Authentication of Travel Documents via the ImageXpert System

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In this study, genuine and counterfeit travel documents were critically measured and analyzed with the aid of the ImageXpert System. A variety of printing processes and security features from both genuine and counterfeit passports were measured using various tools within the software of the ImageXpert System. The data from these measurements was then compared in an effort to discriminate high-quality counterfeits from genuine documents. In addition, any potential links amongst the counterfeits were also noted.

Introduction

The ImageXpert System is an automated image quality inspection system used by the manufacturers of business machines such as printers, photocopiers, and scanners to ensure that consistent quality assurance standards are maintained during production. The ImageXpert System is one of several different types of software packages designed and created by ImageXpert Inc. of Nashua, New Hampshire. This software offers a variety of image quality assessment tools which can be used to quantify a wide range of image attributes. In a typical manufacturing environment, the ImageXpert System is used to measure such characteristics as: the quality of lines, edges, dots, text, color, and halftones; registration; skew (orientation of text); background area attributes (inkjet overspray and miscellaneous satellites); sharpness; and contrast—virtually any integral component of the printing process which is vital to the success of the final product.

Variations of systems such as the one described herein have recently been acquired by forensic document laboratories with the intent of utilizing the measuring power of such systems to advantage in attempting to identify documents as having been produced by specific machines. In this project, however, the focus was on attempting to discriminate genuine and counterfeit printing processes as observed on travel documents such as passports.

For any examiner familiar with travel document examination, altered and counterfeited travel documents can be readily identified as such without the need for such detailed analysis as provided by quality assurance systems such as the ImageXpert System. Historically, the bulk of fraudulent passports involve a photo substitution or data manipulation on genuine passports. Alternatively, only selected pages, usually the biographical page, and/or other counterfoils, are removed and replaced with counterfeited pages. These insertions are typically produced with inkjet or laser printers and are quite easily discernible by a qualified document examiner. However, there still remains a very limited volume of higher-quality fraudulent passports that are counterfeited in part or entirety, with the commercial printing processes that would typically be found on a genuine passport. It is with this latter scenario in mind that an attempt has been made to use ImageXpert to discriminate genuine and counterfeit passports.

Methods & Materials

The equipment utilized in this project included (Figure 1): ImageXpert System complete with Power PC computer and customized image analysis algorithms; Leica microscope, model 12.5; Volpi Intralux 6000-1 lighting source with ring light; Sony CCD black-and-white camera, model XC-ST30; Sony CCD color camera, model XC-003; Epson Expression 1640XL scanner; X-Y motion table with menu-driven interface and joystick; Newport air table; and a passport holder.

It should be mentioned that this paper does not attempt to provide step-by-step instructions as to the methods that were employed in the operation of the ImageXpert System. It is essential that the

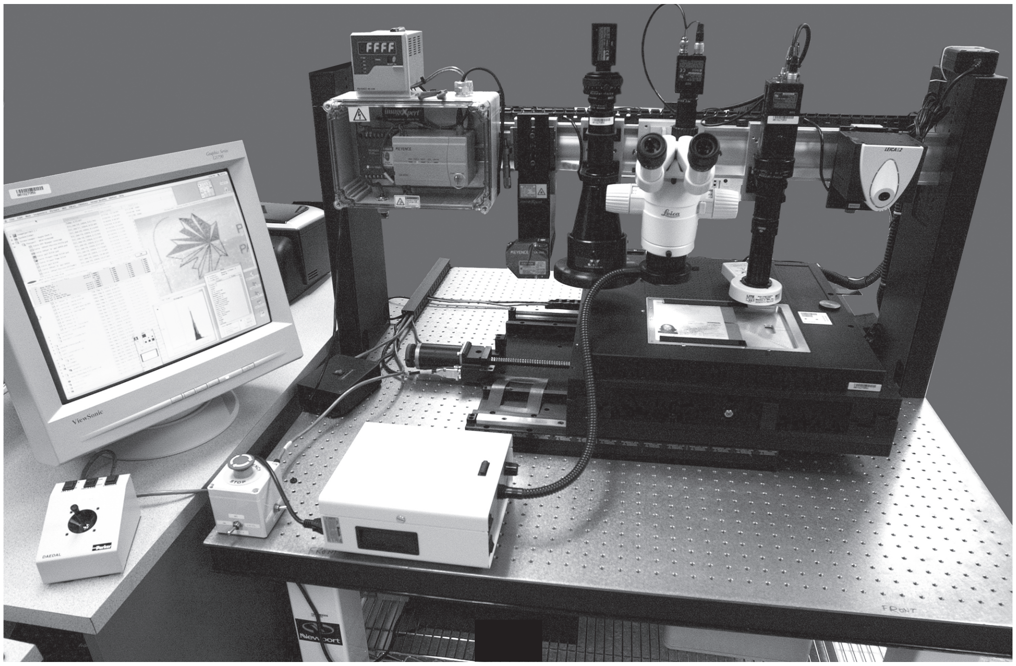

Figure 1. ImageXpert System complete with Power PC computer and customized image analysis algorithms.

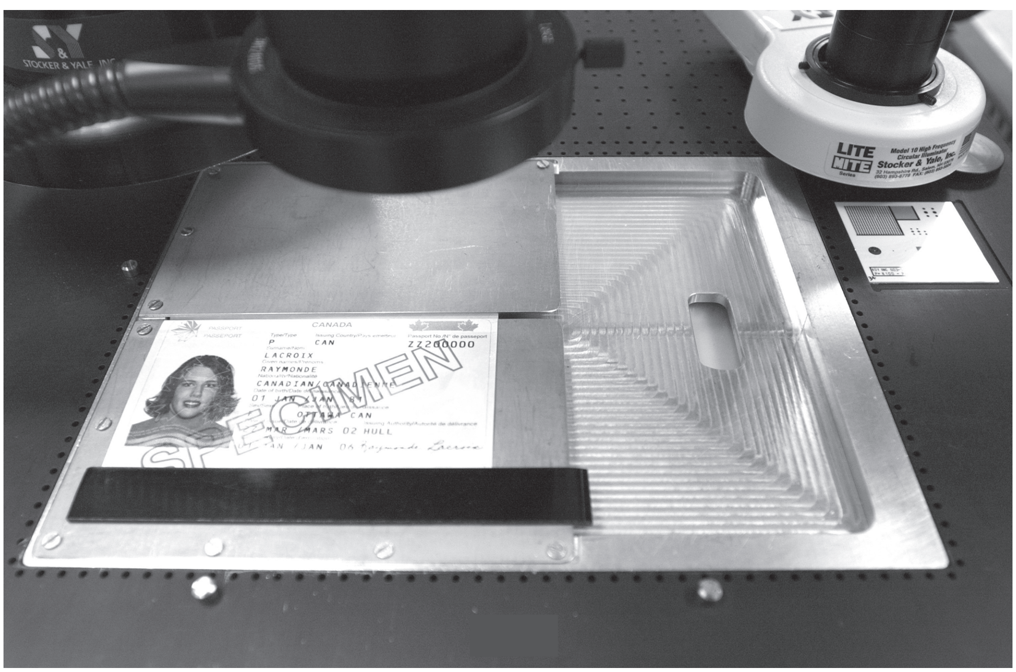

Figure 2. Custom-designed metal passport holder built to fit into a motion table.

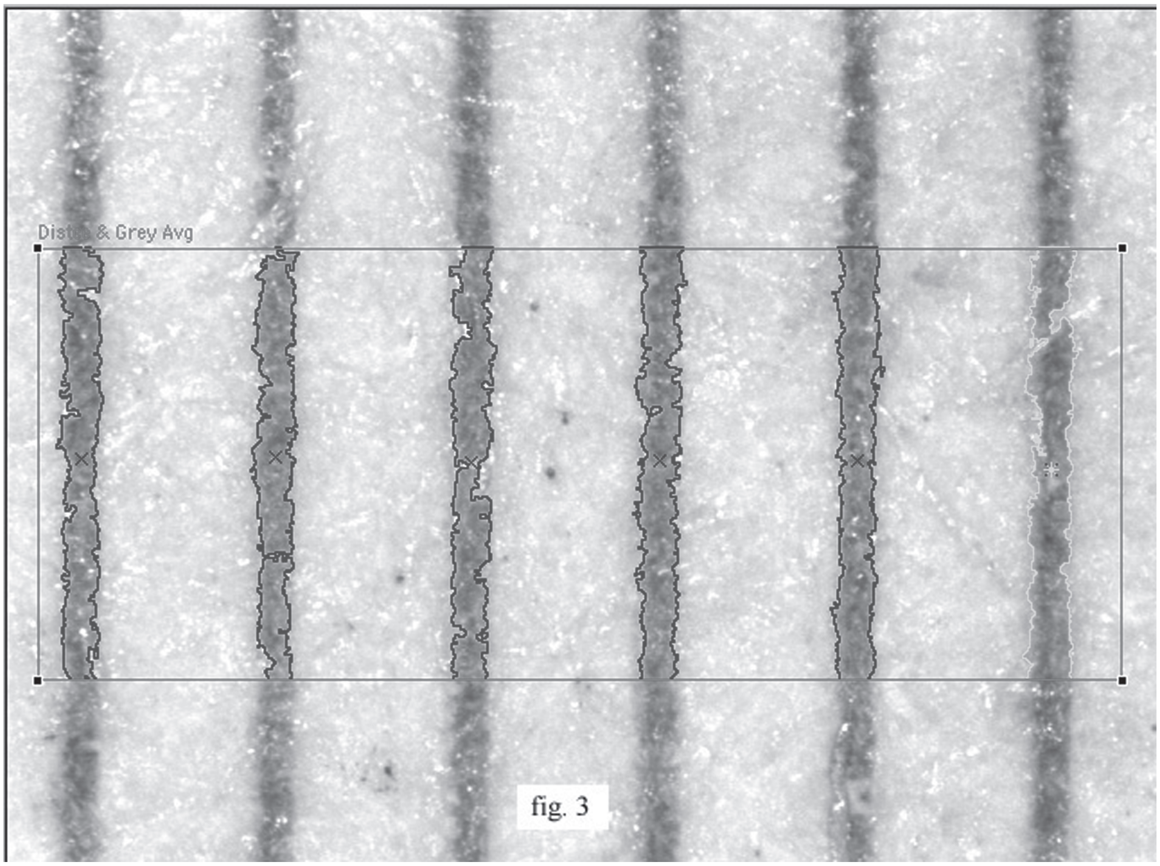

Figure 3. An image of offset microlining in which measurements were calculated by running a pre-programmed series of sequences.

operator of the system be adequately trained and familiar with its capabilities and limitations. The actual creation of the sequences of measurements that were utilized to achieve the results in this study will also not be addressed in detail, other than to mention that it is a critical and essential part of the setting-up and functioning of the ImageXpert System.

As with any type of precision measuring device of this nature, calibration of equipment is a key element to the success of such a venture. For every change in magnification, the computer and camera or scanner had to be calibrated properly as per normal ImageXpert operating protocol to ensure an accurate pixel-to-distance ratio. To do so, the ImageXpert System was calibrated against a National Institute of Standards & Technology (NIST) traceable reticule which was supplied with the ImageXpert System. At the same time, the lighting and focus were also verified to ensure consistency. While calibration to a NIST standard was obviously important to ensure the precise accuracy of measurements, repeatability tests were also performed in order to determine the maximum error rate that could be expected for any particular sequence. For example, a typical error rate of the analysis of the "skew" of a line of microprinting relative to the edge of the page was ± 0.007 mm, while the error rate of the distance between microlines was ±0.001 mm. The size of the error rate would fluctuate depending on factors such as magnification and the type of algorithm being run. Before any sequences were run, every effort was made to ensure that all variables that could adversely affect accuracy and consistency of results were eliminated.

In an effort to ensure that the precision of measurements was optimized, and to expedite the process of making multiple measurements, a metal passport holder was custom-designed and built to fit precisely into the motion table (Figure 2). By doing so, a passport could be precisely positioned into the exact same location on the motion table each time, thereby permitting the motion table to be programmed to automatically move to any number of predetermined specific spots known at the region of interest (ROI) on the passport. Furthermore, the passport holder was designed so that the pages being examined were at the same level as the calibration reticule. This then permitted the pixel/distance calibration to remain valid over the entire surface of the page being analyzed. Once all calibrations and verifications were performed, a processing function would be selected (e.g., line edge); a preprogrammed measuring sequence would then be activated (e.g., mean deviation) which would measure the ROI; and the values would then be instantly generated and displayed accordingly in a data table. Once a site was fully analyzed, the motion table could then be tasked to automatically move to the next pre-selected ROI. In this manner, an extensive amount of data could be quickly generated on numerous different features, which were located at various sites on the passport.

One of the primary challenges of this project was to ascertain which of the multitude of tools offered by the ImageXpert System were most appropriate for discriminating printing processes on passports. Part of the exercise was to both become familiar with the instrument and to assess the viability of quality-assurance software for use in forensic document examinations. With this in mind, it was decided to experiment with a variety of tools to measure and assess a number of different security features observed on the passports. Some of the features assessed included offset printing (microlining, text, microprinting), intaglio printing (design work, text, microprinting), thermal printing, optically variable ink, foil embossing, letterpress printing, and print-wheel typescript.

A few examples of the types of features assessed and algorithms employed during this project are briefly described herein. The analysis of background offset microlining involved several measurements, including the average width of lines and their standard deviation, the average distance between the lines and their standard deviation, and the greyscale value of the inked lines. Another valuable assessment of line structure is the "raggedness" of the edge of the line. This "raggedness" is derived via a measurement of the mean deviation along the edge of the line. Figure 3 depicts an image of offset microlining in which the above measurements were in the process of being instantly calculated by simply running a preprogrammed series of sequences.

Another ImageXpert processing function is "connectivity," which is an effective tool for connecting pixels around and throughout the entirety of a character or "blob." Once identified, this very specific ROI can be further assessed by running any number of desired measurement sequences. Figure 4 depicts offset text in which perimeter, area, average perimeter to area ratios, and greyscale measurements were about to be generated from specifically selected "A"s.

Analysis of optically-variable ink (OVI), with its high reflexivity properties, provided other unique challenges. The "mottledness" or the degree of effective coverage of this ink was assessed by first using a grey scale algorithm to measure the percentage of the white spots (reflective areas) and then adding this value to that obtained from the dark (nonreflective) areas. This combined value was then subtracted from the total area of the ROI, leaving a percentage value of ink coverage. It should be noted that consistent lighting at a fixed angle and distance were critical prerequisites for this type of analysis, as well as the position of the passport (i.e., x, y, z coordinates). Figure 5 illustrates one step of this process in which the reflective (white) areas of the ROI are being analyzed. In the process of doing so, ImageXpert automatically highlights the largest "blob," or component, in yellow, with the rest of the reflective components of the ROI highlighted in blue.

While most of the printing features analyzed in this project were imaged via the Leica microscope using magnifications ranging from 6.3X to 63X, a scanner (at a resolution of 600 dpi) was also used to measure features of a larger scale. For example, a "skew" analysis was calculated on the positioning of a border of intaglio-printed design in relation to the edges of the page (Figure 6). Similarly, the "skew" of the bottom of intaglio microprinting was calculated in relation to the left side of the page. Both measurements provided values reflecting the perpendicularity of the printing in relation to the edge of the paper. This intaglio design was also assessed via a "sharpness" algorithm. This tool measures the nature of the shoulder of the line by calculating the differences in grey values between adjacent pixels, thereby providing a profile of data of the black-to-white transition, and vice versa.

Once the set of features to be analyzed was decided upon, 40 genuine passports of two different valid versions were analyzed, i.e., 20 of each. From this data, minimum and maximum values

Figure 4. Offset text in which perimeter, area, average perimeter to area ratios, and greyscale measurements were about to be generated from specifically selected "A"s.

were recorded for each type of analysis performed. This data quickly established a genuine range of values for each type of analysis conducted on specific printing features throughout the two versions of the passports. Figure 7 depicts just a sampling of the many data collection tables that were used in summarizing some of the more pertinent results obtained from the automated ImageXpert data tables. The table illustrates how values from the suspect passports were compared to the tolerance ranges of genuine passports. For security reasons, the actual data entries have been deleted.

Results

In general, ImageXpert proved to be a useful means by which to further discriminate between genuine and counterfeit passports. Furthermore, measurements from counterfeit passports which were suspected as having originated from the same source tended to have data values which were similar amongst themselves, yet distinct from genuine and other groups of counterfeit passports.

Probably the most intriguing aspect of this project was the realization that there are numerous challenges and issues that must be taken into consideration when attempting to exploit critical measurements of this nature. Some of the challenges found were:

(a) Some measurement strategies were more effective in discrimination than others. For example, measurements of relative positioning and dimensions, such as the width of offset background microlining and the distance between these lines, were often outside the genuine tolerance range, but not by very much. An obvious explanation for this is the fact that when these types of design elements of counterfeits are scanned or photographed during the fabrication process (not created from scratch), their relative measurements are likely to be quite accurate. Thus, it was noted that it is probably more effective to focus measurement discrimination on differences in the printing processes themselves than on elements of design.

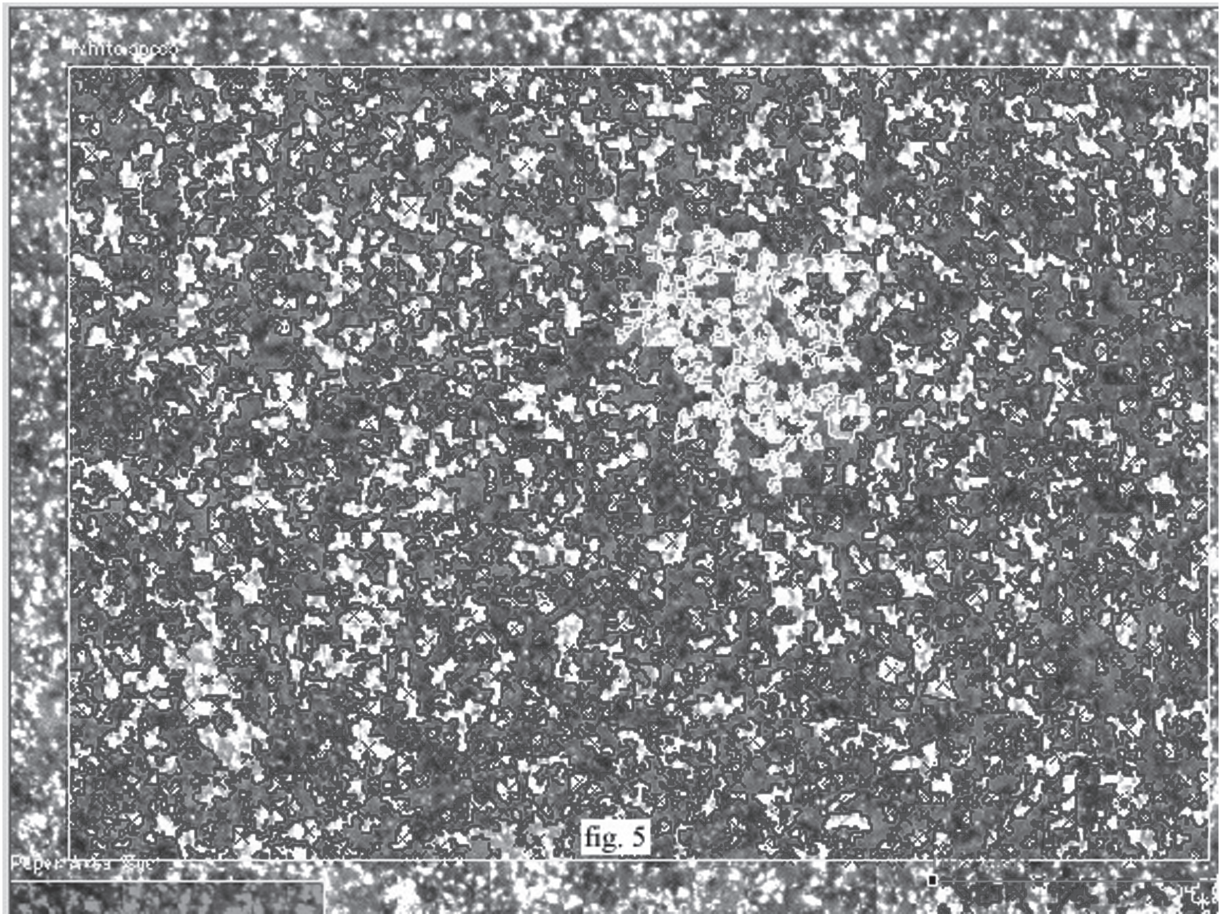

Figure 5. Illustrates one step of the analysis of optically-variable ink in which the reflective (white) areas of the ROI are being analyzed.

(b) Some counterfeited commercial printing processes tended to deviate more than others from the established genuine range of values. While counterfeit offset lithography would often be just outside the established genuine range, more noticeable discrepancies were observed in intaglio and letterpress printing. Good discrimination was usually, but not always, observed in measurements involving line/edge definition, transition zones between light and dark edging, greyscale, and ink coverage.

(c) Detailed measuring of printing processes under 3M Confirm laminate proved to be problematic. The beaded nature of this type of laminate distorted the fine details too much for the results of most measurements to be of any value. However, measurements such as skew and greyscale could still be effective. Clear laminates, on the other hand, did not seem to obstruct the measuring process as much, but caution was again necessary in evaluating the true significance of the data.

(d) Whenever more than one variable is being assessed, there was danger of misleading results. When assessing greyscale through a laminate, one must remember that results could be influenced from both the printing process being assessed as well as from the laminate itself. Similarly, when assessing the raggedness of the edges around two characters, these values typically could be expressed in terms of perimeter or area, or perimeter-to-area ratio. However, this assessment would be more significant if it was certain that the two characters being compared were of equal size to begin with. Unfortunately, some of the variables that can be controlled during quality assurance measurement of business machines on the production line at the factory cannot be controlled in the same way during the forensic examination of travel documents.

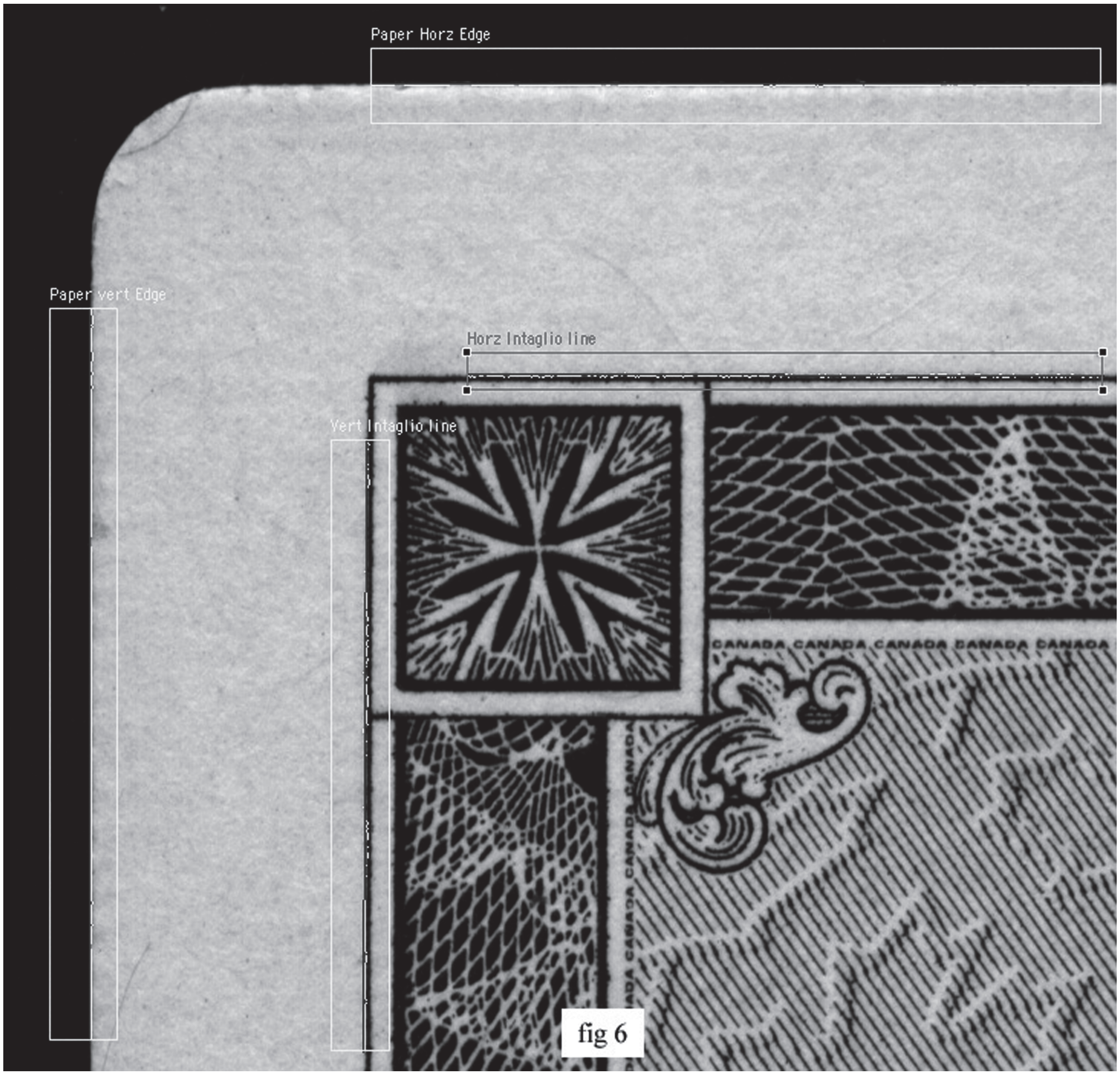

Figure 6. Example of a "skew" analysis calculated on the positioning of a border of intaglio-printed design in relation to the edges of the page.

Discussion

This project was considered to be a good "stepping stone" in the development and familiarization of the ImageXpert System as a valuable tool for forensic document examination. The numerous security features and printing processes observed in a passport forced the participants of this project to explore the wide array of measuring capabilities offered on the ImageXpert System and to assess how best to use these tools to their maximum discriminating advantage. Also, in concentrating on commercial printing processes deployed on a specific official document, a number of variables that could typically hamper attempts to identify a specific personal printer are to some extent bypassed. For example, while the manufacturers of a specific version of a passport are conscientiously utilizing the same machines, materials, inks, and papers, the same cannot be said of a personal printer in which an extended variety of different papers and inks could be used, thereby confounding the identification issue. It should be noted, that while this project mainly assessed passports, the concept obviously applies to any travel or identification document. A similar approach of critical measurement analysis could also be applied to currency, as well as other identification and official documents.

Features	Measurements		Counterfeit Passports			Genuine 1992 Version Passports			Genuine 2002 Version Passports		
			1	2	3	Min	Max	Avg	Min	Max	Avg
Offset printing - Microlining Location: page 3, green maple leaf 3rd row - 3rd leaf from left edge	**Distance**	Distance between lines									
		Average Width of Lines									
	Greyscale	Greyscale Average									
	Line Raggedness	Mean Deviation									
Intaglio printing Location: Inside front cover - top left edge	**Line Raggedness**	Mean Deviation									
		Average Line width									
	Sharpness	Vertical Focusing									
		Horizontal Focusing									
	Width of the Gaps	Horizontal Gap									
		Vertical Gap									
Intaglio printing - Microprinting Location: page 3, 3"A"s in "CANADA..."	**Edge Raggedness**	Average Perimeter (P)									
		Average Area (A)									
	Raggedness	Average Ratio of P/A									
Intaglio printing Location: page 3, top left corner	**Skew**	Angle 1 - Vert edge to Horiz Box 3									
		Angle 2 - Horiz edge to vert Box 3									
		Angle 3 - Microprinting & horiz edge									
Thermal printing Location: page 2, First 2 "A"s in CANADIAN	**Edge Raggedness**	Average Perimeter (P)									
		Average Area (A)									
	Raggedness	Average Ratio of P/A									
OCR Printing (pg 2 <<<)	**Greyscale**	Average Greyscale									

Figure 7

Figure 7. A sampling of the many data collection tables that were used in summarizing some of the more pertinent results obtained from the automated ImageXpert data tables.

While using the ImageXpert System, no attempt was made to link counterfeit passports with absolute certainty. At this point, no effort has been made to try to evaluate every type of commercial printing press or printer that has been used in passport production. The links that have been made in this project are intended for intelligence purposes and meant as investigative leads. However, having admitted that it would be very difficult to assess the exact significance of the similarities observed between the counterfeits (without having conducted extensive research on commercial equipment), a level of confidence in grouping certain passports in this way could be somewhat enhanced simply due to the combination of similarities observed from the various types of features that were measured and the different ways in which they were analyzed.

This project represents a concerted effort to utilize advanced technological resources such as the powerful measuring capabilities of quality inspection hardware and software to more effectively and precisely quantify observations and data gleaned during document examinations. As the quality of fraudulent documentation improves with the use of more technically advanced tools and processes, so must the document examiner in his or her attempt to forensically optimize the significance of the evidence observed. In doing so, however, it will be critically important that the operator of any measuring software such as that presented in this paper be extremely cognizant of exactly what is really being measured, how it is being measured, and the identifying significance of the data accumulated.

Acknowledgments

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