Image Morphing Detection by Locating Tampered Pixels with Demosaicing Algorithms

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ABSTRACT
In this digital world we come across many image processing software that produce doctored Images with high sophistication, which are manipulated in such a way that the tampering is not easily visible to naked eye. The authenticity of a digital image has become a challenging task due to the various tools present in the photo editing software packages. There are number of ways of tampering an Image, such as splicing two different images together, removal of objects from the image, addition of objects in the image, change of appearance of objects in the image or resizing the image. This Image Morphing detection technique detects traces of digital tampering in the complete absence of any form of digital watermark or signature and is therefore referred as passive. So there is a need for developing techniques to distinguish the original images from the manipulated ones, the genuine ones from the doctored ones. In this paper we describe a novel approach for detecting Image morphing. The new scheme is designed to detect any changes to a signal. We recognize that images from digital cameras contain traces of re-sampling as a result of using a color filter array with demosaicing algorithms. Our results show that the proposed scheme has a good accuracy in locating tampered pixels.

Keywords
Image tampering detection, Image Morphing, Digital forensic, image processing, Image forgery detection**.**

1. INTRODUCTION
Image morphing has been the subject of much attention in recent years. There are various powerful tools available in market for Image morphing. This availability brought with it new challenges concerning the integrity and authenticity of digital documents, in particular images. Digital cameras and photo- editing software packages are used to create and edit digital images easily and manipulated without leaving any obvious traces of having been modified. When digital images used as legal photographic evidence then one can no longer take the authenticity of images for granted. Criminal scene photographs which are presented as evidence in court of law plays an important role in giving final result of a particular legal case. Image forensics, in this context, is concerned with determining the source and potential authenticity of a digital image.

Computer graphics morphing was used in the 1974 Canadian animation Hunger. In the early 1990s computer techniques that often produced more sophisticated results began to be widely used. These involved distorting one image at the same time that it faded into another through marking corresponding points and vectors on the "before" and "after" images used in the morph. For example, one would morph one face into another by marking key points on the first face, such as the contour of the nose or location of an eye, and mark where these same points existed on the second face. The computer would then distort the first face to have the shape of the second face at the same time that it faded the two faces. To compute the transformation of image coordinates required for the distortion, e.g. the algorithm of Beier and Neely can be used.

After that, more sophisticated cross-fading techniques were employed that crosscheck parts of one image to the other one by one instead of transitioning the entire image at once. This style of morphing was perhaps most famously employed in the video that former 10cc members Kevin Godley and Lol Creme produced in 1985 for their song Cry. It contain a series of black and white close-up shots of faces of many different people that gradually faded from one to the next. In a strict sense, this had little to do with modern-day computer generated morphing effects, since it was merely a dissolve using fully analog equipment.

Morphing technique continues to advance and many programs can automatically morph images that correspond closely enough with relatively little instruction from the user. This has led to the use of morphing techniques to create slow-motion effects where none existed in the original film or video footage by morphing between each individual frame by the technology called optical flow technology. Morphing has also seen as a transition technique between one scene to another in television shows, even if the contents of the two images are entirely different. The algorithm in this case attempts to find corresponding points between the images and distort one into the other as they cross fade.

As compared to past, morphing is used heavily today. Whereas the effect was initially a novelty, today, morphing effects are most often designed to be seamless and invisible to the eye. This demands a reliable image morphing detection system. Though these manipulation are sometimes not detected by human eye, they do affect the statistics of the image, because of detection of tampering is possible. Thus it becomes very vital to develop efficient techniques which may detect these forgeries which are addition of an object in image, removal of object from image and change of appearance of the object in image.

2. RELATED WORK

Image processing is often not necessary for image manipulation detection. For instance, a picture supposed to be taken in India that shows the China monument in the background will be suspect by inspection. Detection of incongruous textural features, however, may require substantial image processing.

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The process of Image morphing detection can involve several works. These work include, but are not limited to, evaluation of image structure issues include discovery of artifacts consistent with image manipulation or degradation, metadata analysis, and indications of provenance and Image content issues include continuity issues, evidence of manipulation, evidence of staging, and misplacing.

There are several possible techniques for detecting manipulation in the source of a digital image. Image can be authenticated by Digital watermarking. Digital watermarking has two classes of watermarks, fragile and robust. Robust watermarks techniques are designed to be detected even after attempts are made to remove them. Fragile watermarks techniques are used for authentication purposes and are capable of detecting even minute changes of the watermarked content. But, neither type of watermark is ideal when considering "information preserving" transformations (such as compression) which keep the meaning or expression of the content and "information altering" transformations (such as feature replacement) which modify the expression of the content. The drawback of watermark techniques is that one must embed a watermark into the digital image first. Also a watermark must be inserted at the time of capturing the image, which would limit this approach to specially equipped digital cameras. Many other techniques that work in the absence of any digital watermark or signature have been invented.

The set of image forensic tools for passive or blind approach for image manipulation detection can be roughly categorized as pixel-based techniques, format-based techniques, camera-based techniques geometric based techniques.

In this paper we discuss one of the pixel based detection technique which is passive techniques for image manipulation detection which work in the absence of any watermark or signature.

3. COLOR FILTER ARRAY AND DEMOSAICING ALGORITHM

A color filter array is made of color filters in front of the image sensor. Nowadays, the most commonly used CFA configuration is the Bayer filter illustrated here. This has alternating red (R) and green (G) filters for odd rows and alternating green (G) and blue (B) filters for even rows. There are twice as many green filters as red or blue ones, catering to the human eye's higher sensitivity to green light. Since the color sub sampling of a CFA by its nature results in aliasing, an optical anti-aliasing filter is typically placed in the optical path between the image sensor and the lens to reduce the false color artifacts (chromatic aliases) introduced by interpolation. Since each pixel of the sensor is behind a color filter, the output is an array of pixel values, each indicating a raw intensity of one of the three filter colors. Thus, an algorithm is needed to estimate for each pixel the color levels for all color components, rather than a single component.

A demosaicing algorithm is a digital image process used to reconstruct a full color image from the incomplete color samples output from an image sensor overlaid with a color filter array (CFA). It is also known as CFA interpolation or color reconstruction. Most modern digital cameras acquire images using a single image sensor overlaid with a CFA, so demosaicing is part of the processing pipeline required to render these images into a viewable format. Many modern digital cameras can save images in a raw format allowing the user to demosaic it using software, rather than using the camera's built-in firmware.

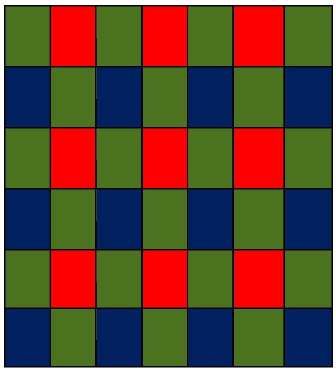

Figure 1.1 The Bayer arrangements of color filters on the pixel array of an image sensor. Each two-by-two cell contains two green, one blue, and one red filter.

A demosaicing algorithm has alias name called color filter array interpolation and it is applied to the raw digital image to calculate the pixel value for each color component. There are two possibilities of interpolation that can be either be linear or adaptive. Each color channel is interpolated separately using only samples from the same color in native interpolation, for example, with bilinear interpolation.

Fig 2: When demosaicing is performed with linear interpolation, the original green pixels have higher variance than the interpolated green pixels. The spatial pattern of variances is the basis for detecting the presence of demosaicing. The green photosites pixel values in the Bayer array are IID with variance σ^2, the above image shows the variance from which each pixel value is drawn.

By considering only the pixel values of the Bayer pattern shown in Figure 1, each missing green pixel value can be interpolated from its four nearest neighbors using bilinear interpolation:

$$\hat{g}(x,y) = \frac{1}{4}[1 \quad 1 \quad 1 \quad 1]\begin{bmatrix} g(x-1,y) \\ g(x,y-1) \\ g(x+1,y) \\ g(x,y+1) \end{bmatrix} \qquad (1)$$

Considering that the original green pixel values are IID and estimated from a normal distribution with variance σ^2, the estimated green pixel values can be shown to have a variance of only 1/4 σ^2 . As the figure 2 show, the green channel is divided into two interleaved quincunx patterns, one similar to the original green pixel locations, and the other similar to the calculated green pixel locations with lower variance. This analysis oversimplifies the demosaicing and for the purpose of illustration this skips the nonlinear image processing. Here the vital point to understand is that demosaicing introduces periodic patterns into the image signal.

4. PROPOSED SYSTEM

Combining the neighboring pixel values, an interpolated pixel value is generated. The variance gets affected by the weight of the neighboring pixels which produce an interpolated pixel value. This forms the pattern of variances which can be detected and serves as the basic idea for detecting demosaicing. For demonstrating our approach we consider channels of only specific color while use of any channel is permitted during actual system implementation.

Figure 3 shows the basic flow of our approach. First highpass operator h(x,y) is operated on the image i(x,y) and low frequency information is removed from it. When demosaicing occurred, embedded periodicity is also enhanced. Operator selection is done:

$$h(x,y) = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \qquad (2)$$

Following figure shows the flow diagram for Photo Morphing Detection:

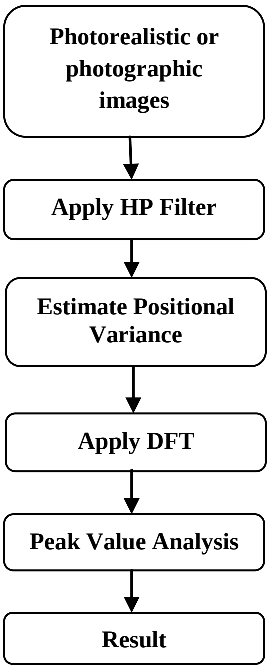

Fig 3: Flow diagram for Photo Morphing Detection. First photographs from digital cameras or computer generated images are given to highpass (HP) filter. Then HP Filter is applied, and then the Positional Variance of each diagonal is calculated. Then DFT is used to find periodicities in the variance signal, then Peak Value is analyzed, indicating the presence of demosaicing in the image.

The variance of the output of operator can be found from a distribution with variance σ^2. If we again make the simplifying assumption that the channel is interpolated with linear interpolation:

$$\sigma_0^2 = 4\left(\frac{1}{4}\right)^2\sigma^2 + 4\left(\frac{1}{2}\right)^2\sigma^2 + (1-4)^2\sigma^2 \qquad (3)$$

$$= \frac{41}{4}\sigma^2 \qquad (4)$$

$$\sigma_i^2 = 0\sigma^2 \qquad (5)$$

σ_0^2 is the variance of the output of application of $h(x,y)$ at positions corresponding to original photosites in the image sensor, and thus nine pixel values from the original sensor contribute to the filter output and four with a coefficient $\frac{1}{4}$, four with a coefficient $\frac{1}{2}$, and position (x, y) itself has coefficient -3. σ_i^2 Corresponds to locations where the green value is interpolated by considering the green channel is interpolated with linear interpolation.

In case, if missing green values were actually estimated with linear interpolation and all other image processing operations in the camera are ignored, then application of the filter h(x, y) yields a value of zero at each pixel location with an interpolated green value. The choice of h(x, y) was made to maintain a large value for $\frac{\sigma_0^2}{\sigma_i^2}$ and testing using a small number of training images. A large ratio of $\frac{\sigma_0^2}{\sigma_i^2}$ aids in the detection of the periodic pattern of variances characteristic of demosaicing.

Our test images are different from the demosaicing operated images. Test images are finished images from real consumer cameras. Demosaicing is performed on nonlinear filter and the image processing path contains various activities such as noise suppression, image enhancement etc.

After that, estimate of the variances is calculated using the method called Maximum Likelihood Estimation (MLE). The statistical variance of the pixel values along each diagonal is found to compute the MLE estimation of variance. This projects the image down to a single-dimension signal, $m(d)$, where $m(d)$ represents the estimate of the variance corresponding to the d^{th} diagonal:

$$m(d) = \frac{\sum_{x+y=d} |h(x,y) * i(x,y)|}{N_d} \qquad (6)$$

Where, N_d is the number of pixels along the d^{th} diagonal and is used for normalization.

To find the periodicity in $m(d)$, the DFT is computed to find $|M(e^{j\omega})|$. A relatively high peak at frequency $\omega = \pi$ indicates that the image is not morphed and it is the characteristic of demosaicing. The peak magnitude at $\omega = \pi$ is calculated as:

$$s = \frac{|M(e^{jw})|_{\omega=\pi}}{k} \qquad (7)$$

Where $\omega = \pi$ high peak value at frequency ω and k is is the median value of the spectrum, by omitting the DC value. Normalizing by k was found to be vital to differentiate between true image and images containing signals with large energy across the frequency spectrum.

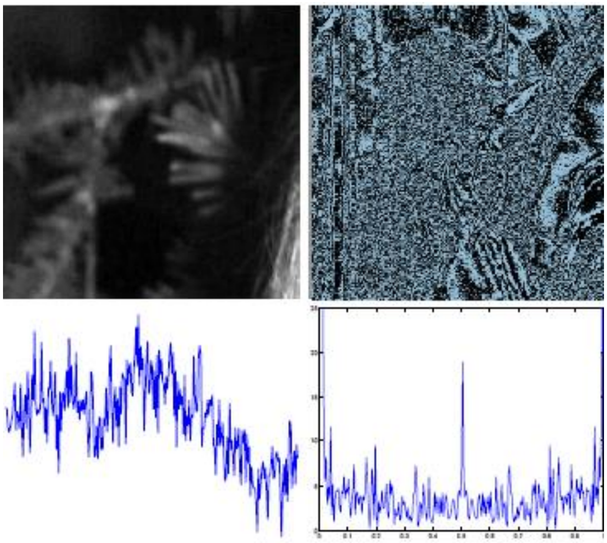

Fig 4: Distinguish between images containing noise with large energy across the frequency spectrum and true demosaicing signals generated by our algorithm. Bottom Left: The signal $m(d)$, which represents an calculation of the variance along each image diagonal. Bottom Right : The spectrum of $m(d)$, represents the characteristic peak at $\omega = \pi$. Generally, uninterpolated images do not contain a peak in the frequency spectrum of $m(d)$.

5. Detecting forged image regions

The algorithm shown in Section 4 can be applied locally to detect regions of an image that have possibly been tampered with. The main work is: demosaicing produces periodic correlations in the image signal. When a image is manipulated, an image piece from another source (it can be from another image or a computer graphic) is pasted over a portion of the image. In general, this image piece is resample to match the geometry of the image.

The application of the highpass filter is the same as previously described. Estimating the variance becomes a local operation.

$$m(x,y) = \frac{1}{2n+1} \sum_{i=-n}^{n} o(x+i, y+i) \qquad (8)$$

Where $o(x,y) = |h(x,y) * i(x,y)|$, the absolute value of the output of applying the filter h(x, y) to the image i(x, y). The parameter n is the size of the local neighborhood; by default we use n = 32. At each position (x, y), a local (256 point) one-dimensional DFT is computed along each row, and the local peak ratio s(x, y) is computed as described before in Eq. (2).

The above equation estimates the variance for detecting forged image regions.

6. CONCLUSION

Our proposed approach effectively detects the morphed image with presence of demosaicing in a digital image. Our algorithm validates two things: distinguishing original images from the manipulated ones and accurately localizing tampered image regions. We state that all of photographic images are compressed JPEG images directly from the digital camera. Therefore they have true demosaicing, nonlinear rendering, and JPEG compression. Morphed image generated from computer graphics systems do not use an image sensor.

7. ACKNOWLEDGMENTS

The authors would like to thank anonymous reviewers for their valuable comments.

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