A THESIS REPORT

ON

"ANALYSIS AND IMPLEMETATION OF SOURCE CAMERA IDENTIFICATION TECHNIQUE"

Submitted in partial fulfillment of the requirement for the award of the degree

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DECLARATION

I hereby declare that all the information in this document has been obtained and presented in accordance with academic rules and ethical conduct. This report is my own work to the best of my belief and knowledge. I have fully cited all material by others which I have used in my work. It is being submitted for the degree of Master of Technology in Electronics & Communication at the Delhi Technological University. To the best of my belief and knowledge it has not been submitted before for any degree or examination in any other university.

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CERTIFICATE

This is to certify that the thesis **"***Analysis and Implementation of Source Camera Identification Technique"* is authentic work of **Mr. Viney** under my guidance and supervision in the partial fulfillment for the Degree of Master **of Technology Degree in Signal Processing & Digital Design** to Department of Electronics and communication Engineering, Delhi Technological University, Delhi, India. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any other degree.

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ABSTRACT

An intriguing issue in computerized legal sciences is that given a digital picture, would it be possible to distinguish the camera model which was utilized to get the picture particularly in this age of fraud. In this thesis work we take a look on the technique which can be used to solve this purpose in simpler way. We studied the four diverse procedure and look at their predominance. Simplified techniques are to check for the features which are unique to camera. These features can be utilized by a classifier to distinguish the source camera of a picture. Also, the recognizable feature components were further classified for changes, by analyses, to improve the accuracy rate of the distinguishing proof. This exploration additionally looked at cameras of changed brand, as well as those of the same maker with comparative models. An inherent component of a camera is PRNU (photograph response non-uniformity). Such unique features can be assessed from various pictures taken by the same camera by method for a denoising filtering operation. With the utilization of a color filter array for catching one and only of the three colors channel for every pixel presents shading interpolation error, while the current techniques for extracting PRNU, incorporate the shading interjection mistake as a feature of the PRNU, which leaves opportunity to get better. So we propose another method for extracting PRNU, called Color-Decoupled PRNU (CD-PRNU), by using the distinction between the physical and artificial color channel of the photographs taken by digital cameras that utilization a color filter array for introducing manufactured color channel from the physical ones. Past proposed camera methods calculations are set up to group the sources for a predefined compression factor quality. Conversely, the compression characteristics of the picture

might be changed amid further processing and altering. Local binary pattern applies on the edges extracted from the information picture. The component demonstrated great strength against JPEG pressure quality varieties. The strategy uncovered its capacities in both high and low quality pictures.

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CHAPTER 1

1.1 INTRODUCTION

In the simple world, a picture (a photo) has by and large been acknowledged as a "proof of event" delineated occasion. In world of computerized age, generation and control of digital pictures is quite straightforward by different processing tools available which are effortlessly and generally accessible. Notwithstanding, digitalized pictures and information can be effectively transmitted and traded quickly by means of the Internet, therefore the protected innovation right of the creators could be truly abused. So legitimacy of pictures cannot be taken as granted, analog or digital. It makes more sense in cases where image is presented as proof for a crime in court or any legal proceedings. Image forensic, in this reference, is worried with deciding some fundamental reality of a picture. For image forensic is the assemblage of methods that endeavor to give definitive responses to inquiries, for example,

It is safe to say that this is picture a "unique" picture or would it say it was made by cut and glue operations from various pictures?

Is it safe to say that certain picture was taken by camera fabricated by A?

We can be sure that this picture was taken by this camera A at certain location B in particular time T?

Is this picture genuinely speaking to the first scene or would it say it was digitally altered to bamboozle the viewer? For instance, is it safe to say that this was espresso recolor really a blood stain that was re-hued?

Is it true that this was picture controlled to implant a secret message? Is it true that this is picture a stego-image [1] or a cover image?

The above inquiries are only a couple of case of issues confronted regularly by examination and rule implementation agencies. But still due to absence of robust procedures which helps them to find definitive answers. Albeit watermarking can be used as source of credibility of pictures, the greater part of pictures that are caught today don't have a digital watermark to show for. What's more, the same situation can be there for long time to come. We can have information about camera and its model, brand, date of picture with time from JPEG header, but it can be changed easily and hence issue of real image source identification can still be a challenge. So instead of going for number of different watermarking strategies we try to create a system which help us proclaim the source of picture with more preciseness.

The issues confronted in Image Forensics are to a great degree troublesome and maybe even hard to plan in a perfect and straightforward way. In this work we take up issue at one of the inquiries over, that is, given a picture would we be able to decide the camera model that was utilized to catch the picture. The distinguishing proof depends on camera qualities [2] [3] [4], for example, flawed pixel areas, noise level, picture position. In any case, this methodology falls flat since the new advanced camera creators have possessed the capacity to take out all the locally available flawed pixels and post-process the lasted pictures.

To address this issue, the analysts have proposed to utilize inherent and unique characteristics which may be incorporated by hardware flaws or software associated patterns left amid the picture pattern as distinguishing features. At the point when the technique for recognizing inherent artifact is embraced, the artifacts such as sensor dust, lens distortion, pattern noise, are utilized to find the source camera unique mark. Besides utilizing equipment blemishes, there have been inquiries about investigating programming related fingerprints like picture elements or the factors like CFA interpolation as arranging components. So here we look upon some of the primitive methods and their limitations to identify source brand and even model of brand if trained with different model as well.

1.2 Camera Basic

When a picture is taken by a system camera, portion of light falls on the camera lens which focuses light on the picture sensor. The picture sensor comprises of picture components, additionally called pixels, that enroll the sum of light that falls on them. Sensors convert measure of light into an equivalent number of electrons. Stronger the light falls; electrons will be produced in proportions. With analog to digital converters we change the electron amount (a voltage level) into proportionate number. The number will produce its equivalent signal by the internal circuitry present inside camera signal. A simple arrangement to store charge and collection of light is shown in Figure1.1 & Figure1.2.

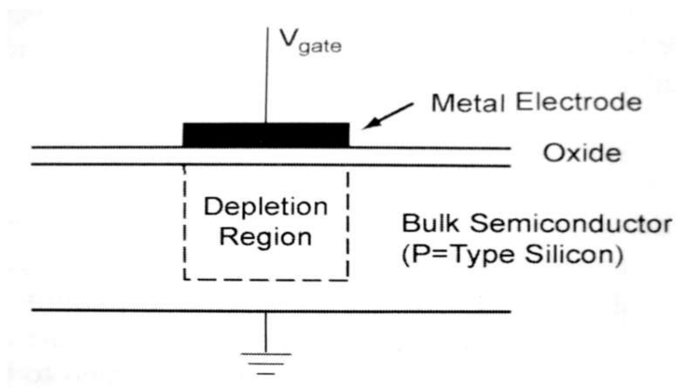

Figure1.1Simple MOS circuit to store the charge

Right away, we have two primary advancements which can serve the purpose of the picture sensor as a part of a camera, (i) CCD (Charge-coupled Device), (ii) CMOS (Complementary Metal-oxide Semiconductor). Both sensor configuration and diverse qualities and shortcomings will be clarified in the accompanying segments at length. Picture sensors enlist

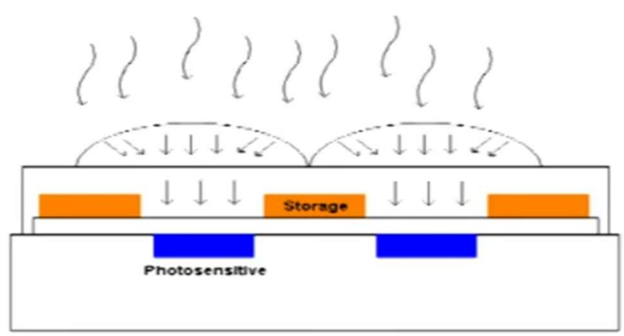

Figure1.2 Lens and different camera element set-up

the measure of light on a scale ranging between dull and bright with no information about color. Color blindness property of both CMOS and, CCD picture sensors, permits a channel before the sensor to allot color shades to every pixel.

There are generally two basic shading enlistment strategies [5] [6]can be used namely RGB where R is red G is green and B is blue (three primary color of spectrum) and CMYG where C is cyan, M is magenta, Y is yellow and G is green. Red, green, and blue are the essential hues, blended in various grouping, can create the greater part of the color noticeable to human eye. Filter array of Bayer's, which has of two square of green and one for red and blue channels and placed in same manner repeatedly, is the widely used RGB filter array, see Figure1.3 (left). As our eyes are more in tune to green than other two colors, the Bayer exhibit has double the same number of green channels. This additionally implies with the Bayer cluster; that if the three color were utilized in equivalent proportions in the channel, our eye can distinguish more detail.

Second approach for channel shading is to use the integral colors-cyan, magenta, and yellow. Corresponding shading channels are frequently consolidated with green channels on sensor to form a CMYG shading exhibit, see Figure1.4 (right). The CMYG framework for the most part offers higher pixel value because of its more extensive spectral response. Be that as it may, the signal should then be changed over to RGB since this is utilized as a part of the last picture, and the transformation suggests we require more handling and noise will be added. Due to noise addition signal to-noise is diminished, and we don't use regularly the CMYG filer array as it is not so precise (just exhibits color precisely). The color filer array of CMYG is frequently utilized as a part of entwined CCD picture sensors, while the RGB framework fundamentally is utilized as a part of dynamic sweep picture sensors.

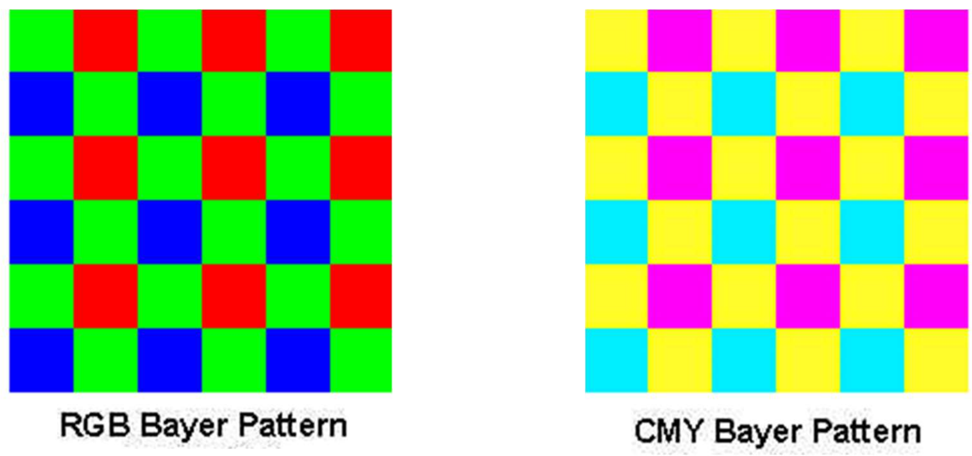

Figure1.3 Different Color filter array

1.2.1 CCD

CCD sensor [5] [7]collects the light falling on its pixel. After this light is converted by MOS into charge and changed over to voltage levels and an analog signal is conveyed. Resultant signal is boosted and changed into digital levels utilizing a suitable analog to digital converter, see Figure1.4. Every times same process repeated and whole scene data is stored.

From the above figure we can conclude that CCD sensor is two-dimensional array containing photo detectors which convert light into charge. Metal oxide semiconductor capacitors characterize a CCD chip, where every capacitor speaks to a picture element(pixel). Every picture element is just like a container for electron to assemble. Either as electric charge or as light we store information on a CCD chip. Amid a presentation, every pixel contains that many

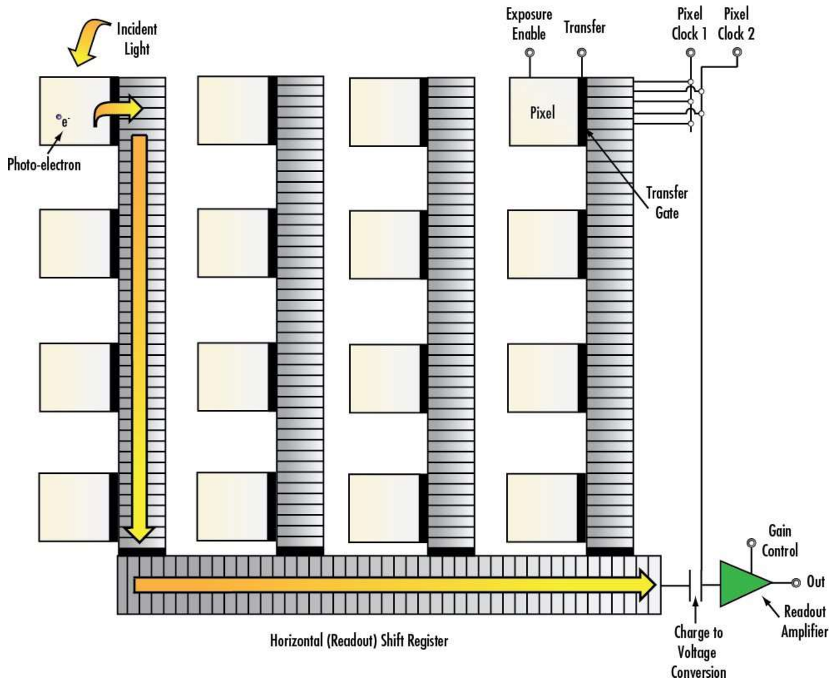

Figure1.4Charge creation and transfer to memory

From the above figure we can conclude that CCD sensor is two-dimensional array containing photo detectors which convert light into charge. Metal oxide semiconductor capacitors characterize a CCD chip, where every capacitor speaks to a picture element (pixel). Every picture element is just like a container for electron to assemble. Either as electric charge or as light we store information on a CCD chip. Amid a presentation, every pixel contains that many electron as their measures of light falling on it. Then CCD takes account of light or electronic info and give an equivalent measure of analog signal. Resultant signal will then be prepared by some other hardware /or programming to either create a picture or come up with user relevant data.

The CCD innovation was produced particularly to be utilized as a part of cameras. We have been using CCD sensors for last 20-30 years. Customarily, CCD sensors and CMOS sensors had some focal points issues like, better light affectability and less commotion. As of late, be that as it may, these distinctions have vanished. CCD sensor have some issues like even after having simple segment it requires more electronic hardware outside the sensor, secondly CCD sensors are very costly and consume lots of power. This high power requirement prompts warmth problems in the camera, which sways picture quality adversely, as well as expansions the expense and ecological effect of the item.

1.2.2 CMOS

CMOS chips were used at an opportune time for capturing the image, yet poor picture quality was main feature of CMOS chip due to lower sensitivity of light. With advent of technology quality of CMOS sensor in respect of capturing an image is on a rise what's more, sensitivity of light of the sensors, have quickly expanded lately.

CMOS chips have a few points of interest. CMOS chip has all component inside sensor like amplifier, analog to digital convertor that bring down the size and expanse of camera as it has every one of the rationales expected to create a picture. Due to presence of electronic hardware inside sensor CMOS pixel has far more capacity and conversion electronics. Notwithstanding, expansion of this hardware inside the chip can prompt a danger of noise properly organized inside the image for example, stripes and different patterns. A quick readout property, with lower power consumption, noise safety and compact size all these feature makes CMOS sensors useful. Initial days of CMOS sensor was quite troublesome when it comes to aligning sensor but with the innovation in technology it is no longer a problem even some of sensors are self-adjusting.

We can easily extract a single picture element out of CMOS sensor, which permits ‘windowing’, that increase flexibility with sensor and we can easily have perused out the certain part sensor zone, rather than the whole sensor ranges on the whole. Along these lines a higher read out rate can be achieved even from a restricted portion of the sensor, and advanced processing techniques like tilt, zoom etc. can be utilized. We can also incorporate accomplish multi-view streaming that permits a few trimmed perspective regions to be seen at the same time from the sensor, reenacting a few 'virtual cameras'.

1.3 Application

In today’s world we see digital world is evolving and hence the problem to authenticate the real source of image. We have seen several cases of manipulation with videos (made of image), images. Also due evolution of internet it become even more troublesome for us to find source of data. So source camera identification find application in all those field where we assume forgery, tempering with the data, doubt over the source.

It can be used by image forensics.

It can be find the place in patent and right department.

1.4 Issues to Source Identification

We see as the compression of image takes place, different source identification techniques are not useful then. Even features based identification remains clueless when number of camera model increases. Techniques likes PRNU still contains lot of scene content which are bound to make our system scene variant. Also we incorporate one defect in simple PRNU technique, is color interpolation error which we remove in CD-PRNU. There are various methods also found wanting where nature of image changes. In simple feature based technique, we are still unsure which feature is contributing heavily in decision making. Limitation still exist in different real situation. There is a long distance to achieve the application level.

1.5 Problem Definition

In our research work, we have studied and implemented the four technique to identify the real camera source. These techniques are feature based, PRNU based, CD-PRNU based, Local Binary Pattern method. We have analyzed every techniques accuracies and their limitations. To measure the result, we have used Dresden's image dataset captured by different camera.

1.6 Thesis Organization

Chapter 1 has already described an introduction to source camera identification technique. This chapter discusses overview of camera basic, different types of image sensor, application of camera identification, and various issues regarding camera identification (Robustness and scalability is one of them).

Chapter 2 describes the basic concepts of Features based Technique, criteria for selecting feature with suitable example, issues.

Chapter 3 presents all about the PRNU and CD-PRNU techniques, their limitation, advantages.

Chapter 4 describes Local Binary Pattern method.

Chapter 5 presents all the results and Performance Analysis.

Chapter 6 describes conclusions and future scope.

CHAPTER 2

2.1 Feature Based Technique

One way to deal with the camera model identification is to determine unique properties called features [8] [9] [10] which assign the qualities related to certain digital camera, afterward utilize these properties for identification of source camera by applying on captured images Despite the fact that the shading picture development process may change broadly inside various makes of digital cameras, nonetheless, it is our belief that the yield picture is effected extraordinarily by the accompanying two parts:

1. CFA setup and the demosaicing calculation

2. The shading processing /transformation

Due to these processing technique, a signal of RGB band certainly produces definite attributes and examples paying little mind to the original picture content so as to catch the uniqueness of fundamental color qualities for different cameras we should pay our attention to digital image's first, second, and potentially higher order insights captured by these cameras.

In result, a determining model was worked for picture distinguishing proof by ordering these picture feature. This study has utilized an aggregate of different characteristics for separating the real camera from other ones. Here we group these features into three class namely (i) color, (ii)image quality matrix, (iii)wavelet [11]. Every element is assigned with an uppercase alphabet: ‘‘C’’ for color highlights, ‘‘Q’’ for picture quality components, and wavelet features are represented by ‘‘W’’. These components are definite in the accompanying passages.

2.2 Color feature:

2.2.1 Average pixel value

It depends on simple logic that all color component of RGB filter array averages a unique gray value, expecting that the pictures have enough shading varieties. Consequently, the elements are the mean estimation of the 3RGB channels. This counts as first feature.

2.2.2 RGB sets correlation

With RGB sets correlation we are trying to find out relationship between various color segment of different camera changes as per camera. Every correlation between color counts as single feature (RG, RB, BG).

2.2.3 Neighbor distribution Center of mass

Neighbor center of mass will be ascertained for every shading channel independently. We start by computing the total number of pixel neighbors for every pixel strength, each pixel will be characterized as pixel’s neighbor which has a difference of 1 or - 1, from the pixel being referred to. We have seen that for a comparable picture two distinct cameras have a fundamentally the same as distribution level, one is the moved variant of the other, see

Figure2.1. So we figured the focal point of mass of gives us a sign of the sensitivity of a camera.

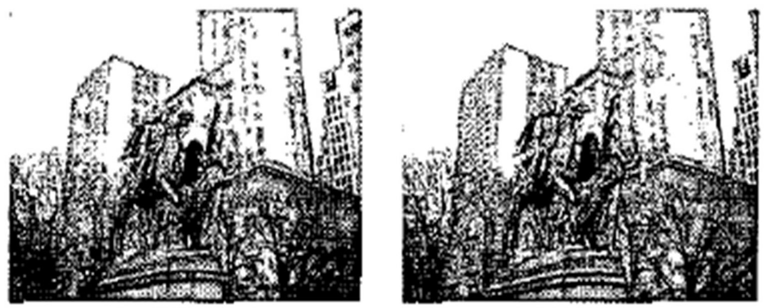

Figure2.1 Image showing center of mass for different camera

2.2.4 RGB Pairs Energy Ratio

We also find out the energy ratio of different combination of color channel. It is important aspect of camera. There will be three feature calculated as:

E_1=|R/B|^2, E_2=|R/G|^2, E_3=|B/G|^2

2.3 Image Quality Features

We exploit the original image and its denoised version image to find out color features. For point distinction of pictures, the picture quality element which incorporates three different methods as follow: (i)pixel difference-based method, (ii)correction based and (iii)spectral based measures was embraced. These components are recorded as takes after.

First method based features are: Mean square error, Minkowski error, Mean absolute error. Correction based features are: Structural Content, Normalize Correlation. Spectral based features contain: Spectral Phase-magnitude Error Block spectral magnitude error, Spectral Magnitude Error, Spectral Phase Error, block spectral phase-magnitude error, block spectral phase error.

2.4 Wavelet Based Features

A picture can be represented both in frequency domain as well as spatial domain. We use different transform technique like Fourier, Laplace, Wavelet etc. But with wavelet transform we may able to achieve both time and frequency resolution. We decompose each shading band of picture into 4 sub-groups. At that point, we take mean value for each of high frequency decomposed group. So for each band we have three features and in total 9 acquired as: W1, W2, W3, W4, W5, W6, W7, W8, W9.

2.5 Algorithm:

A. Distinctive cameras were utilized to take set of pictures individually; some of them are outdoor scenes and the others are indoor scenes with various inclination angles. The indoor also, open air scenes are pre-dissected for grouping.

B. Every picture feature was computed and recorded.

C. 10 pictures were haphazardly chosen from each class and utilized as a part of the classifier plan stage. The gotten classifier was then used to order whatever remains of the pictures.

D. At last we test the network classifier and continue the weighting of the three classified features until we achieve accuracy and no further change.

2.6 Issues

After selecting the features, we sort out the feature suitable for purpose. The total contribution of each type of feature should be assessed keeping in mind the type of image database (as with database texture the weightage changes). The possible issues are as follow:

A. **Natural light**: Digital cameras embrace distinctive picture development model under various lighting atmosphere. For instance, the ISO value will be much less in indoor scene and the noise signal will be limited in the same time when the photos are taken outside. Consequently, diverse setups will impact the arrangement of pictures.

B. **The design of CFA:** Diverse cameras have different CFA setups. Be that as it may, these setups are industrially mystery with little points of interest and won't be discussed here.

The Identification strategy is influenced by comparable camera models or the same CCD. At the end of the day, if cameras are of the same brand and having a place with the same item arrangement, the distinguishing proof results between them will be influenced subsequent to the center core may be alike.

Furthermore, many brand may share comparative basic part that may impact our identification problem. This similarity is because numerous camera manufacturer uses same basic component made of common supplier. So to achieve more preciseness we require camera model from different producer. In any case, present results have demonstrated that features based methodology could distinguish the camera source successfully crosswise over brands even as far as possible still exist.

CHAPTER 3

3.1 PRNU & CD-PRNU

As shot scratches permit forensic inspectors to coordinate a bullet to a specific barrel with unwavering excellence sufficiently high to be acknowledged in courts, a digital alike bullet scratches ought to permit solid matching of a digital picture to a sensor. We propose to utilize the sensor design noise as the obvious "scratches" and demonstrate that recognizable proof is reality even from processed pictures.

The issue of digital picture validation might be drawn closer from a few unique features. The least difficult method is to look for something inside the image itself, it is even possible if we see the hints in header or other present information related to image. If we take an example, in EXIF header we find out camera information, atmosphere in which image captured (exposer, date and time, and so on.). Extra info is also available if we use quantization table in the JPEG header (altered quantization matrix is used by some cameras).

The problem with header information is that if picture is resaved in an alternate format its header will be changed. So our reliability on header information is paralyzed. While the thought to embed the "shot scratches" as a watermark straight forwardly into every picture the camera takes is a rich and enabling answer for the picture verification and camera recognizable proof issue, its application is restricted to a close atmosphere, for example, "secure cameras" for taking pictures at wrongdoing scenes.

Under these controlled conditions, such secure cameras can, in reality, give an answer for the proof of evidence integrity and source. This methodology, be that as it may, can't take care of the issue completely unless all cameras either embed watermarks or implant secure hashes in their pictures.

Another already researched methodology is investigation of pixel imperfections. First of pixel imperfection contributed by hot pixels (dead pixel), could be exploited for dependable source camera distinguishing proof even from compressed JPEG pictures. Notwithstanding, there are cameras that don't contain any of such pixels as due to post-processing we remove out the damaged pixel. For such cameras or sensors, this technique can't be employed.

Now we take the case of pattern noise [12] [13] which even survives above post-processing techniques. In any case, one method is possibly usage of this noise – the dark current noise (additionally called fixed pattern noise), which is a signal gathered from the sensor when it is not presented to light. Dark current must be mined from dull frames. This confines the technique on the grounds that, camera distinguishing proof is unrealistic from normal (non-dull) outlines. The fixed pattern noise is just a little part of the pattern noise. Another, and much robust part that better survives processing, is the pixel non-consistency noise brought about by inconstant sensitivity of pixels to light. The technique proposed in this chapter fundamentally depends on this segment. We take statistical moment of obtained PRNU or we can find out the correlation between PRNU of different sample of different camera.

3.2 Signal Processing in Digital Camera

Soul of each digital camera is imaging sensor, and this sensor has been partitioned into small picture element which can be addressed called pixel. This pixel as explained earlier gather light illumination and translate charge induced by these photons into voltages. This voltage level will be analog signal and by the help of analog to digital converter we get digital equivalent. Before light passes through the sensor it has to face camera lens, an antialiasing (obscuring) channel, and after that through a shading channel cluster (Color Filter Array). Function of CFA is such that it blocks specific bit of band, permitting only one color value to every pixel. Only one sensor that does not utilize color filter array is Foveon™ X3 sensor and can catch each of the three essential hues at each pixel.

As sensor allows to pass single color through, it require to generate original scene to by combination of all three colors hence different color interpolation scheme is employed to get every one of the three essential hues for every pixel. After that we processed the resultant signal for white balance correction and color revision. We can do more with the processing of picture like for image sensor we can make linear response by gamma correction and much more as per requirement. At last, we get the digital image and store it inside camera memory in predetermined format. It will may require extra handling, for example, JPEG compression.

3.3 Noise in Camera Image

There are various wellsprings of flaws and noise that go into different phases of the picture capturing process above. Regardless of the possibility that there will be less changes in intensities of individual picture which are taken after one another. Even if there some change presents it will be due to shot noise (otherwise called photonic noise), which is an irregular segment, and somewhat as a result of the pattern noise – a deterministic part which remains as it is if various photos of precisely the same scenes are taken. Because of above mentioned feature, the pattern noise will be regular feature of camera in every image captured and subsequently can be utilized for camera ID. Since the pattern noise is a methodical mutilation, it might create the impression that it is inappropriate to call it noise. All things considered, by slight misuse of dialect, the pattern noise is an entrenched term in the imaging sensor writing and we acknowledge this wording here also. We take note of that averaging numerous pictures decreases the irregular segments and improves the pattern noise.

Primitive legs of pattern noise to stand on are namely photograph response non uniformity(PRNU) and the fixed pattern clamor (FPN) (see Figure3.1). Second of noise part comes from dark current. Dark current is response of photodetector array response when it is not illuminated. Since it is an added noise, in processing stage camera remove out these portion by subtracting every image from one reference non-illuminated image. Exposure and temperature and are two pillars of FPN noise [14]. In regular pictures, we now have to rely on photo response uniformity noise for our uniqueness of camera.

It is brought about essentially by pixel non-consistency (PNU) [15], that is characterized by inconstant sensitivity or different behavior sensor basic element (pixel) to illumination created by the silicon wafers inconstant behavior and defects amid the process under which sensor produced. So all those about source and character of the PNU noise make it highly unlikely that sensors originating even from the same silicon wafer would show corresponded PNU pattern. In that capacity, the PNU noise is not influenced by encompassing temperature or stickiness.

Dust elements refracts light and optical (lens setting) surfaces and zoom settings additionally becomes a part of PRNU noise. All these additional noises are of low frequency content. Generally, we don't use these noise as part of sensor for distinguishing proof and hence we try to remove out these noise part by suitable low pass filter, and just utilize the PNU segment, which is an inborn distinctive property for the sensor.

3.4 Mathematical model of image

If we consider I be the output image of camera and I' be the noiseless image. Let all another noise present in camera is represented by N. PRNU of picture is K*I' as it is a multiplicative noise and K is PRNU number. So the image can be represented by equation (3.1):

$$\boldsymbol{I} = \boldsymbol{I} + \boldsymbol{K} * \boldsymbol{I} + \boldsymbol{N} \tag{3.1}$$

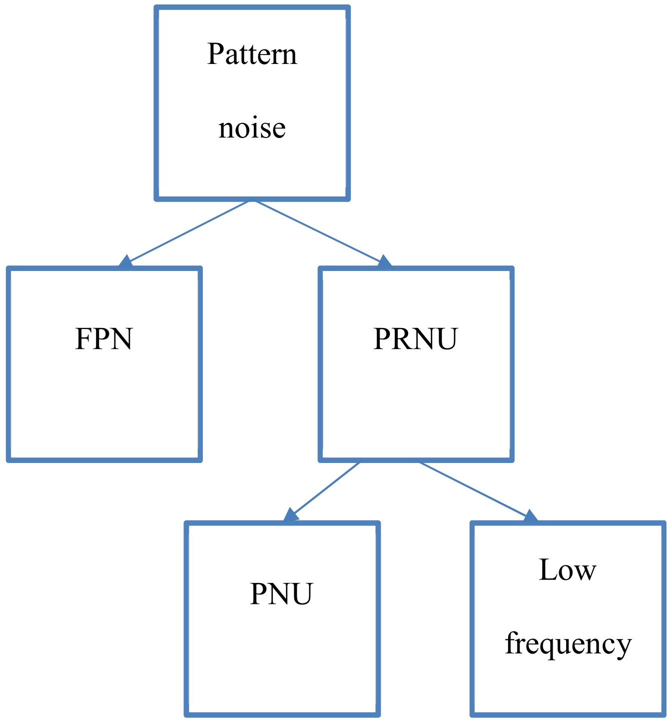

Figure3.1 Pattern noise of camera sensor

3.5 PRNU Calculation

Being brought on by varieties in development and material of basic sensor element, PRNU appear as a high frequency content results. To remove out the high frequency pattern P', we convolve the image with low pass filter and then remove it from original image as described by equation (**Error! Reference source not found.**)

$$P' = I - F * I \qquad (3.2)$$

where F is a low-pass channel with * indicates convolution.

Here Gaussian filter of suitable variance σ^2 is used to remove out low pass content. It will work as wavelet based filtering does, yet requires less calculation time.

If we use wavelet domain denoising technique then we denoised the original image I to get I' and we denoised image from original image to get pattern noise (3.2), i.e.

$$Idenoised = I - I \tag{3.2}$$

3.6 Data Mined Along with PRNU

3.6.1 Scene Content

If we apply high pass channel to get PRNU (as it is high frequency content) certain scene content will also part of PRNU. As needs be, a piece of the scene substance would be considered PRNU. As is unmistakable in Figure3.2, this additional substance is altogether more grounded than the genuine PRNU. We require comprehensive method to remove this scene content.

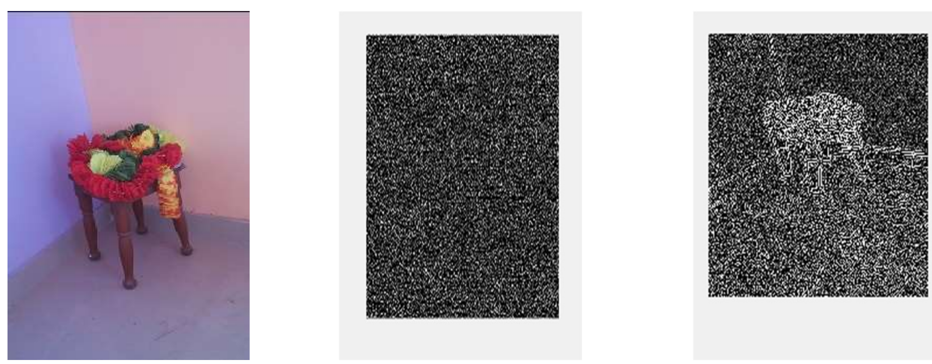

Figure3.2 PRNU Image for test image (a) original image (b)represent clean PRNU(c)represent scene with content

3.6.2 Reference Pattern

In our situation main concern is how to make our PRNU accessible without the scene content influence and make a reference pattern. There are different methods [16] we can give a shot like using flat field photos. After a sensor is constantly lit up by light we get a flat field picture which has very less scene influence. All that info present in above mentioned image is along these lines an aftereffect of PRNU or stochastic noise. Following Eq. (3.3), represent the intensity of certain pixel (j, k) in image I after consistently lit up the sensor.

$$I(j,k) = P(j,k) * C + N(j,k) \tag{3.3}$$

in which C is a steady strength because of the uniform light. Notwithstanding, consummately uniform enlightenment is not effectively accomplished as the sensor and the lens offer ascent to vignetting, lower intensities values towards the edges of the picture. Indeed, even if we remove the optical part out of camera, flat field is difficult to achieve as this requires a uniform strength light parallely falling on sensor. Amending these impacts on PRNU is not so simple just to raise or bringing down the intensity of certain zones as it will also influence the PRNU and noise levels too. Our PRNU of camera is high frequency noise so if try to find it out using Gaussian channel, it should have a high cut-off frequency.

In this manner, we don’t require the reference image to be great flat field pictures until we have all the details is in lower frequency area than PRNU. Consequently, just a simple high-pass channel can be enough to serve the purpose of removing PRNU from reference pictures; we shot a white sheet of paper in glaring light under shifting points to stifle any conceivable steady commitment due to scene content. Where conceivable the cameras were defocused to further maintain a strategic distance from any point of interest.

One simple technique to clear out the scene content from resulting PRNU image is to average out the high frequency component that effectively decrease scene content effect of image (however scene content will still be in picture but with lower magnitude).

Other method can be a correlation between clean PRNU image patches by patches (like 8*8 neighborhood) with the PRNU contain scene. Wherever correlation value is lower we remove out the that portion or average that particular portion. In this manner we can make PRNU technique scene independent.

3.7 CD-PRNU

Despite the fact that PRNU has ended up being an achievable unique mark for real origin of camera as a recognizable proof, also the integrity of content in check, only one point to research on is shading channel array (color filter array) usage in digital cameras. The picture obtaining procedure of an average digital camera has explained above, here every color does not form a part of each pixel physically. Rather, every pixel, uses only one color channel for representing the color, then by 2 × 2 shading design (the part of Color Filter Array), as represented in Fig. 3(a). At last we use an interpolation matrix (IM) [17] [18] [19] [20] to get the missing shading segments by including the adjoining pixels as indicated by the Color Filter Array. We use physical segment for every pixel with same shading as that of relating component of Color Filter Array, what's more, artificial or interpolated shading for rest of two component of color. Issues regarding conventional PRNU withdrawal method are:

• our method assumes both counterfeit and physical segment in one go without assuming the need of separation.

• every wavelet coefficient change utilized as a part of the PRNU extraction process includes numerous pixels, hence include again physical and artificial parts. In the process physical segment will be having more noise thanks to artificial component of shading channel of image.

Since the interpolation operation is not straightforwardly employed to acquire the artificial color from the scene by physical portion, we assume that intrinsic noise pattern called PRNU is free from real parts. And hence much more dependable as compare to artificial channels, that is source of noise added by interpolation. In view of the suspicion there came improvement in previous PRNU extraction method called an enhanced Color-Decoupled PRNU (CD-PRNU) taking out technique. In this method we divide every shading channel into 4 sub-pictures thereafter concentrates on PRNU noise from every sub-picture. Then we collect all the noise pattern of each sub-image to perform color-decoupled PRNU.

To take CD-PRNU out, we separate all shading channels(three) I_c, $c \in \{R, G, B\}$ of a shading picture I of $J \times K$ pixels. As Color Filter Array comprises of rehashing pattern of 2×2 pixels as appeared in Figure1.3. What we have is three color channel for each pixel where one is real and other are fake, hence we perform down sampling for every color channel present in image see eq (3.4). Sampling will be performed both horizontal and vertical dimension to get four sub-pictures, $I_{c,i,j}$, where i and j ∈ {0,1}, such that

$$Ic, i, j\ (x, y) = Ic\ \ (2 * x + i, 2 * y + j) \tag{3.4}$$

where x, ∈ [0, J/2 −1], y∈ [0, K/2 −1].

$n_{c,i,j}$ called PRNU noise, is taken out from every sub-pictures $I_{c,i,j}$, where ∀ i and j ∈ {0,1}. In spite of the fact that, for every color channel, I_c, in spite of knowledge of Color Filter Array utilized by the producer, we are unaware (really we don't need to know) that physical color caught by which pixel and artificial by whom. We decompose picture I_c, into four sub-pictures, $I_{c,i,j}$, we can estimate that the obtained pictures contain only one physical color and rest contains virtual color. So at last we can remove the interpolation error from the physical segment by taking the above procedure and taking wavelet transform process for denoising.

How to get these four sub image and whole algorithm is explained by Figure3.3. Here we consider a test image and by the Bayer CFA consideration makes four matrix of image. The figure shown in next page is for green channel, for other two channel we apply same procedure and get the CD-PRNU of whole image.

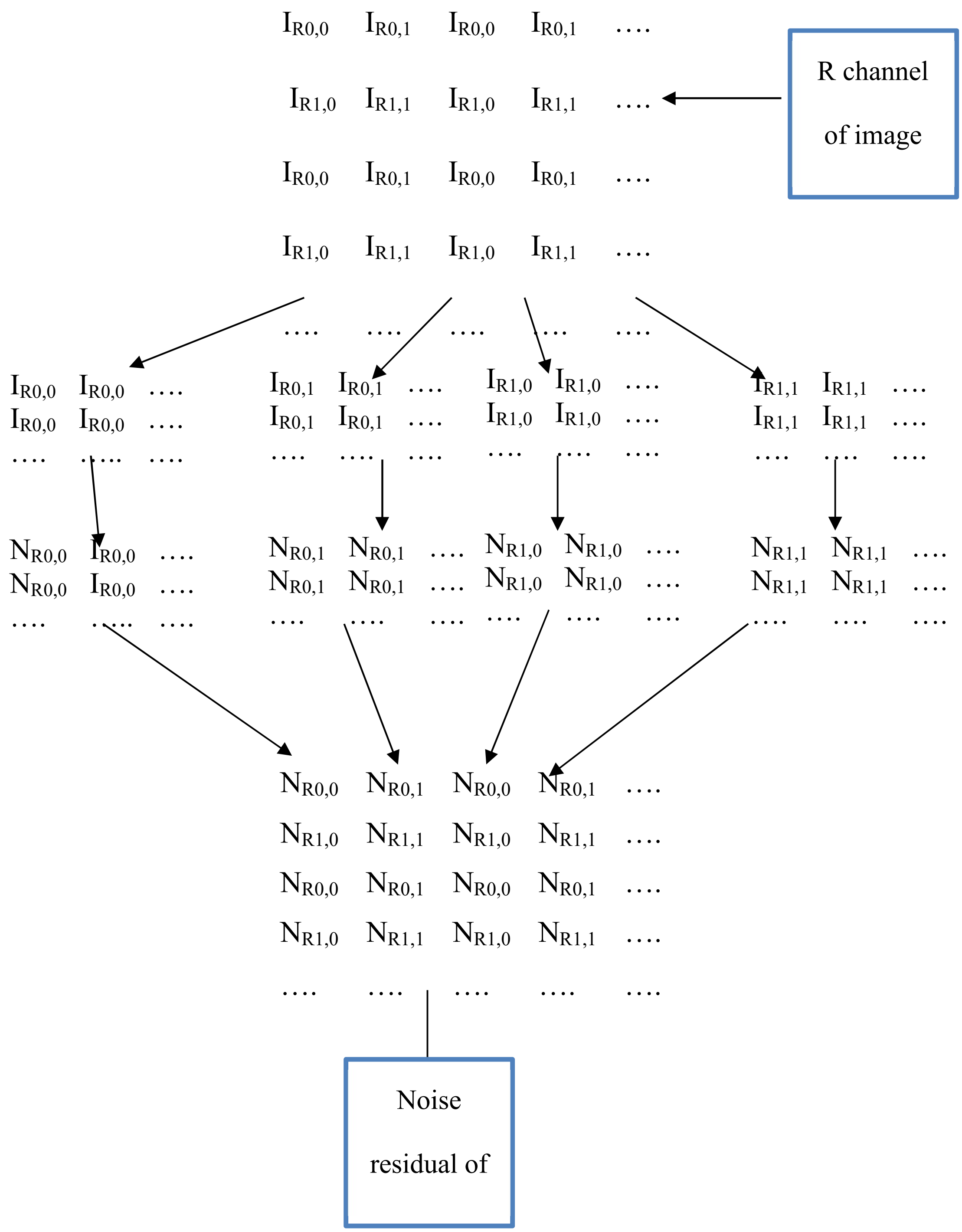

Figure3.3CD-PRNU mechanism

CHAPTER 4

4.1 LOCAL BINARY PATTERN

After the above discussed method, we still remain doubt that when a scale factor [21] [22] [23]of image will change, PRNU and CD-PRNU are reliable or not. We have used a solitary example strategy to identify camera with the help of local binary pattern (LBP). We find the uniform binary code from the red and green channel and form a feature vector to identify the source camera and also the wavelet transforms and the leftover of the picture. The leftover (residual) picture is acquired by subtraction of the anticipated picture from the original picture. We have also taken account of different scale image and local binary pattern robustness against it. In this way, the framework can't be legitimately solid in nearness of low quality pictures or purposeful altering and resaving the picture in photograph processing programming. Our examinations on recreation of this methodology demonstrate that, this method falls pray when the quality of training and test sets quality elements quality are not the same. Albeit twofold JPEG distinguishing proof calculations may uncover this handling, in any case, they can't predict source of caught picture.

4.2 Inspiration

Till now all those proposed methods are not robust against different compression techniques [24]. We cannot guarantee that these techniques predict right source of camera. The problem become much more critical when JPEG header information can also be changed during the compression. So we try to solve this problem by applying the local binary pattern. It has been effective in predicting the right camera even after compression of image.

4.3 Intensity Invariant Local Binary Patterns

Local binary pattern is stretched out to intensity invariant [25] [26] [27] so as to speak the texture of pattern data. In reality, texture data might be ordered into pattern and intensity info. For pattern data our LBP will serve the purpose, even it has no effect of intensity. Application of method is in different machine VISION examination, ID and order applications.

LBP is applicable to grayscale image even if our image is nor gray scale we can either convert it into gray or apply same method to each of channel of image. The quantity of pixels in every piece relies on upon the quantity of neighbors and the neighbor sweep. Neighboring pixel along with threshold makes our LBP code. Threshold value is decided by the intensity of the focal pixel or a pixel out of the piece.

Normally, we take the central pixel as threshold value that whenever in neighborhood pixel has higher pixel value than the central value we take it one else take is zero, and place the value at same place. For our situation, we take a 3*3 neighborhood of pixels. After that we apply above procedure to assign binary codes to each pixel depending on their pixel value. Figure4.1 indicates customary neighboring methodologies where the first (a) was utilized as a part of this study. White center around figures indicates are the limit and other dark circles are neighbors. The range of neighbors is one in (a) and the quantity of neighbors is eight which is signified as a (8,1) LBP. So also, different strategy is named as (16,2) LBPs.

LBP code of a pixel is taken out by following method where a square block's center pixel is compared with all remaining 8 neighboring pixel and code is assigned. As the number is assign is in form of 0 and 1 so we call it binary representation. In Figure4.2, a case of LBP square picture and LBP code extraction is illustrated.

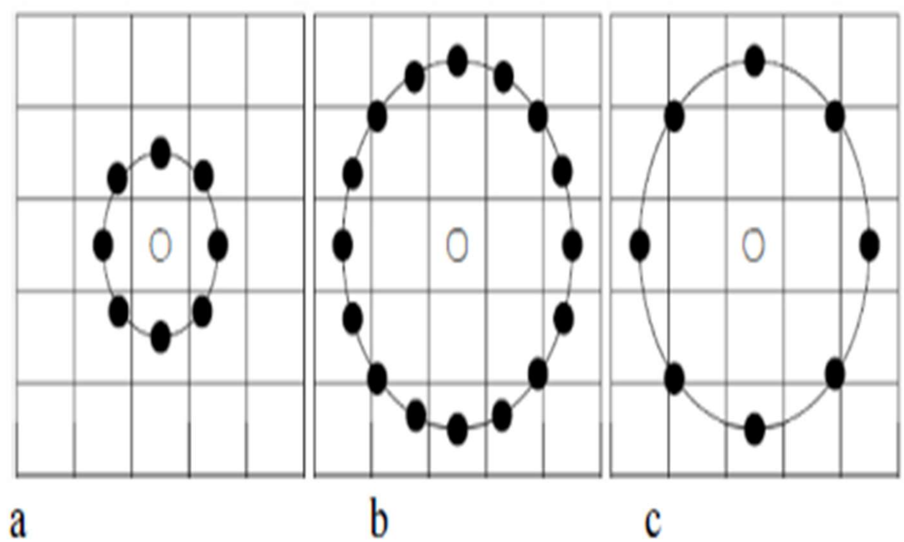

Figure4.1 Circular neighborhood (a) 8,1(b)16,2(c)8,2

We have two type of codes namely: (a)uniform Figure(a) and (b)non-uniform codes Figure(b). If a code has only two transition present in it i.e. from 0 to1 and 1 to 0 then it will be called as uniform code. Uniform codes are vital in light of the fact that they shape no less than 80% of LBP codes of a picture. Furthermore, with the help of uniform code if plot histogram plots we find it extremely useful in texture representation in a picture. On the off chance that the

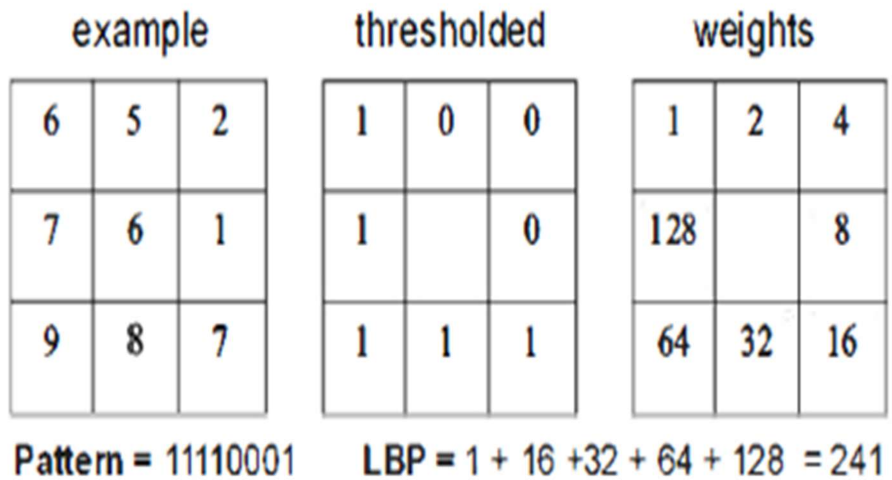

Figure4.2LBP Code generation

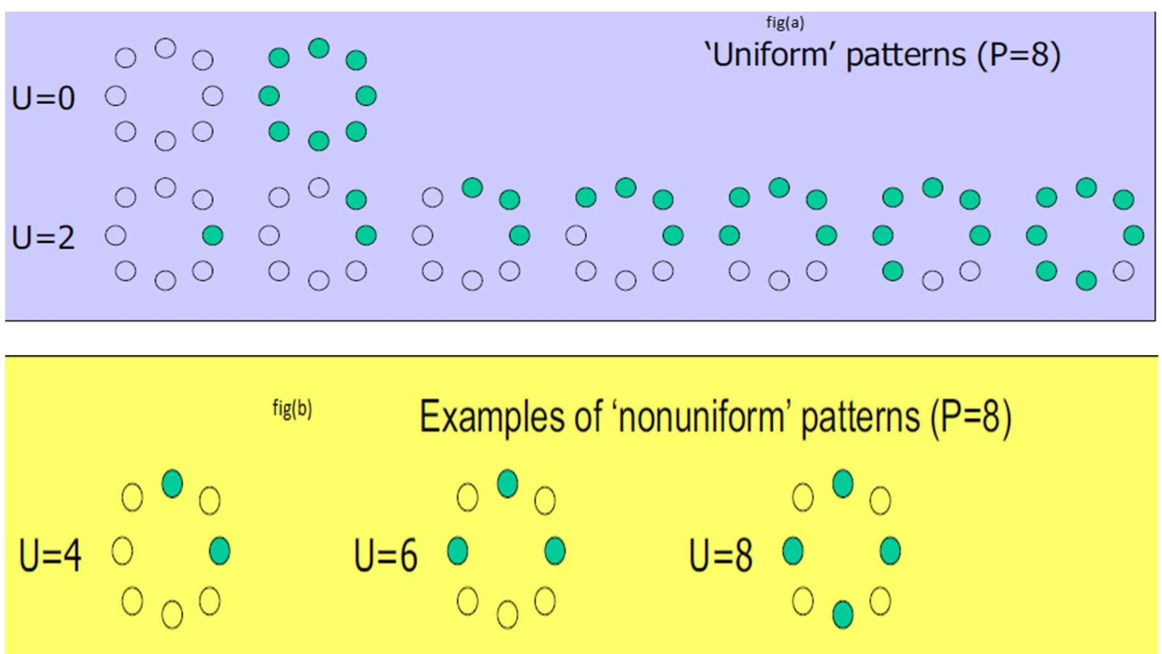

Figure4.3 representing different code (a) uniform code (b) non-uniform code

quantity of neighbor is i for a focal pixel, the quantity of conceivable uniform codes is i*(i- 1) +3. On the off chance that p is equivalent to eight, the quantity of uniform codes is 59 furthermore, no less than 90% of LBP codes are uniform.

In following Figure4.5, we observe the effect of binary representation. To form LBP code, we take 2^k as weight effect as can be seen in following (0.1).

$$LBPk,r(Xc,Yc) = \sum_{k=0}^{k-1} S(gp - gc) * 2^k \tag{0.1}$$

Where k hold account of neighbors and s(x) is step function (0.2);

$$\boldsymbol{S(x) = \{1; x \geq 0} \tag{0.2}$$

And g_k, g_c are central and neighbor pixel respectively.

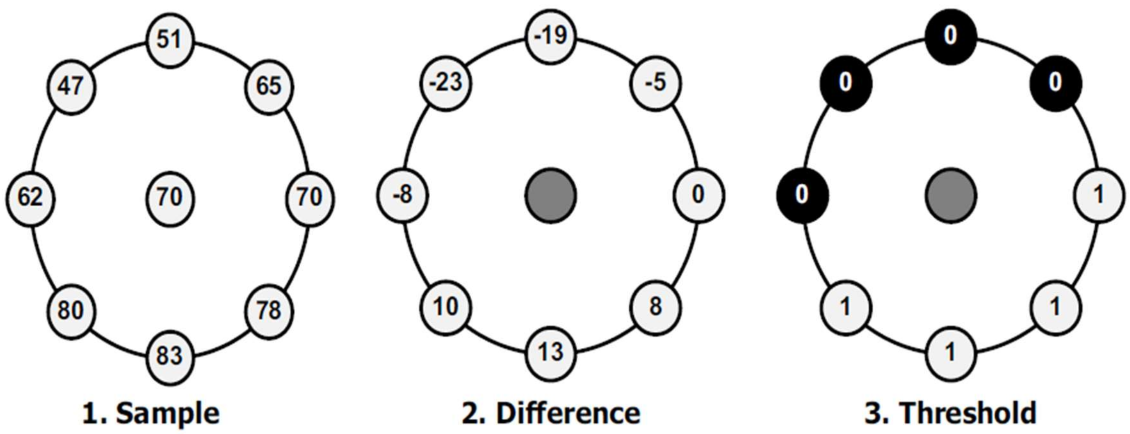

Figure4.4 working of a circular neighborhood by above mechanism

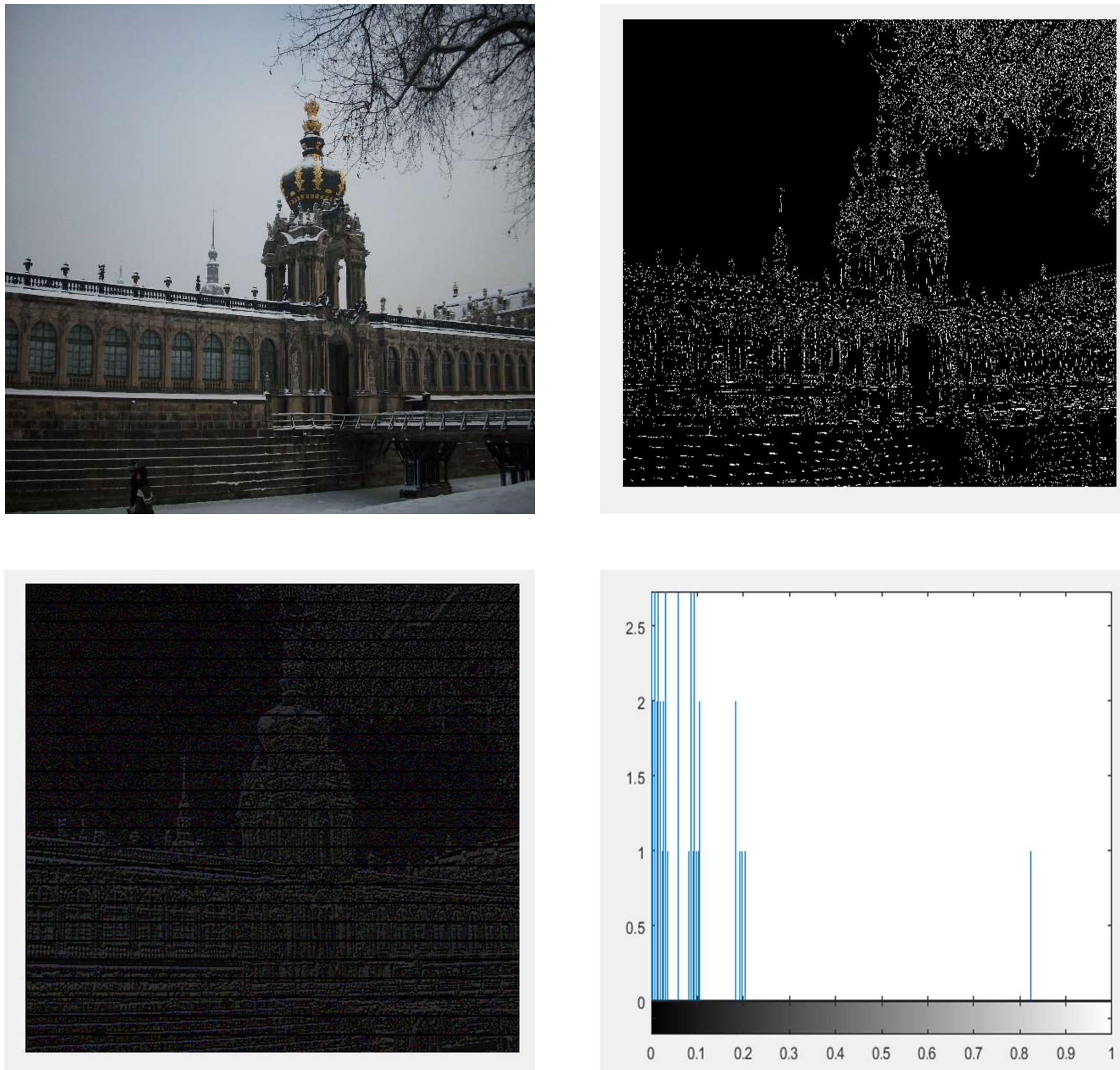

Figure4.5 LBP and edge info of image(a)original image(b)edge of image(c)LBP pattern of image (d) histogram of image

4.4 Purposed Feature Extraction Method

Our main source of inspiration of using this feature model is its great capacity to represent the texture properties even not influenced by intensity variation. The one of the inimitable attributes of a camera can be seen in texture pattern like how different pixel are distributed their symmetricity etc. and it is provided by LBP and all this by disregarding the pixel intensity variation.

We have also utilized the PRNU as the unique camera mark for identification of camera but it has lots of limitation like its influences the pixels' luminance level, particularly in edges. We see that its forms the higher frequency in frequency spectrum. Also scene content present in same region which makes it cumbersome task. So our purpose method aggregates all those features of PRNU and even powerful against picture content changes.

Past results prove that red and blue channel have fundamentally same behavior; Therefore, we dismissed blue direct in this study. So we use red and green channel to find our LBP code. At last we make use of Sobel edge detection technique and thereafter finding out the LBP code for each color channel separately and form a feature vector to identify correct source camera. In this study, we utilized LBP codes with eight neighbors and the focal pixel as the threshold [28].

4.5 Block Diagram of Method Used

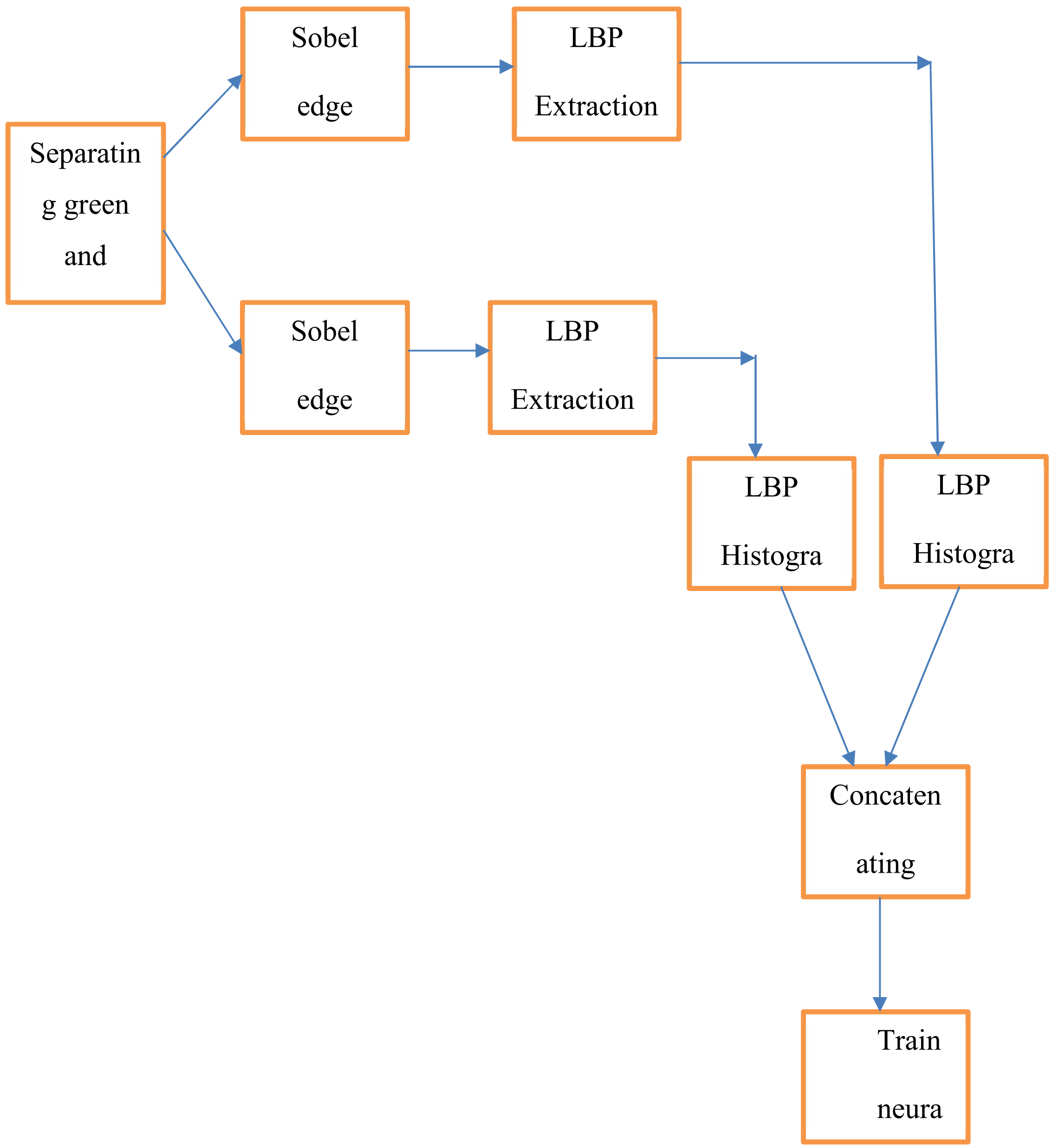

Figure4.6Block diagram of LBP

CHAPTER 5

5.1 Experiment and Result

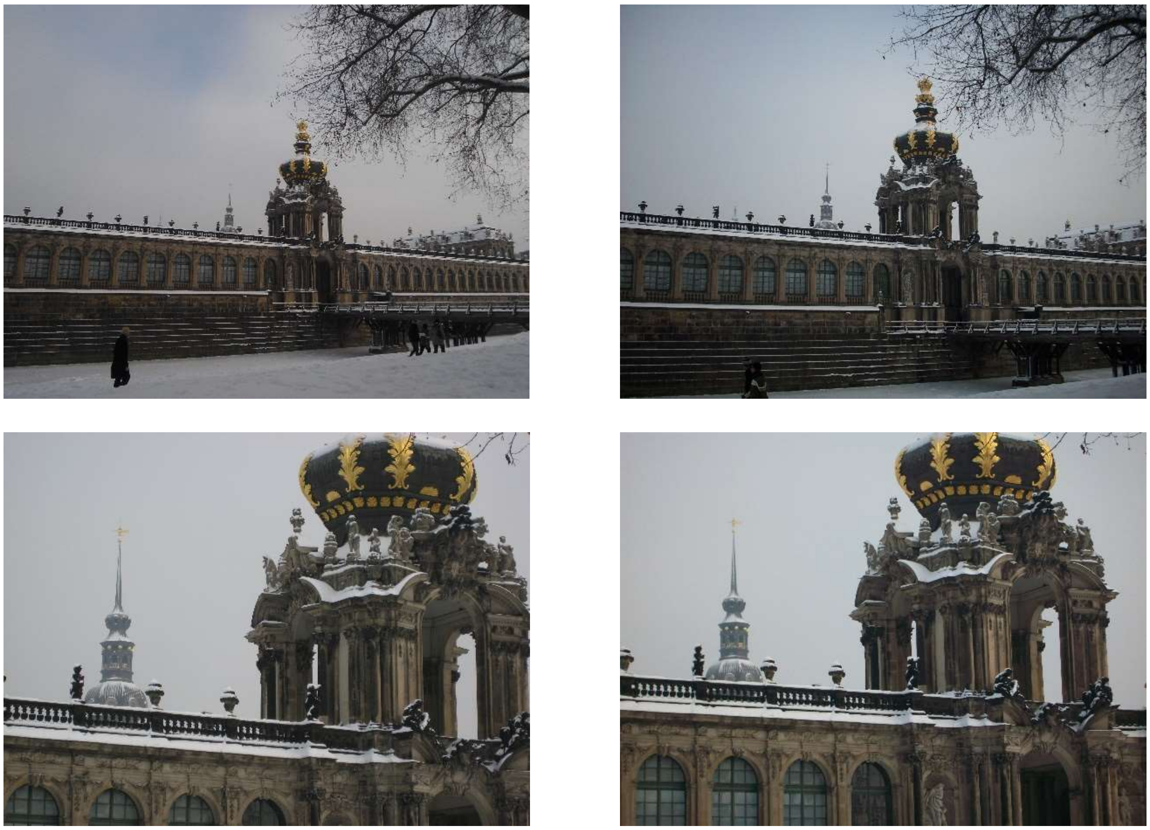

Figure5.1 few example of Dresden's image dataset used in experiment

5.1.1 Feature Based Identification

We take a database for feature extraction of Dresden's image dataset of nine different class. We use 70% image to train our classifier. First we train it for two model only and it gives us the quick result and accuracy high but we then increase the number of model to check the robustness of our method and we get accuracy as high as 91% and validation up to 94%.

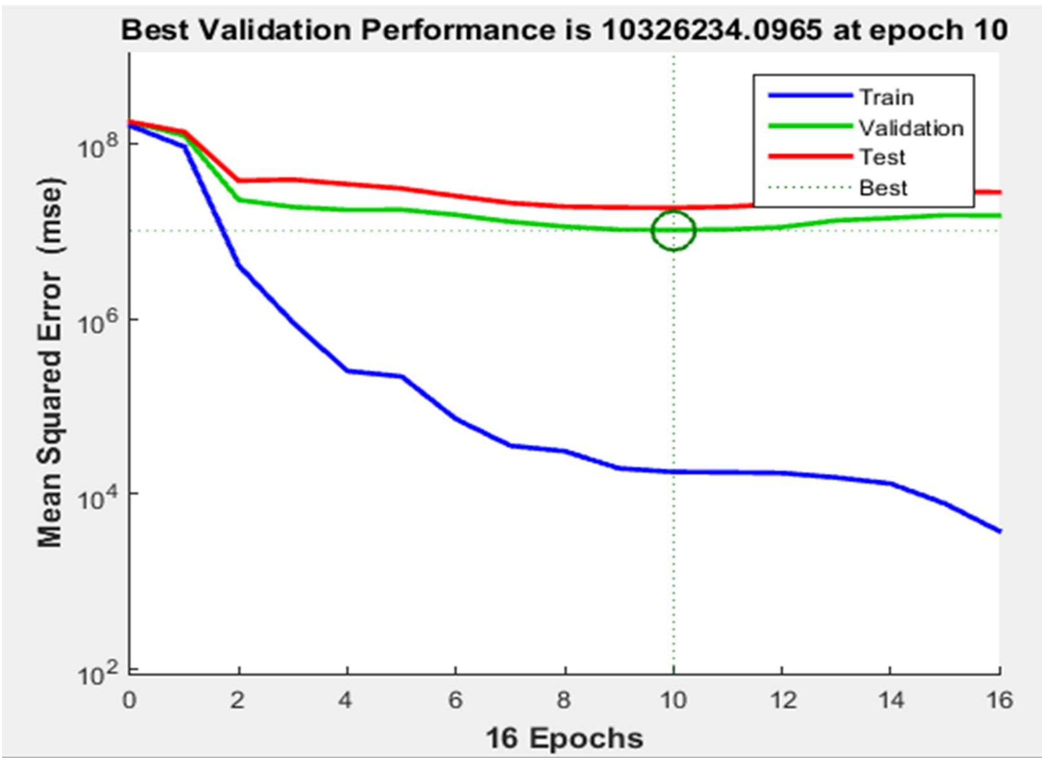

Figure5.2 mean square error between train test and validation

Its overall accuracy is 94.58%. We have shown some of the images of Dresden's dataset image captured by different camera at certain angles in Figure5.1. In Figure5.2 we observe that best performance comes after ten epochs where validation matches the ideal value.

(Here dashed line represent perfect result-output=targets. The solid line represents the best linear regression line between the outputs and targets. R represents the closeness of dashed line with solid line. If R=1, this indicates that there is exact linear relationship between outputs and targets and if R is close to zero then there is no linear relationship between outputs and targets).

We can also improve our results by initializing the network and then train again. We can also increase the number of neuron in hidden layer. In this we have used 15 neurons. In Figure5.3 we have R value of overall is .94 which is quite good.

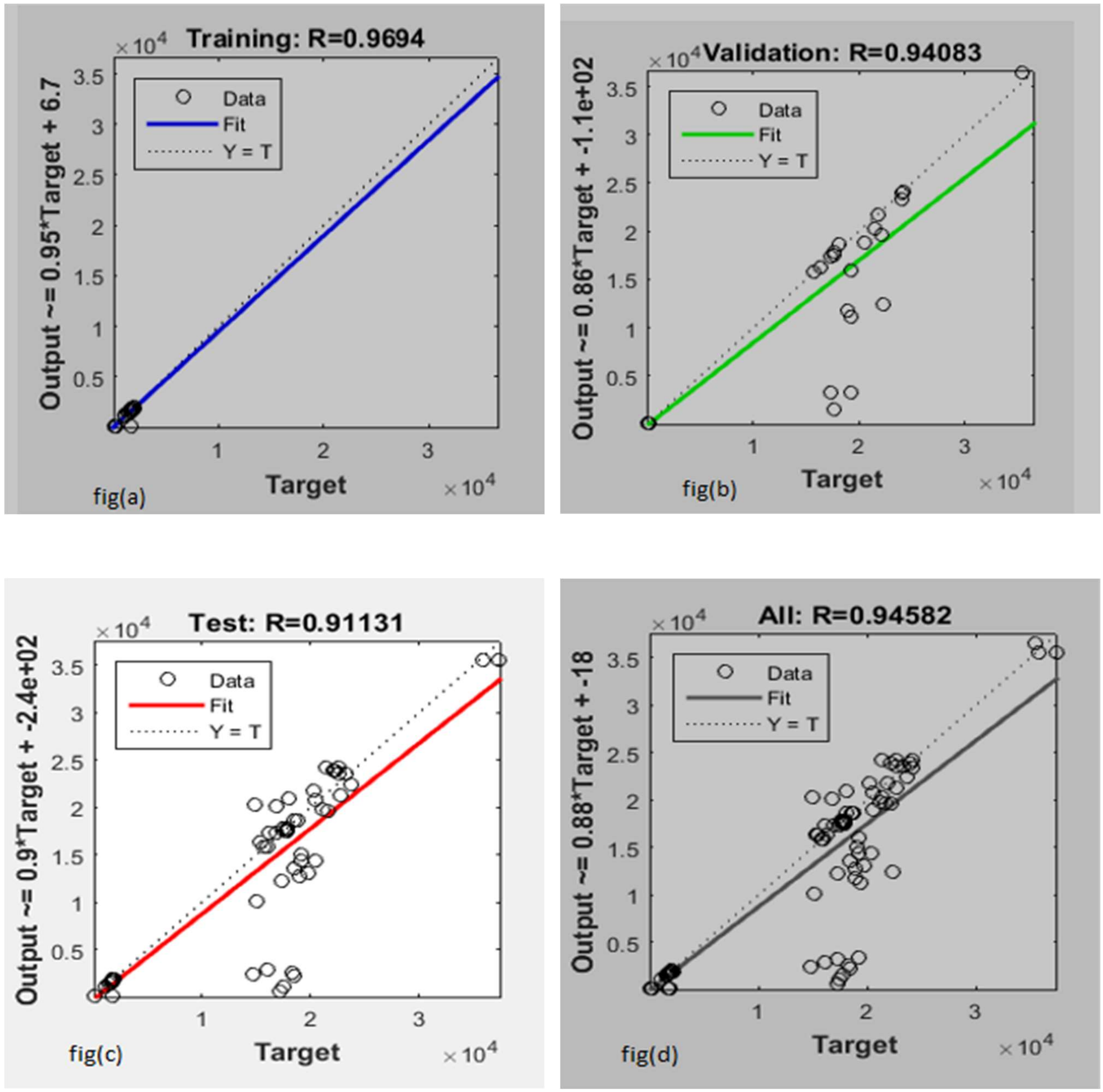

Figure5.3 result of neural network for feature based detection

5.1.2 PRNU & CD-PRNU

We can implement the PRNU via two methods, firstly by finding out the reference pattern (obtained from various image taken by a single camera model) and finding out the correlation with the test image PRNU. We use generally blue sky image as it has less variation hidden inside picture. Secondly via calculating the feature of obtained PRNU image in form of statistical moment like mean, standard deviation, skewness. We don't go for much higher moment as purpose can be served by these only. We can incorporate these features with above mentioned feature based technique and can try out the effectiveness of method. In this we used all above feature to train neural network and test the performance of our method see Figure5.5 & Figure5.4. Figure5.4 physical interpretation is how close on average, the hyperplane drawn by our network gets to the actual cloud of data in our validation set. Now from the Figure5.4 we can have the idea that at 14 epochs itself our data is approaching the real value and it is only half of story and rest will be explained by the Figure5.5 .

From Figure5.5(a) we has testing accuracy of 98.63% and 5.4(b) validation of our method is 98.49%. overall accuracy is around 98%. (Here dashed line represent perfect result-output=targets. The solid line represents the best linear regression line between the outputs and targets. R represents the closeness of dashed line with solid line. If R=1, this indicates that there is exact linear relationship between outputs and targets and if R is close to zero then there is no linear relationship between outputs and targets).

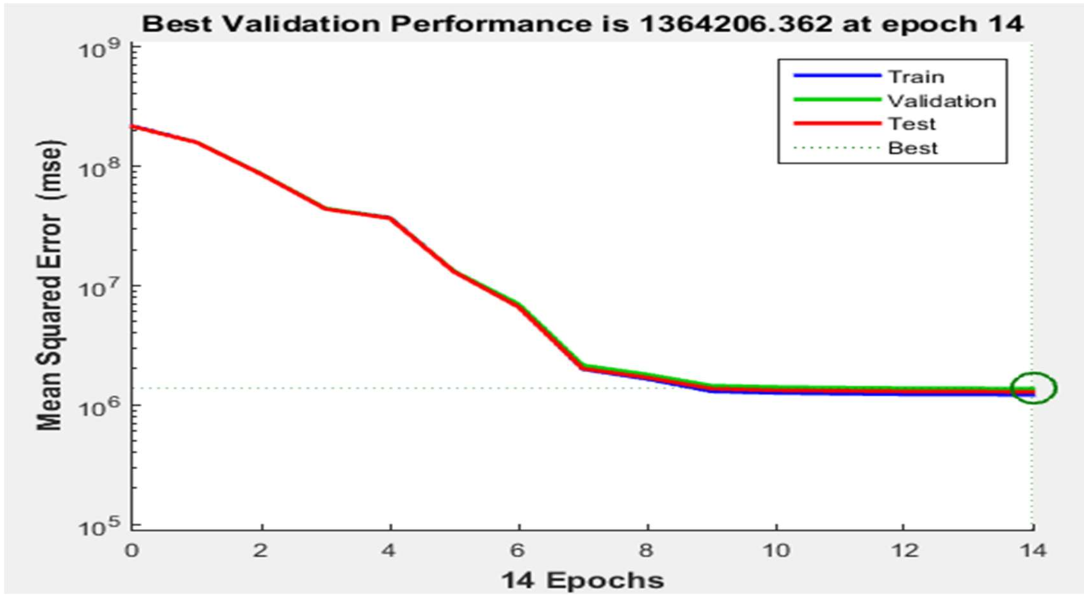

Figure5.4 PRNU mean square error between train test and validation

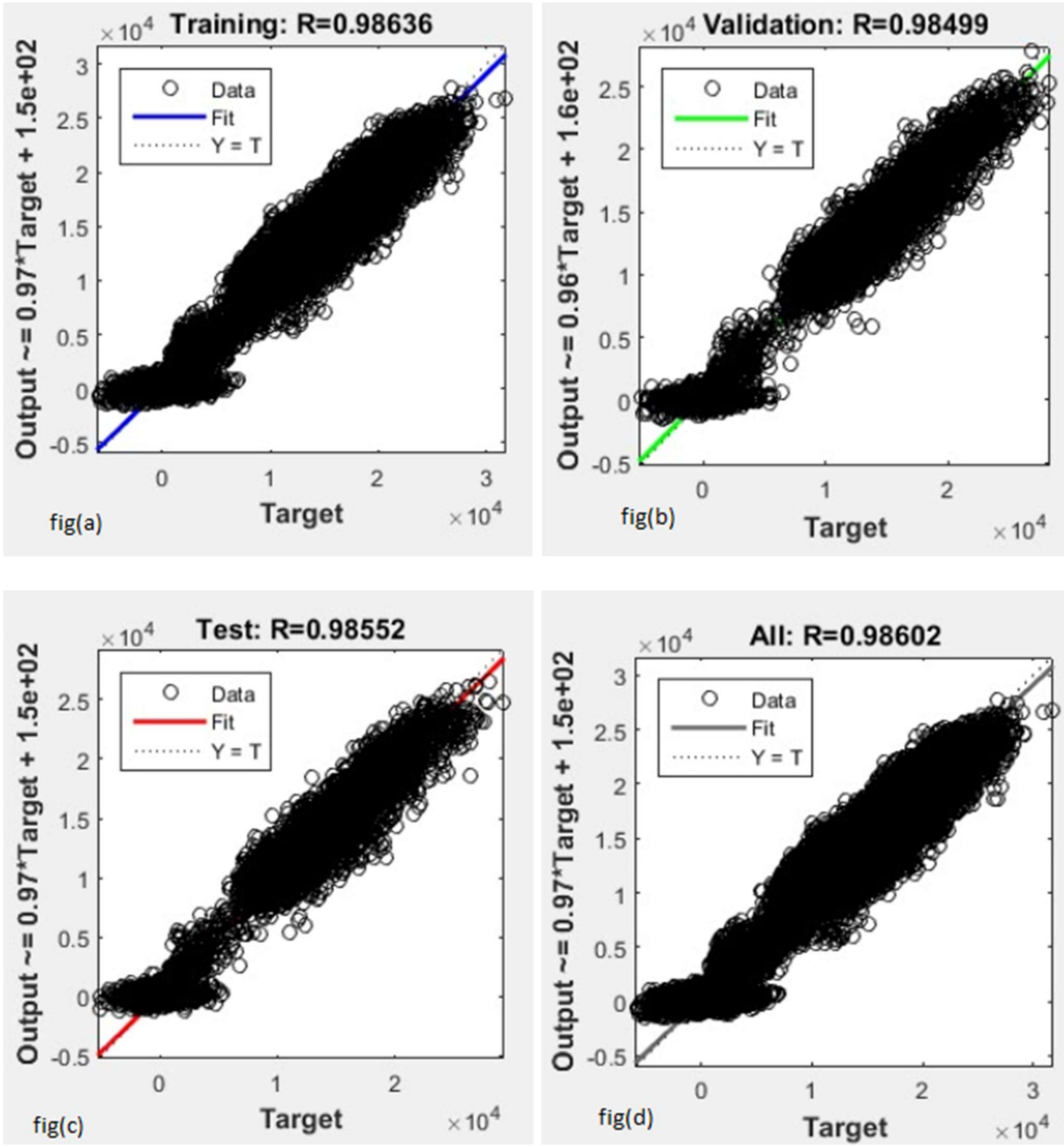

Figure5.5 neural network result by PRNU method

5.1.3 LBP

Here we calculated the feature by the procedure described in Figure4.6 and we get a feature matrix containing texture information then we train neural network by those feature and we get the result shown in Figure5.7 & Figure5.6.

Here we get the overall accuracy of 99% if we used image at same scale level as shown by Figure5.7(d) and validation up to 96% from Figure5.7(b). however, the accuracy decreases when scale factor changes but continue to be high as compare to other method. We get best validation performance at 36 epochs as stated by Figure5.6.

(Here dashed line represent perfect result-output=targets. The solid line represents the best linear regression line between the outputs and targets. R represents the closeness of dashed line with solid line. If R=1, this indicates that there is exact linear relationship between outputs and targets and if R is close to zero then there is no linear relationship between outputs and targets).

As we can see that mean square error is high it due to we have large number of data to solve our problem and we can change it to less value if we use small data and then finding value of mean square error between the sample then it will approach to zeros.

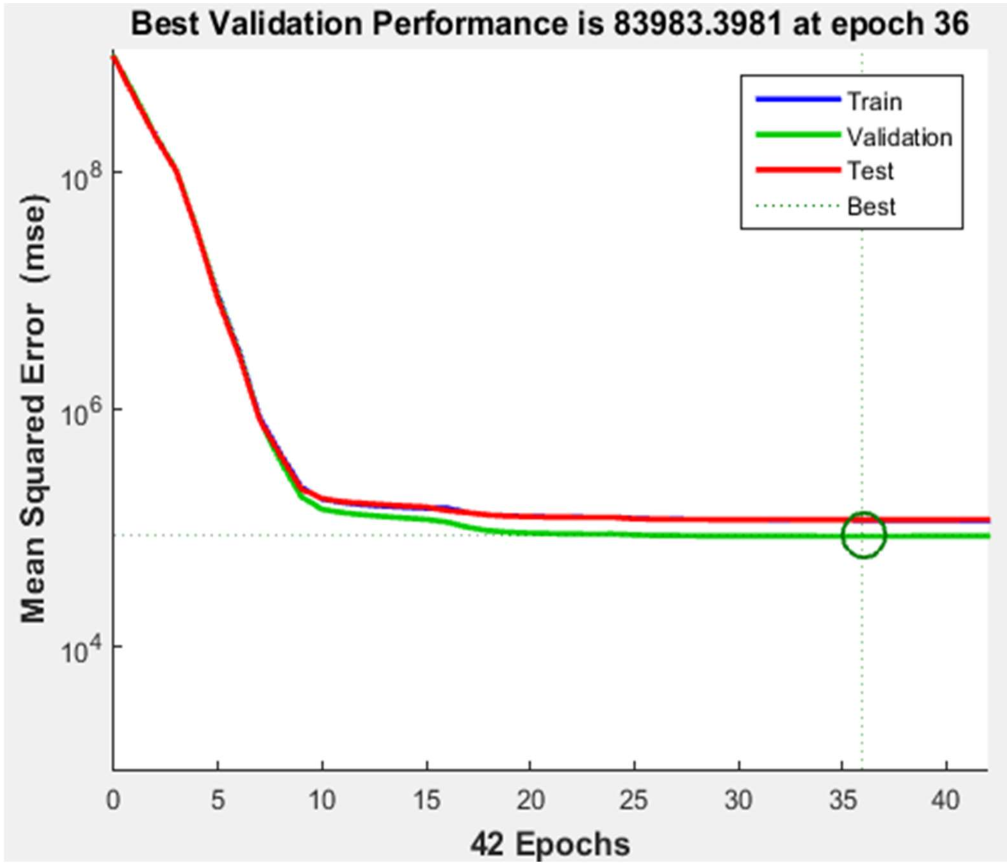

Figure5.6 mean square error between train, test and validation

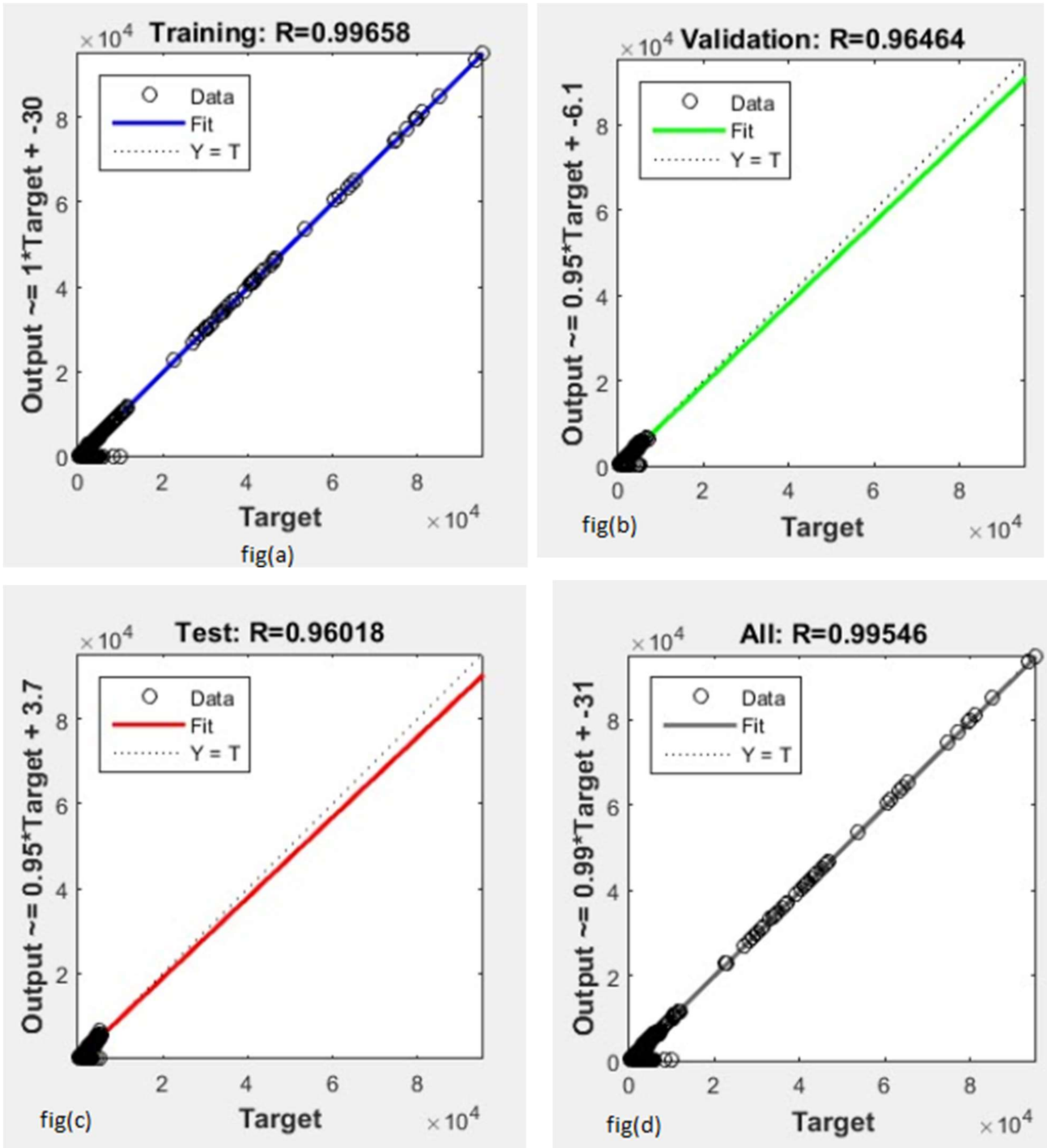

Figure5.7 neural network result of LBP method

Chapter 6

Conclusion and future scope

As clear by above result that local binary pattern is best method but it is quite slow in its approach. The real problem with the PRNU method is the scene content presence in the PRNU image even after applying different suppressing techniques. Second problem with PRNU is color interpolation error. However, this problem can be solved by Color Decomposed PRNU. LBP is nothing but texture information of image so it can vary when image is rotated at some angle. Sometimes same problem is faced buy feature based detection that color distribution of two cameras may be close. In Feature based detection method one problem is also that we don't know what features are contributing to classification in our problem. To solve we can take weighted combination of different features.

All those questions continue to bother us and hence can be base to solve the problem of much improved camera identification techniques. We can also collaborate different technique like PRNU and feature based technique to solve problem. But how can uniqueness of PRNU image matrix described is another question. One simple answer is to use statistical moment of matrix but then till what order?

Also we can improve on the techniques when scale factor of image is changing. Like we can get the best result when we use LBP technique as it uses texture or we can say a pattern in spatial domain. Similarly, we can use all those feature in features based detection when scale changes but features don’t. Also even if scale change then all parameter will change proportionately, this can also serve as base to identify technique. For PRNU technique if we can know about the color filter array we can remove color interpolation error.

One previous method of pixel defect could identify the camera easily but handicapped by the post-processing of camera where it is removed. May be if we can recover it some way by simply making copy of image captured by camera before processing. But that will cost us extra hardware but results will be guaranteed. The last and obvious method is watermarking but which is not present in all camera today and also expensive. So it become available we should focus on all above discussed method and improvement.

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