CHAPTER 4

EXPOSING IMAGE MANIPULATION WITH CURVED SURFACE REFLECTION

Image manipulation is common in every field where visual imagery is found relevant because of the powerful photo editing software such as paint, Photoshop etc. With the advancements made in procedures of the image manipulation, the forgery detection seems more difficult. The image manipulation is performed for intentional entertainment purpose or for malicious purpose. An example for the image forgery in soviet history is Lennin’s second anniversary of October revolution picture taken by L.Y. Leonidov given in figure 4.1. Now this picture is available in Art of Photography in Moscow, but it is found manipulated cropping of two eminent persons in the same original image which is ascertained by the Moscow media King, D., (2006). This manipulation falsifies the historical facts. This case is one example which may not seem important but the impact over the manipulation is obvious. Similar, hindrances increased the need for the forgery detection.

![Figure 4.1. Example for Image Forgery](image-url)

(a) Original Image  
(b) Fake Image

*Figure 4.1. Example for Image Forgery*
Reflections in the image are inevitable Ge, Huayong, and Hafiz Malik, (2014). The reflections are formed in the image when the object in the image scene content obstructs the light from the light source. The reflection handling in image manipulation is crucial. The small change in the reflection image deviates larger in properties. By analysing the photometric properties of the reflections present in the image, the image manipulation can be decomposed Johnson, M.K. and Farid, H., (2007). This chapter tries to develop a new forgery detection methodology based on reflection inconsistency. The utmost intent is to determine the reflection part of the image and to analyse the deviation of the reflection on the original reflection. The main contributions of this chapter are,

**Geometrical Representation technique**-The first contribution of this chapter is geometrical representation technique to identify the reflection of the objects in the image. By the representation, the reflection points present in the image is found without analysing the image. The discovered reflection part is utilized in matching/analysis for exposing the image forgery.

**Collective image segmentation**-The second contribution of this chapter is collective image segmentation analysis. In collective segmentation, the segmentation techniques like top hat filtering, gray scale reconstruction, morphological analysis, thresholding segmentation and super pixel segmentation is utilized for separating the reflection and non-reflection region from the image. The reflection point extracted using the collective segmentation is compared with the reflection point of the geometrical representation technique for validating the authenticity of the image.

In this chapter, the reflection based approaches for the forgery image detection is reported. The chapter is organized as follows; Section 4.1 illustrates the
proposed image tampering detection methodology highlighting the geometrical representation technique for the detection of the shadow region and the collective segmentation analysis techniques. The experimental result of the proposed reflection based forgery detection is presented in the section 4.2 and 4.3 respectively. Finally, section 4.4 shows the conclusion.

In perspective of the reflection based image forgery detection, the utmost aim is to discover the reflection region present in the image. For an input image ‘I’ which contains the reflective objects and original objects, the reflective region in the image must be separated. The deviation in the reflection of the object in regard to the original position of the object reflection resembles the corresponding image as tampered image. Many different reflection based forgery detection approaches have been developed in the recent years. However, every unique detection concepts have some shortcoming which cannot be addressed without any compromise. Some of the challenges are

- The main challenge in the reflection inconsistency based forgery detection is decomposition of the reflection region and non-reflection region from the image. Many segmentation techniques are available for separation M. Johnson and H. Farid, (2005). But the technique which covers minute constraints of the reflection region is necessary.


- Computation time and limitation in reflection constraint also seems problematic in existing reflection based approaches.
These are the major problems present in the existing reflection based forgery detection techniques. From the problem statement, the fact is evident that the report on proper segmentation, feature extraction, reflection constraints representation etc. needs to be addressed.

4.1 Proposed Method: Geometric Technique and Collective Segmentation Analysis based reflection forgery detection

The detailed description about the proposed reflection based image manipulation detection is presented in this section. The block diagram of the proposed image forgery detection based on reflection inconsistency is depicted in figure 4.2. Primarily, using the proposed geometric representation technique, the reflection points in the images are identified. Subsequently, the collective segmentation technique is performed over the subjected image for separating the reflective curve parts from the image. For decomposing the reflective part in the collective segmentation analysis, top hat filtering is performed firstly. Secondly, gray scale reconstruction is performed over the top hat filtered image. Subsequently, Morphological binary segmentation analysis is performed separating the background of the image. Afterwards, thresholding segmentation is performed followed by the super pixel segmentation decomposing the reflection region. The reflected region and the geometrically represented reflected point is matched or analysed for evaluating the originality of the image. In matching/analysis, the deviation in the reflection of the original object discovered by the geometrical technique to the segmented reflective part ensue the forgery.

4.1.1 Geometric Representation Technique:

The proposed geometrical representation technique utilized to locate the reflection point in the image is illustrated in this section.
Generally, to find the location of the image of the object ray diagram is used. The image location procedure in the ray diagram is explained below,

- Rays of the light are drawn from the object to the mirror,
- The directed rays reflected off the mirror
- The image of the object is found at the place where the reflected rays from the mirror intersect
Figure 4.3 Geometrical representation of reflected Image

Figure 4.3 shows the geometrical representation of the image and reflected image. In figure AB denote the original image; M is the plane mirror responsible for the reflection, and ED is the reflected image. Since the focal length of the plane mirror is infinity, a similar thin lens is used instead of plane mirror. The reflected image from the mirror resembles the reflection of the object which obeys the law of reflection. But the problem exists in finding the place where the reflected rays intersect. To find the reflected image, the main objective is to find the focal length of the image. The focal length of the image is expressed as in the equation (4.1).

\[
\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \tag{4.1}
\]

Where, \(d_o\) is the distance between the mirror M and object AB, \(d_i\) is the distance between image and mirror.
To find the distance between the image and mirror \( d_i \), Equation (4.1) is rearranged as in the equations (4.2 to 4.3).

\[
\frac{l}{d_i} = \frac{l}{f} - \frac{l}{d_o} \tag{4.2}
\]

\[d_i = \frac{d_0 f}{d_o - f} \tag{4.3}\]

The value of \( f \) is given by the relation as in the equation (4.4).

\[
\frac{1}{f} = (n - 1) \left[ \frac{1}{R_1} - \frac{1}{R_2} + \frac{(n - 1)l}{R_1 R_2} \right] \tag{4.4}
\]

Where, \( d \) is the thickness of the mirror, and the value of \( n = \frac{c}{v} \), \( c \) is the velocity of light in the object., \( R_1 \) & \( R_2 \) are the radius of curvature utilized to find the radius of curvature of the curved surface image.

The radius of the curvature value is chosen based on the assumption of the parabolic equation and parameters, and it is given by the equation (4.5).

\[
R = \frac{(1 + Y_1^2)^{\frac{3}{2}}}{Y_2} \tag{4.5}
\]

Where, the value of \( Y_1 = \frac{dy}{dx} \) & \( Y_2 = \frac{dy^2}{dx^2} \). For example, consider the parabolic curve \( X^2 = -4ay \) and substitute it in equation (4.5) to get the radius of curvature value.

The magnification ratio of the image is given by the equation (4.6).

\[

\]
Where, $h_o$ is the height of the object and $h_i$ is the height of the reflected image.

By finding the focal length and magnification ration, the location of the reflected image is represented in the proposed geometric technique.

### 4.1.2 Collective Segmentation Analysis:

In this section, the collective segmentation analysis adopted for the reflection based forgery detection is presented.

#### i) Top Hat Filtering

To find the morphological opening of the image, top hat filtering is applied on to the original image subjected to find the shadow inconsistency. Top hat filtering procedure is explained in I-Chen.T et al.(2010) in which top hat generalization procedure is performed in two methods. In the first method, vectorial order in the relevant vector space is utilized; in the second method using the top hat all the openings found in the image is found by making use of the vectorial order. In standard top hat filtering, the subtracting operation is used to find the opening in the proposed collective segmentation instead of the subtraction pixel wise vector distance is utilized. The equation for the top hat filtering is rewritten as in the following equation (4.7).

$$T_w(f) = f - f^©b$$

Where, $f$ is the given function, $T_w(f)$ is top hat transformation, $b$ is the gray scale structure element, and $©$ is the opening operation. The top hat filtering procedure is explained below,

- Primarily, the vectorial order is used to find the opening
• Subsequently, the vectorial distance is calculated between the corresponding pixels in the initial and processed image.

The concept of invariant pixels because of the binary structuring elements Allan Hanbury, and the feature of the images is identified by the top hat transformation function. The top hat filtering output is the gray scale image.

**ii) Gray Scale Reconstruction**

Gray scale reconstruction analysis is utilized in the proposed collective segmentation to segment the desired parts from the gray scaled output image of the top hat filtering. In gray scale reconstruction analysis, initially the gray scale image is accepted and converted into color image. After conversion, the image gradient is generated from the image by the application of the edge detection function. Even for the low contrast images which have the noise that could produce local minima, the edge detection function can generate image gradient Areif H, M. Hahn (2005). The method adopted in Salem Saleh Al-amri1, et al.(2010) where geodesic dilation is utilized to mark an image under the mask can be extended to generate gray scale gradient. The geodesic dilation dilates the marker image by an elementary isotropic structuring element. But the resultant image is forced to remain under the mask. This geodesic dilation function can be defined as in the following equation (4.8).

\[ \delta(J) = J + B \]  

(4.8)

Where, J is the marker image and B is the isotropic structuring element.

**iii) Morphological Analysis**

Morphological image binary analysis is used in the proposed technique to avoid the higher intensity values of the image KamaljeetKaurMukesh Sharma,” (2013). In morphological analysis, skeletonization procedure is performed over the image gradient extracted from the grayscale reconstruction analysis. The utmost intention for the reduction of the high intensity value is to simplify the image more meaningful and easier to analyse.
In morphological analysis, the simplified algorithm for clustering the dissimilar contour is based on the centroid. The centroid for the region separation is obligatory. For the image case with one white contour, the coordinates of the contour centre $X_c$ & $Y_c$ are represented in the equations (4.9 to 4.10).

\[
X_c = \frac{1}{M} \sum_{i=1}^{n} x_i m_i \tag{4.9}
\]

\[
Y_c = \frac{1}{M} \sum_{j=1}^{n} y_j m_j \tag{4.10}
\]

Where, n is the total number of the pixels, M is the sum of intense, $x_i$ & $y_j$ are the pixel location on the image and $m_i$s the pixel intensity value.

**iv) Thresholding Segmentation**

Thresholding segmentation is utilized in the proposed collective segmentation to discriminate the foreground of the image containing the object from the background of the image. In the main, thresholding segmentation is the simple and most widely adopted segmentation technique Salem Saleh Al-amri1 et al.(2010). Thresholding segmentation technique is classified into two types, global threshold segmentation technique and adaptive threshold segmentation technique. In global threshold based segmentation, a single threshold value is used to segment the whole image $[x,y]$ and it is mathematically expressed as in the equation (4.11).

\[
T=T[x, y, p(x, y), f(x, y)] \tag{4.11}
\]

Here, $T$ is the threshold value, $x$ and $y$ is the coordinates of the threshold value point, $p(x,y)$ and $f(x,y)$ are the gray level pixel points.

**v) Super pixel segmentation**
Super pixel segmentation algorithm segments the image into a regular grid of super pixels Salem Saleh Al-amri1 et al.(2010). The super pixel offers useful properties of the image. The super pixel representation of original image pixel is defined as in the equation (4.12).

\[ R^2 = \frac{\sum_{i}(\mu_i - \mu)^2}{\sum_{i}(x_i - \mu)^2} \]  

(4.12)

Where, \( x_i \) is the actual pixel value, \( \mu \) is the global pixel mean value, and \( \mu_i \) is the mean value of individual pixel assigned pixel that contains \( x_i \). The super pixel representation of the original pixel facilitates the segmentation of minute details present in the image which is essential in discovering the reflective curve parts of the object in the image scene content.

4.1.3 Matching/Analysis:

In this step, the reflective part extracted by the proposed segmentation analysis is compared with the reflection point identified by the geometrical representation technique. The deviation in the reflection point reflects the fact that the image is tampered with malicious reflections.

4.2 Experimental results

The experimental result of the proposed geometric technique and collective segmentation analysis based reflection forgery detection is presented in this section.

(i) Experimental Setup

The experimentation of the proposed reflection based forgery detection is performed in a personal computer with the following specifications; (i) Windows 8 Operating System, (ii) Intel Core i-3 processor, (iii) 2-GB Physical Memory. The implementation is done using the MATLAB (R2014a) software tool.
(ii) **Database**

The experimentation is performed over 100 images collected from the internet. The collected images are manually modified with fake reflection using the adobe Photoshop for testing the detection capability of the proposed method.

### 4.2.1 Test Image

The test image with 256*256 resolutions JPEG image considered for analysing the detection capability of the proposed reflection based forgery detection using geometrical representation technique and collective segmentation technique is represented in figure 4.4. Figure 4.4a signifies the original image with the reflection and figure 4.4b signifies the doctored image in which a person with mobile in hand is manually placed in the original image by moving back the car. But the reflection of the car in the mirror is overlooked. The unavailability of public dataset, the input data set can be taken from the website. Totally 120 forgery images are used for the validation purpose.

![Test Image](image)

<table>
<thead>
<tr>
<th>(a) Original Image</th>
<th>(b) Doctored Image</th>
</tr>
</thead>
</table>

**Figure.4.4 Test Image**

### 4.2.2 Segmentation Results

The segmentation results of the collective segmentation techniques adopted in the proposed forgery detection method is presented in this section.
(i) *Top hat filtering Results*

The top hat filtering result of the test image (provided in section 4.3.1) is depicted in figure 4.5. Figure 4.5a specifies the top hat filtering output of the original image and figure 4.5b specifies the top hat filtering output of the forged image.

![Figure 4.5 Top hat filtering](image)

(ii) *GrayScale Reconstruction Results*

Figure 4.6 represents the segmentation result of the grayscale reconstruction technique. In the specified figure 4.6, 4.6a and 4.6b specifies the grayscale segmentation result of the original and fraudulent image respectively.
(iii) Binary Image Segmentation Results

The binary segmentation result of the proposed collective segmentation technique is depicted in 4.7. Figure 4.7a and 4.7b represents the binary image segmentation results of the original image and doctored image with inconsistent reflection respectively.
(iv) **Morphological Segmentation Results**

The morphological segmentation results of the original and doctored image is shown in figure 4.8a and 4.8b respectively.

![Figure 4.8 Morphological Segmentation Results](c) Original Image (d) Doctored Image

(v) **Threshold Segmentation Results**

The threshold segmentation results of the proposed collective segmentation analysis are depicted in figure 4.9. Figure 4.9a specifies the threshold segmentation result of the original image and figure 4.9b specifies the threshold segmentation result of the doctored image.

![Figure 4.9 Threshold Segmentation Results](a) Original Image (b) Doctored Image
(vi) **Super pixel segmentation Results**

Super pixel segmentation results of the proposed collective segmentation analysis are depicted in figure 4.10. Figure 4.10a specifies the super pixel segmentation result of original image and figure 4.10b specifies the super pixel segmentation result of the doctored image.

![Super pixel segmentation results](image)

(a) Original Image  
(b) Doctored Image

**Figure 4.10 Super pixel segmentation Results**

(vii) **Final Segmentation Results**

Figure 4.11a and 4.11b represents the final segmentation result of the proposed collective segmentation analysis or original image and doctored image respectively. It signifies the reflective curved surface region present in the image.

![Final segmentation results](image)

(a) Original Image  
(b) Doctored Image

**Figure 4.11 Final Segmentation Results**
4.3 Discussion

The discussion of the experimental results of the proposed reflection based detection technique for exposing the image forgery is reflected in this section. The analysis is provided in terms of the histogram. The histogram curve for the image is plotted between the number of pixels and pixel count. The analysis is performed over authentic, compressed, and reconstructed input and fake images respectively.

4.3.1 Analysis based on Histogram

(i) Authentic input and fake image

The histogram curve obtained for the authentic input and fake image by the proposed method is given in figure 4.12. When analysing the figure 4.12a, the maximal pixel count value attained is found within 20 which resembles the originality of the image. On the contrary, when analysing figure 4.12b, the maximal pixel count value attained is found exceeding 50 which resembles the fact that the image is tampered.

![Histogram curve for authentic and fake input image](image.png)

Figure.4.12 Histogram curve for authentic and fake input image
(ii) Compressed input and fake image

Figure 4.13 depicts the histogram of the compressed authentic input image and compressed fake image. When analysing figure 4.13, the fact is evident that the maximal pixel count exceeding 50 is obtained in the histogram of the fake compressed image. This signifies the superior performance of the proposed method even after compression procedure.

![Histogram curve for compressed authentic and fake image](image)

(a) Authentic compressed Image  
(b) Fake compressed Image

(iii) Reconstructed Input and fake image

The histogram curve obtained for the reconstructed input and fake image is shown in figure 4.14. When analysing figure 4.14, the maximal pixel count is obtained below 30 for the authentic reconstructed image, at the same time for the fake reconstructed image the maximal pixel count attained is found above 60.

![Histogram curve for reconstructed input and fake image](image)

(a) Authentic reconstructed image  
(b) Fake reconstructed image

Figure 4.14 Histogram curve for reconstructed input and fake image
The analysis value obtained by the proposed method is given in table 4.1. Here $d_o$ is the distance between original object and the mirror, $d_i$ is the distance between the mirror and the reflected object. The image size, process encoding time, bit per pixel, compression ratio and PSNR value of the authentic and fake image is presented in table 4.1. Moreover, the detection ratio in terms of various constraints is also deliberated.

Table 4.1 Analysis of forgery detection in reflected images

<table>
<thead>
<tr>
<th>Input Image Size</th>
<th>Original Image</th>
<th>Fake Image</th>
<th>SNR(db)</th>
<th>MSE</th>
<th>PSNR(db)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$d_o$(mm)</td>
<td>$d_i$(mm)</td>
<td>$d_o$(mm)</td>
<td>$d_i$(mm)</td>
<td>Original Image</td>
</tr>
<tr>
<td>720*576</td>
<td>23.12</td>
<td>27.08</td>
<td>23.12</td>
<td>27.76</td>
<td>33.21</td>
</tr>
<tr>
<td>952*760</td>
<td>31.78</td>
<td>26.70</td>
<td>31.78</td>
<td>26.12</td>
<td>41.21</td>
</tr>
<tr>
<td>240*318</td>
<td>18.12</td>
<td>19.11</td>
<td>18.12</td>
<td>20.05</td>
<td>22.12</td>
</tr>
<tr>
<td>723*904</td>
<td>22.19</td>
<td>23.12</td>
<td>22.19</td>
<td>24.16</td>
<td>31.21</td>
</tr>
<tr>
<td>315*400</td>
<td>35.34</td>
<td>36.12</td>
<td>35.34</td>
<td>39.01</td>
<td>27.12</td>
</tr>
</tbody>
</table>

4.4 Summary

This chapter discusses a new image manipulation exposing scheme based on the reflection inconsistency using the geometrical representation technique and collective segmentation analysis. The effectiveness of the proposed approaches is because of combined action of the segmentation with geometrical representation. The geometric representation technique is used to identify the reflection point from
the image. The collective segmentation analysis comprising top hat filtering, grayscale reconstruction, morphological binary image analysis, thresholding segmentation and super pixel segmentation is utilized to separate the reflected region from the image. The authenticity is performed by comparing the reflection point out of the geometrical representation technique and collective segmentation. The experimentation of the proposed reflection inconsistency based forgery detection scheme is performed over different manually manipulated image with shadow inconsistency. The performance of the proposed detection scheme is validated in terms of the histogram over the existing methods. The experimentation ensued with encouraging results for the exposure of image manipulation with reflection inconsistency.