

The Uniqueness of Facsimile Documents Caused by Changes in Character Pixelation

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The primary objective of this research was to test the hypothesis that every page transmitted individually by a fax machine will be unique due to changes in character pixelation. The secondary objective of the research was to test the hypothesis that the character pixelation changes can be accurately reproduced on a 1st-generation photocopy. The tertiary objective was to test the hypothesis that every page transmitted by the fax broadcast function will bear similar changes in character pixelation due to those documents sharing the same single-scanning process of the sending fax machine.

The test documents were transmitted from 1 fax machine to individual fax machines located locally, interstate, and internationally. These documents were then returned, and microscopic comparisons were made of corresponding characters appearing on the respective documents. The results of this research demonstrate that each page transmitted individually by fax creates a unique pixelation pattern for each character and that this pattern was accurately reproduced on 1st-generation photocopies of these respective test fax pages.

The research demonstrates that changes in character pixelation can assist document examiners to trace the source of a photocopy of a 1st-generation fax document back to the original received facsimile from which that copy(s) was produced.

Introduction

Facsimile documents can present key evidence in criminal investigations and civil litigation. Occasionally, document examiners are required to assist investigators and lawyers in determining the source of a copy of a fax document. To do this, the examiner needs to understand how data is transmitted over a fax/telephone line.

Individual Transmission

The most common form of fax transmission is the individual transmission. This type of transmission is defined by the fact that only 1 fax machine receives the transmission. The individual transmission begins with the operator dialing the number of the receiving fax machine. Once the "call" has been connected to the receiving fax machine, the document is scanned 1 page at a time by the sending machine, and the information is sent simultaneously to the

receiving fax machine. The receiving fax machine then prints the transmitted page(s), as per the information it has received from the sending machine.

Broadcast Transmission

The broadcast facility allows for the same document to be sent to multiple receiving fax machines via a single sending transmission. Some fax machines on the market today are capable of sending a document to as many as 100 fax machines. Before each transmission, each of the receiving fax machine numbers is programmed into the sending machine's memory. The 2nd step involves selection of the preprogrammed fax numbers to which the document will be sent. As with an individual transmission, the document is scanned 1 page at a time, and the information is stored. Finally, after all the pages have been scanned, the stored document is sent to the

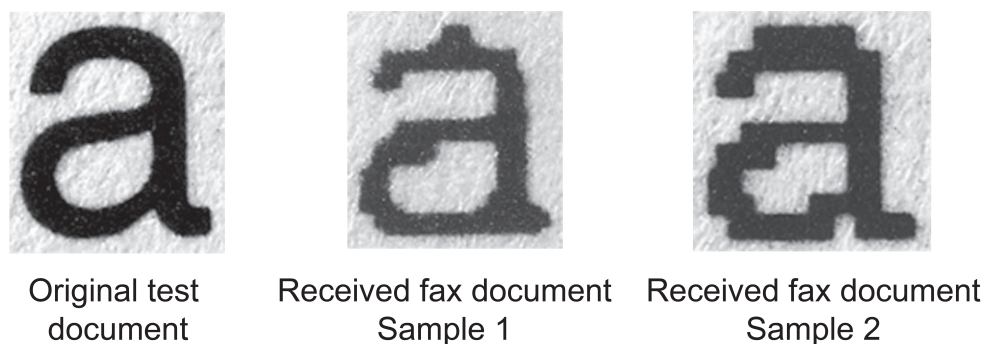


Figure 1. Differences in pixelation changes noted due to facsimile transmission.

preprogrammed destination fax numbers. The receiving fax machines then print the transmitted page(s), as per the information they have each received from the sending machine.

Definition of Differences in Character Pixelation Due to Fax Transmission

A change in pixelation is the presence and/or absence of a particular group of pixels from a particular part of a character. The presence of these groups of pixels can take any shape (Figure 1).

Primary Objective

The primary objective of the research was to test the hypothesis that every page transmitted individually by a fax machine will be unique due to changes in character pixelation caused mainly by the scanning process of the sending fax machine. The secondary objective of the research was to test the hypothesis that the character pixelation changes can be accurately reproduced on a 1st-generation photocopy. The tertiary objective was to test the hypothesis that every page transmitted by the fax broadcast function will bear similar changes in character pixelation due to those documents sharing the same single-scanning process of the sending fax machine.

Case History

A major company in Sydney had to distribute a highly confidential document to its executives at a meeting. On the day of the meeting, 1 of the executives was absent. The absent executive requested that the document be faxed to him by the company. Some days later, a photocopy of the confidential document was leaked to the media and the contents published. The company immediately launched an internal investigation into the

source of the leak. The company retrieved the actual photocopy document from the media agency. The document was then submitted to a private document examination company.

Among other observations, it was noted by the examiner that the document retrieved from the media agency was a photocopy of a fax. The investigators were advised by the document examiner to attempt to retrieve the original document received, which had been printed on the absent executive's fax machine. This request was based on the document examiner wanting to apply the following hypothesis:

That each time a document is transmitted by fax, the resulting document (as printed by the receiving machine) will exhibit unique distortions caused by pixelation of the characters. These distortions are capable of being reproduced by photocopying. Therefore, by matching the respective distortions in pixelation of the characters, the original printed fax document can be identified as being the master from which the photocopy was produced.

This research was undertaken to test this hypothesis. At the time of writing this paper, the investigators were still in the process of attempting to retrieve the original received fax document.

Methods and Materials

A test document bearing an online news article was printed 4 times from a laser printer at a resolution of 600 dots per inch (dpi), producing 4 "original" versions of the same document. These documents were labeled 1, 2, 3, and 4 respectively (the "test documents"). The test documents were then faxed (in standard resolution), together with a

Original test characters



ITTDa1



ITTDa2



ITTDa3

Laser



ITS4a1



ITS9a1



ITS14a1

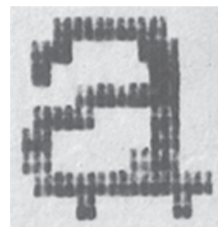
Thermal paper



ITS3a1



ITS12a1



ITS20a1

Thermal transfer



ITS15a1



IT16a1



ITS21a1

Consecutive pages of the same fax transmission



ITS11a2



ITS11a3



ITS11a4

Figure 2. Comparison between original test character “a” and those printed by different types of fax machines, same type of fax machine, and consecutive pages of the 1 fax transmission.

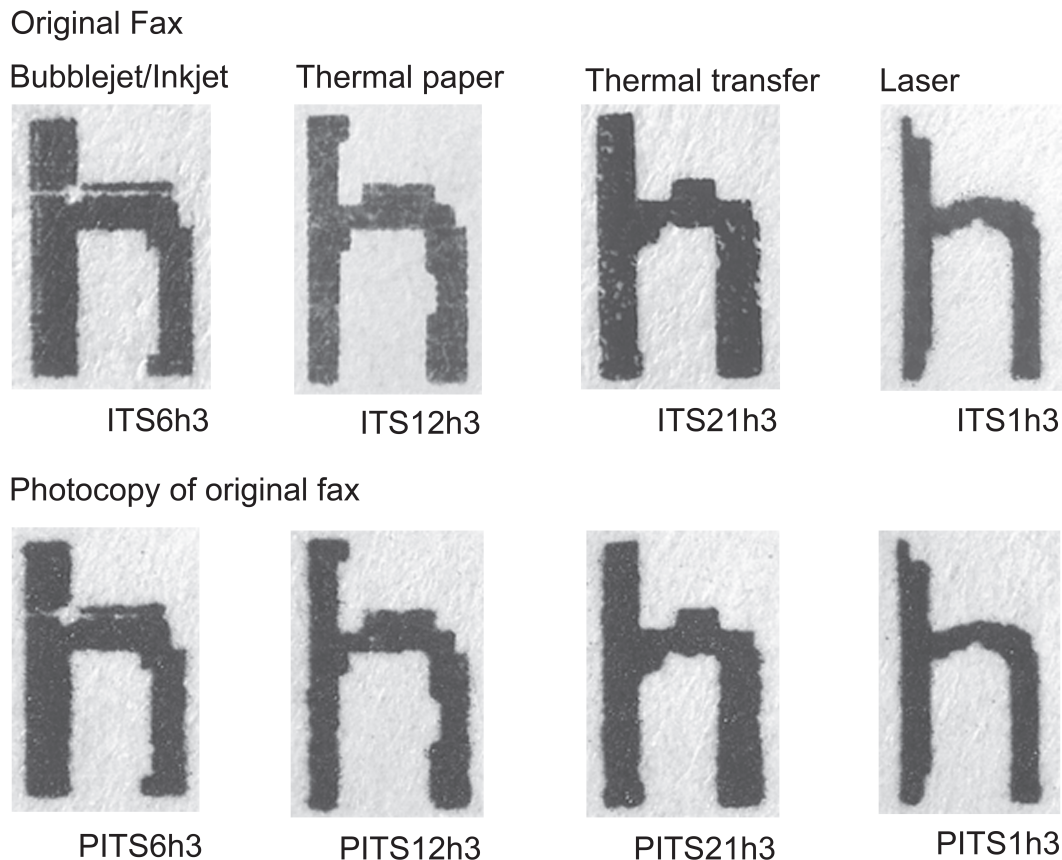


Figure 3. Reproduction of pixelation changes after 1st-generation photocopying.

cover letter and a questionnaire, to 26 individual fax machines located locally, interstate (Australia), and internationally. Participants were asked to mail back all 4 original copies of the test document received on their fax machines and the completed questionnaire detailing the make/model information of their fax machines.

Twenty-three sets of the test documents were returned, and photocopies were made of each of them from a digital photocopier at a resolution of 600 dpi. Comparative microscopic examination of character pixelation changes was carried out on the original test documents and the 1st-generation photocopies of the test documents, as per the requirements of the respective hypothesis.

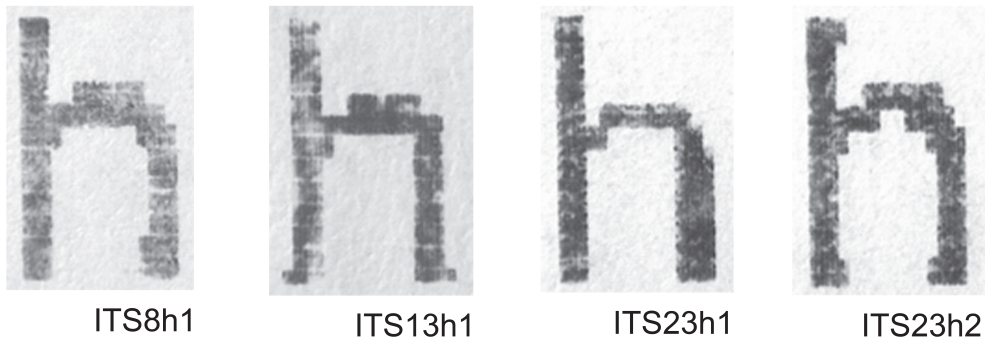
Examinations were undertaken of selected test characters "a" and "h" on each of the documents: the original laser printout, returned fax copies, and photocopies of the returned faxes. Examinations were made using 16X magnifications. During the examinations, images were made of each test character using a stereomicroscope with closed-circuit

camera and video monitor. These images were saved onto a PC using MGI VideoWave III software, after which Adobe Photoshop was used to crop and adjust the size of the images.

The same online news article was printed another 4 times on a laser printer (labeled Broadcast 1, 2, 3, and 4) and then transmitted by broadcast to 10 individual fax machines located within Australia. Nine sets of fax documents were returned. Characters "s" and "w" were chosen for comparative microscopic examination in the same manner as described for individual transmission.

It was considered that curved and angular shapes would potentially produce the most definable examples of pixelation. The characters "a," "h," "s," and "w" were selected on that basis for examination. Each test document consists of 1,657 characters, of which there are 135 characters "a" (8.1%), 115 characters "h" (7.0%), 100 characters "s" (6.0%), and 50 characters "w" (3.0%). The same character placement of "a" and "h" on

Original thermal fax



Photocopy of the original thermal fax

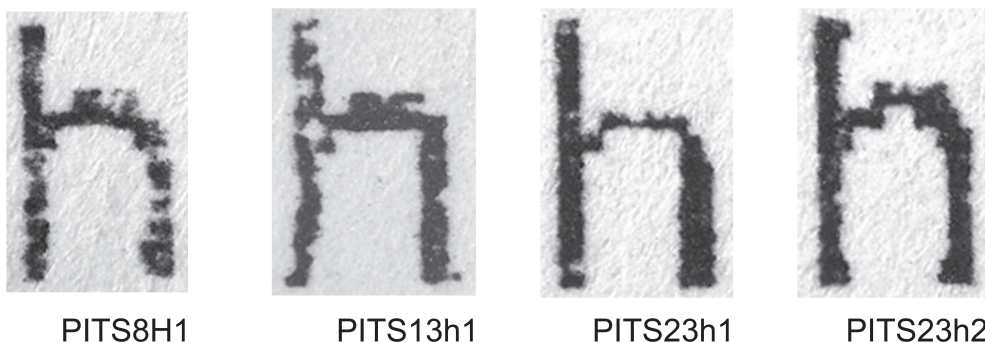


Figure 4. The reproduction of pixelation changes is less noticeable with poor print quality thermal paper fax machine.

each document was selected for examining pixelation changes in the individual transmissions.

The instruments and software used to conduct this research were: Adobe Photoshop 5.0LE, Canon Bubblejet B320, Canon GP215 photocopier, Corel WordPerfect 8, Hewlett-Packard LaserJet 4050N, Intralux 5000 optical light sources, MGI VideoWave III software, online news article, Panasonic WV-GL702 closed-circuit camera, Vicam SCM-1400 color monitor, and a Wild M3Z stereomicroscope.

Results

The types of print engines associated with the fax machines which received individual transmissions were: bubble jet/inkjet, laser, thermal paper, thermal transfer, and laser printer linked to a computer fax.

Changes in character pixelation of corresponding test characters were observed to be different on individual transmissions, irrespective of

whether they were: a) produced on fax machines of different types (e.g., laser versus thermal paper), b) produced on different fax machines of the same type (e.g., laser versus laser), or c) produced on the same fax machine as consecutive pages of the same fax transmission (Figure 2).

It was noted that the changes in character pixelation were accurately reproduced on 1st-generation photocopies of the respective received fax samples (Figure 3). However, it was also noted that the reproduction of pixelation changes was less defined when the printing quality of the receiving fax machine was relatively poor, particularly with regard to thermal paper fax machines (Figure 4).

A number of changes in character pixelation of corresponding test characters were observed to be very similar, but not identical, among broadcast transmissions (Figure 5). Other changes in character pixelation of corresponding test characters on broadcast transmissions were observed to be different, as with the individual transmissions

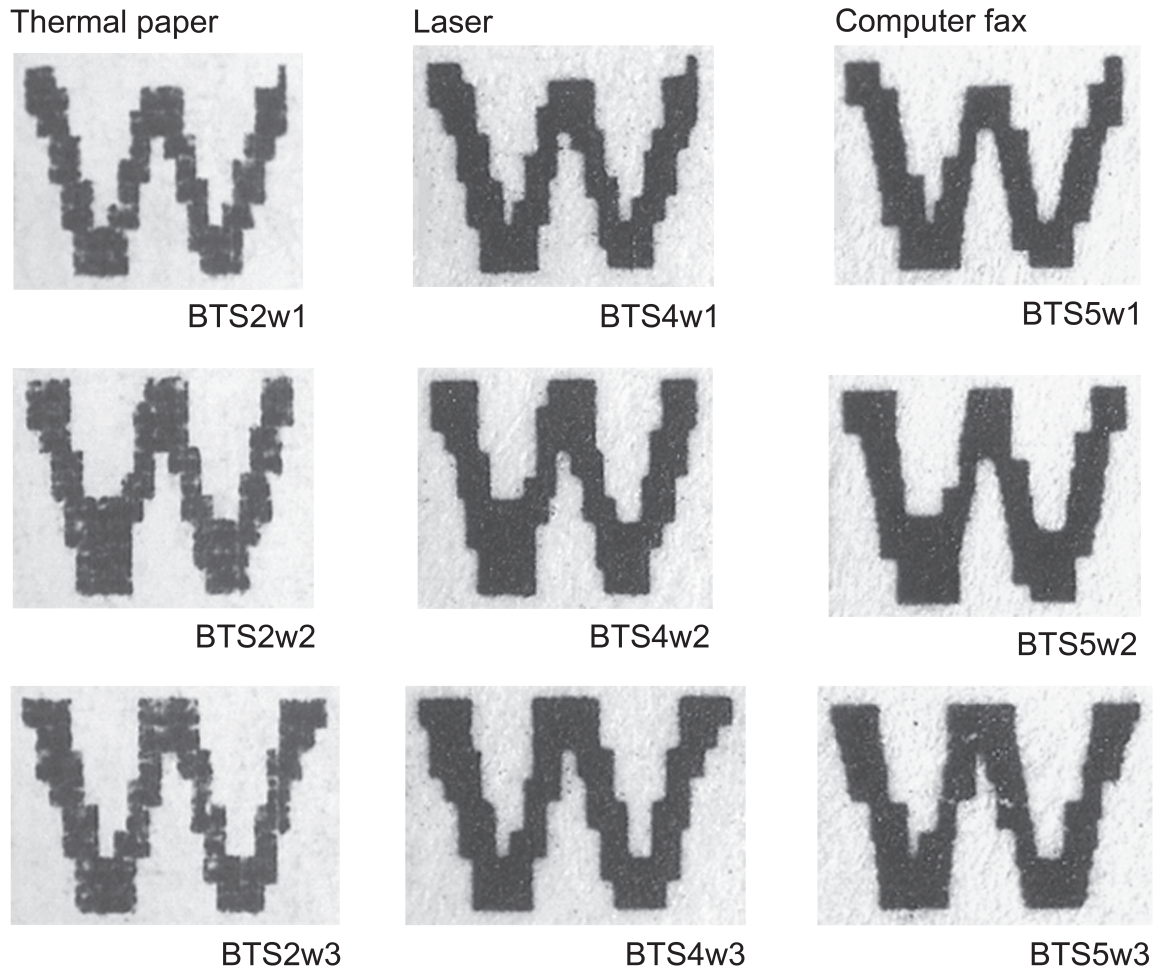


Figure 5. Similar, though not identical, pixelation changes between test characters in broadcast transmissions.

(Figure 6). The existence of less distinctive pixelation changes between broadcast-generated documents, when compared to individual transmissions, suggests that the scanning process of the sending machine is not the only event causing changes in pixelation. That is to say, such changes are most likely to be a combination of events which include the scanning of a document by the sending fax machine and the printing process of the receiving fax machine.

Discussion

During a fax transmission, events can occur in the process of scanning the original document into the sending machine, transmission of the image data between the sending machine and the receiving

machine, and in the printing of the image by the receiving machine. It is believed that these events, in combination, are the cause of changes in character pixelation between the same documents which have been independently transmitted.

The Scanning Process

Each time a document is transmitted through a fax machine, the alignment of the paper with the scanning device, known as a Charged Coupled Device (CCD), is considered random. As a result, the edge of the character or image being scanned does not always record the same reading from the CCD, resulting in a varied pattern of black or white pixels being printed each time (Figure 7).

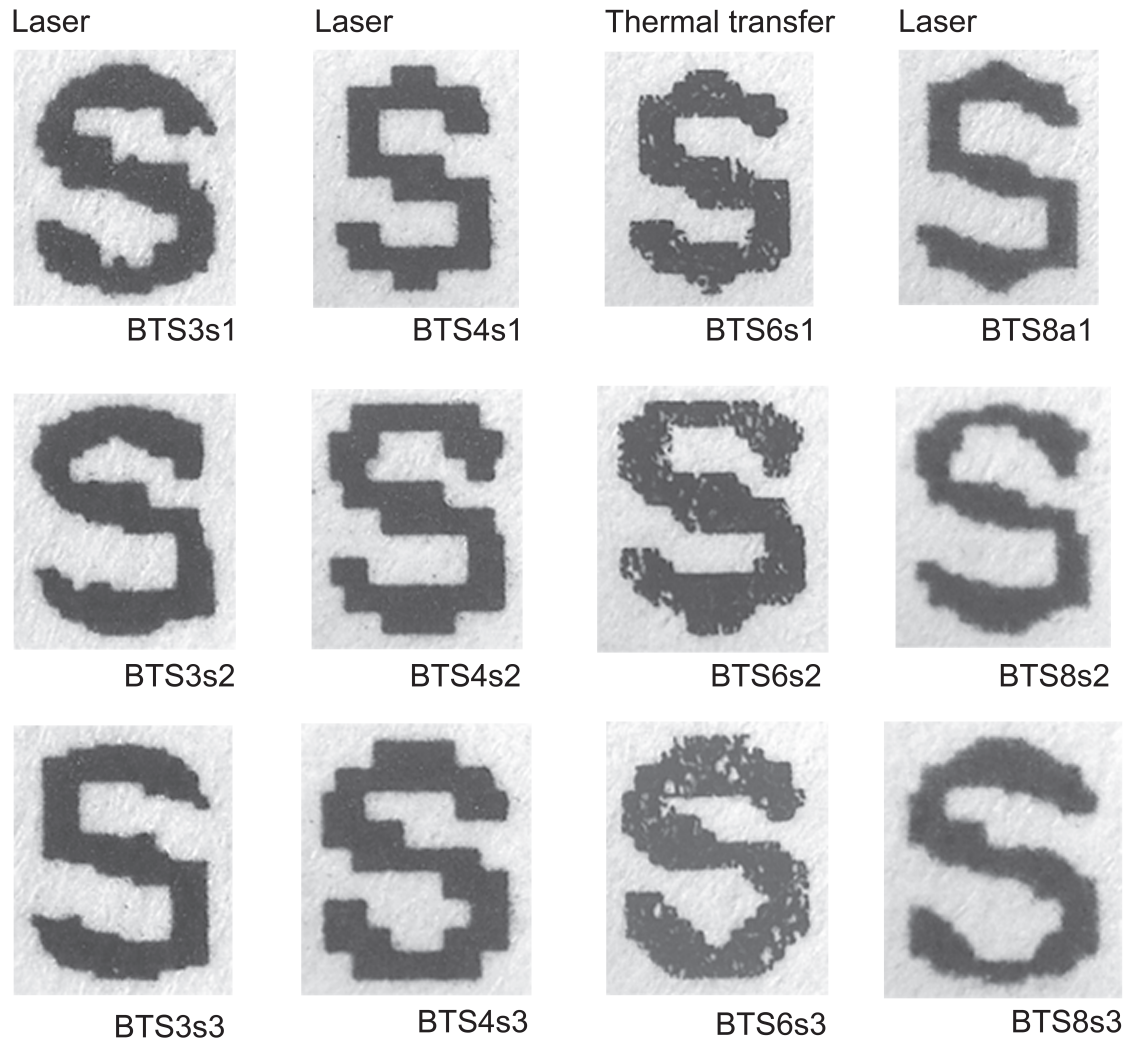


Figure 6. Pixelation changes in broadcast transmissions.

When a document is being scanned through the sending machine, the internal rollers move the document by increments anticipated by the CCD unit. Depending on the chosen resolution of standard, fine, or superfine, these increments will be 0.26 mm, 0.13 mm, or 0.065 mm, respectively (Mudie, 2001). With use, the rubbery material on the outside of the rollers which grips the paper wears. As the rollers wear, they have less ability to grip the paper, and the paper may slip fractionally with each revolution. Even when the paper does not move as anticipated, the CCD unit continues to scan. As a result, the same area of the image is scanned more than once, producing “additional” scan lines. These “additional” scan lines form part of the image which

is sent to the receiving fax machine. The document that the receiving machine prints will thus be elongated with 1 or more scan lines, which appear similar to the respective previous scan line. Over an extended area, such a result will give the image or text the appearance of a “barcode” when the same area is scanned multiple times (Kain, 1991).

Another cause of variations in character pixelation in the scanning process is the skewing of an image caused by the uneven grip of worn rollers or the incorrect tension of the paper guides and rollers. This problem is often observed when thin thermal fax paper is scanned through a sending fax machine and/or with aging and worn fax machines.

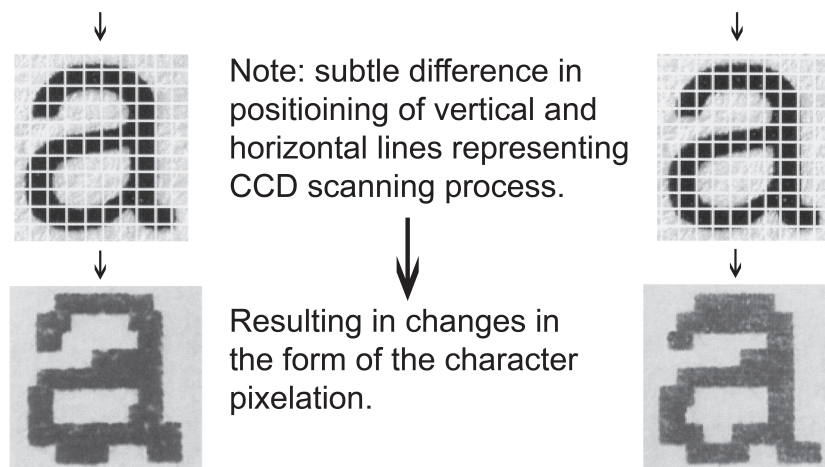


Figure 7. Random alignment of CCD and paper during the scanning process causing pixelation changes in corresponding characters of different versions of the same documents.

The Transmission Process

Phone line noise degrades the quality of signals and data. To overcome this problem, most modern facsimile machines have a feature which allows for the correction of errors caused by noise or dropouts on the telephone line. This feature is known as the Error Correction Mode (ECM), which was introduced in 1988. Its function in the receiving machine is to request the sending machine to resend data which is lost during the transmission (Kain, 1991).

The Printing Process

It is also possible that changes in character pixelation will be caused by the printing process of the receiving fax machine. Thermal paper reproduction systems have lower resolution (fine mode equals approximately 196 dpi) and reproduce an image which is based on the actual

scanned pixel size. However, laser printers which reproduce the image with much higher resolution (e.g., 600 or 1200 dpi) may use “smoothing” of the image by filling gaps between blocks of pixels, thereby attempting to give the image a “rounded” appearance to the eye (Figure 8). The application of “smoothing” somewhat alters the pixelation of the characters, in that they are less pronounced when printed compared to a thermal printhead machine (Mudie, 2001).

To reduce the consumers’ use of thermal paper (that is as a “sales feature,” to minimize cost to the consumer), some manufacturers produce thermal paper fax machines which are able to compress an image vertically, thereby reducing the amount of thermal paper required to print that image. This is done by simply removing individual scan lines. Such an application will primarily result in changes in character pixelation between

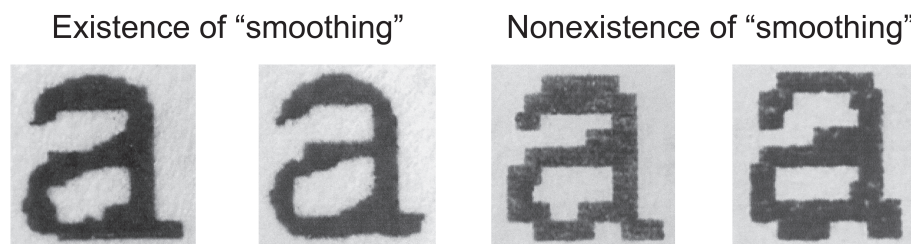


Figure 8. Application of “smoothing” by laser fax machine and reproduction of actual scanned pixel size by thermal paper fax machine.

Sample	Bubblejet/Inkjet	Laser	Thermal paper	Thermal transfer	Computer fax *
1		✓			
2	✓				
3			✓		
4		✓			
5		✓			
6	✓				
7		✓			
8			✓		
9		✓			
10		✓			
11					✓
12			✓		
13			✓		
14		✓			
15				✓	
16				✓	
17		✓			
18		✓			
19			✓		
20			✓		
21				✓	
22		✓			
23			✓		

*Incoming faxes received by a computer modem and printed by a laser printer.

Table 1. Identifies which printer type was used for each respective sample of individual transmission.

Sample	Bubblejet/Inkjet	Laser	Thermal paper	Thermal transfer	Computer fax *
1	✓				
2			✓		
3		✓			
4		✓			
5					✓
6				✓	
7				✓	
8			✓		
9			✓		

*Incoming faxes received by a computer modem and printed by a laser printer.

Table 2. Identifies the same details for broadcast transmissions respectively.

documents received and printed by a fax machine using this feature and another receiving fax machine that does not have this feature activated.

Thermal paper relies on the heat from the printhead causing the ions in the coating of the paper to combine to produce black pixels. Normally the pulses to the printhead element required to combine the ions are very short, just long enough to raise the printhead temperature to produce a black pixel. When the printhead is not given long enough pulses of power (heat) and/or the printhead does not stay long enough on the thermal paper, the necessary chemical reactions will fail to occur. This will result in a lighter or darker reproduction of the respective pixels on the thermal paper, thereby creating variations in character pixelation between documents.

Certain plain-paper fax machines also use an image-reduction feature as standard when receiving a fax transmission. In addition to compressing vertically, these fax machines compress the image horizontally as well. The resulting image is normally 97 to 98% of the original size; the level of distortion being dependent upon the algorithm and resolution of the reproduction system of the fax machine (Mudie, 2001). This feature is designed to ensure that the document being printed fits onto a standard A4 page. When the transmitting machine scans a document which is slightly over A4 size, the receiving machine will receive it in the memory, and after "compression," the information will be sized to fit on an A4 page (Kain, 1991). Such image reduction will again be another cause of distortion in character pixelation.

The reasons mentioned above are the most common causes of changes in character pixelation between independently transmitted documents. However, as the overall process of facsimile transmission involves many complicated steps, it is likely that there exist other unknown factors which may also contribute to changes in character pixelation between documents.

Conclusion

A document examiner may be asked to attempt to determine whether an individual office machine was used to produce a certain document of interest. With facsimile machines, the process of document creation is somewhat more complicated, in that both the sending and the receiving machines impart characteristics to the resulting document. In some cases, these

characteristics are sufficient to allow for a certain model of machine to be excluded or for a particular model of machine to be identified.

The results of this research support the hypothesis that each page sent by individual fax transmission is unique due to changes in character pixelation. These changes are caused by a combination of potential factors, including the scanning process of the sending machine, the transfer of information through the phone line, and the printing by the receiving fax machine. Furthermore, these changes in character pixelation can be accurately reproduced on 1st-generation photocopies of the respective received fax samples (dependent upon the quality of the photocopy machine being used to produce those copies). This being the case, it would be possible for a document examiner to identify the parent fax copy of a photocopy of a fax document. However, changes in character pixelation are less defined when the printing quality of the receiving fax machine is relatively poor, particularly with regard to thermal paper fax machines.

It was also noted that individual 1st-generation documents transmitted by broadcast bear similarities to one another in terms of changes in character pixelation between those documents. The similarity of these changes is due to each individual document having a common origin in the same single fax scanning process.

Acknowledgment

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