A New Non-Destructive Method for Retrieval of Completely Removed Printed Text on Thermal Papers

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Abstract: **Complete removal of printed text on thermal papers obtained from sources like ATM, fax machines and billing has always been a problem in recovery of evidential information out of it. This systematic non destructive technique exercised for the first time, on completely faded thermal paper allows recovering completely removed printed text. All the samples were introduced to different wavelengths of illuminations and exposure tools using Video Spectral Comparator 6000/HS and the results are subjected to image enhancement software available therein to retrieve the naturally removed text. No chemical treatment on document is required thereby retaining the evidential value of the paper even after examination. The method is non destructive, easy to perform and gives excellent resolution of developed text irrespective of the time elapsed after printing, making it completely readable.**

Key words **- Thermal paper, Ultra violet light, VSC-6000/HS, Document analysis, Image processing tool.**

I. INTRODUCTION

Extensive use of thermal papers in facsimile copies, ATM transaction slips, billing at restaurant and shopping malls etc had attracted forensic examiners to extract evidential clues out of them. In spite of excellent source of transaction information, these thermal paper receipts pose a serious limitation that the thermally printed text gets faded or removed in due course of time naturally under ordinary environment conditions making them non readable and inaccessible. Thermal (Thermo-sensitive) recording paper was introduced by the National Cash Register Company in 1968. The chemistry of the thermal papers work is necessarily the same as that of carbonless papers [1].

Lot of research work have been done in forensic fraternity to develop fingerprints from thermal paper surfaces [2-9] and estimating the age of thermal papers has been done by FTIR [10]. But in cases where these thermal papers are produced as documental evidence, it becomes a real challenge for questioned document examiners to read and extract out information from faded or completely removed text on paper. Kelly et al. [11] proposed method for enhancing and retrieving text from faded thermally printed papers by using iodine fuming. Procedure is approvable however the method is destructive. This motivated us to develop a new non destructive and chemical free method for making the faded thermally printed contents visible and readable. The proposed method includes instrumental analyses whose outcome being subjectively improved by image enhancement techniques to make certain features easier to see by modifying the intensities.

II. METHODOLOGY

For the examination, a total of 50 samples of thermal receipts were collected from various sources viz. Point of Sale receipts (10), Fax copies (2), ATM transaction slip (20) and Card Payment receipts(18). All samples were faded over natural course of time and text is fully removed and is not visible to naked eyes and considered as naturally faded samples (NFS).

Prior to any kind of exposure, samples were photographed in their natural state. All NFS were subjected to analysis in Video Spectral Comparator (VSC) 6000/HS (Foster and Freeman, UK). The process includes examination and illumination of samples to various light sources and filters to make completely faded thermal printed text visible. Following systematic step wise examinations were carried out on samples collected.

Step. I – Examination under visible light illumination - In first step all NFS are photographed under flood light in VSC 6000/HS which is being obtained by 4x20W halogen lamps + 2xwhite 1W LEDs. Process is followed under other illuminating sources viz. transmitted light (4x12W incandescent lamps), spot light (20W halogen lamp, gives 25 mm), side light (4x20W halogen lamps + 2xwhite 1W LEDs).

Step. II - Examination under Ultra Violet illuminations - All NFS analyzed across different spectral ranges from UV (a) Long wave 365nm peak wavelength (b) Medium wave 312 nm peak length and (c) Short wave 254 nm peak wavelength as some features respond at specific wavebands.

Step. III - Image inversion and auto correction - In step II images, the thermally printed text was partially visible under background of fluorescence and appeared white, so an image inversion performed which turned text black in color and

further auto correction with image enhancing tool provided with the instrument. Inversion gives a better contrast which enhances clarity. (Image-3&4)

Step. IV - Grayscale conversion - inverted images in previous step where converted to grayscale which provides more contrasting image highlighting the 'invisible' prints.(Image-5)

Step. V - Gamma correction and Noise removal - The last step includes the grayscale images enhancement through gamma correction and noise removal which ultimately improves the brightness, contrast and sharpness of images as a result giving the 'Final Developed Image' with most clarity, contrast and readability of text contents (Image. 6)

III. RESULTS AND DISCUSSION

All the 50 samples selected for the study were subjected to VSC under different illuminating sources like Flood, Transmitted, Spot, Side and UV lights, the contents were visible only under the UV light (Table-1).

Table 1- Results under various illuminations in VSC 6000/hs

Flood light	Not Readable
Transmitted light	Not Readable
Spot light- spot	Not Readable
Side-	Not Readable
Ultra Violet Long wave 365nm peak wavelength,. Medium wave 312nm peak length, 2x8W. Short wave 254nm peak wavelength, 2x8W.	**Readable** (image under 312nm wavelength illumination reveal best details)

The images under visible range of illumination do not give encouraging results, whereas images viewed under UV at 312 nm wavelength illumination revealed best text recovery (as seen in image-2 of Figure-1). Further application of inbuilt Image enhancement tools in VSC6000/HS was used for enhancement of inverted images to obtain maximum contrast for clarity (image-3 of Figure-1) and enhanced automatically by provision in image enhancement tool (image 4 of Figure-1). Grayscale of enhanced inverted image widens the dynamic range of the dark portions of the recovered image, making it much easier to see the thermally printed details (image-5 of Figure-1). The last step includes further enhancement of the grayscale image through gamma correction and noise removal through adaptive filtering increasing overall sharpness giving final developed image with maximum clarity, contrast, sharpness and readability (Image-6 of Figure-1)

In the naturally faded samples (Image.1) only the part which is off-set printed is visible like the bank name, logo and other details which are common to all bank ATM receipts. No thermally printed text is visible.

The samples subjected to flood, transmitted light, spot light and side light showed negative results, the thermally printed text could not be restored. Though wavelengths of ultraviolet radiation- 365 nm, 312 nm and 254 nm revealed thermally printed text, best image was obtained under medium wavelength of 312 nm after enhancement. The quality and clarity of the images obtained depends upon the age and condition of the sample slips.

Data on ATM receipts has an additional evidential advantage over other receipts as it includes financial as well as location details.

After analyzing the entire sample range, a naturally faded sample (A 3), an ATM transaction receipt was found to be printed in the year of 2008. Post development it was seen that the date of the print was 25th of September, 2008. This was the oldest sample that has been developed using the afore mentioned method. Thus it can be claimed that samples up to eight years old can be successfully analyzed by this method. (Fig.2)

3.1 Mechanism of retrieval of text

Colorless or nearly colorless fluoran compounds having proper substituent(s) react with acidic compounds to open their lactone rings resulting in extension of the conjugated double bond system, enabling color formation. This colour-formation reaction is not irreversible but reversible under basic condition resulting in print fading on the thermal paper with the passage of time [1]. Bisphenol-A used in thermal paper gives fluorescence in UV light. When sample is placed under UV, due to Fluoran properties it gives fluorescence and the non fluorescent part is seen as text and then by inverting the image and using image enhancement we can retrieve data available on the sample.

The developed method is a combination of both instrumental as well as image enhancement tool. The developed images are permanent and the original document retains its original state unlike the iodine fuming technique in which the images fade away with time. Humidity is not as crucial in these cases, as the interaction of water vapor and thermal paper is found to be negligible.Further the developed documents by the present method are available for other examinations like developing fingerprints etc.

3.2 Evidential informations/findings from developed text on ATM receipts.

Further, more successful restoration of these faded documents can help in multiple ways, its evidential value in cases of economical frauds, tax receipt forgery, in tracing of criminal (due to his prior use because of which a thermal print was

originated). A probable suspect can be traced to particular restaurant or a bar where he might have done some sort of transaction. With the restored document we can retrieve a probable time stamp which can then be counter-checked with the CCTV footage available at that place. It can be noted that now a day's every ATM, Point of Sale (POS), service desks and billing kiosks have CCTV cameras installed. Revealed dates on the receipts can ensure age of thermal printout without undergoing instrumental analysis as reported by Biao Li [10]. Hence a probable description of the suspect can be extracted from the footage based on the time stamp on the restored slip.

IV. CONCLUSION

The proposed method is completely chemical free, only utilizes illuminating sources and image enhancement tools for restoration of text on thermal papers and does not use any sort of external ingredients or pre-treatment of sample for analysis in spite of delivering good results. Only VSC and image enhancement software tool within is needed for retrieval of removed text on thermal papers. So, for retrieval of removed text from thermal papers an image under illumination of 312nm wavelength subjected to image enhancement through inversion of image to obtain maximum contrast and clarity, grayscale conversion and finally gamma correction and noise removal reveals the text details to its maximum clarity and readability. A sample as old as eight years has been successfully restored with this method. When applied in forensic document examination, the proposed technique will provide investigators with valuable information, which can be used to reconstruct the timeline of events.

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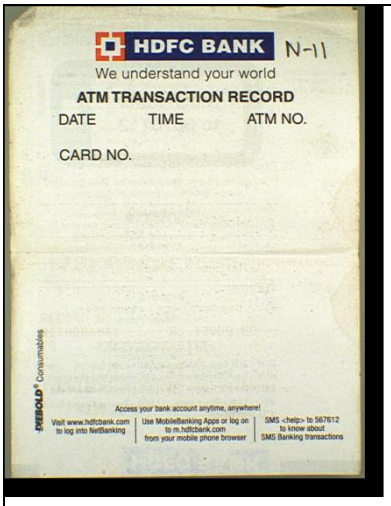


Image.1, Original sample image Thermally Printed text not Visible

Image.2- Sample under 312 nm medium UV wavelength

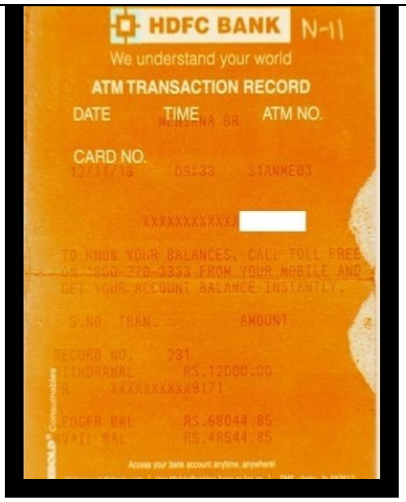


Image.3-Inverted image in image enhancement

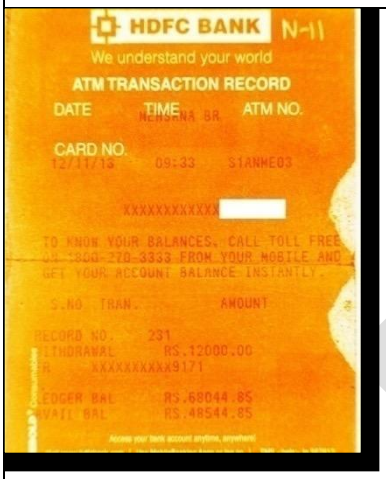


Image.4-Enhanced Inverted Image of Sample

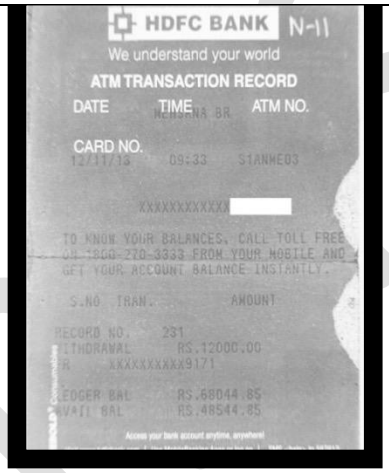


Image.5- Grayscale of Inverted Image

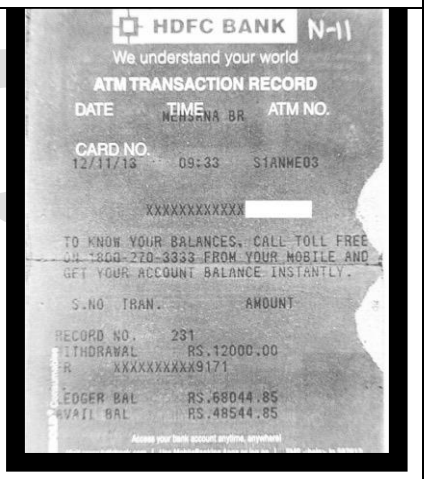
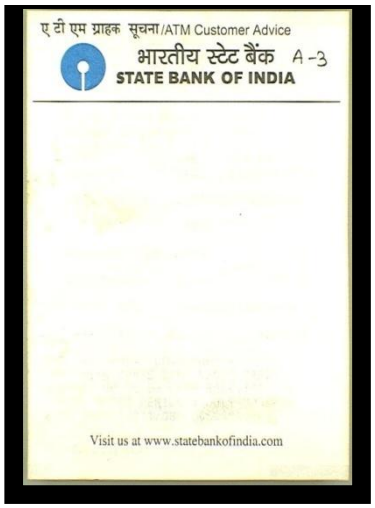
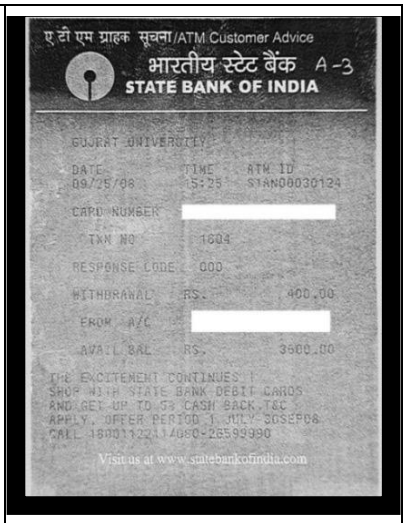


Image.6- Final Developed Image showing recovered text.

Figure 1: A systematic stepwise examination and images revealing details at each step, Images 1 to 6, revealing the removed text from the ATM transaction receipts at each step under 312 nm wavelength illumination. (in images, the account number flashing is hide for security reasons)



(A)



(B)

Original Image	Final developed image

Figure.2. Analyzed results of naturally faded sample marked A3. (A) image under visible light in natural course, no any thermal printed text visible (B) image after applying proposed methodology reveals text and dates back to eight years.