Figure 2. Approach for matching aspect ratio via mirroring.

However, in our case area to be filled is not bounded, and image must be complemented seamlessly. There exist several methods for complementing an image. One of the simplest and most visually pleasing methods is mirroring of several columns (or rows) relatively to the side of the image. Figure 2 illustrates this approach. Without loss of generality we will consider matching aspect ratio from 4:3 to 3:2, for other aspect ratios similar actions can be applied. Mirroring is performed on single or both sides; furthermore width of mirrored strips can vary.

It is clear that this approach is not universal, and depends on the content of a photo. We have analyzed a test set consisting of several hundreds photos and found out that our approach does not produce visible artifacts in about 30% of the photos. It is possible to outline several scene types when mirroring is applicable: scenes with blurred background, for example, portraits and macro, some natural scenes (forests, farmlands, and mountains). Figure 3 illustrates complementing of photo from Figure 1, in this case artifacts are completely absent.

Figure 3. Complementing of photo from Figure 1.

We propose to apply complementing in addition to cropping for matching aspect ratio in photokiosks and photo printers, and provide user with possibility to choose most pleasant version. An automatic classifier was developed for estimating applicability of mirroring and excluding clearly unacceptable cases.

2. SMART COMPLEMENTING

2.1 Detection of proper photos for complementing

Let us consider a case when an image needs to be complemented with *W* columns. We propose to analyze left and right side strips with equal width of *Sd = W/2* to estimate applicability of mirroring. If mirroring is not applicable, width of one of the side strips is decreased up to *W/8* (at the same time opposite strip is enlarged) and analysis is proceeded for these strips. In the extreme case only one side strip with width *W* is considered. In case when mirroring of both strips is possible, mirroring is applied; otherwise processing is terminated. Therefore, the key point is how to analyze side strips.

Algorithm of strip analysis is based on edge detection and edge extent analysis. Elongation of edges can be estimated using area or objects' extent. Mirroring of strips, containing some types of textures, smooth regions will not produce noticeable artifacts. So, mirroring is allowed if there are no sharp edges of big connected regions.

First of all color photo is converted to grayscale image. Then image is downsampled by nearest neighbor interpolation, to reduce computation time and to reveal slightly blurred edges. Downsampled image is filtered with edge detection filter Laplacian of Gaussian according to the following formula:

$$k(x,y) = \frac{(x^2 + y^2 - 2\times\sigma^2)\times k_g(x,y)}{2\pi\sigma^6 \sum_{x=-N/2}^{N/2} \sum_{y=-N/2}^{N/2} k_g(x,y)},$$

$$k_g(x,y) = e^{-(x^2+y^2)/2\sigma^2},$$

where *N* is size of convolution kernel, σ - standard deviation, *(x,y)* – coordinates of Cartesian system with origin at the center of the kernel.

Segmentation is performed using zero-crossings [6]. It is assumed that pixel with coordinates *(r,c)* belongs to an object, if the following holds:

$$(|I_e(r,c) - I_e(r,c+1)| >= T \text{ and } I_e(r,c)<0 \text{ and } I_e(r,c+1)>0) \text{ or}$$
$$(|I_e(r,c) - I_e(r,c-1)| >= T \text{ and } I_e(r,c)<0 \text{ and } I_e(r,c-1)>0) \text{ or}$$
$$(|I_e(r,c) - I_e(r-1,c)| >= T \text{ and } I_e(r,c)<0 \text{ and } I_e(r-1,c-1)>0) \text{ or}$$
$$(|I_e(r,c) - I_e(r+1,c)| >= T \text{ and } I_e(r,c)<0 \text{ and } I_e(r+1,c-1)>0),$$

where I_e is result of Laplacian of Gaussian filtration, and threshold for zero-crossing segmentation I_e is determined by application of the following formula:

$$T = \frac{3}{4H_dW_d} \sum_r^{H_d} \sum_c^{W_d} |I_e(r,c)|,$$

where H_d and W_d are height and width of filtered image.

Further I_e is segmented, and labeled with 8-connectivity. Labeled connected regions with area smaller then some threshold *Ta* are eliminated from processing. Area of a region is defined as number of pixels belonging to it. If there are no objects greater than *Ta* then mirroring of the strip is performed. If some of such regions are found then region *M1* with biggest area is analyzed to find its extent. If width of *M1* is greater *Tw* then this region is rejected and the next biggest region *M2* is considered. Very often in images with natural scenes the most elongated edge is skyline, so we decided to neglect a region with the largest area. If area of *M2* is smaller or equal to *Ts* then mirroring is possible for given strip. Otherwise mirroring is impossible.

Figure 4. Initial photo.

Let us consider example of side strips analysis of the photo from Figure 4. Figure 5 demonstrates absolute value of convolution of downsampled image with Laplacian of Gaussian, which is image of edges.

Figure 6 demonstrates result of zero-crossing edge segmentation and labeling of the 8-connected regions with pixels belonging in the right side strip and with area greater *Ta*. Histogram of areas of connected regions from Figure 6 is shown on Figure 7.

Figure 5. Edges for photo from Figure 4.

Note here that there exist only one enough large region. We neglect it and only small regions are left, with areas are smaller than *Ts*. Right side strip may be mirrored. Similar analysis is performed for the left side strip. Complementing result is shown in Figure 8. The image is visually pleasing, and does not contain visible artifacts.

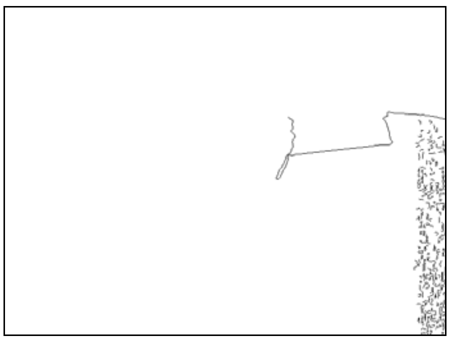

Figure 6. Connected regions with pixels belonging to right side strip

2.2 Additional strip processing

It is worthwhile to apply some modifications to mirrored strips to suppress slightly noticeable artifacts produced by mirroring. These modifications on one hand should make symmetry of mirrored areas less noticeable and on the other hand the boundary less visible. One of possible realizations of this transformation is alpha blending of mirrored strip with its blurred or darkened copy, so that opacity of alpha channel *a* varies smoothly from 1 on the bound with source image to 0.5-0.7 on the edge of the new photo:

$$I = I_m \times a + I_p \times (1-a),$$

where I_m is mirrored strip, I_p is darkened and blurred I_m.

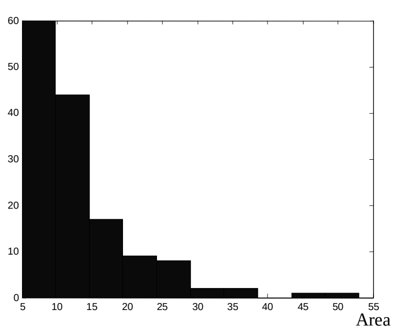

Figure 7. Histogram of areas of connected regions from Figure 6.

Figure 8. Complementing of photo from Figure 4

2.3 Results

We have collected 284 photos with aspect ratio 4:3 such that conventional trimming deteriorates its quality. Photos were taken from private collections and Internet. Photos have various sizes and were taken by different photographers using various models of DSCs and cameraphones. Mirroring of 108 photos was considered to be applicable as a result of classification application.

Number of False Negatives (FN) is 5. FN occurs in cases when source image has sharp background texture, and its edges after zero-crossing edge segmentation stitch together in several large regions. Number of False Positives (FP) is 27. FP are typical for indoor photos and city/architecture photos. Another serious problem is posed by imprinted time/date. Example of FP is shown in Figure 9. In our future research to reduce number of FP we will add detection of imprinted time/date [7] and detection of skin tones [8] in side strips. Also in our opinion indoor/outdoor classification [9] and city/landscape classification [10] can significantly improve results, since in general applicability of mirroring depends on the type of the scene.

Figure 9. Photo with wrong mirrored strip.

Examples of proper complementing are shown in Figures 10-12. Sometimes effect of complementing is slightly noticeable under detailed examination. We have shown these photos to a group of 5 observers, who were not informed about processing method. They did not notice mirrored strips and positively estimated quality of the photos.

Figure 10. Photo with mirrored left strip.

Figure 11. Photo with mirrored both strips.

3. 1. CONCLUSION

An approach is proposed for matching aspect ratio of a digital photo for borderless printing by complementing it with fragments extracted from the same photo. Proposed algorithm can be applied either to color or grayscale or having sepia effect photos. We propose to apply complementing in addition to cropping for matching aspect ratio between digital image and photo-paper in photo kiosks and photo printers, and provide user with option to choose most pleasant version. An automatic classifier is proposed for estimating applicability of mirroring to an arbitrary photo to exclude clearly unacceptable cases. This classifier demonstrates fairly good results. Also we propose several simple ways to improve classifier, such as detection of imprinted time/date, or skin tones, as well as prior indoor/outdoor and city/landscape classification. Slight modifications of mirrored strips are proposed for suppressing poorly noticeable artifacts produced by mirroring of side strips. For this purpose we propose alpha blending of mirrored strip with its blurred and/or darkened copy.

Figure 12. Photo with mirrored right strip.

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