Using Image Analysis Systems in Forensics and Security Printing

Yair Kipman and Kate Johnson
ImageXpert Inc.
Nashua, New Hampshire, USA

Abstract

Image analysis tools are currently in use for a variety of applications in the fields of forensics and security printing. Objective, quantitative data allow for characterization and comparison of a variety of image attributes.

In forensics, document examiners can use quantitative image analysis systems in authentication, detection and analysis of forgeries, counterfeits and altered documents. Statistical analysis enables population characterization that can help in forgery detection and supports the potential for source identification. In security printing, image analysis tools can be applied to measure the quality of printed output and assess wear for bank notes.

Flexible hardware options allow for a broad application of image quality measurements in a variety of image analysis situations. Camera and scanner-based image quality systems can be used for quantitative analysis of image content. A laser-based system can be used for height and depth profiling. Oblique angle illumination and scanning can be used for impression detection. A flatbed scanner can be used in transmission mode for the evaluation of bank note wear and for watermark analysis.

In this paper, we will be discussing the use of a variety of hardware configurations for image analysis in forensics and security printing.

Introduction

Image analysis is usually used to evaluate analytical documents to assess the quality of printers and materials used in printing by their manufacturers. In forensic document examination, the goal is quite different. Documents and their content are usually not under the examiner's control so features that are present must be used as the basis for comparison. Features are often far from ideal, but there are many areas of a document that may be used for objective comparison.

Documents under examination may contain text, halftoned regions, lines, line art and other features. Dot quality, how dots are shaped and formed, may provide a clue about the source of the document. Line quality (measuring characters) can provide insight via line width, raggedness and patterns of overspray and satellites. Color quality can be a key characteristic and is best measured via specialized equipment that can compare color more exactly—such as a spectrophotometer.

Currency and falsified documents may also include a number of image and background details emulating some of the features that are added specifically to make falsification more difficult. Some of these features might be well suited to comparison and characterization as well.

The usefulness of image analysis systems in security printing and forensics is based on the hopeful assumption that no matter how advanced printer technologies have become there are still some differentiating features that can be measured.

For example, different printer technologies have different characteristics. Toner based printers often have microscopically raised letters while inkjet often suffers from line spread.

Even within a specific technology and even the same manufacturer and model, different printers have different characteristics that may aid in identifying the document source.

Measurement Equipment

In spite of the challenges and confounding issues, using objective measurement equipment to augment subjective analysis may be a great benefit to document examiners. Image quality tools can be used for quantitative analysis of image content.

Various types of image analysis equipment exist to aid in analysis. In general, objective systems can provide everything from magnified images that can be saved and catalogued, to hardcore analytical data that can be used as the basis for document comparison and source trace. Clearly one of the most useful attributes of these systems is that all of them are non-destructive and many of them (with the exception the handheld and the scanner) are non-contact.

Portable System

The handheld device uses an optical head that includes a camera and a light source to capture images at very high magnification. The field of view is sufficiently large to capture and assess an entire character up to 16 points in size in common western fonts, while the magnification is high enough for the preservation of significant image detail.

Figure 1 shows a 12 point Courier lower case "f" imaged at nearly 3 microns per pixel.

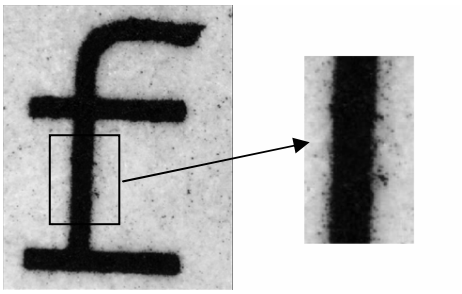

Figure 1. Handheld image with detail shown

There is a window on the device that enables easier placement on a document and images can be captured, analyzed and saved using the powerful software that is the basis of all of the system configurations that we will be discussing in this paper.

Full-Motion System

For larger projects where many samples will be measured (for printer characterization, for example), a full motion system may be appropriate. Using digital cameras mounted above an automated X-Y motion table, samples can be measured automatically in both reflection and transmission modes. Addition of a document feeder can increase throughput and minimize operator intervention.

Image analysis at both microscopic and macroscopic levels are possible using a system configuration like this one. The instruments that are included depend completely on the needs of the user. For example, there can be a spectrophotometer for color measurement or a gloss meter for gloss measurement. A laser height measuring system can be added as well. Figure 2 shows a schematic of a motion system with a variety of equipment including two cameras, a laser and a colorimeter.

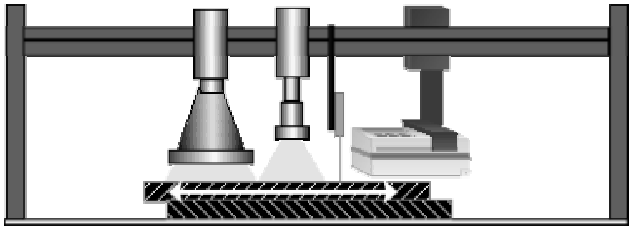

Figure 2. Full-motion system

Flatbed Scanner-Based System

For larger areas or for the analysis of full pages at lower magnifications, there is a flatbed scanner-based system.

This system can be automated or it can be used interactively depending on the needs of a particular project or examination task.

Image registration, color registration, text uniformity, banding and other features are well suited for the scanner system. As is the case with the other systems, the same powerful image analysis software is at the core of this instrument, allowing for objective, image quality measurement. In addition, as with all of these systems, images can be captured and archived for documentation.

Laser Profiling System

The laser height profiling system can be a stand-alone unit or it can be added on to the full motion system highlighted earlier. A laser-based system can be used for depth profiling (useful in analysis of signatures and impact printing) and height profiling (useful in the analysis of toner based imaging and embossing).

Various configurations exist at both higher and lower resolutions, but the most common resolution of the system is 1 micron in the "Z" direction.

By using laser triangulation, the height of a sample can be measured in specific locations or along a scan line, providing data about toner pile height, character impact depth and other attributes that might prove to be important in document differentiation and relational determination.

Figure 3 shows a diagram of this system.

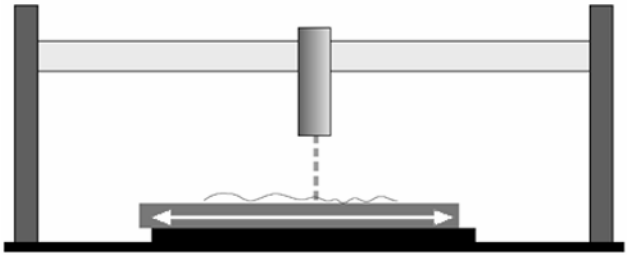

Figure 3. Laser height profiling system

As the laser traces across the surface, data is gathered about the height of the surface at a specific sampling rate that is determined by the requirements of the application. Data can then be viewed in a tabular or graphical format to show the measured height variations.

Line Scan Camera-Based Systems

Sometimes, the image itself is not there. What remains is only the impression. It could be on a second sheet. It could be a fingerprint that leaves a glossy/oily residue. There is a non-contact, non-destructive technology that allows these items to be imaged. Figure 4 shows a schematic diagram of this instrument.

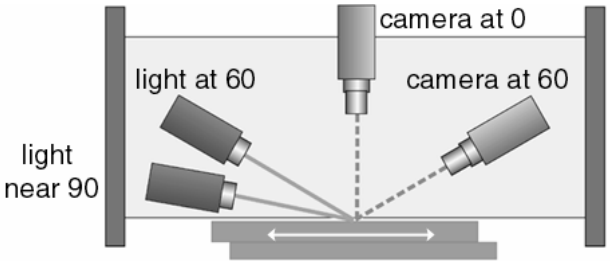

Figure 4. Line-scan camera based system showing various illumination and image capture geometries

The technology is based on a line scan camera and variable angle lighting. This technology has been used for a variety of applications, the most relevant to the current topic being the imaging of specular images.[1] Both the camera and light source can be configured in a variety of different ways depending on the need of the specific application.

A line scan camera is used for image capture to avoid distortion and illumination non-uniformities.

Varying angular configurations for the illumination and the camera result in very different outcomes.

Figure 5 shows a few examples of what an impression image looks like with two different geometries of illumination and image capture.

This sample is from a sheet of paper that was just beneath the sheet where the writing took place.

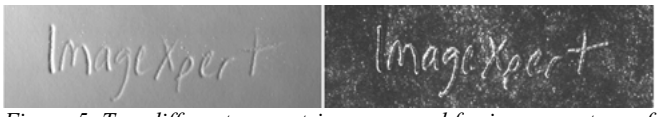

Figure 5. Two different geometries were used for image capture of an impression-only sample. The image on the left was captured with the camera at 0 and the illumination at near 90, the image on the right was taken with the camera and illumination at approximately 60 degrees from normal.

Applications

Full-Motion System

The real world application of these products to security and forensics work is just beginning. Three major studies demonstrate the usefulness of image analysis to security and forensics applications. Oliver and Chen discussed the feasibility of using image analysis tools to characterize specific printing devices.[2] Gaudreau took this concept a step further and proved that characterization could be successful via image analysis.[3] And Estabrooks applied image analysis techniques to show that differentiation was possible between authentic and counterfeit travel documents.[4]

In all three cases, characterization is the first step. A variety of samples are measured and data is accumulated regarding some basic characteristics including attributes such as character and line quality.

When a new sample is acquired, comparing measurement results from the new sample to the accumulated data from the samples that were already characterized might provide information leading to a match between the document and other documents and possibly even a document source.

Challenges

One of the most significant issues facing printer identification, specifically in ink-based printing systems, is the fact that different media (different ink or different paper) radically changes the look and characteristics of an image.[5,6]

Figure 6 shows two different characters printed on the same printer using the same settings on the same substrate. However, one was printed with the OEM ink the other with a third party ink. Notice the complete difference in overspray patterns. It should be noted that there are some potentially identifying features on the upper shoulder of the "f", the differences between the two are considerable.

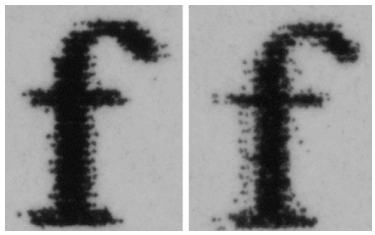

Figure 6. The character printed with the OEM ink is on the left, the character printed with the third party ink is on the right.

Flatbed Scanner-Based System

The scanner-based system does require contact with the sample surface since a sample needs to be placed face down on the glass platen for image analysis in reflection mode. However, the scanner system does provide efficient large field analysis in both reflection and transmission and has a variety of uses in both forensics and security printing. Here are two examples.

Banknote Wear

The scanner can be used to assess banknote wear. A relatively low resolution scan can be made in transmission mode, and edge raggedness, perimeter length, number and area of holes, total area and other features can be measured and reported. Figure 7 shows an example of a banknote image.

Figure 7. An image of a banknote scanned in transmission to assess wear.

Character Uniformity

Another example of a real-life application is the characterization of printers by measuring the distribution of character sizes at different locations on a page. It was hypothesized that the differences in character area in different locations on a print might be a differentiating characteristic between printers.

Specifically, the area of the lower case letter “e” was chosen since it is common in English documents.

Prints were made using 3 different Hewlett-Packard LaserJet 5Si laser printers using the same settings on the same paper type. Images were scanned in at high resolution using a flatbed scanner. The area of the character “e” was measured in 5 different locations on multiple sheets from each printer and the averages were tabulated for graphing and comparison.

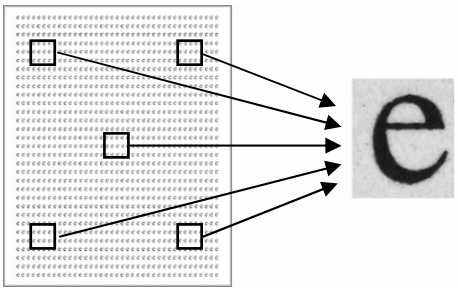

Figure 8. Comparison of 5 locations per page shows printer-to-printer patterns in both average character size and size distribution over the page

The results of this analysis showed several interesting things. First, the three printers had very different average character sizes regardless of page position. All of the characters from all of the prints from each printer had area values that tended to cluster at different average values. Second, in all three printers, there seemed to be a unique pattern to the distribution of relative sizes that may be usable as an additional differentiator between individual printers of the same make and model.

Figure 9 shows a graph with the results from the three printers. The individual data points are not as interesting as the overall clustering of values around different average values.

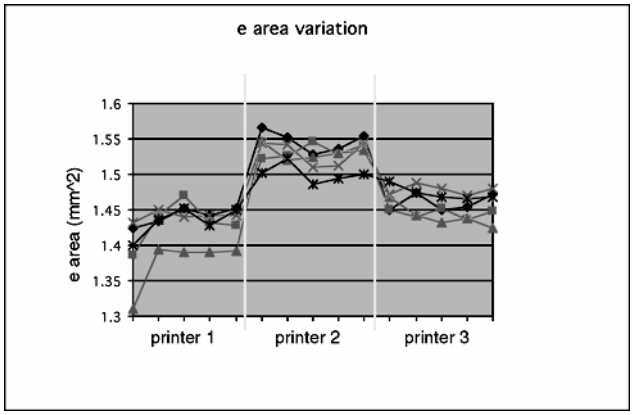

Figure 9. Character area measurements for three printers of the same make and model

The positional dependence data was not quite as decisive, but it was certainly intriguing. Figure 10 shows a graph of the distributions of the areas across the page for the three printers. Each data point is the average of 5 samples.

Although none of the results is conclusive, the results are certainly informative and indicate the possibility of looking at size distributions over a page as a potentially differentiating or identifying characteristic.

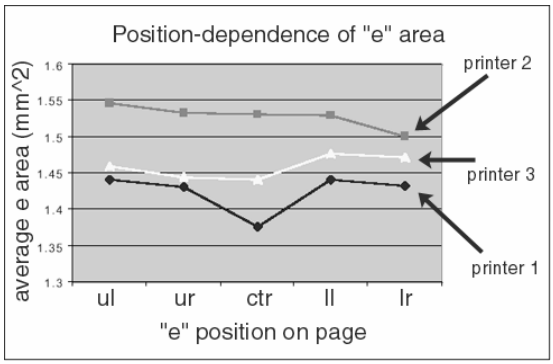

Figure 10. Position dependence of the areas of the "e" characters on prints from three different printers of the same make and model

Laser Profiling System

The laser profiling system can be used to detect impressions from impact printing, assess toner height or embossing profiles, and it can be used to assess impression depth of signatures.

Figure 11 shows an image of a signature and the corresponding graph showing the profile data taken across the signature from twenty evenly spaced scan lines.

Figure 11. Signature Impression Depth Analysis

Comparison of two signatures created by two different people showed different depth patterns across the signatures. This method of analysis might be a helpful adjunct in signature analysis.

Conclusion

Although the usefulness of image quality analysis is just beginning to be recognized in the fields of forensics and security printing, image quality equipment has been at the core of several important research projects aimed at printer characterization and counterfeit detection. In all configure-ations, system flexibility allows for both interactive and automated measurement, which is critical, since image content is not always under the control of the examiner or examining organization. Multiple hardware options allow for both optical feature characterization and height profiling analysis. The use of multiple imaging and analytical modalities expands the usefulness of the systems and can provide a broader range of tools for use in these very specialized applications.

References

1. Prashant Mehta et al, *A New Method of Measuring Gloss Mottle and Micro-Gloss using a Line Scan CCD-Camera Based Imaging System*, IS&T NIP17 Proceedings, p. 714-717 (2001)
2. John Oliver and Joyce Chen, *Use of "Signature" Analysis to Discriminate Digital Printing Technologies*, IS&T NIP18 Proceedings, p. 218-222 (2002)
3. Marc Gaudreau, *Forensic Application of Print Quality Measurement*, Presented at the IMI 1st Security Printing Conference, 2004
4. Colin Estabrooks et al, *Authentication of Travel Documents Via the ImageXpert System*, Presented at the ASQDE Annual Conference, 2004
5. Glenn Menin and Kate Johnson, T*he Impact of Third-Party Inks on Image Quality*, IS&T PIC Proceedings, p. 370-375 (2003)
6. Kate Johnson, *The Hidden Costs of Third Party Inks*, Presented at the IMI 10th Annual Digital Printing Supplies Conference, 2003

Biography

Mr. Kipman is the president of ImageXpert Inc., the industry leader in automated image quality inspection systems. Since founding ImageXpert in 1989, Mr. Kipman has guided the company to the forefront of the image quality industry. Mr. Kipman holds a M.S. in mechanical engineering, with a major in electro-optics from the University of Connecticut and a B.S. from the Technion Institute of Technology.