TECHNICAL NOTE

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Examination of Sequence of Strokes with an Image Enhancement System

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ABSTRACT: An image enhancement system was employed in the examination of sequence of strokes. Eleven problems and their variations were examined with the use of five filter routines. The results were evaluated to determine whether the filter routines of the image enhancement system were the proper tool in an examination of sequence of strokes problems.

KEYWORDS: questioned documents, sequence, image enhancement system, document examination, filter routines

In an attempt to study sequence of strokes, a less traditional method was employed—an image enhancement system. This system has many capabilities and various routines with which to examine document problems. However, only one of the many possible routines was used for this type of examination. The filter routine consists of five distinct filtering processes, two light sources, and two displays. A combination of these factors was used in the examination of four different stroke sequence problems that involved a total of eleven variations. Two hundred and twenty examinations were made of all the possible variations.

Equipment

The image enhancement system consists of a camera/scanner, light source, keyboard, joystick control, digitizer, and a display module. Digitizing is the process by which an optical image is sampled and mathematically converted to an electronic image on the display module [*1*]. The sample to be examined is placed under the camera/scanner. That image is digitized by the computer and shown on the display module, a television-like screen. The digitized image can be displayed in either color or black and white, despite the color of the original sample. Various computer routines available within the system can manipulate the digitized image.

Since one of the routines, the filter routine, presented a unique display image, which at first appeared to solve a questioned sequence problem, it was selected as the routine for this study.

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Filter Routine

Various routines can manipulate and edit the digitized image. One of these is a filter routine in which five separate filters are used. The available filters can remove various background shading from the digitized image while enhancing its borders or edges or both [*1*].

Horizontal filter Vertical filter	These filters allow the user to enhance edges on their horizontal or vertical axes and eliminate edges that are along the opposite axes.
Edge filter	Marks the outline of the digitized image, creating a sharply outlined image.
Laplacian filter	Maximizes light intensity values within a digitized image.
High pass filter	Enhances the digitized image by removing low frequency noise; produces a negative image.

With each filter, the display can be represented in either black and white or color.

The Sequence Problems

The four different sequence problems and their variations are as follow:

1. Two black ink strokes; two variations: left to right stroke over right to left stroke and right to left stroke over left to right stroke.
2. Red ink and black ink; four variations: red ink cross stroke over black ink down stroke, black ink cross stroke over red ink down stroke, red ink down stroke over black ink cross stroke, and black ink down stroke over red ink cross stroke.
3. Black ink, red ink, and typewriting; four variations: black ink over typewriting, typewriting over black ink, red ink over typewriting, and typewriting over red ink.
4. Typewriting: one sample—typewritten lowercase "t."

The latter typewritten character was used as a control since all points of the typewriter character should strike the paper simultaneously. The character's design is one unit. Therefore, there should be no indication of sequence at the intersection of the staff and the cross stroke.

With the eleven aforementioned variations, two different lighting sources were used in the examination—transmitted light and overhead light.

Examination

To examine sequence of strokes, Harrison states:

> before any attempt is made to interpret the phenomena which are observed at intersections, other portions of the intersections of the intersecting lines should be given the same close scrutiny [*2*].

Given the limitations of the digitized image, other factors that affect a sequence examination, such as skipping [*3*] and migration of ink lines [*4*], were not examined.

For purposes of this experiment, only the intersection points were studied with magnification of the digitized image up to ×128. Each intersection was studied with the aforementioned filters, light sources, and displays.

Results

The results of the examination were recorded as three possible responses: right answer, wrong answer, and no opinion. Of the problems and their variations only the control problem (typewritten lowercase "t") had two possible responses—right answer and wrong answer.

Table 1 demonstrates findings for the given sequence problems and their variations.

Table 2 demonstrates the findings of the filtering process, each having 44 possible variations.

Figures 1 and 2 illustrate Sequence Problem B with different filters and different answers.

Conclusion

While image enhancement can be a useful tool in the examination of questioned document problems, it does not provide all the answers. In just one routine of the entire image enhancement system, it was discovered that while the digitized image may provide the examiner with a conclusion regarding stroke sequence, it may be the incorrect one. With this system, if the wrong answer is displayed, the variables in the system can be manipulated to achieve any conclusion. Note that one of the variables produced correct results in the control problem. When the Laplacian filter was used on the control problem, all the variations (light sources and displays) produced the correct answer. However, the Laplacian filter also produced misleading answers on the other sequence problems (see Table 2).

This is not to say that the system is unsuited to document problems, as there are other routines that are applicable in various other examinations. Even the filter routines are useful to other document problems. However, these filtering routines with the specified sequence problems produce questionable results and are not recommended for the examination of sequence of stroke problems.

TABLE 1—*Problem* × *filter* × *light source* × *display (color or black and white).*

PROBLEM 1—40 possible variations	PROBLEM 2—80 possible variations
42.5% wrong	29% wrong
27.5% right	20% right
30% no opinion	51% no opinion
PROBLEM 3—80 possible variations	**PROBLEM 4—20 possible variations**
23.75% wrong	45% wrong
38.75% right	55% right
37.5% no opinion	

TABLE 2—*The findings of the filtering process each having 44 possible variations.*

HORIZONTAL FILTER	EDGE FILTER
45.5% wrong	25% wrong
22.7% right	43.2% right
31.8% no opinion	31.8% no opinion
VERTICAL FILTER	**LAPLACIAN FILTER**
43.2% wrong	20.4% wrong
20.4% right	34.1% right
36.4% no opinion	45.5% no opinion

HIGH PASS FILTER
20.4% wrong
36.4% right
43.2% no opinion

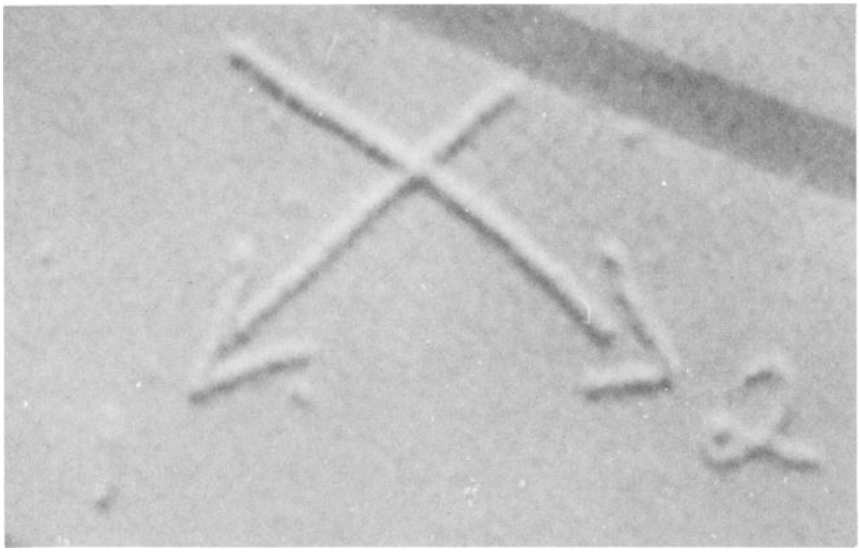

FIG. 1—*Sequence Problem B with the vertical filter produced the right answer.*

FIG. 2—*Sequence Problem B with the horizontal filter produced the wrong answer.*

This experiment was not conducted as a blind study because the examiner knew the sequence in which the strokes were actually written. The conclusions were reached by one examiner through a subjective interpretation of the displayed images. Since the use of image enhancement is relatively new to document examination, further research needs to be done. Certain routines produced conclusions which were correct or at least inconclusive. A blind study with the same variables may produce results that support or negate the usefulness of these routines.

References

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