J32 The Effects of Heating and Laser Printing on Paper Surface Textures as Assessed by Discrete Two-Dimensional Fast Fourier Transforms and One-Dimensional Power Spectra

Walter F. Rowe, PhD, The George Washington University, Washington, DC 20007; Richik Haldar, Thomas Jefferson High School for Science and Technology, Alexandria, VA 22312*

Learning Overview: After attending this presentation, attendees will understand the value of the discrete two-dimensional fast Fourier transform in documenting the surface textures of paper samples, such as common office and copier papers. Attendees will also understand how the two-dimensional fast Fourier transforms (2D-FFT) can be converted into one-dimensional power spectra (1D-PS), which are convenient for comparing different paper samples.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by demonstrating that paper surface textures are not adversely affected by temperature and passage through laser printers.

The manufacture of modern paper products from pulp typically involves a series of steps: extrusion of the pulp onto a wire screen, removal of water (dewatering), vacuuming with a suction roll, and drying while being pressed with canvas fabric against a drying roll.[1] These forming and drying processes impart periodic patterns of marks to the finished sheet of paper. Because different paper manufacturers use different machinery, it is possible to differentiate their products from one another using 2D-FFTs.[1-3]

Previous research on paper textures has relied on scanning the textures using transmitted light.[1-3] However, not all flat-bed scanners have light sources with sufficient intensity to acquire usable transmitted light images through single sheets of paper. This is particularly true of the widely used all-in-one printers, which also incorporate scanners. One objective of this research was to determine if reflected light images of sheets of paper could provide 2D-FFTs capable of distinguishing different brands of office and copier paper.

Ten brands of office and copier paper were used in this research project. Paper surface textures were scanned in reflectance mode as bitmap images at a resolution of 600 dots per inch (dpi). Two scanners were used: an Epson® Perfection V500 Photo flat-bed scanner and an Epson® WorkForce WF-3640 all-in-one printer. The Epson® scanner and Epson® all-in-one printer were controlled by Epson® Scan software (version 3.7.7.0). ImageJ software version v.1.4.3 was used to equalize and normalize the histograms of the scanned images of paper surface textures. An ImageJ macro modified from Sasaoka et al was used to compute all 2D-FFTs and 1D-PS.[3] The paper brands examined in this project could be readily distinguished by their 2D-FFTs and 1D-PSs obtained by scanning in reflectance mode.

To assess the effect heat on the surface textures of paper, paper samples were heated in the oven of a conventional domestic gas range. Two temperatures were selected for this part of the study: 149°C (300°F) (the temperature at which paper begins to turn brown) and 216°C (420°F) (a temperature just below the autoignition temperature of most papers).[4] Samples were held at each temperature for one hour. The oven temperatures were monitored using a Digi-Sense® Digital Thermometer with a Type K thermocouple. The calibration of the digital thermometer was National Institute of Standards and Technology (NIST) certified. Six 4.0cm X 4.0cm areas were scanned on each paper sample. These areas were located at the upper left, upper right, center left, center right, lower left, and lower right on each page. The 2D-FFT and 1D-PS were calculated for each sample using the six scans. The paper samples heated to 149°C (300°F) showed only slight discoloration, while those heated to 216°C (420°F) were friable and a yellow or brown color. It was found that the 2D-FFT and the 1D-PS were not altered by heating.

In laser printing/copying, toner particles are transferred to the paper surface, then fused to the surface with an elevated temperature. A Canon® imageRUNNER ADVANCE C5560 printer was used to copy a template with black borders, a vertical black stripe, and small colored blocks (red, blue, and green) onto samples of each of the brands of office and copier paper. The surface texture of each sample was scanned before and after laser copying. The surface textures in the areas where no toner was deposited were unaffected. The laser copier embossed a grid pattern on the fused toner particles. This grid pattern contributed to the 2D-FFTs and 1D-PSs of the paper surfaces but did not obscure the contributions of the paper surfaces.

This project demonstrated that 2D-FFTs and 1D-PSs capable of differentiating brands of office and copier paper can be obtained from paper surfaces scanned in reflectance modes in flat-bed scanners and popular all-in-one printers. The 2D-FFTs and 1D-PSs are not affected by heating paper samples close to their autoignition temperature. The 2D-FFTs and 1D-PSs are not affected by passage of the paper through a laser printer.

Reference(s):

1. Myata H., Shinozaki M., Nakayama T., Enomae T. A discrimination method for paper by Fourier transform and cross correlation. *J Forensic Sci* 2002:47:1-8.
2. Berger C.E.H., Ramos D. Objective paper structure comparison: Assessing comparison algorithms. *Forensic Sci Int* 2012:222:360-367.
3. Sasaoka S., Saito K., Higashi K., Limwikrant W., Moribe K., Suzuki S., Yamamoto K. Design of one-dimensional power spectrum using two-dimensional fast Fourier for discrimination of paper-based kraft tapes. *Forensic Sci Int* 2015:257:329-336.
4. Café, T. *Physical constants for investigators*. www.tcforensic.com.au/docs/article10.html accessed June 24, 2020.

Fourier Transforms, Paper Textures, Flatbed Scanners

Copyright 2021 by the AAFS. Permission to reprint, publish, or otherwise reproduce such material in any form other than photocopying must be obtained by the AAFS.

*Presenting Author