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Touch HDR: photograph enhancement by user controlled wide dynamic range adaptation

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ABSTRACT

High Dynamic Range (HDR) technology enables photographers to capture a greater range of tonal detail. HDR is typically used to bring out detail in a dark foreground object set against a bright background. HDR technologies include multi-frame HDR and single-frame HDR. Multi-frame HDR requires the combination of a sequence of images taken at different exposures. Single-frame HDR requires histogram equalization post-processing of a single image, a technique referred to as local tone mapping (LTM). Images generated using HDR technology can look less natural than their non-HDR counterparts. Sometimes it is only desired to enhance small regions of an original image. For example, it may be desired to enhance the tonal detail of one subject's face while preserving the original background.

The Touch HDR technique described in this paper achieves these goals by enabling selective blending of HDR and non-HDR versions of the same image to create a hybrid image. The HDR version of the image can be generated by either multi-frame or single-frame HDR. Selective blending can be performed as a post-processing step, for example, as a feature of a photo editor application, at any time after the image has been captured. HDR and non-HDR blending is controlled by a weighting surface, which is configured by the user through a sequence of touches on a touchscreen.

Keywords: High dynamic range, local tone mapping, histogram equalization, touch screen, touch HDR

1. INTRODUCTION

Many current devices are available for capturing images. For example, current digital cameras and modern cell phones and tablets can all capture and display digital images to a user. In most cases, these devices capture images using a pre-defined dynamic range of illumination across the entire captured image. For example, these cameras may capture images at a preselected exposure level and a predefined contrast range.

In digital photography, high dynamic range (HDR) [1,2] technology enables photographers to capture a greater range of tonal detail by capturing a greater dynamic range between the lightest and the darkest areas of a captured image. The dynamic range of the real world is large, and can usually be more than five orders of magnitude at the same time. The dynamic range of everyday scenes can hardly be recorded by a conventional sensor. Hence, a conventional image may contain portions that are over-exposed or under-exposed. HDR technology may be used to bring out detail in a dark foreground object set against a bright background or vice versa.

Multi-frame HDR imaging techniques allow the possibility to reconstruct a radiance map that covers the full dynamic range by combining multiple exposures of the same scene [1,2]. Multi-frame HDR technology typically consists of (1) acquiring a wide dynamic range image and (2) adapting the wide dynamic range image to fit to the display range of the device. The first part is achieved by combining two or more images captured at different exposure levels and combining them together to produce an image representative in both dark and bright areas. The second part locally adapts the tone mapping function to the display range of the device; thus it effectively enables local re-use of the available range [3,4,5]. Local tone mapping methods sacrifice the global contrast of an HDR image to facilitate its display on a device with a lower dynamic range.

While local tone mapping usually results in a reduction of the overall image contrast, it is capable of producing very sharp images with an exaggerated local contrast [3,4,5,6]. Single-frame HDR methods skip the aforementioned first stage of processing in multi-frame HDR, and work by applying a local tone mapping function to an original image captured at a fixed exposure level. Local tone mapping ramps up the contrast in darker regions of the image, and makes

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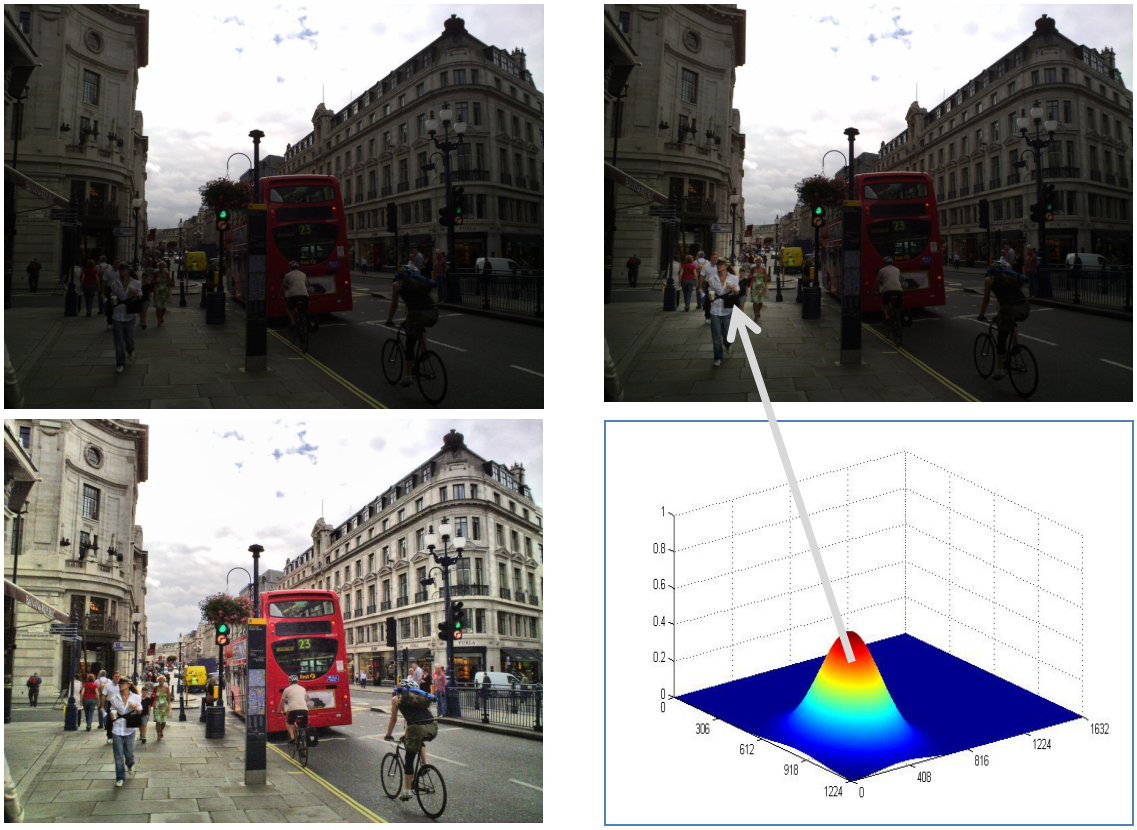


Figure 1. (Top-left) Original image. (Bottom-left) HDR image. (Bottom-right) Weighting function W for blending original and HDR images. (Top-right) Hybrid image generated by Touch HDR.

details in these areas more visible. In this paper, we refer to an image before local tone mapping as non-contrast adapted and an image after local tone mapping as a contrast adapted image.

The downside of both multi-frame and single-frame HDR imaging is that HDR images can often look unrealistic or unnatural when compared to a traditional photograph taken at a single exposure. A captured scene is often well illuminated with the exception of some salient areas, such as a face or other important element. Adaptation of the entire image can be undesirable since natural backgrounds such as foliage, land, and ocean have pre-stored representations in the brain and artificially changing the contrast can change the image perception.

In this paper we describe a photo editing technique, referred to as Touch HDR, which enables a user to selectively blend HDR and non-HDR versions of the same image to create a more appealing hybrid image that shows a higher contrast in some areas, but retains a more natural looking contrast in other areas. The touch HDR system enables the user to specify the adaptation area in order to limit the correction to only desired areas. It also enables the user to specify the adaptation aggressiveness and decay range. For example, it may be desired only to enhance small regions of an original image, such as a subject's face, while preserving the original background. Another example may be to brighten a specific region of a non-contrast adapted image to bring attention to a particular feature, such as an advertisement. Touch HDR achieves this goal by enabling precise control over where and how much of the HDR version of the image to blend with the non-HDR original. Either multi-frame or single-frame HDR technology can be used to generate the HDR version of the image. Therefore, it is not necessary for the image to have been captured on a multi-frame HDR capable camera. HDR and non-HDR blending is controlled by a weighting surface. The weighting surface is configured by the user through a sequence of touches of a touchscreen or clicks of a mouse. Figure 1 illustrates how a weighting function W can be used

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to selectively merge HDR and non-HDR versions of an image to generate the blended output of the touch HDR algorithm.

2. TOUCH HDR ALGORITHM

The user captures a standard and an HDR version of a scene of interest. The HDR image can be generated by either capturing multiple images of the same scene at different exposure levels and then merging them together into a single HDR image, or applying a local tone mapping function to contrast-adapt a single image captured at a given exposure level. For the simulation results presented in the paper, we take the latter approach.

We use constrained local histogram equalization, similar to the one described in [7], to compute a spatially-adaptive tone reproduction operator for contrast-adapting each pixel in the original image. Our local histogram equalization algorithm works by dividing the original image into a total of 8x8 = 64 non-overlapping rectangular regions. For each of the 64 rectangular regions, a 1-D accumulated normalized histogram, or cumulative distribution function, of pixel luminance values in the region is computed. For each pixel (x,y) in the image, the tone mapping function $T_{xy}(.)$ is constructed as a linear combination of cumulative distribution functions of its 4 nearest rectangular regions. The weights for the linear combination are based on the normalized horizontal and vertical distances of the pixel of interest from the centers of the 4 nearest histogram blocks, as in bilinear interpolation. Once the tone mapping function for a given pixel location has been determined, the luminance value L, and the chrominance values C_b and C_r of the pixel at location (x,y) are re-mapped using the following set of equations:

$$r_{xy} = \max\left(\min\left(\frac{T_{xy}(L)}{L}, M\right), m\right);$$

$$L^{new} = \min(255, Lr_{xy});$$

$$C_b^{new} = \max(0, \min(255, (C_b - 128)r_{xy} + 128));$$

$$C_r^{new} = \max(0, \min(255, (C_r - 128)r_{xy} + 128));$$

where m and M are user-selected constants and can be used to control the aggressiveness of tone adaptation. Contrast adaptation boosts details in shadows, exaggerates local contrast, improves sharpness, and provides an appearance of capturing greater dynamic range in the contrast adapted image.

Next, based on the user-generated sequence of touches or mouse-clicks, a boundary in the original image is defined. The region inside the boundary of the original image is replaced by the contrast-adapted HDR image. A user-generated weighting function W is used to determine the proportion of the HDR image that gets merged with the original image inside the selected boundary. Assuming S_{ORIG} denotes the original image and S_{HDR} denotes the contrast-adapted version of the original, the hybrid image S_{HYB} is generated using the aforementioned boundary and weight information as follows:

$$S_{HYB}(x,y,c) = (1 - W(x,y))S_{ORIG}(x,y,c) + W(x,y)S_{HDR}(x,y,c),$$

where x and y denote the spatial coordinates of the pixel and c denotes either of the red, green, or blue channels. The weight applied to the contrast-adapted image at image coordinate (x,y), $W(x,y)$, has a continuous value in the range [0,1]. Typically, the initial value of W is 0 everywhere, so that the hybrid image is initially identical to the original image. Finally, the hybrid image is displayed on the output device.

The overall weighting surface, W, is computed as a sum of a collection of weighting functions, W_T, where each W_T denotes the weighting surface generated per touch or click on the screen by a user. The weighting surface per touch is a function of user generated actions and touch configuration settings, which include: (1) Selection of the boundary for

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HDR enhancement; (2) Selection of region size for HDR enhancement; and (3) Selection of the aggressiveness of HDR enhancement.

The touch configuration settings that allow the user to control the weighting function per touch include: Touch profile, Touch size, and Touch weight. The configuration settings can be changed anytime during the sequence of touches.

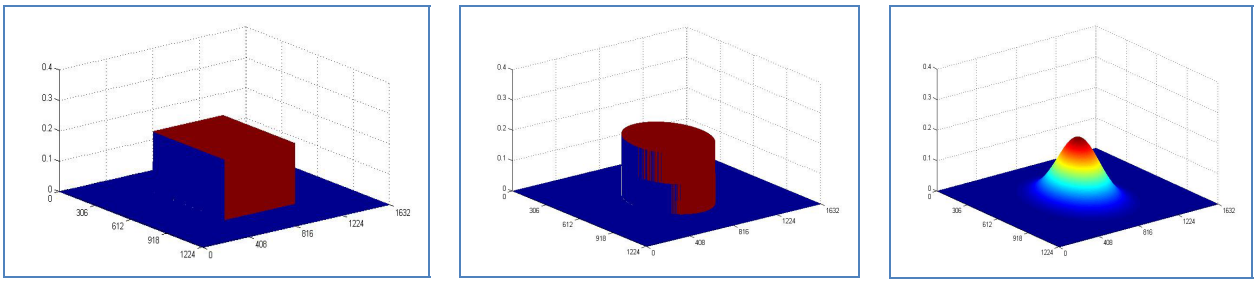


Figure 2. Touch profiles for the pre-defined geometries that can be selected by the user. (Left) Box, which applies a uniform weighting to a square region of length *l* on each side. (Middle) Cylinder which applies a uniform weight to a circular region of diameter *d*. (Right) Bell, which applies a Gaussian weighting profile to a circular region determined by the standard deviation *s* of the Gaussian function.

2.1 Setting Touch Profile

Touch profile defines the boundary of the weighting surface for each touch. The user can either elect to create a custom boundary shape or select a boundary from a pre-existing list of boundary shapes. The on-screen location of the boundary traced or selected by the user is detected and mapped to the spatial coordinates of the standard image that will have a contrast adapted image applied to it.

User-defined geometries are created by tracing a closed contour or a boundary shape with a continuous touch. As the user's finger moves along the touch screen to create a closed contour or boundary shape, the system captures and tracks the locations on the screen touched by the user, maps them to the spatial coordinates of the standard image, and stores the boundary information in memory.

Pre-defined geometries are applied with a single touch or click on the screen. The user can select one of the following pre-defined geometry shapes: (1) a uniformly-weighted box shape, which applies a uniform touch weight over a square region of the image; (2) a uniformly-weighted cylindrical shape, which applies a uniform touch weight over a circular region of the image; and (3) a bell shape, wherein a non-uniform weight is applied over a circular region of the image, where maximum weight is applied to the center, and the weight tapers off radially from the center according to a Gaussian function. The profiles for the three pre-defined boundary shapes are shown in Figure 2.

The boundary weight determines the amount of the contrast adapted image that is chosen to replace the original image. The weight of the boundary region determines "how much" HDR effect will be added to the region. For example, a high touch weight would result in a relatively large percentage of the original image to be replaced by the contrast adapted image, whereas a low touch weight would result in a relatively small percentage of the original image being replaced by the contrast adapted image.

The non-uniform profiles (for instance, bell) result in soft, continuous boundaries, whereas uniform profiles (for instance, box and cylinder) result in hard, discontinuous boundaries. Any uniform weight geometry can be transformed into non-uniform weight geometry by convolution. For example, the hard edges of a box may be tapered by applying a half bell profile along each side.

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2.2 Setting Touch Size

Once the boundary shape for each touch has been selected, the user can select the size of the selected shape. Touch size defines the dimensions of a pre-defined boundary profile in the image plane.

For example, for a box shape, the user may enter the length *l* of an edge of the box. For a cylindrical shaped profile, touch size defines the diameter *d* of the circle. For a bell shaped profile, touch size defines the standard deviation *s* of a 2-dimensional Gaussian function. The size may be defined in absolute terms, such as pixels, or as a proportion of the total image's height or width profile along each side. For example, a bell profile's standard deviation can be set to (image height) / 4.

2.3 Setting Touch Weight

The amount of the original image inside the boundary that is replaced by the contrast-adapted HDR image is calculated based on the total touch weight, W. Specifically, the total touch weight W defines the proportion of the HDR image added to the original image inside the boundary region. The weight W is determined by detecting the number of taps or clicks within the chosen boundary by the user. The weight of a single touch depends on the touch configuration settings, which can be changed at any time during the sequence of touches. For example, if the weight per touch is set to 0.2, the user may click or touch (touch via a sequence of screen taps) the screen to add 0.2 to the total touch weight, W. The total touch weight, W, ranges from 0 to 1, inclusively. The maximum touch weight W is 1, so if the touch weight is set to 0.2, the user may tap or click the screen 5 times before reaching the maximum limit. Further taps or clicks will simply saturate the total touch weight W to 1. This is illustrated in Figure 3.

For a uniform touch profile wherein the same weight of touch is evenly distributed across the chosen boundary, the touch weight W is applied uniformly. For non-uniform touch profiles, the touch weight W is maximum at the center of initial touch by the user on the touchscreen and decreases smoothly as the distance from the center increases.

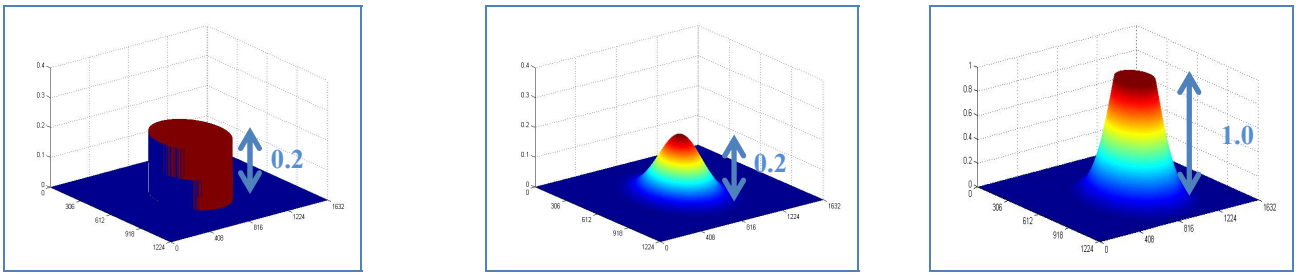


Figure 3. Setting touch weights for the pre-defined geometries selected by the user. (Left) Cylinder, weight per touch = 0.2. (Middle) Bell, weight per touch = 0.2. (Right) Saturated Bell, weight for 8 touches = min(8*0.2,1) = 1.0.

3. EXPERIMENTAL RESULTS

The Touch HDR system described above was implemented on a Samsung tablet. The experimental results are shown in Figures 4-6. The top-left picture in each figure shows the image captured by the rear-facing camera on the tablet, referred to herein as the original image. The original image was contrast-adapted using the local histogram equalization algorithm discussed in Section 2 to generate the HDR image. The HDR version of the original image is shown in the bottom-left pictures in each of the Figures 4-6. The top-right images in these figures are generated by merging the original and HDR images together. The weights used for merging the two images are shown in the bottom-right pictures in each of these figures. The value of the weight function represents proportion of the HDR image that gets merged with the original image.

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The weight function used in Figure 4 uses a cylindrical touch profile. The height of the cylindrical function is (0.2)(2) = 0.4. The weight per touch in the touch configuration settings is set to 0.2. Thus, the user taps the screen twice at the center of region of interest to generate the local HDR effect shown in the top-right picture in Figure 4.

In Figure 5, the touch screen is first tapped twice in the left section, with the touch profile set as box, and 4 times in the right section of the image, with the touch profile set as bell. With weight per touch in touch configuration set to 0.2, the height of box function is set as 0.4, while the maximum height of the bell function is set as 0.8. The overall weight function W used to blend the standard and HDR images is shown in the bottom right image of Figure 5, while the resulting hybrid image formed by merging is shown in the top-right image of the same figure.

Finally, in Figure 6 we show an example where the touch profile is selected as bell and the screen is tapped 8 times. The peak of the bell function saturates at min(8*0.2,1) = 1.0. The overall weight function W is shown in the bottom-right picture, while the blended image is shown in the top-right picture.

From the examples of locally blended HDR images in Figures 4-6, we notice that box and circular weighting functions are useful when it is desired to brighten a specific region of an original image to bring attention to a particular feature, such as an advertisement or person. The bell function provides a softer blending of original and HDR images to create a more appealing hybrid image that shows a higher contrast in some areas, but retains a more natural looking contrast in other areas.

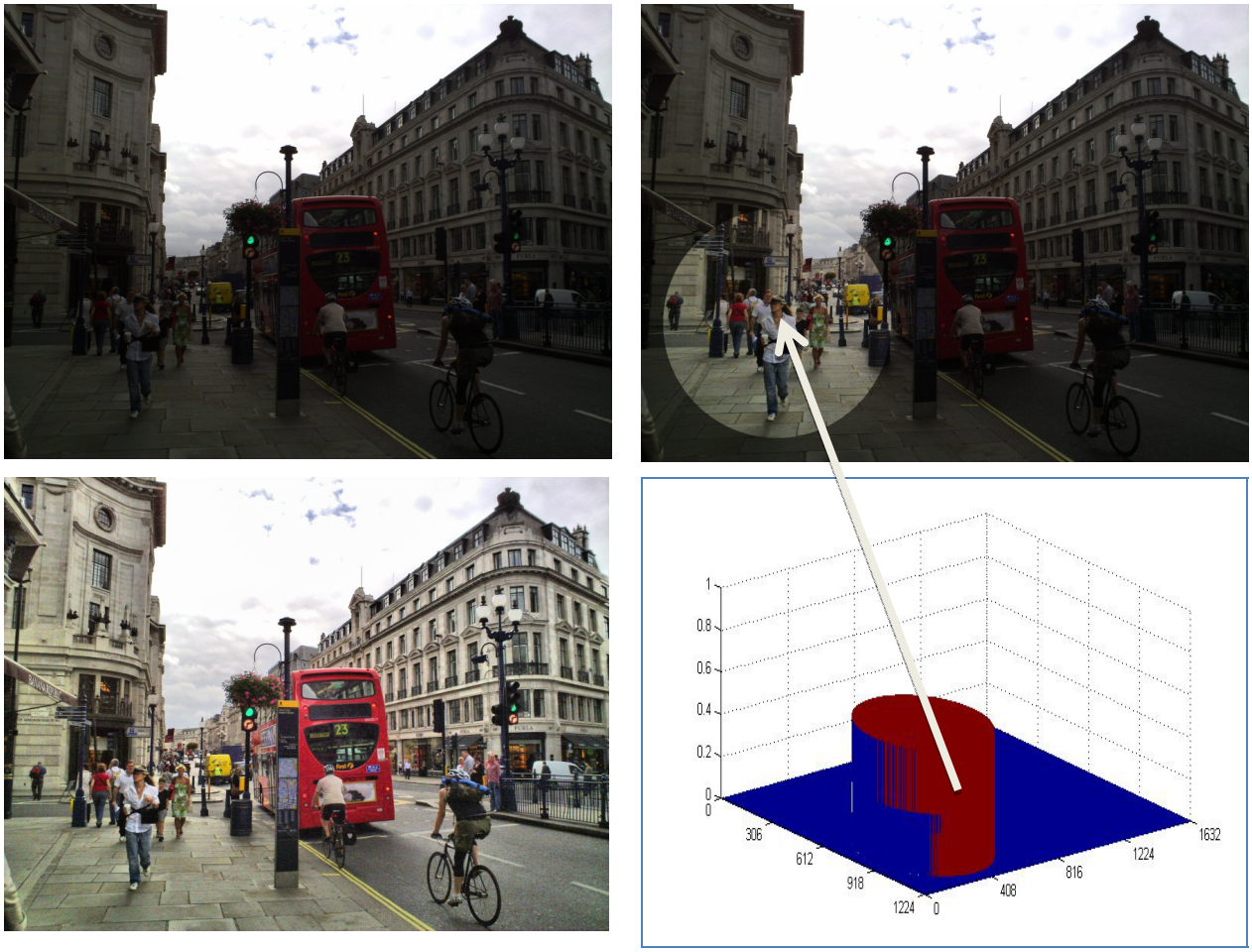


Figure 4. (Top-left) Original image. (Bottom-left) HDR image. (Bottom-right) Weighting function W for blending original and HDR images. (Top-right) Hybrid image generated by Touch HDR.

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4. CONCLUSION

In this paper we described a photo editing technique, referred to as Touch HDR, which enables a user to create a new image by selective blending of HDR and non-HDR versions of the same image. High dynamic range (HDR) technology enables photographers to capture a greater range of tonal detail. It is commonly used to bring out detail in a dark foreground object set against a bright background. Images generated using HDR technology can look less natural than their non-HDR counterparts. Sometimes it is desired only to enhance small regions of an original image, such as a subject's face, while preserving the original background. Touch HDR achieves this goal by enabling precise control over where and how much of the HDR version of the image to blend with the non-HDR original. HDR and non-HDR blending is controlled by a weighting surface. The weighting surface is configured by the user through a sequence of touches of a touchscreen or clicks of a mouse.

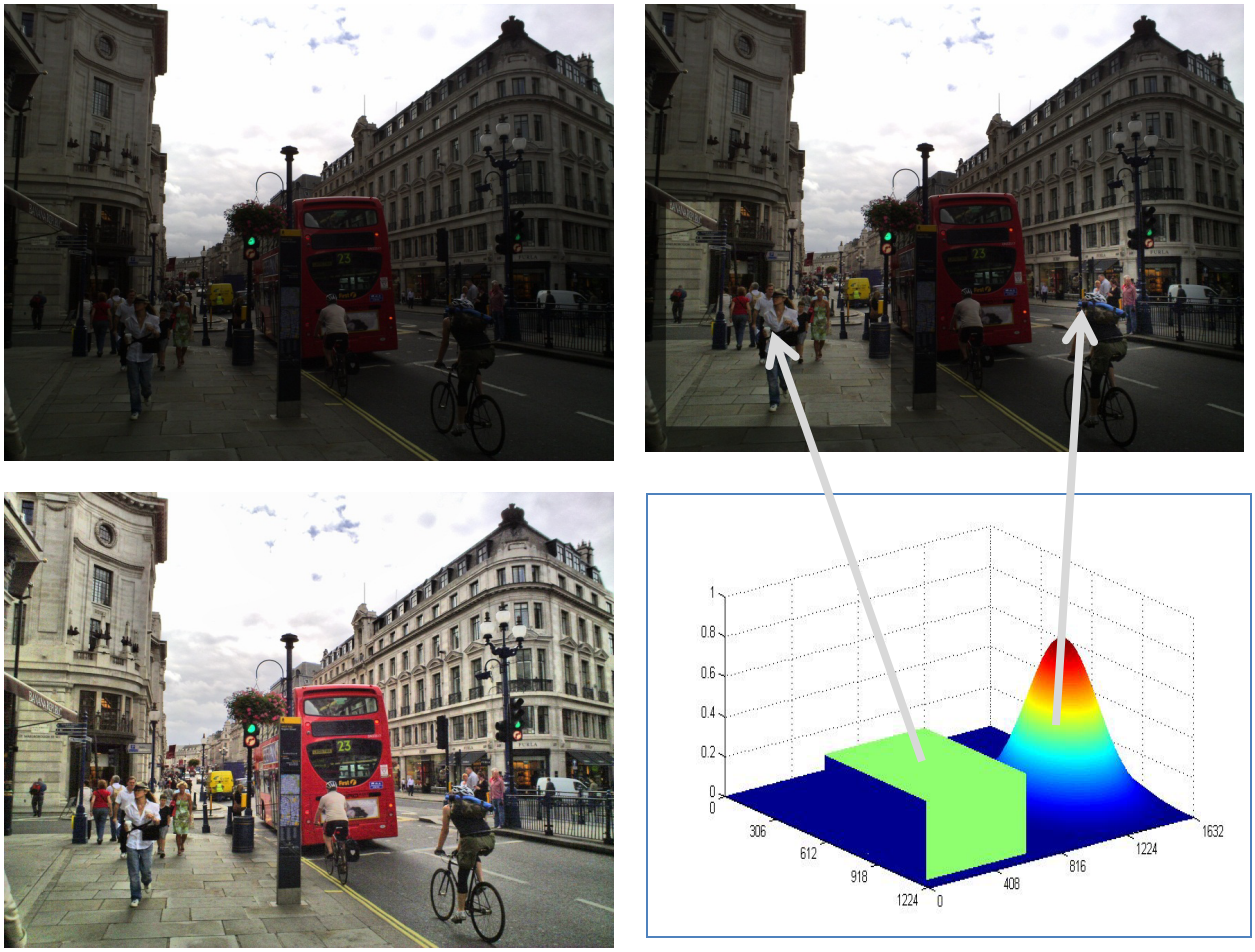


Figure 5. (Top-left) Original image. (Bottom-left) HDR image. (Bottom-right) Weighting function W for blending original and HDR images. (Top-right) Hybrid image generated by Touch HDR.

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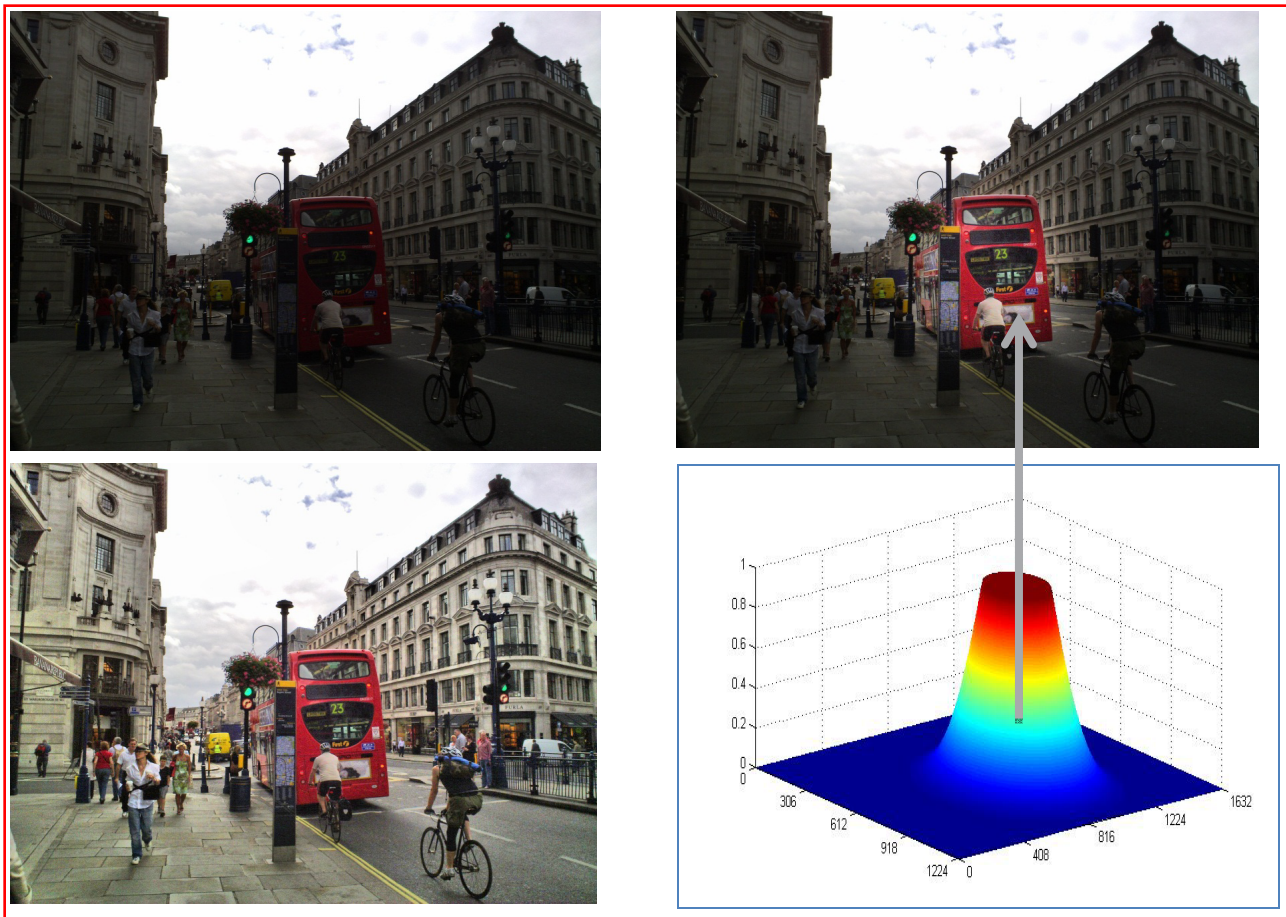


Figure 6. (Top-left) Original image. (Bottom-left) HDR image. (Bottom-right) Weighting function W for blending original and HDR images. (Top-right) Hybrid image generated by Touch HDR.

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