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Image Thumbnail With Blur and Noise Information to Improve Browsing Experience

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Abstract

Image thumbnail is used by many state-of-the-art consumer electronic products, such as digital camera, smart phone, and camcorder. Image thumbnail, which is a smaller image version of the original image, helps the user to inspect the general objects' composition contained in the acquired image. However, it is difficult to embed blur information inside the thumbnail, which can improve the user's satisfaction in taking pictures significantly. Therefore, in this paper, a new method to embed blur information inside the thumbnail has been proposed. This method is simple to be implemented in electronic products. This method uses two small images, which are the direct down-sampled image, and the corresponding smoothed image version. The method's sensitivity towards blur and noise can be adjusted by using three parameters. Experimental results show that the proposed method gives the best distortion indication when compared with four other image thumbnail algorithms.

Keywords: Image Thumbnail, Image Down-sample, Image Decimation, Digital Image Processing, Image Browsing.

1. INTRODUCTION

The demand for digital pictures in our daily life is now increasing. This is because digital pictures are cheaper, never degrade and easier to be acquired as compared with the traditional film based photography [1]. Therefore, in addition to digital camera and camcorder, most of the modern consumer electronic products, such as smart phone, are now being equipped with image sensor and capable to acquire digital images. In order to function as a "what you see is what you get (WYSIWYG)" system, image browsing using image thumbnails is a common approach used by most of these consumer imaging products. This approach is used because these electronic products are only equipped with a display screen of limited resolution [2].

Image thumbnail presents the original image as a smaller size image. These thumbnails allow the user to see the image's composition roughly, and judge the overall quality of the original image. For example, during a digital photography session, normally the user will judge the quality of the acquired picture based on the image thumbnail for each shoot. From this judgment, then the user will decide whether he want to keep the picture, or to delete it and has a reshoot [3]. Unfortunately, most of the current image thumbnail algorithms are not able to indicate the present of noise or blur in the original image. As a consequence, this mostly will lead to the user's frustration when the picture is printed, or displayed on higher resolution equipment.

The image thumbnails can be constructed by many ways. The commonly used method is the standard image thumbnail, which is also known as Pixel-based Down-sampling with Anti-aliasing Filter (PDAF) [4][5]. PDAF consists of two stages, which are low-pass filtering process, and down-sampling process. This method uses low-pass filter to limit the frequency components of the image, in order to avoid aliasing from happen in the image thumbnail. Unfortunately, because only low frequency components of the original image are retained in the image thumbnail, PDAF is not able to preserve noise information as the noise mostly dominated in high frequency components of the original image. Therefore, PDAF cannot indicate the presence of noise correctly as its generated image thumbnail is always appears clean [4]. It is also worth mentioning that although PDAF smoothes slightly the image thumbnail [5], some of the blurry regions in the original image are not represented correctly by PDAF [4].

Other image thumbnail algorithm which is known as Direct Pixel-based Down-sampling (DPD) creates the image thumbnail by down-sample the original image directly, without applying any filtering process [5]. If the original image is being down-sampled by factor *L*, DPD selects one out of every *L* pixels to be included inside the thumbnail. This can be described by the following equation:

$$f(x,y) = F(Lx, Ly) \tag{1}$$

where $f(x,y)$ is the pixel value of the image thumbnail at coordinates (x,y) and F is the original image, with larger size than the thumbnail. Image thumbnail generated by DPD is sharper than the one by PDAF because there are higher image frequency components inside it. However, similar to PDAF, DPD cannot indicate correctly the presence of blur in the original image.

In order to increase the apparent resolution of an LCD display, a similar method to DPD, which is called Direct Sub-pixel-based Down-sampling (DSD) [5], has been proposed in [6]. This method only works for color digital images. If the input image $\mathbf{F}$ is constructed by three color components (i.e. red, green, and blue), DSD treats $\mathbf{F}$ as three images (i.e. $\mathbf{R}$, $\mathbf{G}$, and $\mathbf{B}$), correspond to the three color channels. Similarly, the thumbnail version of $\mathbf{F}$, which is $\mathbf{f}$, is also been represented by three images (i.e. $\mathbf{r}$, $\mathbf{g}$, and $\mathbf{b}$). Thus, DSD is given as the following equation:

$$\begin{aligned} r(x,y) &= R(Lx, Ly) \\ g(x,y) &= G(Lx+1, Ly) \\ b(x,y) &= B(Lx+2, Ly) \end{aligned} \tag{2}$$

Although the implementation for both DPD and DSD are relatively simple, these methods suffer from aliasing artifacts. Furthermore, DSD produces image thumbnails with chrominance distortion. Therefore, Fang and Au [5], proposed Min-Max Directional Error (MMDE) in order to reduce the color fringing artifact while increases the apparent resolution. Unfortunately, implementation of MMDE requires unique software to be used, and direct implementation of this method failed to produce any output as it is very high in computational cost. Therefore, MMDE with Visual Relaxation (MMDE-VR) and MMDE with Edge Relaxation (MMDE-ER) have been proposed, also in [5]. Yet, both methods still require long processing time, and therefore are not suitable to be implemented in consumer electronic products.

It is worth noting that all the above mentioned methods deal with the works on producing sharper image thumbnail. None of them are developed with the ability to embed blur and noise information, therefore those thumbnail cannot presenting the actual quality of the acquired image. As noisy images still appear as clean images in the image thumbnails, and blur images still appear as sharp images in the image thumbnails, browsing using these image thumbnails might lead to errors and inefficiency. Therefore, works by Samadani et. al in [3],[4], and [7], proposed an image thumbnail scheme which able to present blur and noise. In this paper, this method is referred as Thumbnail with Blur and Noise Information (TBNI). In general, the processes involved in TBNI can be divided into two stages. In the first stage, a blur map is used to present the local blur information. This map is created by inspecting the intensity ranges within image blocks from eleven blurred thumbnail versions. During the second stage, the noise information is added to the thumbnail obtained from the stage one by using a modified wavelet based soft thresholding de-noiser.

In this paper, a new method to generate image thumbnail is presented. This proposed method is simple, yet still can preserve the blur and noise information. This method will be described in Section 2. Evaluation of this method will be presented in Section 3. Section 4 then concludes the findings obtained from this paper.

2. THE PROPOSED IMAGE THUMBNAIL SCHEME

Following the image model given in [3],[4], and [7], the original distorted image, $\mathbf{F}$, which has been degraded by space-varying blur $\mathbf{B}$ and noise $\mathbf{N}$, is described as:

$$\mathbf{F}=\mathbf{BC}+\mathbf{N} \tag{3}$$

where $\mathbf{C}$ is the ideal, clean and undistorted image. In this equation, blur function $\mathbf{B}$ presents the blur due to camera shake, motion blur, and depth-of-field blur [3].

If the image thumbnail is generated by using PDAF method, image $\mathbf{F}$ needs to be filtered by an anti-aliasing low-pass filter $\mathbf{A}$, then followed by down-sampling process, $\mathbf{S}$, which has been given by equation (1). Thus, for PDAF case, the thumbnail $\mathbf{f}$ can be presented as:

$$\mathbf{f}=\mathbf{SAF}=\mathbf{S}(\mathbf{ABC}+\mathbf{AN}) \tag{4}$$

Generally, noise $\mathbf{N}$ is dominating high frequency components of the image. Interestingly, the low-pass filter $\mathbf{A}$ applied in (4), removes high frequency components. Therefore, this condition results $\mathbf{AN}\approx 0$. Furthermore, the spectrum bandwidth of $\mathbf{B}$ is normally wider than $\mathbf{A}$, and thus, $\mathbf{AB}\approx\mathbf{A}$. As a consequence, (4) can be simplified to become:

$$\mathbf{f}=\mathbf{SAC} \tag{5}$$

This equation shows that PDAF method always produces $\mathbf{f}$ that is clean (due to $\mathbf{AN}\approx 0$) and sharper than $\mathbf{F}$ (because $\mathbf{AB}\approx\mathbf{A}$), even though if $\mathbf{F}$ has been blurred by $\mathbf{B}$, and corrupted by noise $\mathbf{N}$ [3].

On the other hand, if the image thumbnail is created by using DPD method, the thumbnail $\mathbf{f}$ can be represented by equation (6).

$$\mathbf{f}=\mathbf{SF}=\mathbf{S}(\mathbf{BC}+\mathbf{N})=\mathbf{SBC}+\mathbf{SN} \tag{6}$$

This equation shows that DPD is able to embed noise information inside its thumbnail, as indicated by $\mathbf{SN}$. This equation also shows that DPD can portray blur information into the thumbnail, as indicated by $\mathbf{SBC}$. However this condition is only valid if the blur areas created by $\mathbf{B}$ are larger than the down-sampling factor L used by $\mathbf{S}$.

The proposed image thumbnail scheme in this paper is actually an extension to DPD method, and uses DPD thumbnail as the base thumbnail. The main aim of this method is to deal with the problem when the blur areas are smaller than L. In order to do this, each pixel in $\mathbf{f}$ created from DPD method presents its corresponding region in $\mathbf{F}$. They will be classified into one of these three categories; uniform region, edge region, or noisy region.

The uniform regions are mostly dominated by low frequency components. Thus, matrix $\mathbf{B}$ in equation (3) does not play much role in the uniform regions. DPD method, as given by equation (6), is able to present uniform region correctly. Similarly, this equation also shows that DPD can present the noise information correctly too. Therefore, the pixel value obtained from DPD will be used in the proposed scheme to present both the uniform and noisy regions.

As the human visual system is more sensitive towards edges [8], the information about the blur around the edges is crucial. This is the reason why the edge region becomes one of the categories under the consideration of this scheme. If the blur has been detected on the image edge, the corresponding pixel in $\mathbf{f}$ will be presented by an intensity value which able to indicate blur. In this proposed scheme, the blur indicator value is obtained from thumbnail $\mathbf{g}$, which is the blurred version of $\mathbf{f}$, as given in (7):

$$\mathbf{g}=\mathbf{f}\otimes\mathbf{G} \tag{7}$$

where $\otimes$ presents the convolution operation, and $\mathbf{G}$ is a square Gaussian filter of size $W\times W$. The standard deviation σ used by $\mathbf{G}$ is calculated by using the following equation [9]:

$$\sigma=\sqrt{-\frac{\lfloor W/2\rfloor^2}{2\ln(0.001)}} \tag{8}$$

Work in [10] indicates that the blur versions of the image can helps in determining the blur regions. Therefore, in this proposed method, **f** from (6) and **g** from (7) are used for this purpose. First, the intensity difference Δ between **f** and **g** is calculated.

$$\Delta(x,y) = | f(x,y) - g(x,y) | \tag{9}$$

Then, edge or blur regions are determined based on Δ.

$$\alpha(x,y) = \begin{cases} 1 & : \alpha_{\mathrm{L}} \le \Delta(x,y) \le \alpha_{\mathrm{U}} \\ 0 & : \quad \text{otherwise} \end{cases} \tag{10}$$

where α_{L} and α_{U} are both the threshold values. These values, together with W in (8), control the sensitivity of this thumbnail scheme towards blur and noise. By using the rule set in [11] as a guide, α_{L} is set to 10 and α_{U} is set to 30.

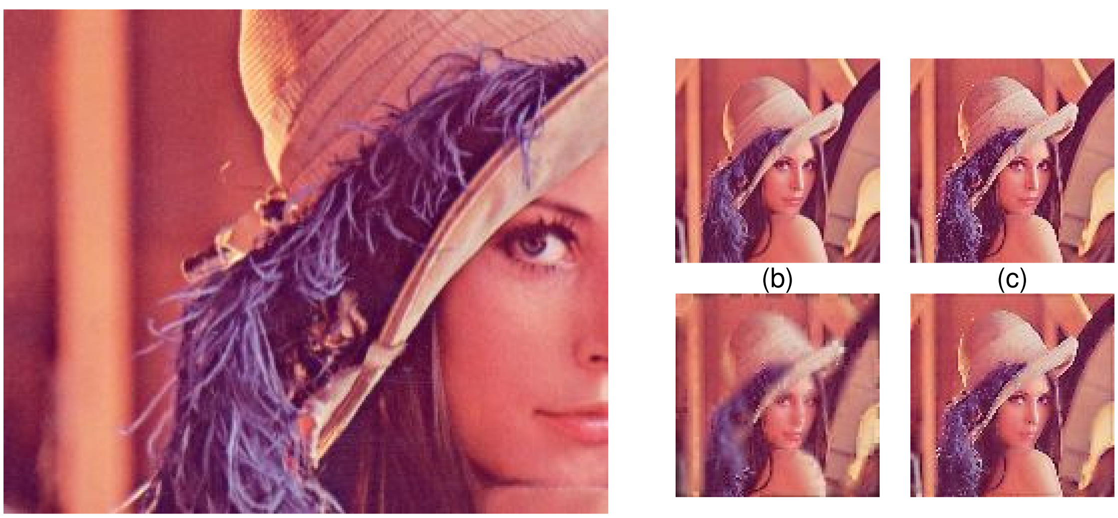
The output from this thumbnail scheme **h** is given as:

$$h(x,y) = [1 - \alpha(x,y)] f(x,y) - \alpha(x,y) g(x,y) \tag{11}$$

Unlike [3], this proposed method is applied to each color component of the image (i.e. red channel, green channel, and blue channel). Thus, each color channel is treated as an independent image.

3. EXPERIMENTAL RESULTS

The performance of the proposed method is compared with PDAF [4][5], DPD [5], and TBNI [3][4][7]. In this experiment, W is set to 5, α_{L} is set to 10 and α_{U} is set to 30. A few of the results, by using these parameter settings, are shown in Fig. 1 to Fig. 5.



(b) (c) (d) (e)

(a)

FIGURE 1: (a) Cropped portion of "*Lena*", shown in the actual scale. (b) Image thumbnail generated by PDAF. (c) Image thumbnail generated by DPD. (d) Image thumbnail generated by TBNI. (e) Image thumbnail generated by the proposed method.

Fig. 1 shows the results obtained by using "Lena" as the input. The original size of this color image is 512×512 pixels, and the thumbnails are in size of 102×102 pixels. This standard input image can be considered as clean from noise. As shown in Fig. 1(a), the feathers on the hat have many details. The background of the image blurs due to depth-of-field. The color of the hat is also almost similar to the background, and thus has a low contrast. As shown by Fig. 1(b) to (e), DPD method produces sharper thumbnail as compared with PDAF. TBNI produces blur thumbnail, whereas the proposed method produces much better output. In Fig. 1(e), we can see in the thumbnail the blur background, and the sharp hat's feathers.

Results in Fig. 2 are obtained by using “Picnic” as the input. The original size of this picture is 1600×1200 pixels, and the thumbnails are in size of 160×120 pixels. This image is suffers from blurs, due to wrong focus and motion. Yet, PDAF and DPD produce sharp and clear image thumbnails. Only TBNI and the proposed method successfully create thumbnails with blur.

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

FIGURE 2: (a) Cropped portion of “*Picnic*”, shown in the actual scale. (b) Image thumbnail generated by PDAF. (c) Image thumbnail generated by DPD. (d) Image thumbnail generated by TBNI. (e) Image thumbnail generated by the proposed method.

Image of “Bat” is used as the input in Fig. 3. The original size of this picture is 1280×960 pixels. The thumbnails are in size of 160×120 pixels. The background blurs due to depth-of-field, and the object at the front is not in focus. As shown by this figure, all methods produce almost the same results. However, TBNI produces the thumbnail with the most blur.

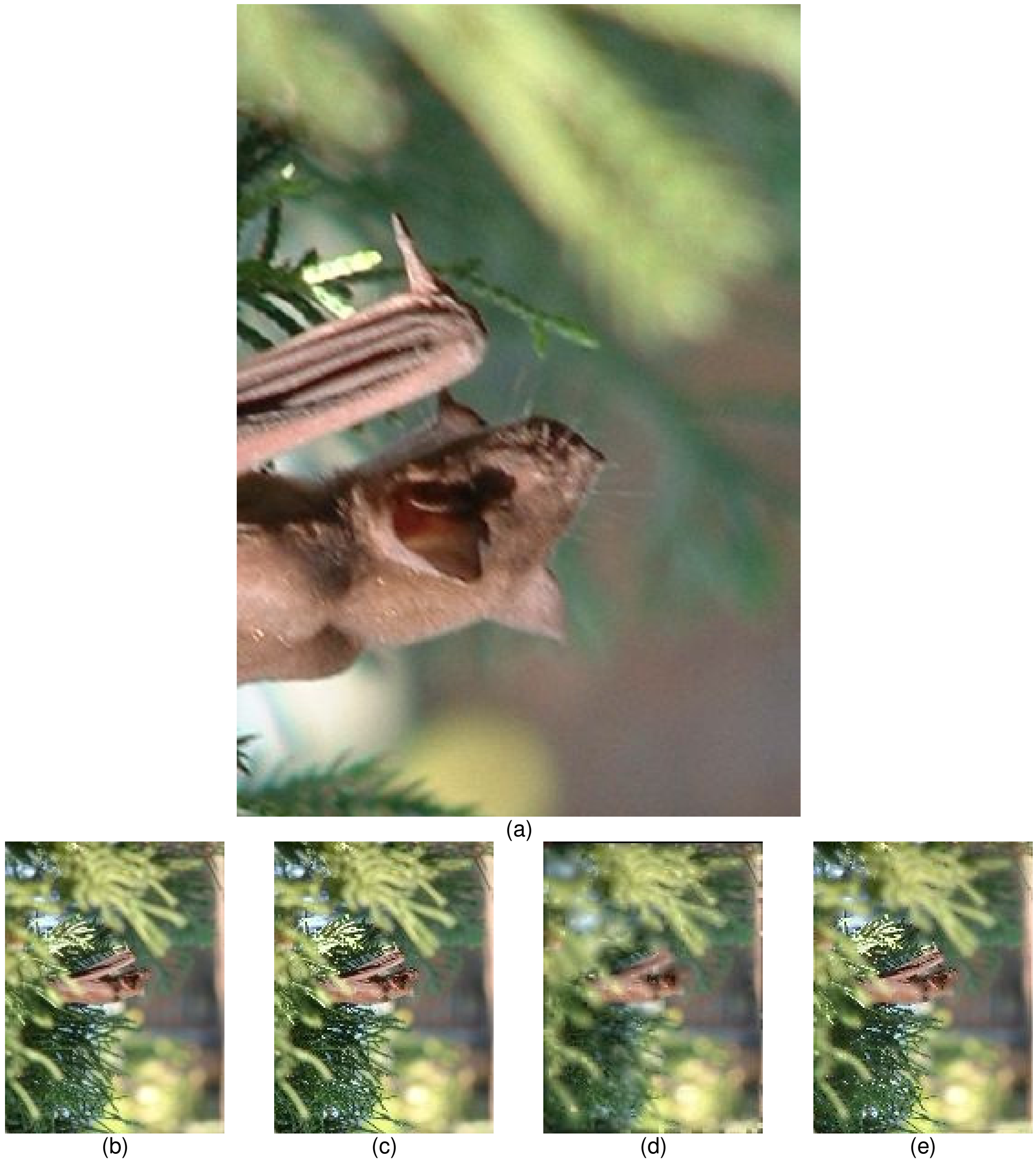


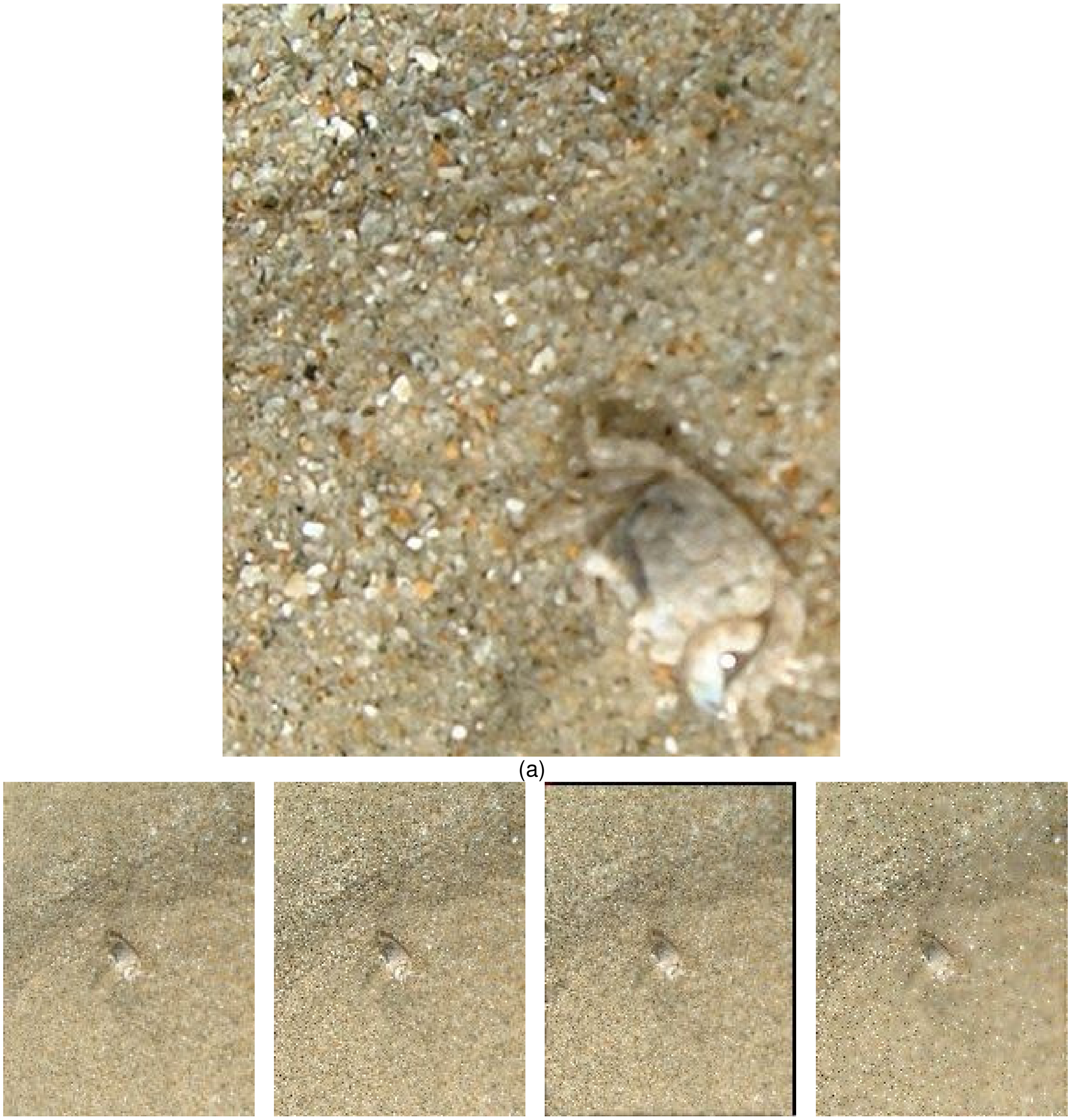
FIGURE 3: (a) Cropped portion of "*Bat*", shown in the actual scale. (b) Image thumbnail generated by PDAF. (c) Image thumbnail generated by DPD. (d) Image thumbnail generated by TBNI. (e) Image thumbnail generated by the proposed method.

Fig. 4 uses "Orchid", a picture with size 1280×960 pixels, as the input. The thumbnails are in size of 182×137 pixels. The flowers in this picture are in focus, while the background blurs due to depth-of-field. Because the blur has been detected in almost every picture's patches, TBNI produces the thumbnails with too much blur. DPD produces a sharper thumbnail as compared with PDAF. Yet, the proposed method is the most successful method to portray the image correctly into the thumbnail. As shown by Fig. 4(e), the flower's buds are correctly been blurred by the proposed method.

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

FIGURE 4: (a) Cropped portion of "*Orchid*", shown in the actual scale. (b) Image thumbnail generated by PDAF. (c) Image thumbnail generated by DPD. (d) Image thumbnail generated by TBNI. (e) Image thumbnail generated by the proposed method.

"Crab" is used as the input in Fig. 5. The original size of this picture is 1280×960 pixels. The thumbnails are in size of 182×137 pixels. Some portion of the picture is in focus, while other portions are out from focus. As shown by Fig. 5(a), the sand grains on the top left area are in focus. The crab is not in focus. However, PDAF, DPD, and TBNI fail to portray this into their thumbnail. On the other hand, the proposed method successfully indicates that the crab is inside the blur area.



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

FIGURE 5: (a) Cropped portion of "*Crab*", shown in the actual scale. (b) Image thumbnail generated by PDAF. (c) Image thumbnail generated by DPD. (d) Image thumbnail generated by TBNI. (e) Image thumbnail generated by the proposed method.

In order to show that the sensitivity of the proposed method towards blurs and noise is tunable, other experiment has been carried out. Fig. 6 shows the thumbnail generated by the proposed method, by using different values of W. If W is set to 1, the output thumbnail is sharp and exactly the same as the one produced by DPD. As shown by this figure, the sensitivity of the method towards blur can be increased, by the increment in W. On the other hand, the sensitivity towards noise, or high frequency components, can be increased by reducing the value of W.

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

FIGURE 6: Image thumbnail generated by the proposed method using different values of W, with $\alpha_L = 10$ and $\alpha_U = 30$. (a) $W = 1$. (b) $W = 3$. (c) $W = 5$. (d) $W = 7$.

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

FIGURE 7: Image thumbnail generated by the proposed method using different values of α_L, with $W = 5$ and $\alpha_U = 30$. (a) $\alpha_L = 0$. (b) $\alpha_L = 10$. (c) $\alpha_L = 15$. (d) $\alpha_L = 30$.

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

FIGURE 8: Image thumbnail generated by the proposed method using different values of α_U, with $W = 5$ and $\alpha_L = 10$. (a) $\alpha_U = 10$. (b) $\alpha_U = 15$. (c) $\alpha_U = 30$. (d) $\alpha_U = 255$.

Fig. 7 and Fig. 8 show the results obtained by using different values of α_L and α_U. These figures shows that when α_L is set to be equal to α_U, the proposed method produces image thumbnails similar to the one produced by DPD. It is also can be inspected that the sensitivity towards blur can be increased by increasing the gap between α_L and α_U.

4. CONCLUSION

A new method in generating image thumbnail is presented in this paper. This method is simple, and suitable to be implemented in consumer electronic products, as the calculations involved only use images in thumbnail size. The method successfully portrays blur and noise inside the original image into the thumbnail. Furthermore, its sensitivity towards blur and noise can be adjusted easily by manipulating three parameter values.

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