QUESTIONED DOCUMENTS

Aurora Dumitra,[1] M.F.S.; Anna Guzowski,[1] B.S.; Alynka Jean,[1] B.S.; Melvin Shaw,[1] M.F.S.; Grace Warmbier,[1] B.S.; and Patricia Zippo,[1] B.S.

Distinguishing Characteristics of Robotic Writing*

ABSTRACT: Advances in robotic handwriting technology create new challenges for forensic document examiners. In the past, devices such as the autopen were used to replicate signatures of government officials and corporate companies. In today's technology, companies such as Bond utilize robots to create written documents, which mimic natural patterns of handwriting. They generate customizable written samples by simulating pen movements and letter formations. Four forensic document examiners were given various reproduced questioned documents and utilized a modified ACE-V (analysis, comparison, evaluation, verification) methodology to determine their genuineness. Examiners were able to make a distinction between the human writing samples and the skilled robotic equivalents. Several distinct features that are not seen in natural handwriting, such as even pen pressure and the superimposition of letterforms were observed in the robotic samples. Careful examination of identifying features of the Bond produced documents resulted in an opinion of nongenuineness.

KEYWORDS: forensic science, questioned documents, robotic writing, autopen, handwriting analysis, natural handwriting, variation

Handwriting is believed to be a unique habit that makes it individual to each person. Handwriting identification is based on the principle that no two people write alike (1). It would be difficult to repeat the natural flow of letters onto the paper and the individuality of one's writing by another person.

The execution of handwritten words is a skill that in an age of technology can be appreciated by many. When someone receives a handwritten letter as a correspondence, the recipient cannot help but subconsciously feel the personalization associated with the message.

The field of robotics has made strides in developing handwriting technology. What once was solely a human task can now be mimicked by robots. Can handwriting be simulated by robots with the same individual characteristics as a person? To what extent can robots simulate handwriting once the human element is removed? From a forensic document examiner's standpoint, it is the individual and idiosyncratic characteristics of writing (e.g., speed, pressure, and form) that make it identifiable. The human factors and natural variation are what makes each person's handwriting individual and will be missing with robotically produced writing. Even if technology has advanced to duplicate writing formations, it may never replicate those human influences.

Background

Robotic handwriting dates back to the eighteenth century where writing machines have been simulating genuine signatures for individuals as important as the President of the United States of America. Friedrich von Knauss, a German watchmaker and inventor, is credited with being the first to successfully create a writing robot (2). Von Knauss adapted clock mechanisms in his robot machine which could write short phrases. Some other people to experiment with the idea were Jean-Eugène Robert-Houdin and his famous automaton writing and drawing figure, Henri Maillardet who built the Draughtsman-Writer, and M. F. Wiesendanger who invented a writing machine powered by an electronic motor (3). In the 1930s, an early version of an autopen was developed. It was called the Robot Pen and consisted of an automated writing instrument used as a storage unit device capable of recording a signer's signature. In 1942, Robert De Shazo developed the first commercially successful autopen.

The autopen is a simple mechanical instrument that advanced the field of writing machines by providing high-quality signature replications in large quantities. The autopen could use any type of writing instrument, vary the speed of its execution, and allowed for some variation in line quality due to operator use. The autopen invention brought the advantage of helping influential leaders and business executives to apply their time elsewhere without removing the touch of their personalized correspondence or authenticity of official documents. Since the 1960s, the autopen-signing machine has been used not only by government agency officials, but also major corporate executives (4).

In today's digital era, companies with robotic instruments have developed technologies to facilitate mechanical handwriting. In 2013, Sonny Caberwal founded the robotic startup company Bond and has proprietary rights to their software and

[1]New York City Police Department, Police Laboratory, 150-14 Jamaica Ave, Jamaica, NY 11432.
Corresponding author: Melvin Shaw, M.F.S.
E-mail: melvin.shaw@nypd.org

programming (5). Bond can generate entire documents mimicking someone's actual handwriting pattern (Fig. 1). Bond brings the written word and technology together to create customized, written documents for time-restricted customers. Software and mechanics work together to encompass pen positions, speed, and letterform and then translate that to writing on paper executed by a robot. The robot can simulate pen movements by operating along three linear axes that move simultaneously.

Purpose

Companies like Bond pride themselves on the quality of work done by these robots and the beauty of their art (6). Although this work appears almost flawless to a layperson, from a forensic document examiner's point of view, that is potentially the technology's biggest downfall. Each time a person writes (signature, hand printing, cursive); they are influenced by conditional factors such as writing position and pen grip, physical factors such as writing instrument and substrate, and psychological factors such as stress and emotion (7,8). These elements are just a few of the parameters that influence the resultant handwriting but do not begin to encompass all of the environmental factors that come into play. Such factors are attributed to the individuality of the writing and why all free and natural handwriting displays variation (9). The robotic program technology is executed in controlled environments and may be difficult to incorporate these influences or conditions. Therefore, the writing will appear too perfect and unnatural to a forensic document examiner.

Even so, with the rise of such technology, comes the potential for people to abuse it. It is a concern of forensic document examiners that forgeries and nongenuine documents will become more common and less detectable. How will this affect future court testimony or influence the opinions of forensic document examiners? As the times change and these advancements occur, it is the responsibility of forensic document examiners to familiarize themselves with this technology. This research aims to aid forensic document examiners in recognizing the trace characteristics of mechanical robotic handwriting. The goal of this study was to determine whether forensic document examiners can make the distinction between the genuine writing samples and their skilled robotic equivalents.
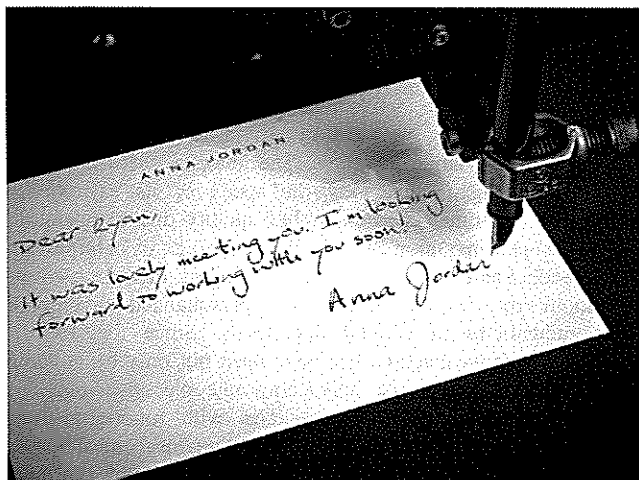
Materials and Methods

Bond Robot (Fig. 2)
Writing instrument: Blue-black Pilot G-2 0.7-mm gel pen
5"×7" Neenah Classic Crest 120# Solar White Paper
Bond Software: text renderer
Stereomicroscope: Nikon Model # SMZ18 with a magnification range of 3.75x-270x
Crimetech loop: 4.5×
Adobe Photoshop CS6
3M Transparency Film for Laser Printers
Epson Scanner 300–1200 dpi
Documents for examination

In this research, a modified ACE-V procedure was used to analyze the submitted documents. ACE-V stands for analysis, comparison, evaluation, and verification, a method universally accepted in various forensic disciplines, including Questioned Documents (10). The use of the ACE-V method is designed to reduce bias in the analysis and consists of the following sequential process:

In the analysis phase of ACE-V, a document examiner examines the questioned and the known writing samples or questioned to questioned writing samples separately for the presence of identifying features. Identifying features are those peculiar, unconscious features which are part of an individual's handwriting habit resulting from pen impulse movements that repeat consistently at the same contextual locations in the writing (11).

In the comparison phase, the identifying features from the questioned and the known writing are examined and compared side by side. Comparisons may include questioned documents to known documents and questioned documents to questioned documents.

In the evaluation phase, the forensic document examiner will evaluate the significance of any similarities or dissimilarities observed during the comparison process in order to formulate an opinion.

For the verification phase, a second forensic document examiner would perform an independent examination of the questioned and known writing samples and reach an opinion without input from the first forensic document examiner. Since this research was conducted to test the quality of robot-generated writing, the verification portion of ACE-V was not performed.
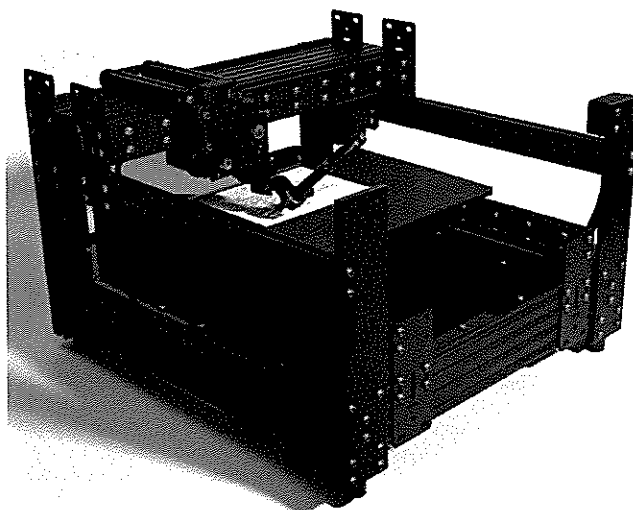

FIG. 1—*Bond produced note.*

FIG. 2—*Bond Robot.*

Documents for Examination

1 Directed Exemplars: London Letter form, U.S. Postal Form 582, in-house requested exemplars
2 Collected Exemplars.

All forensic document examiners received reproduced copies of genuine and nongenuine exemplars. The genuine exemplars submitted for analysis consisted of two types of documents: directed and collected exemplars, all handwritten by various authors in original ink and in a free and natural manner. The nongenuine exemplars submitted for analysis consisted of robotic writing samples produced by Bond.

Directed exemplars are requested writing samples in which the verbiage to be written is dictated to the author. For this study, the directed exemplars included the London Letter, the U.S. Postal Form 582 and an in-house passage (12,13). Both the London Letter and U.S. Postal Form 582 are forms commonly utilized by document examiners to obtain known handwriting exemplars of all upper and lower case letters, punctuation, and symbols of the Latin alphabet. For this study, the authors volunteering the exemplars were instructed to complete the handwriting samples in an environment that was most comfortable for them, with no time limit or restrictions on the writing instrument used.

Collected exemplars are previously executed writings of an author, prepared as ordinary course of business. These exemplars are known to be genuine to that author. For this study, the collected exemplars were comprised of two handwritten samples from the authors such as personal handwritten notes and other job-related documents. The collected exemplars were samples written contemporaneously with the Bond submissions.

The nongenuine robotic writing exemplars consisted of various documents created in the handwriting of six authors, rendered and executed by the Bond robot. Only one Bond exemplar from each author was submitted for analysis. The Bond exemplars mirrored the same verbiage used in a submission paragraph entitled "Albuquerque" to allow for an adequate comparison.

Bond Manufacturing Process

The Bond process starts with an author submitting handwritten samples of their writing using an intake form provided by the company (Fig. 3). The writing submission forms are completed and scanned electronically to the Bond website.

The submitted exemplars are then digitally designed into an author's "font" using Bond's proprietary handwriting software. As a normal policy of the company, Bond utilizes this software to retouch the submitted handwriting without compromising the font of the writing. Some retouching techniques are darkening of strokes, finishing incomplete letter formation, and baseline correction. This is done in an effort to make it more aesthetically pleasing. For the purpose of this study, it was requested to eliminate the retouching process on our handwriting exemplars.

Aided by a human operator, the software creates a "render." A render is a version of the person's writing habit consisting of alternate forms of letters, numerals, and symbols. The render is then converted into a code and communicated to the Bond robot, which will interpret the code to produce a hard copy of the writing.

The robot is equipped with a mechanical arm to hold a writing instrument and a platen, which stabilizes the substrate to provide a writing surface. The robot operates by reading the code


FIG. 3—*Bond submission intake forms.*

Albuquerque, NM 87154; Jersey City, NJ 07310; Zion, UT
35269; Fairfax, VA 98426 Quarry Glen, OK Upper River, WV Las
Palmas, TX Queen's Edge, NY South Ember, RI 'Kojak, OR'
"Xenia, PA" (Craggy Bluff, DE) [Zenith, AZ] {Beachview, FL}
<Hillgaze, WY> SC/ SD/ GA/ HI/ IL/ LA/ ME

FIG. 4—*Smooth, drawn like overall appearance of the robotic writing.*

and moving the mechanical arm holding the writing instrument along the *X*, *Y*, and *Z* axes. The combined use of all three axes incorporates pen lifts and imitates the movements of human writing.

As this robot moves through the three linear axes, it produces letters, words, and sentences. A written document is produced, and the process is complete. This manufacturing process can be repeated if numerous quantities of the same document are requested by the customer. This is an easy way to produce personalized thank you notes or greeting cards without having to take the time to write them.

Handwriting Examination

Four forensic document examiners participated in this study. Each examiner has met the SWGDOC training requirements. One examiner has a combined work experience in municipal and federal government laboratories for over 30 years. The other three examiners each have over 15 years of work experience in a municipal government laboratory. The examiners have all received internal training from their respective organizations. In addition, external training was received by each document examiner from manufacturers and other governmental agencies.

The forensic document examiners were given thirty-seven documents, which were comprised of the directed, collected, and Bond produced samples. They were instructed to consider all documents submitted for examination as questioned documents with unknown authorship.

The examiners were requested to:
- Examine each document provided in the packet.
- Compare all questioned documents and if possible, group the documents based on common authorship.
- Determine if possible, whether or not the documents were prepared in a regular manner.
- The analysts were also asked to elaborate on features chosen and briefly describe their findings including the reasoning on which they based their opinions.

Results

The forensic document examiners analyzed the documents to see if they were pictorially similar. Each forensic document examiner successfully grouped the questioned documents submitted based on the samples' consistency (common authorship). The fonts created by the Bond digitization process appeared similar to the actual letterforms of the respective genuine author.

NATURAL HANDWRITING

ROBOTIC WRITING

FIG. 5—*Natural handwriting versus uniform, even pen pressure in the robotic writing.*
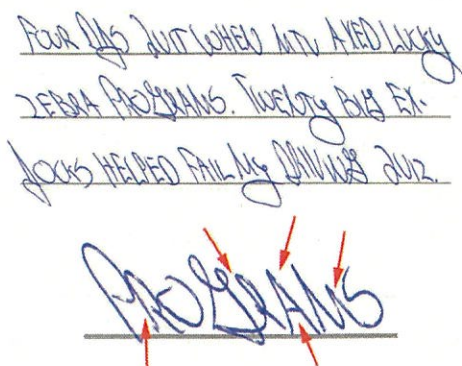
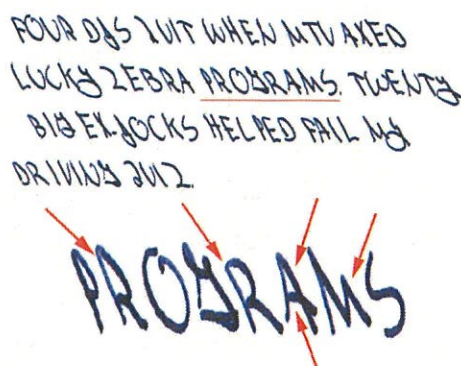**NATURAL HANDWRITING**   **ROBOTIC WRITING**

FIG. 6—*Natural handwriting versus unnatural shading in the robotic writing.*

Pictorially, the Bond exemplars appeared to be good representations of an author's handwriting.

Despite the robot's font rendering process, the forensic document examiners were able to determine that the Bond produced documents were nongenuine. Different combinations of identifying features aided the examiners in their conclusions. The following is a compiled list of characteristics the examiners noted in regard to the Bond robot produced exemplars:

- Overall appearance of strokes is smooth and appears to be drawn (Fig. 4)
- Strokes exhibit uniform even pen pressure (Fig. 5)
- Unnatural shading within the strokes of the characters (Fig. 6)
- Blunt strokes, lack of tapered strokes, and drag strokes (Fig. 7)
- Spacing between words and letters are consistent and equidistant (Fig. 8)
- Robotic samples exhibit alternate forms of letters repeated to mimic variation (Fig. 9)
- Characters can be overlaid precisely (Fig. 10).

Discussion

All four forensic document examiners were able to determine that the Bond produced exemplars were nongenuine. They identified telltale signs of unnatural writing in the Bond exemplars based on their training, experience, and the

NATURAL HANDWRITING   ROBOTIC WRITING

FIG. 7—*Natural handwriting versus blunt intro and terminal strokes in the robotic writing.*

handwriting identification principles. One of these fundamental handwriting identification principles is that no one can write the same way twice (14). Due to natural variation, multiple executions of letterforms cannot be made to coincide exactly. In genuine writing, the fluid movement of the human hand will produce written strokes exhibiting lightness and darkness of the upstrokes and the downstrokes as the pen moves swiftly across the paper.

The Bond robot does not mimic human handwriting in regard to the complex writing movement of the human hand and the directionality of the strokes constructing the letters. The physical robot setup may be responsible for even pen pressure, blunt strokes, lack of tapered strokes or drag marks, and shading features in the writing. The superimposition of characters and other automated features observed, such as overall precise spacing, is likely the result of computer programming. The authors of the submitted writing samples and the forensic document examiners decided to incorporate the Bond produced London Letter (Figs 8 and 9) for representation purposes of the results.

Forensic document examiners should be aware that robotic writing exists and recognizes the trace characteristics of a mechanical robotic reproduction. When reporting the findings, a forensic document examiner may opine whether the writing is genuine or nongenuine (simulation by another writer, simulation by a robot). A suggested format of this statement: "The handwriting appearing on the evidence exhibits unusual even pen pressure, lack of rhythm, blunt strokes, and lack of tapered strokes, suggesting that the executed writing was not freely and naturally written. The evidence embodies an appearance of being slowly executed (drawn). The manner of execution suggests simulation, and therefore, the questioned writing may not have been written by the known author."

Natural handwriting is an acquired, complex motor skill, which requires coordination of the mind and body. It is an individual's habit repeated within a typical range based on a mental image used as a model pattern. This typical range represents slight variations of the master pattern and reflects the dynamic characteristic of genuine natural handwriting. Variation is integral to natural handwriting and occurs due to the lack of precision in the human body and other factors influencing the physical and mental condition of the writer (15). Lacking this "naturalness," robotic writing can be distinguished from freely written genuine handwriting. This research
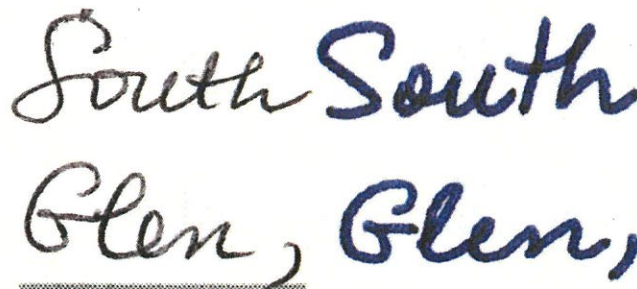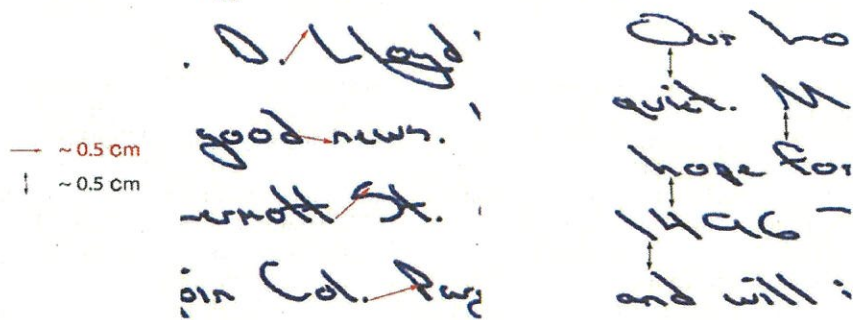
FIG. 8—*Consistent, equidistant spacing in the robotic writing. *Note: Spacing between characters differ depending upon the author's writing style but are consistent throughout the document. Each spacing is based upon the ending of a character to the start of the following character.*

FIG. 9—*Simulated variation in the robotic writing.*

Albuquerque, NM 87154; Jersey City, NJ 07310; Zion, UT 35269; Fairfax, VA 98426 Quarry Glen, OK Upper River, WV Las Palmas, TX Queen's Edge, NY South Ember, RI 'Kojak, OR' "Xenia, PA" (Craggy Bluff, DE) [Zenith, AZ] {Beachview, FL} <Hillgaze, WY> SC/ SD/ GA/ HI/ IL/ LA/ ME
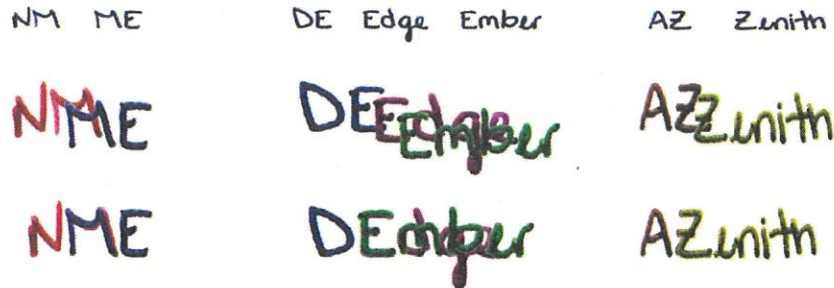
FIG. 10—*Superimposed letters of the robotic writing.*

serves to demonstrate new challenges for forensic document examiners with the ever-changing and evolving handwriting technology.

Acknowledgments

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