ICIC Express Letters
Part B: Applications
Volume **8**, Number **11**, November **2017**
ICIC International ©2017 ISSN 2185-2766
pp. 1473–1480

GREEN SCREEN MATTE REFINEMENT WITH MULTIPLE FILTERS

Thanathorn Phoka

Department of Computer Science and Information Technology
Faculty of Science
Naresuan University
99 Moo 9, Tambon Tha Pho, Muang, Phitsanulok 65000, Thailand
thanathornp@nu.ac.th

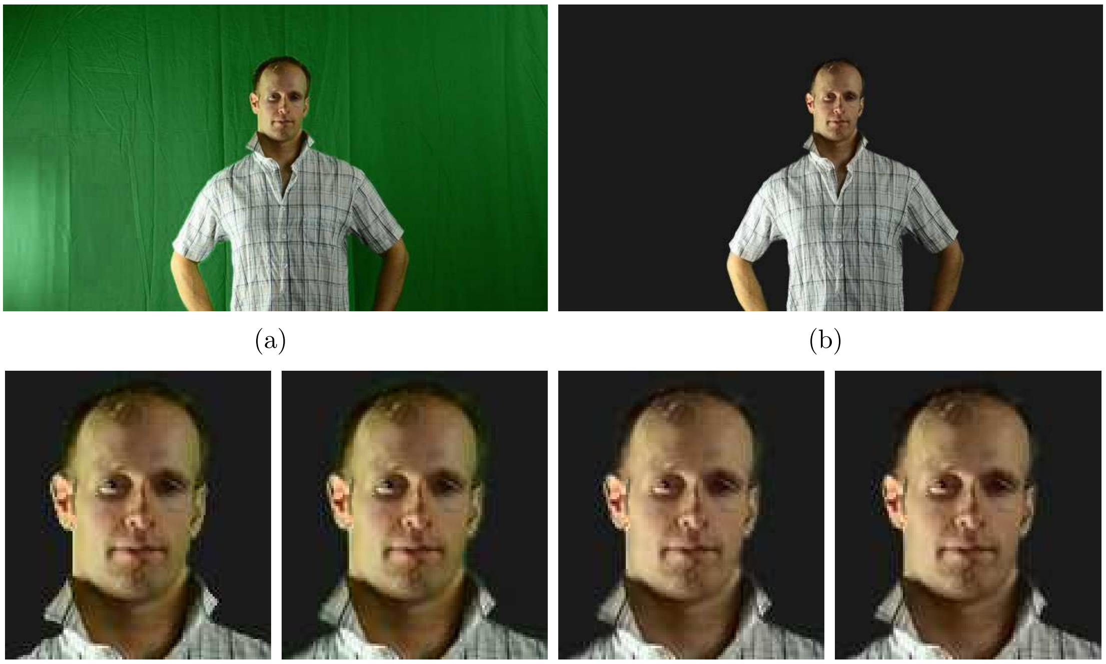
Received May 2017; accepted August 2017

Abstract. *This paper considers all procedures required in the process of a green screen matte refinement which are alpha matte smoothing, green spill suppression and compositing. An extracted matte usually has ridges on the edge and exceeding green spilling on the subject. Furthermore, the artifact on the edge of the original green screen image always exposes in the compositing procedure. These lead to the necessity of applying the green screen matte refinement. For simplicity, a popular conventional approach used for alpha matte smoothing is applying the Gaussian filter on the extracted matte but it may produce over-smoothing edge. The existing spill suppression approaches are to clamp the excess green based on the values of the red channel and the blue channel. This causes a hue shift and a brightness drop problem in a final composite. Unspill operation is the other existing approach proposed to relief the brightness drop problem but the hue shift problem remains. In order to resolve these limitations, this paper proposes the uses of multiple filter approaches for all procedures. Guided filter is the main filter applied in this paper for alpha matte smoothing and suppressing green spill because of its capability of smoothing an image while the details of the image are preserved according to a guidance image. Gaussian filter is taken into account for blending the edge of the matte and a new background because the artifact on the edge of the input image is sometimes needed to be removed. The experimental results will show that the proposed approach can produce high quality compositions.*
Keywords: Green screen matte, Alpha matte smoothing, Spill suppression, Edge blending, Guided filter, Gaussian filter

1. **Introduction.** Digital compositing is the digital process that adjusts and combines multiple images to produce a final image. An important procedure in digital compositing is filming a subject with a green screen plate and extracting the subject from the screen to be used in a compositing. The process of extracting the subject from the green screen is referred to as green screen matting or matting while the resulting extraction is referred to as a green screen matte or matte consisting of the foreground, background and alpha matte. Once a matte is acquired, it is then combined with a new background to produce a final composition. However, directly composting the matte may cause a nonnatural composition.

For an input example in Figure 1(a), the final composition with the proposed refinement is shown in Figure 1(b). Let us look in more details. The zoom-in compositions without any refinement, with smoothing, with spill suppression and with edge blending are shown in Figures 1(c)-1(f), respectively. We can see from Figure 1(c) that the unrefined composition has ridges at the edge and looks unnatural because of green spill. Therefore, the alpha matte smoothing is usually needed to remove ridges on the edge of the extracted matte.

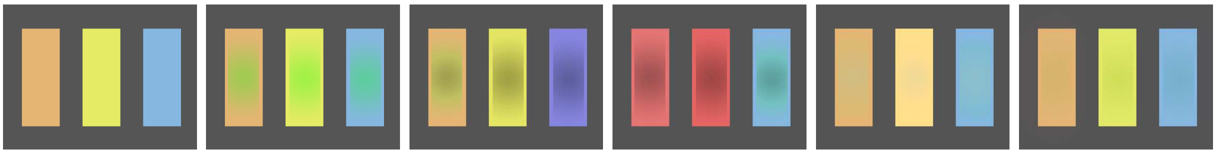
A main defect of the input image is from improper lighting. It may cause problems both on the green screen and the subject. A matte suffers from improper lighting especially



(a) (b)

(c) (d) (e) (f)

FIGURE 1. Refinement procedures



(a) (b) (c) (d) (e) (f)

FIGURE 2. Spill suppression artifacts

when a subject is underlit since scattering green light will shine on the subject as appearing on the left side of the face in Figure 1(a). More clearly, the composition without spill suppression in Figure 1(d) expresses a low quality composition with green glowing on the edge of the subject and green spill on the face. This leads to a necessity of applying spill suppression on the subject.

The conventional spill suppressions remove exceeding green or compensate by increasing blue and red values. The approaches globally adjust red, green and blue values that may cause brightness drop and hue shift artifacts as stated in [1]. The image in Figure 2(a) presents a test plate consisting of three strips which present skin tone, yellow and light blue. A modified test plate by filling green gradients is in Figure 2(b). The results from clipping exceeding green by red value and blue value are presented in Figures 2(c) and 2(d). They are severely affected by brightness drop and hue shift and still leave relative green on the skin tone strip in Figure 2(c) and the light blue strip in Figure 2(d). The unspill approach which concurrently decreases green and increases blue and red values can avoid the brightness drop but the hue shift still maintains as shown in Figure 2(e).

The main contribution of this paper is to propose the uses of multiple filters for matte refinement especially in the spill suppression procedure that avoids both brightness drop and hue shift artifacts by applying an iterative guided filter for diffusing proper differences between the green value and the blue and red values. A result from the proposed approach indicating a strong point compared to the existing approaches is presented in Figure 2(f) that is almost exactly the same as the original test plate. However, Figure 1(e) presents a result of the proposed spill suppression, and the result looks more natural but still leaves light gray glowing on the edge of the subject. This leads to another contribution of this paper to propose a heuristic for edge blending. Brightness of a new background is used as a constraint for the edge blending. Gaussian filter is then applied to generating weights for the edge blending. A result from the edge blending is shown in Figure 1(f). It decreases the glow artifact and produces a high quality final composition.

The organization of this paper is as follows. Related work and detail on matting, filters and spill suppression are described in Section 2. The proposed matte refinement procedures are explained in Section 3. The experimental results are presented in Section 4. The conclusions and an extension of this work are discussed in Section 5.

2. **Related Work.** Three main topics about matting, filtering and spilling suppression will be discussed in this section. Generally, matting is the process of extracting a subject from a natural background image to produce a matte in the form of alpha image, foreground and background color image. Before compositing the matte with a new background, the alpha matte smoothing process is usually needed to remove ridges on the edge of the matte. Filtering is then taken into account for this task. However, the green screen may leave some artifacts on the subject by spilling green color on them. The spill suppression is applied to removing the unwanted green from the foreground subject.

2.1. **Matting.** Given an image, matting is the process that extracts a foreground subject from a background. It can be modeled as a convex combination of foreground and background color as

$$C_i = \alpha_i F_i + (1 - \alpha_i) B_i, \tag{1}$$

where C_i is the input color, F_i is the foreground color, B_i is the background color and α_i is the opacity or blending of a pixel i. All these values of all pixels in an image are called a matte and let the opacity be called an alpha matte. From the equation, F_i, B_i and α_i have 7 unknown values but there are only 3 linear constraints. This makes matting be an ill-posed problem.

Natural image matting needs constraints to compute a result matte. Additional information such as trimap or scribbles determining the foreground, background and unknown regions has to be defined beforehand. There are two main approaches solving the natural image matting: propagation-based approaches [2, 3, 4] and color sampling-based approaches [5, 6, 7, 8, 9].

In this paper, the background color is assumed to be a green color and an extracted matte is given. The analysis of the green screen matting problem was presented in [10]. In practice, color difference and chroma-key are the fundamentals of commercial softwares for the green screen matting used in digital compositing [1]. Recently, an extension of the color difference was proposed to allow a user to fine tune color difference thresholds based on luminances [11].

2.2. **Filters.** Filtering is applied for smoothing an alpha matte. Box filter and Gaussian filter are commonly used because of their simplicity but they may decay the edge detail of the alpha matte. Bilateral filter [12] was proposed as an edge preserved filter. However, an alpha matte does not present the detail of an image. Joint bilateral filter [13] computes weights from another guidance image that is the color input image in this paper. The main drawback of the joint bilateral filter is that it may suffer from gradient reversal artifacts when neighboring pixels of a smoothed pixel are too different. Nonlocal filter [14] considers similarity of square patches to compute weights. A use of the nonlocal filter for an alpha matte smoothing was proposed in [15]. The filter can smooth a matte while preserving edge detail but the complexity of the algorithm is $O(Nr^2m^2)$ where m is the radius of a square patch used in weight computation.

Guided filter [16] is another edge preserved filtering with $O(N)$ complexity. Assuming a local linear model between the guidance image I and the filtering output image q, the guided filter smooths the input image p while preserving edge information transferred from the guidance image I:

$$q_i = a_k I_i + b_k, \quad \forall i \in \omega_k, \tag{2}$$

where k is the center of a window ω_k, the radius of which is defined by r, and (a_k, b_k) are constant linear coefficients in each ω_k. Finding the solution of the coefficients (a_k, b_k) can be cast into a minimization problem solved by the ridge regression and the solution is given by:

$$a_k = \frac{\frac{1}{|\omega|}\Sigma_{i\in\omega_k} I_i p_i - \mu_k \bar{p}_k}{\sigma_k^2 + \epsilon}, \tag{3}$$

$$b_k = \bar{p}_k - a_k \mu_k, \tag{4}$$

where μ_k and σ^2 are the mean and variance of I in ω_k, $\bar{p}_k$ is the mean of p in ω_k and ϵ is a regularization parameter.

A pixel i gets involved in all windows containing it; therefore, q_i is computed from the averages $\bar{a}_i = \frac{1}{|\omega|}\Sigma_{k\in\omega_i} a_k$ and $\bar{b}_i = \frac{1}{|\omega|}\Sigma_{k\in\omega_i} b_k$ as:

$$q_i = \bar{a}_i I_i + \bar{b}_i. \tag{5}$$

There are two parameters that can be adjusted, r and ϵ. As presented in [16], r and ϵ are corresponding to the variances of spatial and range values used in the bilateral filter, respectively. This paper applies the guided filter for alpha matte smoothing and spill suppression which will be described in Section 3.

2.3. **Spill suppression.**

Spill suppression is applied to handling with exceeding green from a matte based on some constraints. Some simple but practical constraints are described in [1] which are limiting the green value by the blue or red value as follows:

$$C_{i,G} = \min\left(\beta C_{i,R} + \gamma C_{i,B}, C_{i,G}\right), \tag{6}$$

where β and γ are user-defined parameters. The green value is trimmed by the proportion of the red value when $\beta > 0$ and $\gamma = 0$ or of the blue value vice versa. The parameters can be freely adjusted by a user not restricted to the previous conditions to produce the best appearance. Applying this constraint is referred to as despill operation. However, the despill operation has two main artifacts which are brightness drop and hue shift. The brightness drop comes from decreasing the most influential color channel on brightness, the green value. The hue shift is from adjusting the green channel only. Modifying one channel in the RGB space clearly affects hue change.

The other practical spill suppression described in [1] is called unspill operation. The unspill operation implicitly provides brightness adjusting by allowing a user to decrease the green value and increase the red and blue values concurrently as follows:

$$C_{i,c} = C_{i,c} + g_c\left(C_{i,G} - \frac{C_{i,R} + C_{i,B}}{2}\right), \quad c \in \{R, G, B\}, \tag{7}$$

where g_c are user-defined gains for each channel, g_R and g_B are normally positive while g_G is negative. Even though the unspill operation relieves the brightness drop but it still suffers from the hue shift since all pixels share the same gain adjustments.

3. **Matte Refinement.**

This section will describe all the procedures necessary to refine an obtained matte for a good final composition in order.

3.1. **Alpha matte smoothing.** Alpha matte smoothing is the first procedure applied to the extracted matte to refine the edge of the matte. As stated in [16], the guided filter can be used for guided feathering which is the alpha matte smoothing in this paper. The guided filter is directly applied by assigning I to be the input color image, p is an alpha matte obtained from a matte extraction procedure and q is the smoothed alpha matte. The intuition of this process is to smooth the alpha matte while preserving edge detail appearing in the input color image to avoid oversmoothing.

3.2. **Spill suppression.** This paper remodels the spill suppression by considering the differences between the green value and the remaining channel values. Once such differences are obtained, the new values of the red and blue channels are from the following:

$$C_{i,c} = C_{i,G} + D_{i,c}, \quad c \in \{R, B\}, \tag{8}$$

where $D_{i,R} = C_{i,R} - C_{i,G}$ is the difference between the red and the green values and $D_{i,B} = C_{i,B} - C_{i,G}$ is the difference between the blue and the green values. Let such differences be called spill differences. The next stage is to find spill differences of each pixel that retain the appearance of the original input image, remove green spill but induce less artifact than the existing approaches in both the hue shift and the brightness drop.

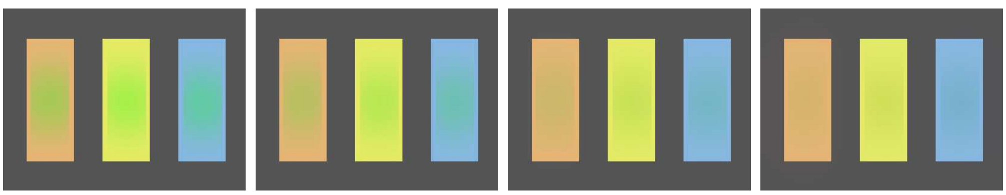
Assuming that pixels spilled by green is the minority, the guided filter is again used in this stage not only for smoothing but also for propagating spill differences. In theory, expanding r is not sufficient to propagate the spill differences and may smooth out edge detail so that an iterative guided filter is then applied instead. The guided filter in Equation (5) is reformulated as follows:

$$D_{i,c,t} = \bar{a}_{i,c,t} I_{i,t} + \bar{b}_{i,c,t}, \tag{9}$$

where the subscript t is the iteration of applying the guided filter. The color image I_t is updated for the next iteration by:

$$I_{i,c,t+1} = \max\left(I_{i,G,t} + D_{i,c,t}, I_{i,c,t}\right), \tag{10}$$

where I_0 is the composition of the smoothed matte from the alpha matte smoothing and a new background and $D_{i,c,0} = I_{i,c,0} - I_{i,G,0}$. The max function is applied to obstructing relative green diffusion. The value of $D_{i,c,t}$ that induces lower values of red or blue channels has to be blocked from the diffusion. The advantage of performing spill suppression on the composition is that it concurrently decreases the effect from the green background and increases the effect from the new background. The intuition of the iterative guided filter is that for each iteration the spill differences are smoothed according to the edge detail transferred from the composition. The composition is then updated by the smoothed spill differences and used in the next iteration. With proper adjustments of r, ϵ and t, the iterative guided filter can produce high quality spill suppressed results presented in Figure 3. The test plate is then again used to demonstrate an evolution of applying the iterative guided filter. The values of r and ϵ are assigned to be 20 and 0.05 while t is varied from $\{1, 5, 10, 15\}$ and the associated results are expressed in Figures 3(a)-3(d),



(a) (b) (c) (d)

FIGURE 3. An evolution of applying the iterative guided filter

respectively. As we can see from Figure 3(a), the original guided filter cannot handle with this situation but the iterative guided filter produces better results through iterations.

3.3. **Edge blending.** The proposed spill suppression works well in regular situations but not under some conditions such as edge enhancement from an image capturing device or ringing artifact from an image compression. These artifacts will leave glowing effect on the edge of a composition when the brightness of the original green background and of the new background is extremely different. The other artifact is from the spill suppression model in Equation (8) that $D_{i,c,t}$ is often greater than $D_{i,c,0}$ in the regions that are spilled by green. This makes the overall foreground of the spill suppressed composition look a little brighter.

In order to alleviate the artifacts, this paper proposes a heuristic for edge blending based on the brightness of the original foreground and the new background. The proposed heuristic not only blends the edge but also constrains the brightness of a spill suppressed foreground back to the original one. The first step is to blur the alpha matte obtained from the alpha matte smoothing procedure from the border to the inner side using the Gaussian filter and let the blurred alpha matte be denoted by α_b. Secondly, the input color image, new background image are converted from the RGB space to the YUV space and let S and T denote the Y channels of the input image and new background image, respectively. The brightness U of the output from this process is cast into the following convex combination:

$$U_i = \alpha_{b,i} S_i + (1 - \alpha_{b,i}) T_i. \tag{11}$$

However, green spill naturally induces the brightness drop so that the brighter foreground of the spill suppressed composition is sometimes preferred. In this situation, S can be replaced by the Y channel of the spill suppressed composition. Once U has been obtained, it is merged with the UV channels of the spill suppressed composition. The result is then recomposited with the new background to produce the final composition.

4. **Experimental Results.** For all experiments, the images in Figures 1(a) and 4(a) are from the Internet where their resolutions are 640×360 and 1440×1080, respectively. The machine used in the experiments consists of 3.4 GHz CPU and 16 GB ram. The proposed procedures are implemented in C++ language with OpenCV library. The results are compared among the proposed procedures. As stated in Section 1 that all proposed procedures are needed to produce a high quality composition, Figures 4(c)-4(f) show the zoom-in versions of the compositions without refinement, with guided filter applying to the alpha matte, with spill suppression and with edge blending, respectively. The results look better for every single procedure applied until the last step that produces the final composition expressed in Figure 4(b).

The spill suppression approach is evaluated by varying the values of the number of iterations t and the radius r while the regularization parameter ϵ is treated as a constant with the value 0.05 to avoid over propagation. The zoom-in results from adjusting these parameters are presented in Figure 4(g). The compositions look more satisfying by properly removing excess green when t and r are increased. However, the running time is increased according to the number of iterations performing the guided filter as expressed in Table 1.

The running times in Table 1 measured in the spill suppression procedure show that adjusting r does not affect the running time but increasing t does. The running time goes up linearly according to t. This complies with the complexity analysis and experiment in [16] that the guided filter runs in $O(N)$ time complexity. An image with resolution 1920×1080 is also considered in the running time measurement and the comparisons reflect that the number of pixels also influences the running time. The running times of the alpha matte smoothing for the 640×360, 1440×1080 and 1920×1080 inputs are

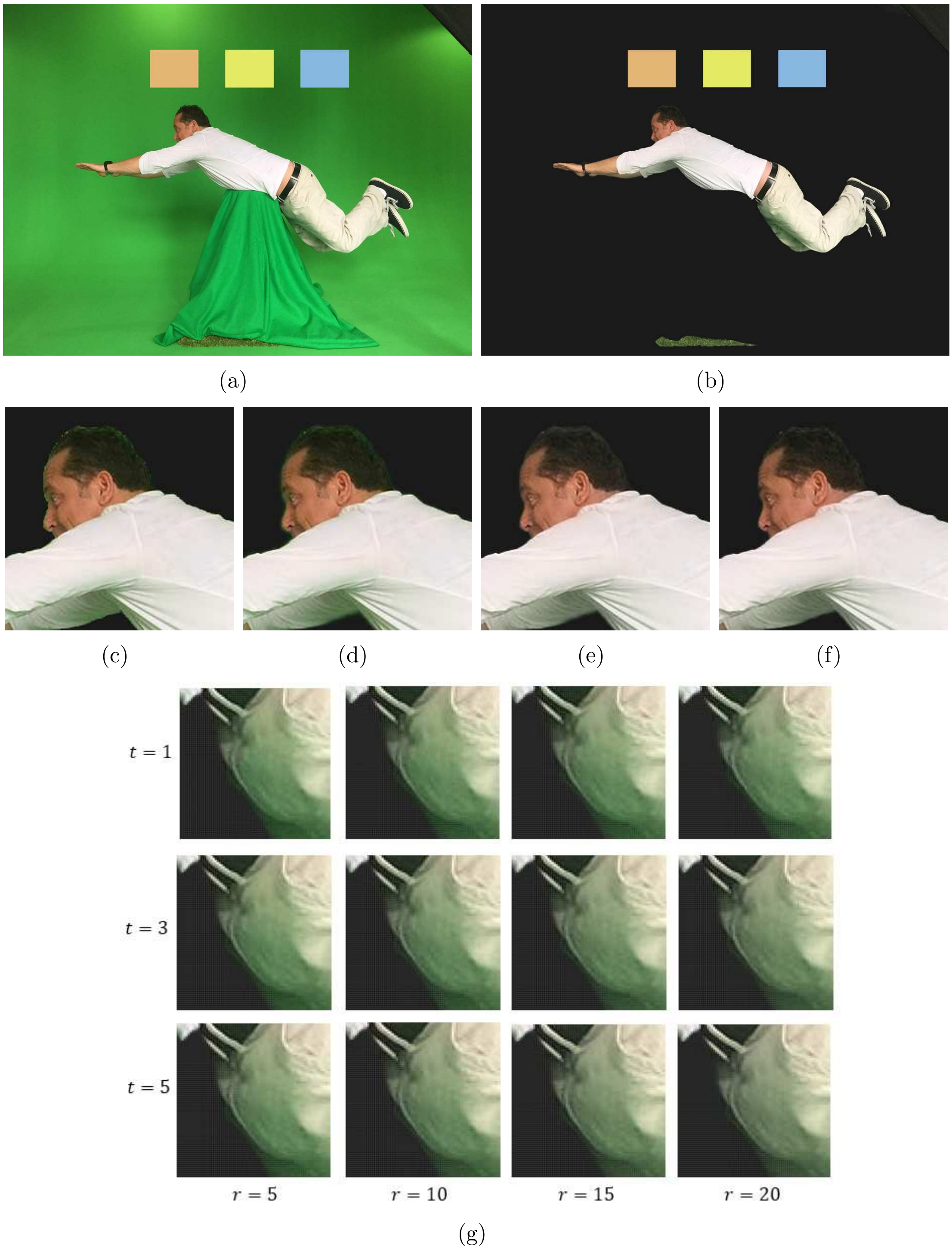


FIGURE 4. Experimental results

0.05, 0.36 and 0.48 and the edge blending procedure takes 0.04, 0.11 and 0.13, respectively which indicate the linear relations between the procedures and the number of pixels.

Furthermore, the spill suppression approach proposed in this paper aims to resolve the hue shift and brightness drop artifacts. As we can see from Figure 4(a), the three color blobs are intentionally added into the image, skin tone, yellow and light blue colors. The final composition expresses that the proposed approach can avoid both artifacts while removing the unwanted green.

5. **Conclusions.** This paper has proposed the procedures of a green screen matte refinement based on the guided filter and the Gaussian filter. The guided filter is the main

Table 1. Running times in seconds

t \ r	640 × 360				1440 × 1080				1920 × 1080			
	5	10	15	20	5	10	15	20	5	10	15	20
1	0.059	0.059	0.059	0.065	0.775	0.775	0.793	0.797	0.932	0.917	0.94	0.931
2	0.12	0.125	0.129	0.14	1.514	1.577	1.606	1.622	1.962	1.933	1.918	1.892
3	0.183	0.185	0.197	0.206	2.307	2.377	2.436	2.42	3.026	3.021	2.926	2.866
4	0.236	0.269	0.273	0.282	3.116	3.209	3.301	3.22	4.161	4.097	3.917	3.848
5	0.311	0.325	0.344	0.354	3.948	4.013	4.075	4.008	5.322	5.2	4.943	4.872

filter used in the alpha matte smoothing and the proposed iterative version is applied in the spill suppression procedure. The edge blending step applies the Gaussian filter to producing parameters for the convex combination in the Y channel of the YUV space of the foreground image and a new background image. The experimental results show that the proposed approaches can produce high quality compositions but the main drawback is the running time that linearly depends on the number of iterations applying the guided filter. However, the proposed approaches can be further implemented and optimized on a GPU because of their parallelism which is an extension of this paper.

Acknowledgment. This work is partially supported by research grant R2560C057 from Naresuan University which is greatly appreciated.

REFERENCES

[1] S. Wright, *Digital Compositing for Film and Video*, Focal Press Visual Effects and Animation Series, Elsevier/Focal Press, 2010.

[2] A. Levin, D. Lischinski and Y. Weiss, A closed-form solution to natural image matting, *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol.30, no.2, pp.228-242, 2008.

[3] P. G. Lee and Y. Wu, Nonlocal matting, *IEEE Conference on Computer Vision and Pattern Recognition*, pp.2193-2200, 2011.

[4] Q. Chen, D. Li and C.-K. Tang, KNN matting, *IEEE Conference on Computer Vision and Pattern Recognition*, pp.869-876, 2012.

[5] E. S. L. Gastal and M. M. Oliveira, Shared sampling for real-time alpha matting, *Computer Graphics Forum*, vol.29, no.2, pp.575-584, 2010.

[6] K. He, C. Rhemann, C. Rother, X. Tang and J. Sun, A global sampling method for alpha matting, *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, pp.2049-2056, 2011.

[7] D. Rajan, Weighted color and texture sample selection for image matting, *Proc. of the 2012 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, Washington, DC, USA, pp.718-725, 2012.

[8] E. Shahrian, D. Rajan, B. Price and S. Cohen, Improving image matting using comprehensive sampling sets, *Proc. of the 2013 IEEE Conference on Computer Vision and Pattern Recognition*, Washington, DC, USA, pp.636-643, 2013.

[9] W. Wang and J. Zhao, Robust image chroma-keying: A quadmap approach based on global sampling and local affinity, *IEEE Trans. Broadcasting*, vol.61, no.3, pp.356-366, 2015.

[10] A. R. Smith and J. F. Blinn, Blue screen matting, *Proc. of the 23rd Annual Conference on Computer Graphics and Interactive Techniques*, New York, NY, USA, pp.259-268, 1996.

[11] T. Phoka and A. Sudsang, Fine tuning for green screen matting, *The 9th International Conference on Knowledge and Smart Technology (KST)*, pp.317-322, 2017.

[12] C. Tomasi and R. Manduchi, Bilateral filtering for gray and color images, *The 6th International Conference on Computer Vision*, pp.839-846, 1998.

[13] G. Petschnigg, R. Szeliski, M. Agrawala, M. Cohen, H. Hoppe and K. Toyama, Digital photography with flash and no-flash image pairs, *ACM Trans. Graph.*, vol.23, no.3, pp.664-672, 2004.

[14] A. Buades, B. Coll and J. M. Morel, A non-local algorithm for image denoising, *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, vol.2, pp.60-65, 2005.

[15] T. Phoka and A. Sudsang, GPU-based nonlocal smoothing for alpha matting, *The 13th International Joint Conference on Computer Science and Software Engineering (JCSSE)*, pp.1-6, 2016.

[16] K. He, J. Sun and X. Tang, Guided image filtering, *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol.35, pp.1397-1409, 2013.