

A Novel Interactive Image Matting Framework

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Abstract

The image matting problem is to extract a foreground layer from an arbitrary natural image. The foreground layer consists of color channels and opacity image.

In this paper we propose a user-assisted matting workflow. Starting from a sparse manual marking, we perform hard segmentation and allow the user to quickly turn the segmentation result into a trimap. Then we apply soft matting process and allow the user to refine the result by fine-tuning the matting parameters in distinct image regions or by directly touching up the opacity channel.

Keywords: *Bayesian Matting, interactive matting, image editing, digital compositing, foreground extraction.*

1. INTRODUCTION

In this paper we address the problem of foreground object extraction also known as the image matting problem. The source image C is assumed to be a composite of two image layers F and B (foreground and background) with opacity channel α . In each pixel their RGB values should satisfy the compositing equation:

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

where C , F and B are 3D vectors of RGB values, $0 \leq \alpha \leq 1$. The problem is to reconstruct the α , F and sometimes B images from the source image C using some additional user input.

Image is usually accompanied by a trimap – ternary image which divides the image area into three regions: foreground, background and unknown. The former two act as hard constraints while the latter denotes the area matting algorithm is applied to.

In the next section we outline previous approaches and advert to their strengths and weaknesses. In the third section we propose a framework for fast and simple (from the user’s point of view) image matting procedure. We show how the result can be edited by the user if it is unsatisfactory. Our framework takes advantage of hard-segmentation as a quick method for initial trimap segmentation.

2. PREVIOUS WORK

Many algorithms have been proposed to constrain and solve the under-constrained matting problem. Earlier algorithms ([1], [8], [11]) are aimed to work with precise trimaps, and quickly lose their quality when the trimap has large unknown region. Recent algorithms ([4], [14], [15]) are aimed to work with sparse trimaps, however, they tend to produce incorrect result in confusing areas

unless many additional strokes are added to the trimap. Such algorithms also have greater processing time.

Several approaches were used to take the advantage of typical alpha matte structure: large areas with $\alpha = 0$ or 1 with rather thin soft edge between them ([1], [7], [13]).

Soft scissors algorithm [13] tries to overcome this problem by forcing the user to draw pretty accurate unknown region, giving in return a quick and interactive result computation and preview.

GrabCut algorithm [7] uses interactive hard segmentation and border matting by constraining the shape of soft object edge.

Coherence matting algorithm [9] uses hard segmentation and a smoothness constraint which attracts alpha to a precomputed value obtained from edge feathering. However, this works well only for blurry but distinct edges, i.e. with focusing or anti-aliasing effects. Large fuzzy areas cannot be processed in this way.

Bayesian Matting algorithm [3] and its improvement [10] require precise trimap but demonstrate high processing speed because of non-iterative local matte optimization (as opposed to iterative and/or global optimization approaches of [1], [4], [11], [14], [15]).

3. PROPOSED WORKFLOW

3.1 Workflow overview

We propose an approach that uses a sparse trimap (i.e. several strokes) to make a hard (binary) segmentation of an image which is then quickly turned into a trimap. The trimap can be easily refined and used in a soft segmentation, i.e. matting. We use Bayesian Matting [3] as the algorithm base, supplemented with smoothness feature from [10] and several heuristics that account for the fact that trimap originates from a binary mask.

We start by performing hard segmentation of an image from sparse manual marking. For this step we use GrowCut algorithm [12] for interactive hard segmentation, though some other algorithms can possibly be used, e.g. Graph Cut [2]. We aim to get accurate segmentation near hard image edges and some approximate segmentation in fuzzy areas.

Then we construct a trimap by doing morphological erosion of both foreground and background areas, thus obtaining an unknown area. Radius of the erosion is controlled by the user via a slider and is previewed in real-time. At this step the user should adjust edge width to cover most of hard edges, depending on their overall blurriness and fuzziness.

Large fuzzy areas (e.g. hair) are added by the user using a trimap extension tool that we propose. It allows quick drawing of the approximate outer or inner boundary of a fuzzy area and extends

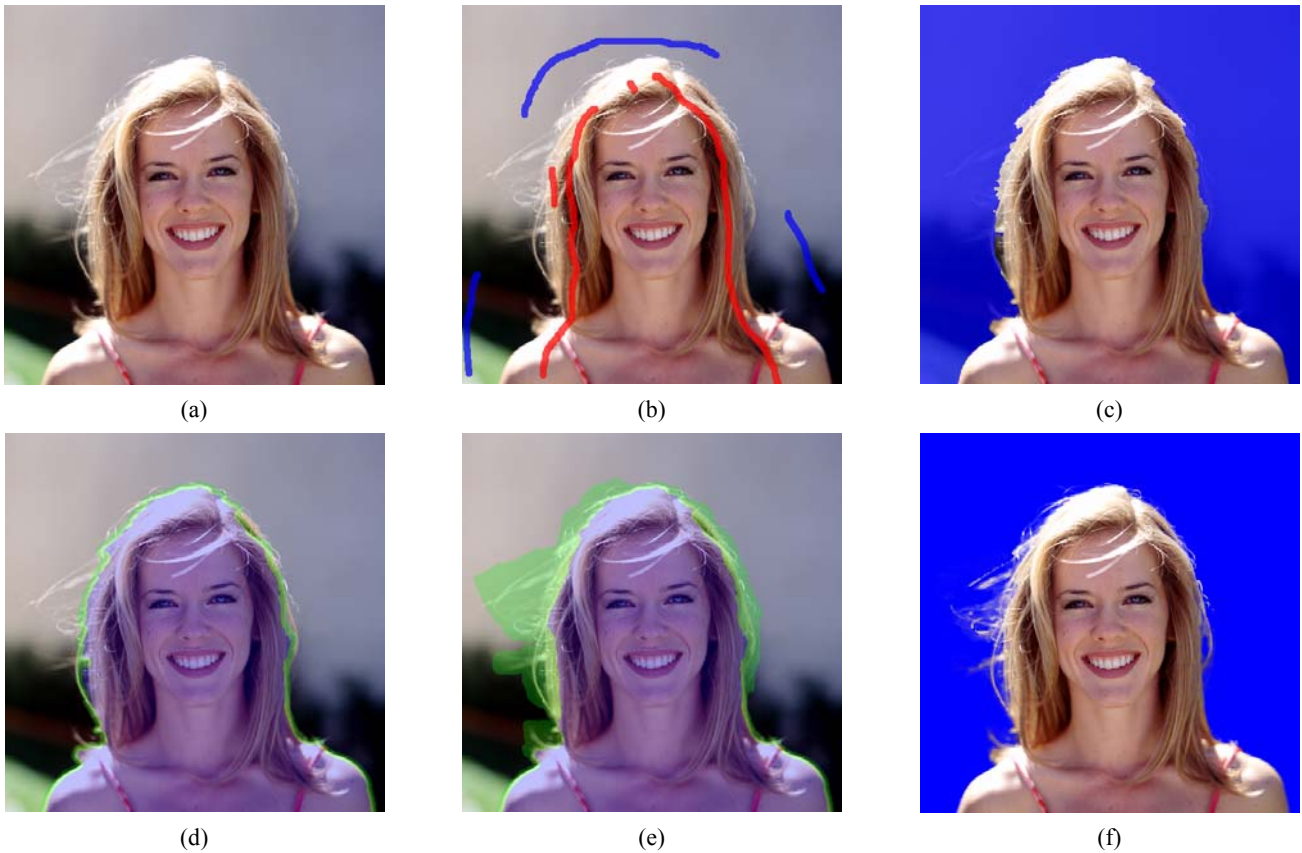


Figure 1 An example of image matting using our workflow. **(a)** Source image. **(b)** User strokes for GrowCut (red = foreground, blue = background). **(c)** GrowCut segmentation result. **(d)** Trimap obtained from hard segmentation using morphology operation with constant radius (green = unknown area, bluish = foreground area, the rest is background). **(e)** Trimap quickly refined by the user using our trimap extension tool to include fuzzy areas. **(f)** Final matting result with little user refinement (using proposed refinement tools) composited onto a constant color background.

unknown area to include marked region. This tool is described in detail in the next section.

Next, we perform an improved Smooth Bayesian Matting with user-adjustable smoothness setting. For large images user can use hierarchical processing by selecting a downscaling factor (as described in [10]).

Finally the user can refine the result using several tools. These include simple manual retouching the alpha channel, retouching with foreground color recalculation, and applying matting with different parameters to an arbitrary rectangular region (with possible trimap editing).

3.2 Trimap generation and editing

Hard segmentation process is performed using the GrowCut algorithm. Because of interactive editing requirements, in order to cope with large images, we use hierarchical version of GrowCut. At first we apply GrowCut to a downscaled image and then refine the result in the original image.

This (as well as consecutive steps) is illustrated in Figure 1.

The result of segmentation is converted to a trimap by allowing the user to set the edge width. We use morphological operation with a disk structure element to construct unknown region of given width on top of the hard segmentation result. The operation

is fast so the user sees semi-transparent unknown region while adjusting the slider.

For fuzzy and semi-transparent areas which cannot be handled by binary segmentation + morphology, we propose a Trimap Extension Tool. It allows quick adding of large unknown regions connected with existing ones (though small strokes of foreground/unknown/background can be painted directly by using a brush tool, when needed). This tool works as follows:

1. The user draws a stroke around a fuzzy area inside either foreground or background region.
2. Ends of the stroke are connected with existing unknown area using lowest-cost path finding algorithm, similar to Intelligent Scissors approach [6]. Color similarity between neighboring pixels is used for path cost function. Dijkstra's algorithm is used for path finding.
3. Ends of found paths are connected inside existing unknown region.
4. The polygon formed of the four paths is filled with the 'unknown' label in the trimap (the four paths are: the user-drawn stroke, 2 connections of stroke ends to unknown area, connection of their ends inside the unknown area).

Stroke at step 1 can also be performed using intelligent scissors approach. Figure 2 demonstrates the above steps.

The proposed method is intuitive and efficient for quick extension of the existing unknown region into fuzzy areas. This approach is obviously quicker than drawing the new region manually and at the same time is more accurate (gives smaller unknown region).

For faster preview of constructed paths while the stroke is being drawn, a map of path costs and directions can be precomputed using the unknown regions as a set of starting points.

3.3 Matting process

Using the trimap from previous step we perform Smooth Bayesian Matting algorithm with an addition described below.

Standard [3] and Smooth [10] Bayesian Matting algorithms traverse pixels by uniformly contracting the unknown region from both foreground and background sides. We use another approach – pixels along the unknown area borders are placed into a priority queue based on their color similarity to nearest pixels, either already processed or marked as known in the trimap. After each pixel is processed new border pixels are also added to the queue. This heuristics improves both smoothness and accuracy by providing better estimation of α_0 and fg/bg color samples which are collected from pixel neighborhood.

Smooth Bayesian Matting tends to attract smooth object edge to the skeleton of the unknown area when color statistics fails to separate foreground/background distributions and is overpowered by smoothness term. This is especially true in large fuzzy areas.

Our approach tends to converge to a real object edge in the image independently of unknown region shape and at the same time encourages large fully transparent/fully opaque areas ($\alpha = 0$ or 1) which is true for most images. Figure 3 shows an example where this helps to suppress noise while preserving the overall foreground object shape.

However, around simple edges hard segmentation usually marks the edge correctly, so the user can force simpler algorithm here (by changing matting parameters and using the rectangle recalculation tool – see below), because in such case the skeleton of unknown area lies near the original hard segmentation boundary.

Separate processing of clear and fuzzy edges is possible using rectangle recalculation tool which allows the user to recompute the result inside a rectangle using different parameters, while using α values on the sides of the rectangle as fixed ones.

3.4 Result editing

It is also possible to touch-up the opacity value using a set of tools (brushes) and optionally recalculate foreground color values for new α values in the affected region.

The tools are:

- Soft foreground/background brushes, which draw with 1/0 value in the opacity channel. The brushes have controllable soft radius. If alpha value becomes equal 0 or 1 it is also added to trimap for possibility of result recalculation.
- Contrast brush, which allows making an oversmoothed edge harder by increasing the contrast in opacity channel.

- Blur brush to increase edge smoothness and/or reduce small noise.
- Rectangle recalculation tool (described at the end of Section 3.3)

4. CONCLUSION

In this paper we have proposed a framework for user-assisted image matting. It makes the process of image matting simpler and faster by using efficient hard segmentation before applying a less reliable (in terms of result robustness) soft matting process. Both trimap and result refining tools were proposed to create an effective user-assisted approach.

We plan to perform a subjective evaluation by comparing the time required by several users to achieve nearly the same results using different image matting workflows.

5. REFERENCES

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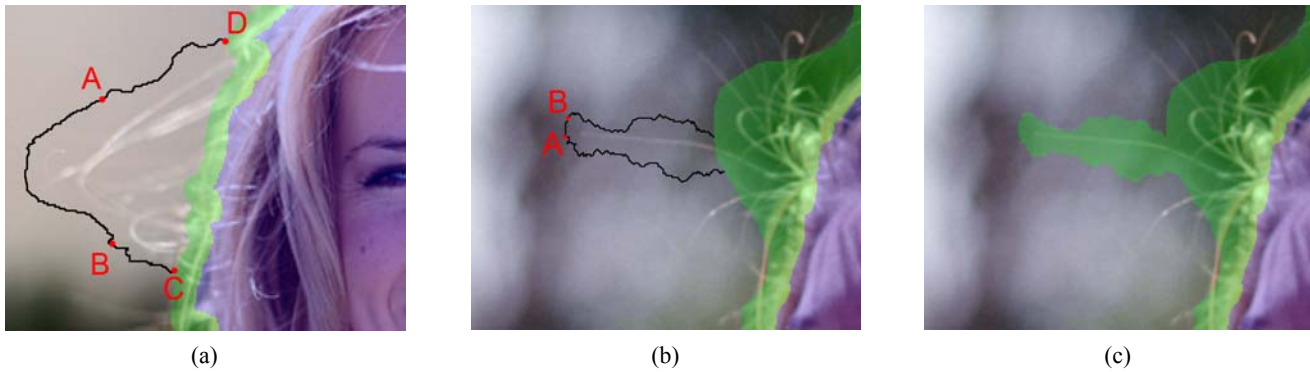


Figure 2 A demonstration of the Trimap Extension Tool. **(a)** Trimap overlaid onto a source image (image from [3]). A-B is the user-drawn stroke. B-C and A-D are automatically constructed paths from points A and B to the unknown region. C and D are also connected inside the unknown region. The full polygon ABCD is then filled with the ‘unknown’ label in trimap. Path A-B can optionally be constructed with the same lowest-cost path method instead of direct usage of the user-drawn trajectory. **(b)** An isolated hair can easily be added to the trimap by a short stroke A-B without the need to trace the hair accurately (image from [3] website). **(c)** Filled trimap result for (b).

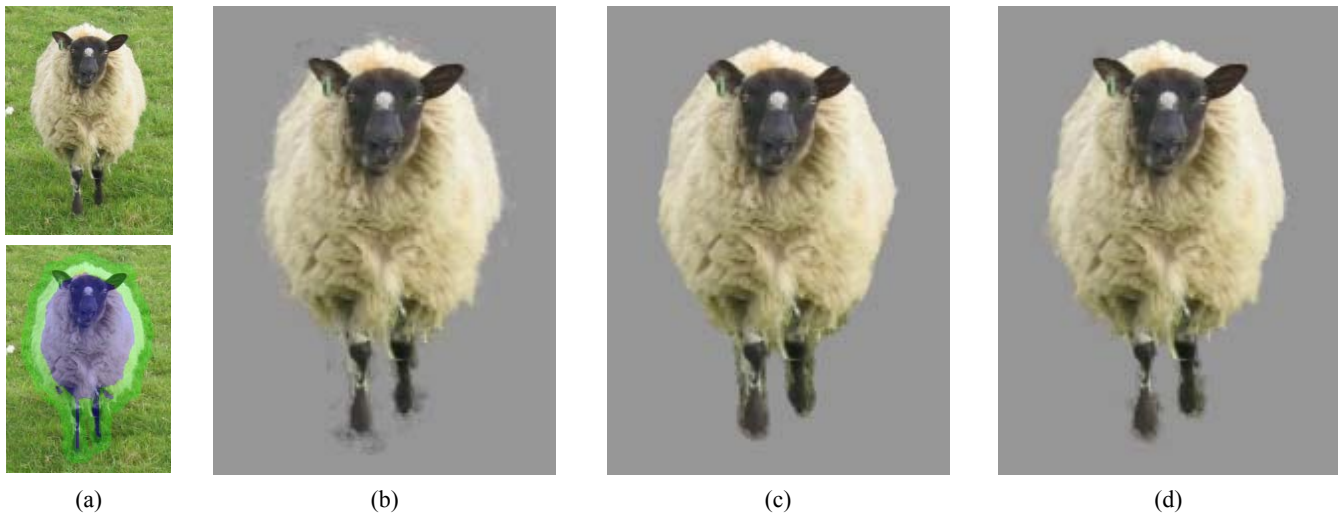


Figure 3 Sheep image from Berkeley Dataset [5] processed using different variants of Bayesian Matting. **(a)** Source image (top), source image overlaid with trimap (bottom). **(b)** Result of Bayesian Matting (our implementation was used) – much visible noise. **(c)** Result of Smooth Bayesian Matting – noise is suppressed, but overall shape of the object is distorted (influenced by the trimap shape); note the cropped ears, widen legs and oversmoothed fur contour. **(d)** Proposed approach – most of noise is suppressed while preserving the overall shape of the object. Note that (c) and (d) have the same matting parameters (including smoothness strength), except the pixel processing order.