IDENTIFICATION OF TAMPERED DOCUMENT BASED ON HOMOGENEOUS REGIONS OF IMAGE: A FORENSIC PERSPECTIVE

Dr. M. Umadevi[1], Dr. C. RaghavendraRao[2]

[1]*Professor, Dept. CSE-AI, Chalapathi Institute of Engineering and Technology, Lam, Guntur, Andhra Pradesh, India.*

[2]*Professor, School of Computer and Information Sciences, University of Hyderabad, Hyderabad, Telangana, India.*

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Abstract: The technology used to produce documents continues to evolve; the methods used to produce forgeries are ever more sophisticated; the expectations of lawyers and courts are yet more demanding. When the document's legitimacy is in question, methods are needed to non-intrusively analyse distinguishing features of document in order to learn more about its origin. Various image analysis tools like GVM model based and Print index metric based on printed text of document are developed to identify the print technology used to produce the document. This paper presents methodology to identify the tampered document based on homogenous regions of document. Window-wise analysis of variogram with varying window size captures mixed/combination of print pattern existing in the documents. Results for varying window size in identification of tampered regions also demonstrated.

Keywords: Questioned Document, Variogram , Sill Consistency Coefficient

1. INTRODUCTION

Document is any material that contains written or printed information conveying some meaning or a message to someone. Documents suspected of being fraudulent or whose source is unknown are called Questioned documents [1]. Being the legal evidence of transaction, it is necessary to state the genuineness of document. In the context of printed questioned documents examination, forensic analyst has to answer questions like

1. Is the document consistent, i.e., content printed in the document is prepared from a single source?

2. Identification of source printer or printing techniques like ink jet, electro-photography printing etc.

3. Are two documents similar, i.e., printed using same technology or printer?

4. Differentiate between photographic and photorealistic images

Printed document is spatial distribution of marking material. The knowledge of spatial pattern produced by various print technologies are helpful in determining the source printer that produced these patterns.

A document which is altered by adding or deleting some parts of the document deliberately [2] is referred to as Tampered document. Most of the documents involved in malicious or illegal activities are altered form of original documents. These documents are generated by altering text content or picture content of the document. For example, picture content in the documents like letter heads and logos are altered by antisocial elements for performing illegal activities.

Fraudulent documents are generated by gathering content from various documents or altering the content within a document. Alterations in text content of a document has been addressed in [3], demonstrated text characterization method for checking consistency of text content in the document based on printing technology. In case of documents having both picture and text content, uniform color regions of picture in the document are also to be studied for checking consistency. The pictures contained in the document may be generated by combining different parts, which are collected from different printed documents. It is the concern of a document examiner to analyse the document for identifying whether a document might have been tampered with or not. When soft copy of the document is not available, digitized printed documents are used for creating tampered documents. The following sub section discusses ways the tampered documents are created from digitized print documents.

1.1. Types of tampered document

Tampered documents are classified into two types depending on the printing patterns or techniques contained in the document.

- Document having various print technology, that is some portions of the document are printed with one printing technique and the other portions of the document with some other print technique.
- Documents having mixing or combination of print technology that is reproducing the document by scanning original document and then reprinting on another printer. In this method the reproduced document contains the features of first print features mixed with following printing technique.

2. RESEARCH IN DOCUMENT FORENSIC

Recent research publications demonstrate various approaches suggested for discriminating printing techniques. Research activities on characterization of electro photographic printers in [4] applied gray level co-occurrence feature in [5] and most frequently occurring letter "e" and the techniques of Gaussian mixture model(GMM) in [6] are used for printer identification. In GMM, principal component analysis is used as dimension reduction technique to obtain 1-D projections of the extracted text character. These researches are exclusively for the identification of electro photographic printers. Characterization of electro photographic printers [L6] is for finding intrinsic signature of printers based on banding signals to discriminate various electro-photographic printer models. Machine identification code project [7] identifies pattern of yellow dots appear in color laser printouts, which represent printer serial number. This is not applicable to all electrophotographic printers as some printers do not show the presence of these yellow dots. Some printers like Samsung clp-510 series, Hp laser 8550 series are not showing any yellow dots. Still there is some forensic information to keep track of the printer model. Identification of printing process using HSV color space by Haritha [8][9], is based on hue histogram for identification of printing process and photocopy. Hue contrast, periodicity and ink overspray are the features selected for classifying ink jet, laser jet and photocopies. This is based on color image processing technique using HSV color space. Identification and linking fake documents to scanner by Gaurav Gupta[10] proposed new method for identifying fraudulent documents and linking it to color laserjet priter or color inkjet printer. In this proposed work they captured images text using high resolution cameras LEICA MZ 8, LECIA MZ 12.5 to capture magnified image of single character and directly transfer the images to computer. Unique color count and texture feature uniformity and intensity variation are used as parameters for distinguishing fraud documents. Gray level features, proposed by Lampert [11] for discriminating ink jet from laser jet print, are based on high resolution scanned images, e.g. 3200 dot per inch. Recent research is concentrated on evaluation of gray level features like perimeter based edge roughness of the text [12] for print technique classification, based on low resolution image for high throughput document management system..

GVM[13][14] is used to identify print technology of source document based on uniform colour region or homogeneous colour region: Gaussian Variogram Model (GVM) model, for identifying the print technology which produced the given document. This method characterizes print technology based on spatial variability. Homogeneous colour region of images are taken as samples for the GVM data generation[15]. The generated GVM data is taken as input to generate Reduct based Decision Tree(RDT), which gives rules to identify the source printer for the given test data. GVM method assists the document examiner in finding basic print pattern of printers and it is also helpful in classifying different print technology.

Identifying print technology based on printed text focuses on frequently used word like 'the' as test sample for characterizing printed text[2]. The novelty of this approach is that the selected printed text is modelled as mixture of three Gaussian models namely text, noise and background. The associated patterns and features of the models are derived using Expectation Maximization(EM) algorithm [16] and few indices are proposed based on these parameters. One of the indices called Print Index(PI) for text is used for basic print technology discrimination.

In [17]Statistical measures skewness and kurtosis of histogram are selected as features for distinguishing inkjet print from its photocopy.

From the literature review, one finds that, identification of print technology in forensic perspective is a very challenging area and there is a great need to develop forensic examination techniques to characterize the documents based on the printing processes

3. PRINT TECHNOLOGIES AND SAMPLES COLLECTION

With emergence of print technology various types of printers are available. Commercially available printers are categorized as Electrostatic, Inkjet, Thermal and Photography [18]. Electrostatic print technology uses static charge pattern or selective charge pattern to attract toner particles. Thermal printers use heat to transfer marking material. Ink Jet printers use continuous stream of droplets selectively towards paper or use drop-on-demand process. The way the marking material is placed on the paper varies with technology. This spatial distribution of marking material on the paper is base for characterization of a printed document. Identification of tampered document involves identification of associated print patterns as features or characteristic of printed document. Hence they vary in print pattern. The inkjet printers include continuous, drop-on demand, thermal print types. Dropon-demand thermal ink jet print technology uses heat to generate vapor bubble to eject a single drop of ink through print head nozzles only when activated. Conventional color inkjet printer places up to 8 different colors for dot. But HP Photo

REt technology uses tiny drops to produce photo-realistic images. It can place maximum up to 29-32 drop per dot by decreasing size of drop to 4-5 Pico liters. Study of spatial statistics of homogeneous color regions of images printed by various printers is used for its identification. Documents like certificates, identity cards, and letter heads containing uniform color region, reveal spatial features of print pattern of source printer.

Due to lack of existing data base for experimentation, few synthetic samples are prepared and identification of tampered parts are demonstrated using these synthetic samples. This sample preparation for the experiment involves tampering a uniform colour region of an image. This involves replacing some part of an image by parts of the same image produced by another printer. Steps are

a) Same sample picture is printed using different printing mechanism with fixed resolution on two printers namely Deskjet930c and Hppsc1608 at 600dpi. These two samples are then scanned at 2400 dpi to get images as shown in Fig. 1.

b) Now uniform colour regions of these two images can be used for tampering. Fig. 2 shows uniform colour regions of Deskjet930 image and HPpsc1608 image. Uniform colour region of this Deskjet930c image is identified as regions 1, 2, 3 and 4. These regions are replaced with same spatial parts of uniform colour region of HPpsc1608 image. Spatial coordinates of top left corner and bottom right corner of each window region are mentioned in the form of s(x,y) and t(x,y). Spatial coordinates of region 1 are $s_1(10, 10)$, $t_1(20, 20)$, region 2 are $s_2(60, 60)$, $t_2(80, 80)$, region 3 $s_3(100, 60)$, $t_3(120, 80)$ and for region 4 $s_4(100, 100)$, $t_4(120, 120)$.

c) The resultant image is a Deskjet image containing some HPpsc parts scattered in uniform colour region, which is referred to as tampered image and is shown in Fig. 3.
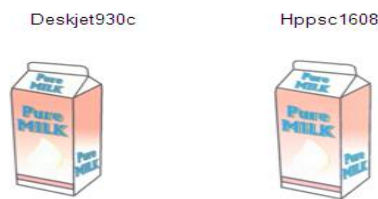

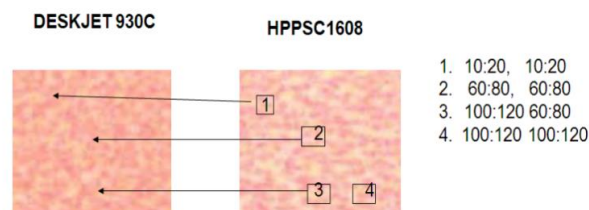**Fig -1:** Sample images printed on deskjet and hppsc

Fig- 2: Uniform colour regions of images printed on Deskjet930c and Hppsc1608

Fig-3: Tampered image of Deskjet930c with scattered Hppsc1608 parts

4. IDENTIFICATION OF TAMPERED PART OF THE DOCUMENT

Study of spatial statistics in uniform colour region of document provides information for the identification of print technology. In our experiment, while tampering images in a document some regions of Deskjet930 image is replaced with HPpsc1608 image. To the naked eye, the tampered parts also look similar to the original, but the spatial statistics of marking material

differs as the image contains regions having different print patterns. These patterns can be identified by a study of variogram generated for an image.

4.1. Window-wise analysis of variogram

Variogram [19], [20], [21] is a statistical tool that characterizes spatial continuity or roughness of data set. It gives an average dissimilarity between points separated by distance h in specific direction d. Variogram is calculated as shown in Equation 1. The separation distance h is usually referred to as lag.

$$V_d(h) = \frac{1}{n}\sum_{i=1}^{n} \quad f(x_i + hd) - f(x_i))^2 \text{ ---------- Eq(1)}$$

where $V_d(h)$ is the variance in the direction d with lag h. Maximum variance in variogram is referred as sill and even at zero distance or lag there is some variability which results in nugget effect. Range represents the distance at which variables have no correlation. The plot of lag h versus V(h) provides graphical representation of variogram. Directional dependence of data present in the image is visualized by employing directional content in variogram concept.

Window wise analysis involves moving fixed size window over tampered image for generating variograms and comparing them to inspect any dissimilarities. For example, variograms generated for homogeneous regions of genuine(Deskjet930c) image and tampered image shows an increasing variance of tampered image and as shown in Fig. 4. The increase in the variance of the tampered image has been observed but this does not reveal whether the image has been tampered or not. If it is a tampered image then we need to identify the tampered regions. By generating variogram for fixed size non-overlapping windows of sample[22], it is possible to interpret the distinguishable features in the sample which do not belong to the original image. The proposed method of window wise analysis of variogram assists a document examiner in interpreting the altered parts of the document which contains pictures or images. The steps for identifying tampered regions in uniform colour region are explained in Algorithm 1.
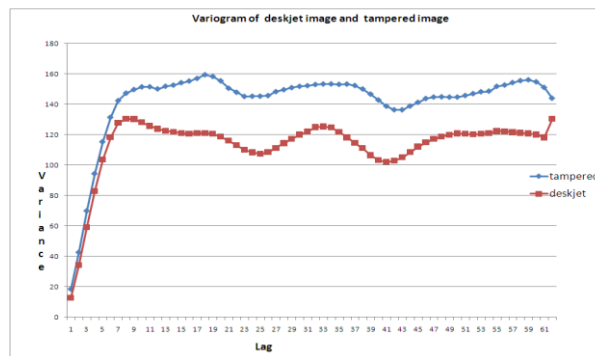

Fig- 4:. Variograms of Deskjet image and tampered image

4.2. Algorithm for identification of tampered part of the document

Algorithm 1 Algorithm for identification of tampered part of the document

 findtamperregions(sample,d)

 Input: Sample image of size M by M

      d is direction in angle

1: [V, S, A nugget, Range] = variogram(sample, d)

//Fix window size say R

2: R ≥ Range and R ≥ M/4

//Fix Number of windows say N

3: N= square(floor(M/R) //Where M=size of the sample

4: for i = 1 to N do

5: [V_i , S_i , A nugget$_i$, Range$_i$] = variogram(W_i , d)

6: P_i = $1/R^2 \sum_{j=1}^{R} \sum_{k=1}^{R} W$ (x_j , y_k) //Calculate variogram and picture value for each window

7: end for //Where V_i , S_i , P_i is variogram, sill, picture value for the region of W_i in the sample

8: Coeff var = $\sigma(S_i)$/Mean(S_i) //Where σ is standard deviation

9: if (Coeff var) > 31 then

10: for i = 1 to N do

11: tindex$_i$ = $S_{(i)}$/S;

12: if tindex$_i$> 1 then

13: W_i is tampered window

14: end if

15: end for

16: else

   The image is not tampered

17: end if

Once the dissimilar windows are identified, these are compared with corresponding windows of the genuine image to ensure that identified windows are tampered regions.

4.2.1. Fixing window size

  Fixing the window size is key point in this algorithm. Window size for variogram depends on the spatial statistics of the print technology. Each printed document has its own fixed window size depending on the spatial features owned and size of the underlying texture or periodicity of print granules which is determined by the range of variogram. Thus, the window size should be greater than or equal to the range of tampered image. If the window size is too small, the dissimilarity measure resembles the image feature. Hence window should not be less than one fourth of x or y dimension of the sample.   The variogram along x-axis of tampered image in Fig. 5 shows the range is 36 i. e. at the lag/distance 36, the correlation graph reaches zero that is the variables are uncorrelated. Thus, select window of size 40 is selected for window wise analysis of image. Tampered sample is the homogeneous/uniform colour region of 127 by 127. For identifying tampered part in this sample, we adopt window wise analysis where the sample is divided into non overlapping windows of size 40 by 40 and labelled as W_1, W_2, W_3, W_4, W_5, W_6, W_7, W_8 and W_9 which is shown in Fig. 6.
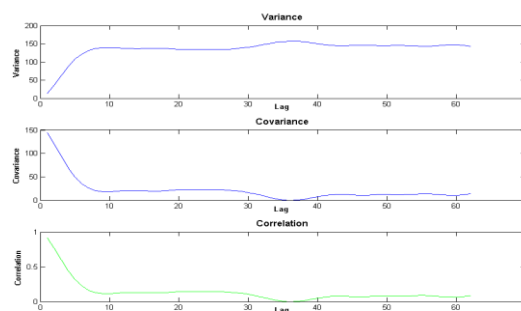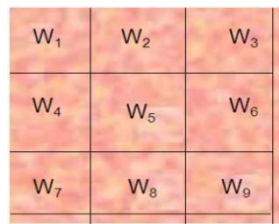

Fig.-5: Range of tampered image

Fig- 6: Window of size 40 by 40 labeled on tampered image

4.2.2. Calculate window wise variogram and picture value

 For each window, generate the variogram V along the selected direction. It can be directional variogram or variogram along x-axis. If it is directional variogram, the same direction is to used to generate variogram for all the windows in the sample. Window size is fixed based on the range of variogram along x-axis. Thus, the same direction is to be used to generate variogram in each window. The influence of direction in capturing underlying spatial statistics of sample is discussed in[14]. Selection of direction is an important factor which plays a vital role in identification of tampered parts. Fixing size of window and direction along which variance has to be measured are parameters which influence the accuracy in identification of tampered parts. Compare the variogram V_1 to V_9 generated for windows W_1 to W9 and shown in the form of graphical representation in Fig.7. Parameter of variogram, namely, sill for each window is taken as feature for identification. The intensity of pixels within the window provides the feature to distinguish dissimilar parts in the window. Average intensity of all the pixels lying within the window is referred as picture value. Picture value for windows W_1 to W_9 are P_1 to P_9 respectively.
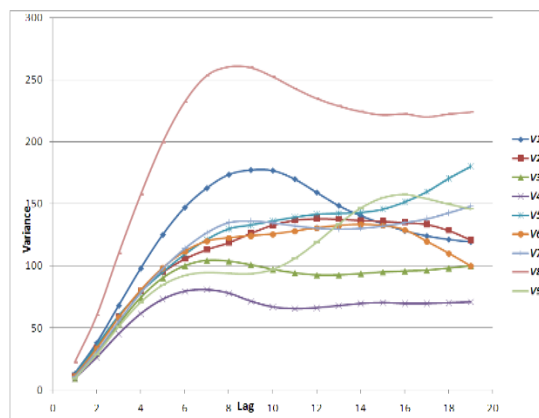

Fig- 7: Window wise variograms of tampered image

        Plot the sill of the variogram in each window of tampered image. S_1, S_5, S_8 and S_9 are sills of V_1, V_5, V_8 and V_9. These are slightly higher than the remaining sills as observed in Fig. 7. Fig. 8 shows comparison of the sills of tampered image in each window. Observing Fig. 9, it is identified that the windows W_1, W_5, W_8 and W_9 have distinguishable picture values compared to the other neighbour windows.
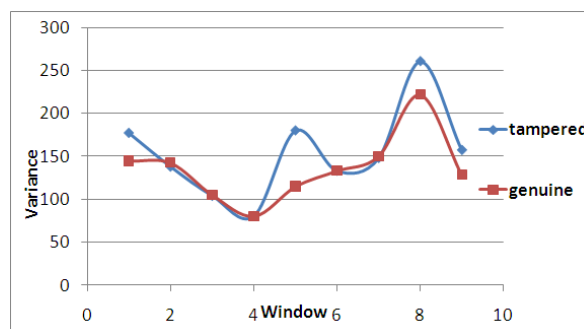

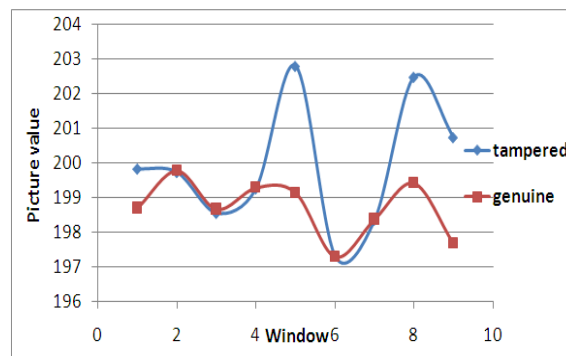**Fig- 8:** Plot of window versus sill

Fig.-9: Plot of window Vs Picture Value

4.2.3. Compute Sill Consistency Coefficient(SCC)

The Coefficient of variation indicates consistency/stability of the data and it is free from units. This coefficient of variation can be adopted for tampered document classification. Hence coefficient of variation for the window wise sill values is referred to as Sill Consistency Coefficient (SCC). If the questioned document is identified as tampered with the help of Sill Consistency Coefficient, then one need to identify proper region of tampered data. For tampered image in Figure 3 the Sill Consistency Coefficient is greater than 31. Then it is considered that given image is a tampered image. Thus one need to compute tamper index to identify tamper windows. The windows having t_index greater than 1 is considered as tampered. Observing Fig.10, the windows W_1, W_5, W_8 and W_9 showing the tamper index value greater than 1. To ensure that the identified windows are tampered, compare these with the corresponding sill and picture values of the genuine image.
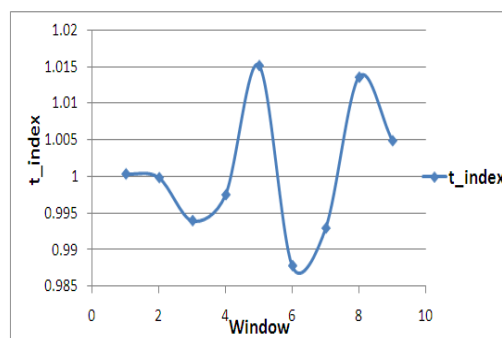

Fig-10: Tamper index for windows of tampered image

5. IDENTIFYING MIXING PRINT TECHNOLOGIES

5.1. Documents produced using combination of print technologies

Often fake documents are created by scanning original documents and reproducing them using printing technology. Sometimes more than one print technology is used in the process of forging the original document. When a printed document is scanned and reproduced using some other printing technique, the reproduced document inherently contains the spatial statistics of both printing techniques. The spatial characteristics of homogeneous/uniform colour region of reproduced document reveals the features of original printed document and reproduced printer characteristics. Hence, fixed size window variogram generated for such tampered documents should not contribute to specific print technology as it inherently contains both features of print technology. While scanning the original document, the original print features are captured by scanners and are reproduced with the print features while taking the print. Variogram of different window size can capture global and local patterns of the document. Adopting variogram of varying size of window will contribute to identifying hierarchical printing techniques contained in the document.

5.2. Variogram of mixed print document

In our experiment, uniform colour region of image produced by using laser printer is taken as source document. It is scanned at 2400 dpi and printed on inkjet printer Deskjet 840c at 600dpi. Test sample is produced using LaserJet4650 printed image scanned and again printed on Deskjet840c and it is shown in Fig. 11. Variogram generated for the test sample differs

depending on the size of the window. If size of window is small, variogram resemble the local pattern, if window size is large variogram resembles the global pattern.
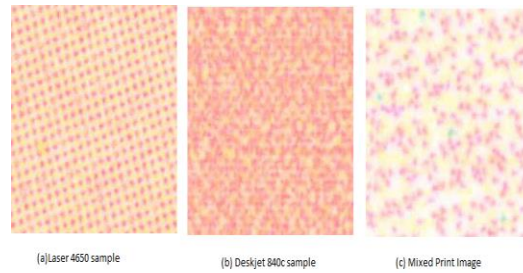

(a)Laser 4650 sample   (b) Deskjet 840c sample   (c) Mixed Print Image

Fig-11: Sample image of mixed print technology

5.3. Analysis of window-wise variogram to identify the mixed print technology

The steps for window wise analysis of mixed print sample are explained in Algorithm 2. It generates variogram for sample of various window sizes.

Algorithm 2

$[v_1,v_2,v_3]$=findmixedprint(image,d)

Inputs: Sample image of size M and d is direction, d=0 for x-axis

1: W_1=image(x,y) for x=1 to M/4 and y=1 to M/4

2: W_2=image(x,y) for x=1 to M/2 and y=1 to M/2

3: W_3=image(x,y) for x=1 to M and y=1 to M

4: for i = 1 to 3 do

[V_i , S_i , $Anugget_i$, $Range_i$] = variogramx(W_i , d)

5: end for{V_i , S_i are variogram, sill for the window of W_i in the sample}
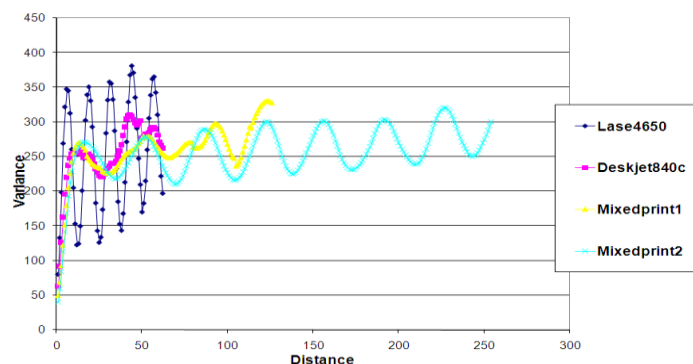
6: Plot variogram of each window

Fig-12: Directional variogram 20 degree angle of window size 127 and 255
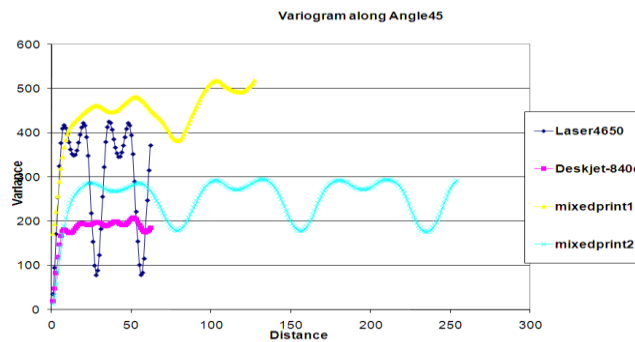
Fig-13: Direction variogram 45 angle of window size 127 and 255

Adopting analysis of variogram with varying window size on sample of mixed print such as laser image printed on Deskjet shows the pattern of laser and inkjet print technologies. The variogram results for the mixed print sample (laser image printed on Deskjet) for window size 256 and 512 are demonstrated here. Window size of 256 is labelled as mixed print 1 and for the size 512 it is labelled as mixed print 2. The Fig.12, Fig. 13 indicates that directional variogram varies with the window size. In both the Figure variogram corresponds to smaller window size 256 revealed the Deskjet Characteristics(local), whereas variogram corresponds to larger window size 512 exhibits laser printer characteristics (global).

5.4. Results

Inkjet and laser combination of printers are selected for preparation of samples to analyse performance of window wise variogram in identifying mixed printing technology. Few samples are prepared using inkjet printers like HPofficejet6110, HPphotosmart3188 printer. These inkjets print images are again printed on laser printers. For example, HPofficejet print is scanned and printed on HPlaser4550N, HPofficejet6110 print is scanned and printed on SamsungCLP-510 laser printer. Similarly, HPphotosmart3188 print is scanned and printed on HPlaser4550N, HPphotosmart print is scanned and printed on SamsungCLP-510 printer. These samples are all inkjet prints again printed on laser printers. For the above four combinations, samples are generated and the uniform colour region of these samples are analysed employing window wise variogram analysis. Variograms of these gray converted samples for varying window size reveals mixed print combination.

The samples and corresponding variogram (along x-axis) of window size 256, 512, 1024 are labelled with its source printing combinations and shown in Fig. 14, Fig.15, Fig. 16 and Fig.17. In all of the above combinations, local pattern shows periodicity resembling laser print pattern and global pattern shows irregularities in overall trend resembling the inkjetprint. Hence, variogram with varying window sizes uncovers the mixed printing combination in uniform colour regions of an image.
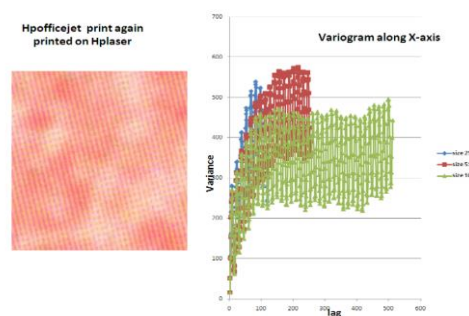

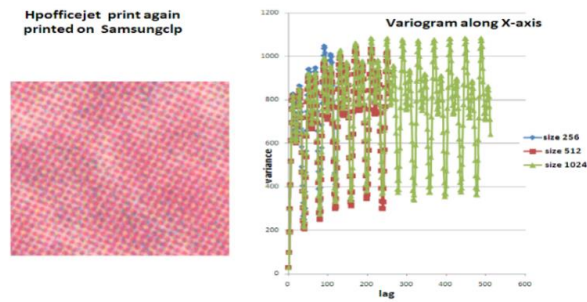**Fig -14:** Officejet image printed on laser printer and its variogram of size 256, 512 and 1024

Fig- 15: Officejet image printed on samsung printer and its variogram of size {256, 512 and 1024}
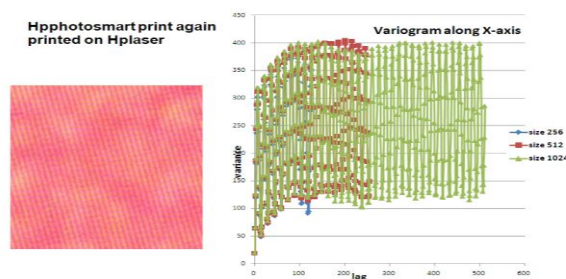

Fig- 16: Photosmart image printed on Hplaser printer and its variogram of size 256, 512 and 1024
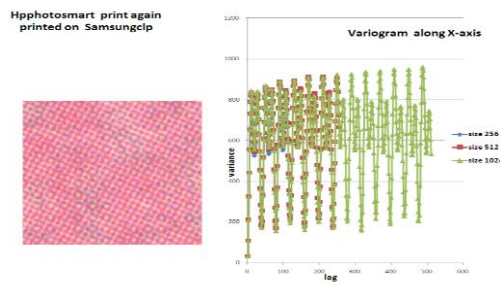

Fig-17: Photosmart image printed on Samsung printer and its variogram of size 256, 512 and 1024

6. CONCLUSION

Uniform or fixed window size has potential to classify documents tampered or not and to identify tampered regions. However, this works only for uniform regions. Varying window size analysis has potential to describe hierarchical printing techniques used in producing the questioned document and it also captures the variations in periodic characteristics of printing techniques involved in producing the document.

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