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A Computer-Aided Seal Discriminating System

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ABSTRACT: A computer-aided system for seal discriminating is developed. The system uses the state-of-the-art technology of digital image processing. The conventional methods such as diagonal match and full match are computerized. The advantage of the computerized method is that it is nondestructive and fast. With the use of proper optical lens, it offers good accuracy. The computerized method can compare the geometry and the intensity variation, while the conventional method is limited to the geometry match. The intensity variation carries information about the seal surface smoothness, the ink concentration, the seal material, the paper material, the paper support, and so forth. The seal surface smoothness is the kind of characteristic which cannot be reproduced easily. It is believed that the surface smoothness is the key to breaking the advanced forging techniques. The system was made and is used at the Central Investigation Bureau of Taipei, Taiwan.

KEYWORDS: questioned documents, seals (personal identification), computers, digital image processing

Seals have been used in China and many other oriental countries in lieu of signatures as a legal means for personal identification. Many important documents such as bank checks, business contracts, government ordinance, and so forth are stamped with a seal to prove authenticity. Seals are commonly made of wood, marble, ivory, fishbone, or other materials that are sufficiently hard. Seals can be carved either by hand or machine. Forging another person's seal is criminal. The very advantage of a seal is that they do not deform. Their shape and size stay the same after seals are made. In addition, it is not possible for a sealsmith to duplicate exactly by hand a seal from its imprints. Handmade forged seals are rather easy to discriminate, based upon the size, the shape, the stroke structure, and the stroke imperfections. It normally takes 3 to 4 h for a bank clerk to learn how to discriminate seals with the naked eye. "Seals are hard to forge" was true 20 years ago. With today's advanced technology in optics, laser imaging and carving, and lithography, it is now possible to reproduce a seal from imprints. The reproduced seals have negligible geometric distortion from the imprints they were made from. Consequently, imprints from the forged seals and from the authentic one are not distinguishable by the naked eye. Even with magnifiers and microscopes, they are hard to tell apart.

Counterfeiting seals with advanced technology will definitely collapse the foundation of using seals as a person's identity. Its consequence is disastrous. This motivates us to use the latest computers and digital image processing techniques to counter counterfeiting seals with advanced technology. The objective is to develop a tool for the seal discriminating spe-

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cialist such that imprints from counterfeiting seals can be detected with high probability. We approach the objective by: (1) computerizing the existing methods such as the diagonal matching method, the enlargement and match method, and the transparency and cut method and (2) developing an intensity variation analysis method such that a specialist can see the change of the intensity of a seal imprint with ease. The first approach is most appropriate for detection of geometric distortion such as changes in the area of the seal boundary, in the width or length of strokes, in the absence of imperfection, and so on. Computerizing the existing methods will make them more accurate and nondestructive. The second approach is intended to detect the variation of ink as the result of pressing the seal against the paper. This variation will suggest the possible counterfeit by imaging the imprint of a seal.

A working system based upon the two aforementioned approaches has been established. It is a system based on the IBM personal computer (PC) and the added on digital image processing peripherals. Basically, the image of a seal imprint is digitized and stored in the memory accessible by the IBM PC. A set of software is developed to process the stored images. The software include the image taking routine, the diagonal match routine, the full match routine, and the intensity variation analysis routine. A vidicon camera mounted with a zoom and macro lens is used for image taking. Image enlargement is done via the zoom lens.

Digital Representation of an Image

An image seen by our eyes can be viewed as a two-dimensional spatial distribution of light intensity. The intensity distribution is analog in nature. Computers do not process analog signals. An analog signal must be converted to a digital format to be acceptable by a computer. The digital representation of an image is generally characterized by a rectangular matrix of dimension n by m. Each element of the matrix represents the intensity, and its indices represent the spatial location of that intensity. The elements in the matrix are commonly referenced as pixels. The matrix is commonly referenced as a digital image. Normally, each pixel takes on nonnegative integers in a certain region. For instance, one may say a digital image of size 256(H) by 256(V) with 8 bit per each pixel. This means that a picture matrix is of dimension 256 by 256. The pixels take on value between 0 and 255.

The size of the digital image and the number of intensity values a pixel can assume are dependent on the domain of application. In the case of seal discrimination, a vidicon TV camera is used as an imaging device. The vidicon is made to meet the EIA RS170 standard. The luminance component of the video signal has a maximum frequency of 3.58 MHz. The sampling rate, which is twice the bandwidth, is therefore 7.16 MHz. Ignoring the vertical and horizontal blanking signal in the RS170 format, we conclude that the minimum digital representation of a black-and-white television (TV) image should be a matrix of dimension 384(H) by 485(V). At this resolution, no loss of spatial resolution occurs. Each pixel should be able to assume 256 intensity values to avoid observable blocking effects. Therefore, the digital representation of a TV image takes about 190 K byte of memory space.

Imaging Technology

The hardware of the imaging component of the computer aided seal discriminating system includes a vidicon TV camera, a zoom lens, a macro lens, a camera stand, lighting fixtures, and a video board housed in the personal computer. The output of the vidicon camera is the RS170 video signal which is fed into the video board. The video board is an interface board plugged directly into one of the expansion slots of an IBM compatible PC. The video board has an analog-to-digital (A/D) converter circuit which can be locked to the sync signal built in the external RS170. This video board can convert the analog TV image into its digital representation in real time, that is, 1/30 s per one TV frame. The video board has a bank of random access memory (VRAM). The memory is large enough to hold one digital image of a

TV frame. More precisely, it is of the size of 192 K byte. The memory is organized as a triple ported memory. One port is for the output of the real time A/D circuit such that the digitized image can be fed into the VRAM in real time. One port is to allow the IBM PC central processing unit (CPU) to access the VRAM. Another port is connected to a D/A conversion circuit in the video board which converts a digital image into an analog TV image which can be seen on a TV monitor. The hardware configuration is seen in Fig. 1.

The VRAM is organized such that each bit plane of the VRAM can be protected so that only CPU or the input video data or both can be written to it. This protection facility is used widely in the computer aided seal discriminating system. In addition, there are two input look-up tables associated with the video input boards and six output look-up tables associated with the video output port. The output look-up tables are grouped into three sets, simultaneously accessible by the output port. Each set has its own D/A converter and its own output analog video signal port. If we let each set represent one of the red-green-blue (RGB) prime, then we can convert the luminance signal into a color signal. This process is referred to as pseudo coloring.

There is also a switch between the input analog-to-digital circuit and the VRAM. The switch is software controllable. If the switch is disconnected, then only the CPU can modify the data stored in the VRAM. All the software programs related to the seal discrimination are written to manipulate the data stored in the VRAM, to set the appropriate look-up tables, and to set the switches.

The thermal noise is always observable in any electronic circuit. The thermal noise can be seen in the RS170 signal as a kind of snow on the screen. It is especially noticeable if the lighting of the environment is low. The thermal noise will reduce the discriminating power of our system. A simple yet effective temporal integration method is employed to reduce the negative effect of the thermal noise. The imprint of a seal is placed under the lens of the TV camera. The same imprint image is digitized n times with all the camera settings unchanged and the imprint in the same position. Let P^k_{ij} denote the i,j element of the kth digital image. Then we can get a new digital image P whose i,j element is: $P_{ij} = 1/n \sum P^k_{ij}$, that is, the

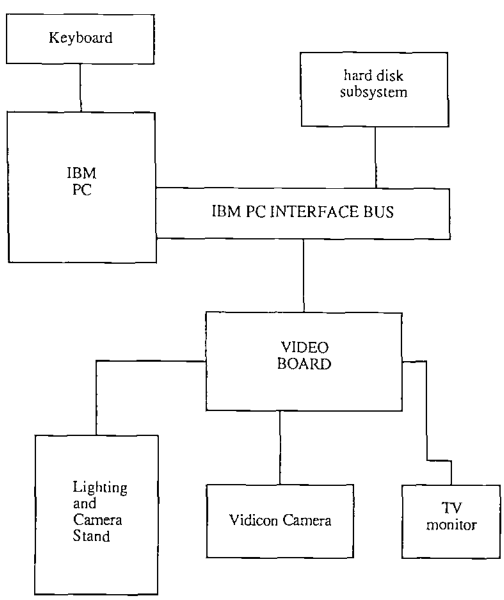

FIG. 1—*The hardware configuration of the seal discriminating system.*

average of n pixels separated temporally. Theoretically, the averaged image P's thermal noise energy is $1/n$th of the single-shot digital image. This temporal integration process is implemented in the software command call SEALINTG. By invoking this command, the user is asked to indicate the number of integrations which is the n in the above formula. Normally, the larger n will give a better quality image, but it takes longer processing time too.

Image zooming, which is the enlargement of the observed seal image on the screen, can be done by turning the zoom ring of the lens. Image zooming is especially useful in seal discrimination. Many minor differences can be observed through the zooming process. Since the zooming is done by the lens, rather than by the digital method, it does improve the spatial resolution. Here is an example. Suppose that we have a seal of 1- by 1-cm area. If we digitize this seal into a 100 by 100 square matrix, then each pixel represents a 0.1- by 0.1-mm area. If we zoom the image by a factor of 2, and digitize the zoomed image into the same 100 by 100 square matrix, each pixel will then represent a 0.05-m by 0.05-mm area on the real object. As the resolution becomes finer, minor differences can be detected easier.

Diagonal Matching

The diagonal match method for seal discrimination has been used for years. One of the seal imprints is folded. The folded seal is placed on top of the other. If it can be aligned so that the folding edges can match a line on the other seal imprint, and the composite image, whose one half is from the folded imprint and the other half is from the other imprint, appears consistent, it can be said that these two seal imprints are from the same seal. One disadvantage is that the folded seal imprint gets destroyed. Another disadvantage is that this method fails if the forged seal is made with the advanced lithographic technique.

Our computer implementation of the diagonal match method can eliminate the destructive nature of the conventional ones. It will also allow the application of this method to any region of these two seals with the small region zoomed to full scale to provide better resolution. It will also render pseudo colors to the two imprints to make their difference more outstanding to our eyes. The difference of the two imprints along the folded edge is plotted on the screen so that one can visualize and analyze the difference better.

The image of one of the imprints is taken first. This image is digitized and stored in the lower four bits of the VRAM of the video board. These four bit planes are locked so that the video input cannot write them. At this moment, the screen displays the first imprint. A software cursor is used to determine a folding line on the image of the first imprint. The half of the first imprint above the folding line is blacked out. This is equivalent to folding the first imprint so that only the lower triangular part can be seen. After this, the second imprint is placed under the camera lens. The second imprint is digitized and put to the upper four bits of the VRAM. The shade of the second imprint is inversed, that is, black becomes white and white becomes black. With appropriate selection of the output look-up table, in the lower triangular portion, one sees the difference of intensity of these two imprints, and in the upper triangular portion, one sees the second imprint in inverse shades. Since the digitization of the second image is in real time, one can move the imprint under the lens to make the difference minimal. Once the minimum is reached, one can grab and freeze the second imprint image. The difference of intensity along the folding line will be plotted on the right side of the second imprint. The larger difference shows a higher magnitude.

The computer implementation not only follows the basic principle of the conventional diagonal match method, it also takes advantage of the enlargement and match method, and the transparency and cut method. This is easy to see since in the lower triangular portion, it is effectively the same as overlapping one transparency over the other. There is no limitation on where the folding line is and this process can be repeated as many times as one wants, with possibly different enlargements. This makes it have the same discriminating power as the transparency and cut method.

A software program called SEALN33 is developed as the computer implementation. The program allows the image of the first imprint either from the camera or from the disk which holds a previously digitized image. The previously digitized image may be the result of the program SEALINTG. The image of the second imprint, after appropriate alignment, can also be saved on disks. Note that if the first image is from the disks, then both the first and the second image can be stored on disks with appropriate alignment.

Full Matching

The enlargement and match method for seal discriminating is to imprint one of the seals, normally the true one, on a piece of transparency. The transparency is then placed on the other imprint to see if there is any significant difference. The computer implementation of this method employs the same technology as the implementation of the diagonal match method. One difference is that the image of the first imprint is not blacked out. Therefore, on the screen, one sees the differences of the two imprints over the full extent. Another difference is that, after the alignment of the second imprint, the difference along both diagonals are plotted on the two vertical sides of the second image.

The computer implementation has several advantages over the conventional ones.

1. It can be applied to two imprints. The conventional method requires at least one seal.
2. Any one seal imprint can be placed on top of the other. There is no inherent constraints that the transparency must be on the top.
3. Imprints can be zoomed first then overlapped. This gives better spatial resolution.
4. The display of the difference along two diagonals makes it easier to visualize and analyze these two imprints.

The computer implementation of the enlargement and match method is done in the program SEALN44. This program is similar to SEALN33. In general, either SEALN33 or SEALN44 can be employed to detect geometric distortion between two imprints.

Intensity Variation Analysis

If two seal imprints have no observable geometric distortion, it is still not sufficient to assert that these two imprints are from the same seal. The modern advanced duplicating technology may fool us. The intensity variation analysis gives a seal specialist a precise feeling about the change of shades of two imprints at corresponding locations.

Two aligned seals are stored on the disks first. These two seals are placed vertically, roughly on the left half of the TV screen. A contrast enhancement method may be applied to any rectangular portion of these two images. The contrast enhancement is based upon the histogram stretch method with both the upper 1% and the lower 1% ignored. The contrast enhancement technique will enable one to see better on areas where ink is smeared out. The rectangular region is selected by the use of the software cursor.

The profiles, which are the intensity variation, along any horizontal line of one image, and that along the corresponding horizontal line of the other image, can be displayed on the screen on the lower right quarter. These two profiles are displayed horizontally. That of the top image is on the top. That of the bottom image is on the bottom. The center line is coincident. The closer to the center line indicates the smaller the intensity value. This arrangement makes the comparison of these two profiles easier. The difference profiles, which are the absolute value of the intensity difference along the horizontal direction, of the selected horizontal line pair can be displayed. These two profiles are displayed side by side in the same manner as the intensity variation. They are shown under the intensity variation display. The selection of the horizontal line pair is done by a software cursor.

A vertical cursor can be invoked. This vertical cursor can move horizontally along the profiles. It can help us to compare these profiles on the same horizontal location.

A horizontal difference image of a digital image is obtained by taking the absolute value of the difference of a pixel (i,j) and the pixel to the right of it, that is, $p(i,j + 1)$. In other words, the pixel $Pd(i,j)$ of the difference image is defined as $Pd(i,j) = |P(i,j + 1) - P(i,j)|$. Normally, the larger the value of the horizontal difference is, the sharper the edge is at that point. The horizontal difference image of the top image can be displayed on the top right quarter. Both the top and bottom image can be transposed. Therefore, there is no need for the vertical difference image calculation process.

The intensity variance analysis is implemented in the software called SEALANAL. All the above mentioned functions are menu selectable.

Past Works and Discussion

In Ref *1*, a system to automate the process of seal identification is reported. The automated system is intended to be used in applications where a large number of cases are processed a day. It does not consider the case where a person intentionally forges a seal to obtain some illegal advantages. Hence, the automated system is used more or less as a prescreening system rather than a discriminating system. Our tool is intended to help a specialist to assess whether two imprints are from the same seal. Note that, presently, in practice, to make the judgement that two imprints are not from the same seal is easier than to make the judgement to confirm that two imprints are from the same seal. To make the former judgement, one needs only to find one or a few spots where two imprints are not consistent in geometry. To make the second judgement, one has to assess that on certain areas of these two imprints, they share the same characteristics which cannot be reproduced with current counterfeiting technology. Because of the laser imaging and carving technology, the geometrical shape is the kind of characteristic which can be reproduced with error less than that caused by ink concentration. The manual methods as described in Ref *2* measure only the characteristics based upon the geometrical shapes. As a result, they failed to counter the advanced counterfeiting technologies. The computer aided system we have developed can compare the geometrical similarity as well as the intensity variations. The intensity variation of the image of a seal imprint along a straight line has to do with the surface smoothness of the seal, the material of the seal, the ink, the paper surface, the paper support, and so forth. The surface smoothness of a seal is a unique feature of a seal. It is not known yet that there is a counterfeiting technique that can reproduce the surface smoothness of a seal from its imprints. As a result, if one observes that two seals are of the same geometry and that along one or a few strokes with proper inking, the intensity variations are similar, one can assert that these two imprints are from the same seal. Otherwise, one can disclaim it. By proper inking, we mean that the inking is thin, not thick.

Experimental Results

The system we developed is now in use at the Central Investigation Bureau of the Republic of China. It is reported that it has shortened the discriminating time by as much as 90% in comparison with the manual methods. For now, the computer aided system is used along with the manual method.

Figures 2 and 3 show the pictures shown on the screen.

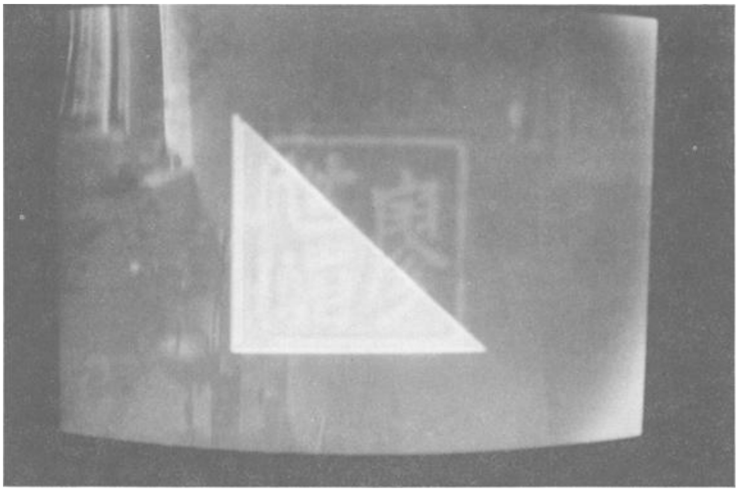

FIG. 2—*The screen picture of the diagonal match method. Two imprint images are shown in different colors.*

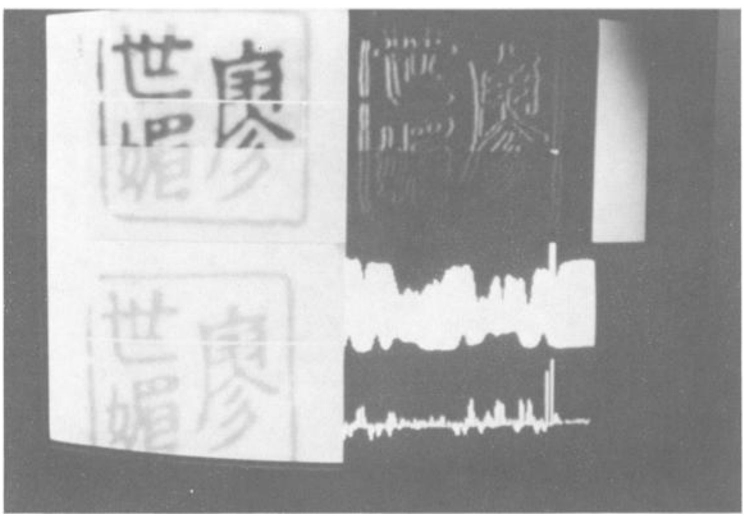

FIG. 3—*The screen picture of the intensity variation analysis program. The upper half of the upper left imprint is contrast enhanced. The right upper half is the gradient image of the upper left imprint. The curves are the intensity and gradience profile along the marked horizontal line.*

Conclusion

We have developed a computer-aided system for seal discriminating. The system is designed to counter the advanced counterfeiting technologies. The system can compare the geometry as well as the intensity variations. It is believed that the intensity variation carries characteristics of a seal which cannot be duplicated with the present forging technology. Conventional imprint matching methods are computerized. The seal discriminating procedure with the use of computers is nondestructive. The future research work along this line should include the injection of the expert knowledge to the discriminating system and the establishment of quantitative measurement of the similarity between two imprints. To extract the appropriate features from the intensity profile such that the effect of the seal surface smoothness can be isolated from the other factors such as the paper surface, the ink material, the paper support, and so on is another problem worth further probing.

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