CHAPTER 3

EXPOSING IMAGE MANIPULATION WITH CONSISTENT SHADOWS USING VANISHING POINT

Now a day, in the visual imagery trend image manipulation appears to be in every domain or field where imagery plays a significant role. From newspapers, articles, magazines to scientific research papers, image manipulation is blow-out. To authenticate the originality of the image, several forgery detection methods are applied (as mentioned in chapter 2). In the main, to enlighten the impact of the image forgery an example of fake image generated in real life is reflected; ‘Robert Cape’s Falling Soldier photograph’ captured during 1936 Griffin, M., (1999). The image specifies the moment of the death of a Spanish civil war soldier who is twisting towards the ground. This image is considered one of the shines in the photography. But now the thing has changed, the same image is found to be manipulated with different background. Robert Cape’s controversial image was taken in age when the visual imagery is not more sophisticated, even then the image is manipulated. But now the imagery is within the palm of a person which increases the chance of forgery. Thus the need for the forgery detection is increasing.

Shadows in an image are unavoidable. The shadows are present in the image because of the objects in the image scene content. When an image forger tries to manipulate the image containing shadow, special effort should be shown to make the shadow inconsistency in the image clueless. Either the shadow of the object in the image has to be copied from different image containing same object or shadow of the objects is distinctively copied and pasted on to the image. By analysing the photometric properties of the shadow present in the image, the image forgery can be detected Q. Liu, et al.(2011). This chapter tries to develop a new forgery detection methodology based on shadow inconsistency. The intent is to estimate the position of the light and shadow vanishing point of the image and to compare the vanishing
point. If any difference in vanishing point exists, it resembles the inconsistency of the shadow present in image and judge whether the image is tampered. The main contribution of the forgery detection algorithm developed in this chapter is,

**Geometric representation technique**- The first contribution in this chapter is geometrical representation technique to identify the shadow of the objects in the image. By the representation, the light and shadow vanishing points present in the image is found out without analysing the image. The discovered light and shadow vanishing points are used in the matching/analysis for exposing the manipulation.

**Collective image segmentation**- The second contribution in this chapter is collective image segmentation analysis. In collective segmentation, the segmentation techniques like morphological image analysis, thresholding segmentation, and super pixel segmentation is utilized for decomposing the shadow and non-shadow region from the image more precisely. The shadow point from the shadow region is compared with the shadow point of the geometrical technique using distance as the measure based on which the image originality is validated.

In this chapter, the shadow based approaches for forgery image detection is reported. The chapter is organized as follows; Section 3.1 presents the proposed image manipulation exposing methodology. The detailed description about the proposed geometric technique and collective segmentation analysis is also provided. The experimental results and discussion of the proposed shadow based forgery detection is presented in section 3.2 and 3.3 respectively. Finally, section 3.4 concludes the paper.

In the view point of the shadow based forgery detection, the utmost intend is to discover the shadow region from the image for the analysis. The input image ‘I’ subjected for forgery detection contains the shadow and non-shadow region. The combined action of image analysis techniques separates the shadow region from the
image. However, additional concepts concerned with shadow vanishing point which is optimal in an image are required for finding the inconsistency in shadows present in image. The problem statement for the evolution of new shadow based detection technique is presented below,

- The main challenge in shadow based detection technique is decomposition of image into shadow and shadow free image. Many image analysis techniques are available for separating the shadow and non-shadow region. However, the technique which covers the minute constraint of the shadow is necessary Ke, Yongzhen et al.(2014).


- Difficulty in handling shadow constraints and time consumption for the detection is another limitation in shadow based image manipulation exposure techniques Kee et al.(2014).

- Common requirement of independent number of shadow properties of shadow projector is not fully analysed for the authenticity verification Cao et al.(2015).

These are the major problems present in the existing shadow based detection techniques. From the problem statement, it is clear that report on the proper segmentation, geometrical representation of shadow constraints, etc. needs to be addressed.
3.1 Proposed Method: Geometric Technique and Collective Segmentation Analysis based shadow forgery detection

The detailed description about the proposed shadow based image manipulation detection is presented in this section. The block diagram of the proposed geometric technique and collective segmentation analysis based shadow forgery detection is depicted in figure 4.1. Primarily, the shadow vanishing point and light vanishing point present in the image is discovered by making use of the proposed geometrical representation technique. Subsequently, the collective segmentation analysis is performed over the subjected image. The collective segmentation is performed in sequence for separating the shadow region from the image. At first, morphological image analysis is performed which separates the structural information of the image which enhances the shadow region separation. Secondly, thresholding segmentation is performed over the morphological segmented image. Lastly, super pixel segmentation is performed over the image. The collective segmentation provides shadow region. From the shadow region, the shadow and light vanishing point is extracted. Afterwards, the shadow and light vanishing point discovered by the geometrical technique and the point resultant from the collective segmentation analysis is compared using a distance measure. The deviation in the distance measure signifies the inconsistency in the shadow of the image which judges the image as the tampered image.

3.1.1 Geometric Representation

The proposed geometrical representation technique to identify the shadow and light vanishing point in the image is discussed in this section.

The shadow of the image exploited using a geometrical representation with relationship of light source to the object. The shadow present in the image has some vanishing point. By discovering the vanishing point, the inconsistency can be
analysed. The shadow vanishing point is not similar to the standard construction vanishing point.

Figure 3.1 Proposed Geometrical Technique and Collective segmentation analysis based Shadow forgery detection

The vanishing point present in the image shadow is of two types; light vanishing point and shadow vanishing point. The steps involved in geometrical representation for the identification of the shadow vanishing point is given as follows; In order to create a believable shadow, object in the image scene content must be placed transparently because the back corners of the object is needed to make the shadow disappear behind the object. After object placement, the light source about the object is requisite. The light source must be placed aptly because improper positioning of light source distorts the shadow. The light source resembles
the light vanishing point and the shadow vanishing point lies in the vertical intersection point of the light vanishing point to the surface where the shadow is originated. The extreme edges of the shadow are marked by sending the shadow convergence line through the bottom corner of the object up until they intersect with the light lines. Figure 3.2 represents the geometrical representation technique for identifying the shadow and vanishing point. In figure 3.2, red dots epitomize the extreme edge of the shadow.

Figure.3.2 Geometric representation of Light Vanishing Point and Shadow vanishing Point

The geometrical relation for representing the vanishing point (VP) is reflected as follows;
The image plane is initially converted from 3D to 2D for the VP identification. Let us consider the camera capturing image from xyz with focal length f is converted to the image coordinate x y and the image plane is represented as in the equation (3.1).

\[ Z = f \frac{y}{Z} = Y \text{or} \]
\[ x = \frac{x}{f} = \frac{X}{Z}, f \left( \frac{X}{Z} \right) \text{or} \]
\[ y = f \left( \frac{Y}{Z} \right) \]

Where, \( x \) and \( X \) are the vectors with three elements and it is given by,
\[ x = (x, y, f)^T, \text{and } X = (X, Y, Z)^T \]

The parallel line light and shadow meets at the same vanishing point and it is represented in three dimensions as in equation (3.2).
\[ X(\mu) = A + \mu D \] (3.2)

Where, \( D \) is direction expressed using crammers rule in terms of \( X, Y, \) and \( Z \). In order to convert the three dimensional to two dimensional, Homogeneous projection matrix is considered Trigs, B., (1995). For the homogeneous projection matrix 3X4, the value of projection matrix is represented by the following equation (3.3).

\[
\begin{pmatrix}
  x_1 \\
  x_2 \\
  x_3 
\end{pmatrix} = \begin{bmatrix}
  1 & 0 & 0 & 0 \\
  0 & 1 & 0 & 0 \\
  0 & 0 & 1 & 0 
\end{bmatrix} \begin{bmatrix}
  X \\
  Y \\
  Z 
\end{bmatrix} = \begin{bmatrix} I & 0 \end{bmatrix} \]

(3.3)

The above homogeneous image coordinates aptly represents \( x = f \left( \frac{X}{Z} \right) \). Perspective linear map projection is performed over the homogenous points. The vanishing point is homogenously expressed as in equation (3.4).

\[
\begin{pmatrix}
  x_1(\mu) \\
  x_2(\mu) \\
  x_3(\mu) 
\end{pmatrix} = \begin{bmatrix}
  A \\
  D 
\end{bmatrix} + \mu \left( \begin{bmatrix}
  A \\
  0 
\end{bmatrix} \right) = \frac{1}{\mu} \begin{bmatrix}
  A \\
  0 
\end{bmatrix} + \begin{bmatrix}
  D \\
  0 
\end{bmatrix} \]

(3.4)
For an image with infinitive intersection point, the vanishing point with direction $D$ is expressed as in the following expression (3.5).

$$v = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix} D = \begin{bmatrix} D_x \\ D_y \\ D_z \end{bmatrix}$$

(3.5)

Equation (3.5) represents the vanishing point present in the image with respect to the direction.

### 3.1.2 Collective segmentation Analysis

In this section, the detailed description about the collective segmentation analysis introduced for the shadow based forgery detection is presented.

i) Morphological Image Analysis

Morphological image analysis operation is performed centred on the sets of pixels Areif H, M. Hahn, (2005). In the binary morphology analysis, for the segmentation of the image a membership function with an indifferent pixel value corresponding to grey level, colour etc. are utilized. The significant advantage of the morphological image analysis is that it efficiently extracts the structural information of the image. Geometrical transformation and measurements are the two basic steps involved in the morphological image analysis. The morphological transformation includes dilation, erosion, opening, and closing. In binary dilation, the pixel sets are combined using the vector sum of elements. The dilation transformation operation is defined as in the following equation (3.6).

$$X_b = \{ z \in E^n | z = x + b \text{ for } x \in X \} ; x \in X$$

(3.6)

Erosion transformation operation is the complementary dilation operation i.e. two pixels sets are combined based on the vector differences. The erosion transformation operation is defined by the equation (3.7).
\[ X \oplus B = \left\{ z \in E^n \mid z+b \in X \text{ for } b \in B \right\} X \in E^n, \text{ and } B \in E^n \]  

(3.7)

The iterative dilation and erosion transformation eliminates the structuring elements less than the threshold preserving the global geometric structure of the image features. The opening transformation operation is performed based on the dilating results and it is defined by the equation (3.8).

\[ X \circ B = (X \oplus B) \oplus B \]  

(3.8)

The opening operations smooth the contours of the image with assistance of cutting and suppression. Closing transformation operation is complementary operation of opening and it is defined by the equation (3.9).

\[ X \circ B = (X \oplus B) \oplus B \]  

(3.9)

\( \text{ii) Thresholding segmentation} \)

Thresholding segmentation is adopted in the proposed detection strategy to handle the grey scale image containing image composite. Here, an antistrophic diffusion model Radhakrishna Achanta et al.(2011) is accepted as the thresholding model. The basic concept for the segmentation is based on the squared error measure. The image which is subjected to segmentation is approximated within a region \( R_i \) based on its mean value \( \mu_i \) and the segmentation is performed by merging the region with same mean value. The error measure between the segmentation and the original image is expressed as in the following equation (3.10).

\[ E = \sum_i E_i \]  

(3.10)

where the error measure value \( E_i \) is given by the equation (3.11).
\[ E_i = \sum_{R_i} (1 - \mu_i)^2 \]  \hspace{1cm} (3.11)

The merging of the two regions will increase the total error. Let \( R_i \) and \( R_j \) be the two regions which are merged based on the mean value, and then the new region is expressed as in the equation (3.12).

\[ R_{ij} = R_i \cup R_j \]  \hspace{1cm} (3.12)

The region merging alters the mean value of the individual region as \( u_{ij} \). The non-negative change in the error measure in the merged region is defined by the equation (3.13).

\[ \Delta E_{ij} = E_{ij} - E_i - E_j \]  \hspace{1cm} (3.13)

Where, the error measure value \( E_{ij} \) in appropriate region is given by the equation (3.14).

\[ E_{ij} = \sum_{R_j} (1 - \mu_{ij})^2 \]  \hspace{1cm} (3.14)

This error measure based region merging concepts has been utilized in the proposed method for developing a computational method to segment the brightness, colour and texture of the images. The experimentation of the proposed concept based thresholding segmentation obtained promising results. In Ng T.T et al.(2004), Salem Saleh Al-amril et al.(2010), the thresholding segmentation is performed based on the similarity between the pixels and is not centred on the minimization criterion function. Based on which a fuzzy set based framework is developed to obtain the mathematical model of similarity based segmentation concepts. The proposed minimized criterion function based approaches and existing similarity based approach are comparatively analysed and the proposed approaches resulted in improved segmentation results even for the multimodal histograms. The superior performance is because of the following reasons,
The local minima trap is avoided in the existing approaches by neglecting the global minimum detection Chen. T, et al.(2010). Such attempt doesn’t corresponds the absolute minimum of the histogram in segmentation which fails to properly segment the background and foreground scene content of the image.

The proposed thresholding segmentation approaches is not limited to restrictions of number of images.

The signal to noise ration used herein is defined as in the equation (3.15).

\[
SNR = 10 \log \left[ \frac{\sum_{r=1}^{N_r} \sum_{c=1}^{N_c} I^2(r,c)}{\sum_{r=1}^{N_r} \sum_{c=1}^{N_c} (I(r,c) - I_n(r,c))^2} \right] \tag{3.15}
\]

Where, \( I(r,c) \) represents the intensity of the \((r,c)^{th}\) pixel of reference image and
\( I_n(r,c) \) represents the intensity of \((r,c)^{th}\) pixel of test image, \( N_r \) represents the number of rows of the image and \( N_c \) represents the number of the columns of the image.

**iii) Super pixel segmentation**

Super pixel segmentation of image is performed by combining the pixels sets with different distance into a single measure RadhakrishnaAchanta et al.(2011). The normalization of the color proximity and spatial proximity is obligatory with respect to their maximum distance within a cluster. The distance measure of colour proximity is represented by the equation (3.16).

\[
d_c = \sqrt{(l_j - l_i)^2 + (a_j - a_i)^2 + (b_j - b_i)^2} \tag{3.16}
\]

Where, \( d_c \) is the distance measure of color proximity, \( I_i, I_j \) are the Intensity of the pixel and \( a_i, a_j, b_i, b_j \) are the parameters.
The distance measure of the spatial proximity is represented by the equation (3.17).

\[ d_s = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \]  \hspace{1cm} (3.17)

Where, \( d_s \) is the distance measure of the spatial proximity \( x_i, x_j, y_i, y_j \) are the pixel location on the image.

The combined single measure distance measure is expressed as in the equation (3.18).

\[ D^* = \sqrt{\left(\frac{d_c}{N_c}\right)^2 + \left(\frac{d_s}{N_s}\right)^2} \]  \hspace{1cm} (3.18)

Where, \( d_c \) is the distance measure of color proximity, \( D_s \) is the distance measure of spatial proximity, \( N_c \) is the maximal color distance and \( N_s \) is the maximal spatial distance.

The maximal spatial distance \( N_s \) is equal to the corresponding sample interval \( S \) i.e. given by the equation (3.19).

\[ N_s = S = \sqrt{\frac{N}{K}} \]  \hspace{1cm} (3.19)

The color similarity distance is not optimal as the cluster distance varies significantly from cluster to cluster and image to image. So the maximal colour distance is equated to \( m \). The modified distance measure is expressed as in the equation (3.20).

\[ D^* = \sqrt{\left(\frac{d_s}{m}\right)^2 + \left(\frac{d_c}{S}\right)^2} \]  \hspace{1cm} (3.20)

The colour distance element \( m \) in the distance measure permits to weight the relative importance between colour similarity and spatial similarity. The lager \( m \) value resembles the better spatial proximity and the resultant super pixels are compact inside the imagery. The smaller \( m \) value resembles the better colour
similarity, and the resultant super pixels are compact alongside the boundaries with the limitation in regular shape and size.

The variance is normally used to find how each pixel varies from the neighbouring pixel (or centre pixel) and is used in classify into different regions. The variance of the given image is,

\[ s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 \]  

(3.21)

where \( n \) is the sample size and \( x-bar \) is the sample mean

3.1.3 Matching

In this section, the manipulation matching analysis is presented. From the segmented image containing separate shadow and non-shadow region, the distance points are selected from the shadow region. The distance between the two points say D1 and D2 are calculated using equation (3.20). Similarly, the distance between the light and shadow vanishing points identified by the geometrical representation technique is calculated. The deviation in the distance measure implies the inconsistency in shadow. The inconsistency in shadow judges the image as the tampered image. Thereby, based on the distance measure, the originality of the image is validated.

3.2 Experimental results

In this section, the experimentation results of the proposed geometric technique and collective segmentation analysis based shadow forgery detection is presented.

(i) Experimental setup

The experimentation of the proposed shadow based forgery detection is performed in a personal computer with the following specifications; (i) 2 GB
Physical Memory (RAM), (ii) Window 7 Operating System, (iii) Intel Core i-3 Processor. The software tool used for the implementation is

(ii) Database

The experimentation is performed over the images collected from the internet. The collected images are manually doctored using different photo editing software such as Photoshop, Photo editor pro etc.

3.2 Test image

Figure 3.3 depicts a test image with 256*256 resolution JPEG image from the bulk image database utilized in the experimentation procedure. The unavailability of public dataset, the input data set can be taken from the website. Figure 3.3a represents the original chair image with its shadow and figure 3.3b represents the manipulated image in which the chair shadow is modified using photo edit software. Totally 120 forgery images are used for the validation purpose.

![Test Image](image)

(a) Original Image          (b) Doctored Image

Figure.3.3 Test Image

3.2.2 Segmentation Results

The segmentation results of the collective segmentation techniques utilized in the proposed detection method is presented in this section.

(i) Morphological Segmentation Results
The morphological segmentation results of the test image specified in section 3.2.1 is shown in figure 3.4. Figure 3.4a depicts the morphological segmentation result of original image and figure 3.4b depicts the morphological segmentation result of the fake image.

![Morphological Segmentation](image)

**Figure 3.4 Morphological Segmentation**

*(ii) Thresholding Segmentation Results*

The thresholding segmentation results of the proposed collective segmentation analysis are depicted in figure 3.5. Figure 3.5a and 3.5b represents the thresholding segmentation result of the original image and doctored image with inconsistent shadow respectively.

![Thresholding Segmentation](image)

**Figure 3.5 Thresholding Segmentation**
(iii) Super pixel Segmentation Results

Figure 3.6 depicts the super pixel segmentation result. Figure 3.6a depicts the super pixel segmentation result of original image and figure 3.6b depicts the super pixel segmentation result of doctored image.

![Original Image](image1.png) ![Doctored Image](image2.png)

(a) Original Image (b) Doctored Image

Figure.3.6 Super pixel segmentation

3.3 Discussion

In this section, the discussion of the experimental results of the proposed shadow based detection technique for exposing the image forgery is presented. The analysis is provided in terms of the periodicity map and the performance of the proposed method is compared with the existing method Kee, E., et al.(2013).

3.3.1 Analysis based on periodicity map

The comparative analysis based on periodicity map for the original image is given in figure 3.7. Figure 3.7a illustrates the periodicity map of the original image attained by the proposed method and figure 3.7b illustrates the periodicity map of the original image attained by the existing method. From the analysis curve, the fact is evident that the periodicity map of the proposed method is increased than that of the existing method which expose photo manipulation with inconsistent shadows Kee, E., et al.(2013). The increment in periodicity map demonstrates the enhanced performance.
The periodicity map analysis curve for the forged image is specified in figure 3.8. Figure 3.8a and 3.8b represents the periodicity map for the forged image attained by the proposed method and existing method Kee, E., et al. (2013) respectively.

Figure 3.7 Periodicity Map for Original Image

Figure 3.8 Periodicity Map for Forged Image
3.3.2 Vanishing Point Computation

In this section, the vanishing point computation exploited in the proposed method for the forgery analysis is presented. Table 3.1 list the vanishing point computation of four images considered in the experimentation.

From the table 3.1, the fact is evident that for original image the computed light vanishing point and shadow vanishing point is unique, on the contrary for fake image the computed vanishing point varies which exemplifies the inconsistency of shadow.

<table>
<thead>
<tr>
<th>I M A G E</th>
<th>Input Image Size</th>
<th>Vanishing Point Computation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Original Image</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light Vanishing Point</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D1 (mm)</td>
</tr>
<tr>
<td>Original Image</td>
<td>Fake Image</td>
<td>720*576</td>
</tr>
<tr>
<td>1</td>
<td>723*904</td>
<td>723*904</td>
</tr>
<tr>
<td>2</td>
<td>315*400</td>
<td>315*400</td>
</tr>
<tr>
<td>3</td>
<td>1152*768</td>
<td>1152*768</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.4 Summary

This chapter discusses a novel image manipulation exposing scheme based on the shadow inconsistency using the geometrical representation technique and collective segmentation analysis. The geometrical technique is used to identify the shadow points from the image. The collective segmentation analysis is done utilizing Morphological analysis, Thresholding segmentation and Super pixel segmentation. Collective image segmentation analysis is performed to decompose the shadow region from the image. The authenticity is performed by comparing the geometrically computed light and shadow vanishing point with the point of the segmented region utilizing the distance measure. The experimentation of proposed detection scheme is done over manually altered diverse images. The performance of the proposed detection scheme is validated in terms of the periodicity map over the existing methods. The experimentation ensued with promising results for the exposure of image manipulation with shadow consistency.