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A New Approach to Automatic Comparison of Striation Marks

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ABSTRACT: A database for toolmarks (named TRAX) has been developed on a PC with Microsoft Windows. The database is filled with video-images and administrative data about the toolmarks (width, kind of toolmark, etc.). A comparison screen in TRAX makes it possible to compare images of toolmarks.

The system works with the Screen Machine multi media-board. A new algorithm for the automatic comparison of digitized striation patterns has been developed. The algorithm works well for deep and complete striation marks and will be implemented in TRAX.

KEYWORDS: forensic science, striation patterns, toolmarks

In the Netherlands, there are about 100,000 burglaries a year. In 10,000 cases toolmarks are cast by the police. Of these 10,000, only 200 cases are solved by comparison of toolmarks.

More burglaries may be solved when the computer is used in comparing tools with the toolmarks. This is the main reason why we have developed a computer system for comparing video-images of toolmarks in a database.

In the past systems have been developed with images of striation and impression marks for cartridge cases (Drugfire [*1*])and bullets (Bulletproof [2]).

Equipment

For this project, a videocamera on a comparison microscope is used to scan the striation patterns. A normal microscope would also be suitable. The videocamera is connected to a PC with a Screen Machine card in it. The Screen Machine card digitizes the image. The digitized image becomes available in Microsoft Windows for the database and for comparison algorithms which are partly written in our research laboratory in Turbo C++.

Database

Figure 1 shows the screen for entering data. The data fields per each piece of evidence are:

- number of piece of evidence
- type of tool used (screwdriver, hammer, pliers. . . .)

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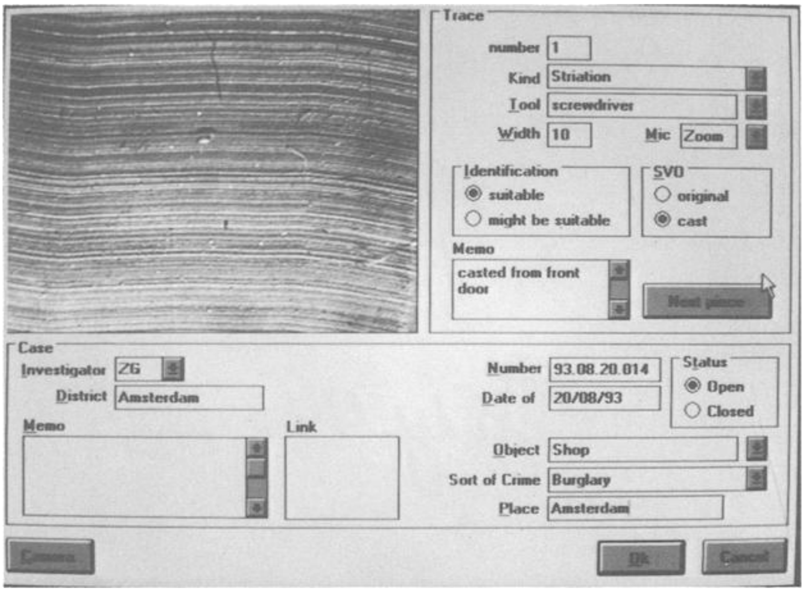

FIG. 1—*The screen for entering data.*

- width of toolmark
- magnification of microscope
- free text-field

The data fields per case are (lower part of figure):

- case number
- date of offense
- place of crime
- request from
- location
- category of offence
- investigator
- free text-field

The user can search on all these datafields. For the data given in these fields the computer gives the number of candidate matches found. The images in the database will be shown on the right of the computer screen and the real time microscope-image will be shown on the left for comparison. Using buttons, the investigator can browse through the list of candidate matches in the database. It is possible to shift the images in relation to one another with the sliders (Fig. 2).

At present, the comparison of the images has to be done visually; however for striation marks this process is extremely time consuming. For a normal screwdriver the investigator has to make at least 4 test marks in different angles from each side of the screwdriver. When the test marks are viewed from two opposing angles this results in (at least) 16 comparisons of test striation marks. For this reason we have developed an algorithm for the automatic comparison of striation marks.

In the past, different approaches were used for automatic comparison of striation patterns [2–7]. Most of them use binary black and white information for the comparison algorithm.

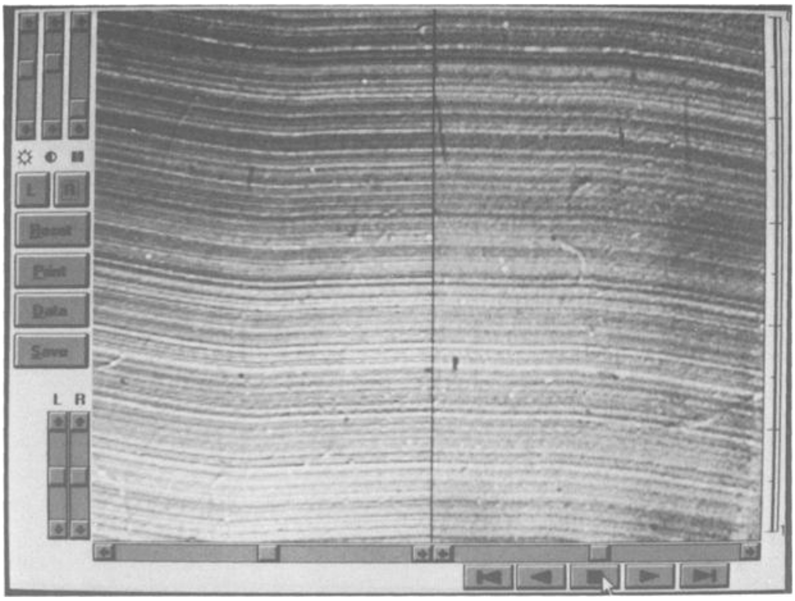

FIG. 2—*The screen for comparison.*

Since the calculation speed of computers becomes better each year, more complex algorithms can be used.

Data Reduction

Before the comparison can be made, it is necessary to reduce the data. Otherwise the comparison would be very slow. This is done by reading in one vertical line of an image with greyvalues. The left of the picture in Fig. 3 illustrates the horizontally magnified line of fifty pixels which is characteristic for the complete striation pattern.

Stability

For the testing and developing of the algorithm, striation marks are made in wax with different screwdrivers, resulting in stable striation patterns. The striation patterns are cast with grey silicone casting material.

In the first stage of the development the differences between the vertical lines of the striation patterns from one screwdriver are studied, to ensure reproducible data-acquisition.

The differences between the vertical lines may be due to

noise from the videocamera;

differences in the striation pattern; or

differences in the light source

Noise

The problem of noise in the videocamera is solved by integrating more images. The differences that are in the striation pattern itself cannot be solved, the algorithm for comparison has to take this into account.

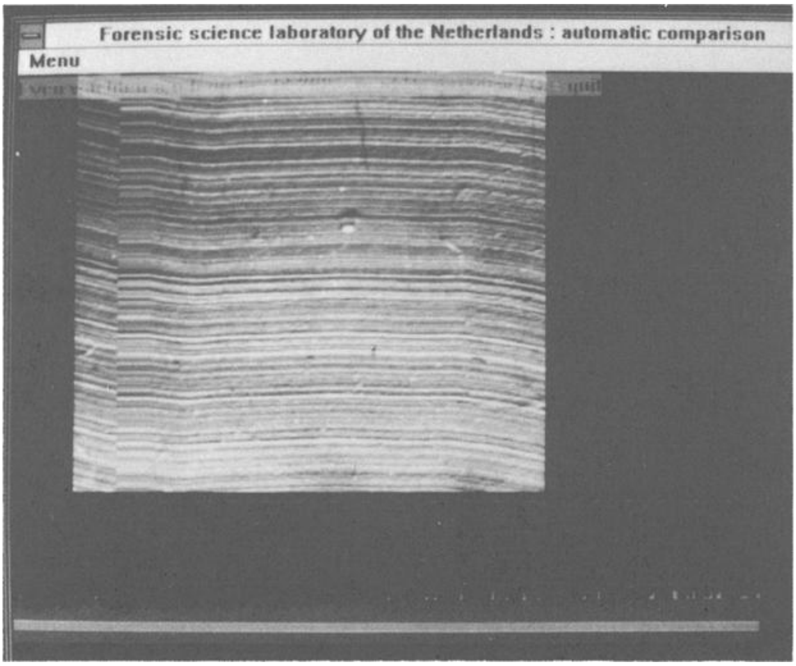

FIG. 3—*The screen of a horizontally magnified line of 50 pixels.*

Light Source

Point light sources have a non-uniform light distribution, and are therefore not suitable. A fluorescent tube is preferable because of the uniform light distribution.

Angle

The most stable data-acquisition is achieved when using an angle of about 45 degrees for the light source with the plane of the striation mark.

Casting

The best casting material appeared to be the Finnish grey casting material. This casting material gives the best contrast in the digitized image. Usage of fingerprint powder on casting materials enhances contrast, but should be avoided, because the grains of fingerprint powder introduces a lot of noise.

Magnification

For small magnification differences a zoom-option is implemented. This zoom-option is developed for the differences in the striation marks themselves and works automatically. In this way small differences with a maximum of twenty percent will be corrected.

Calibration

The Screen Machine card has to have standard parameters (for contrast etc). The system is calibrated with a test stroke. The test stroke being used is a test striation mark. With this calibration the computer corrects the influence of the light source and checks if the standard conditions are correct. The program suggests what to do to correct the situation: shifting the light source etc. Otherwise look up tables will be used for the correction.

Comparison Algorithm

The comparison algorithm uses grey values instead of black-and-white images. This has distinct advantages, because in the conversion from real image to thresholded black-and-white image information about the striation pattern is lost.

The actual comparison is made by shifting the test-striation marks of a screwdriver with the striation marks of a screwdriver in the database until the deviation in difference is smallest. Some problems emerged when using comparison algorithms of spectra in chemistry. Our spectra of striation marks are not completely linear to each other. Sometimes striation marks of a particular screwdriver may (partly) differ in size. To solve this problem, we developed an adaptive zoom algorithm.

The adaptive zoom algorithm compares three pixels from the test-striation mark with three pixels of the striation mark found at the scene of crime. If the deviation is local, a shift will be performed. The size of each shift is calculated, and if the shift often goes to one direction the conclusion will be higher. In this way a 20 percent zoom between two striation marks can be compensated for.

The final conclusion is based on fuzzy logic. The fuzzy rules are developed by reading in the results of a set of trials performed by the human investigator.

It would take a lot of time to compare all data from these striation lines to each other. To reduce computing time it is necessary to make a preselection based on

frequency spectra—how many striation lines are in the spectrum per centimeter on average;

contrast comparison—how rough is the striation mark;

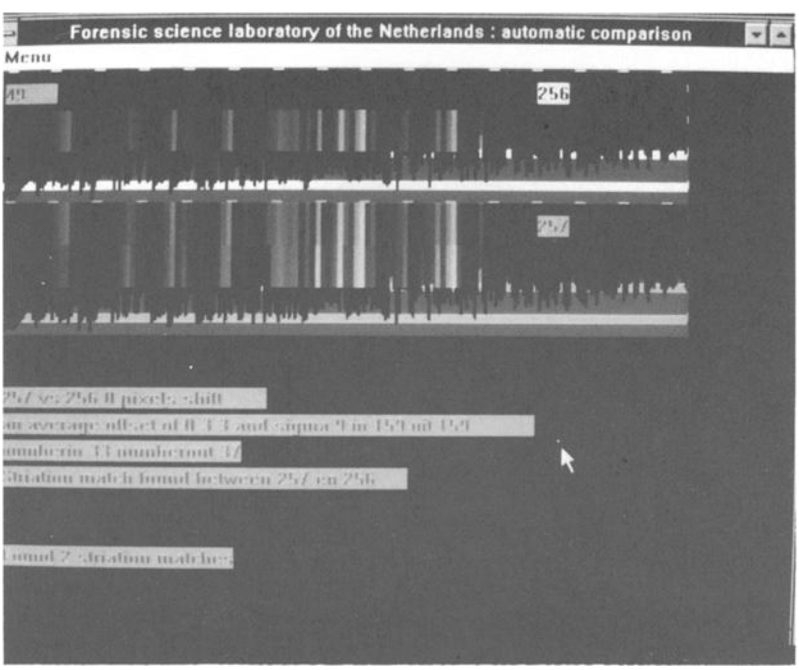

FIG. 4—*The screen for the automatic comparison.*

partial comparison—only a part of the striation mark will be compared on greyvalues per pixel. If this gives a good result, more will be compared.

In the top half of Fig. 4 a test-striation mark is given and on the bottom half a striation mark from the database. The two spectra match, so this hit might be interesting to examine visually.

Results

The system was tested with 10 screwdrivers of the same brand. The striations marks of these screwdrivers are the same in structure, so this is the hardest for comparison. For screwdrivers of different manufactures, or screwdrivers which have been damaged through use, it is much easier to make a preselection.

The results of this automatic comparison are very promising—all striation marks were identified with the right screwdriver. In the comparisons the difference between the mean standard deviation were computed, for those cases the standard adaptive zoom-algorithm was used. In table I some results are given. With this comparison algorithm, results lower than 0.50 indicate mismatches and higher than 0.9 indicate a 'hit'. If two striations are exactly equivalent 1.0 will be computed, if they are completely different 0.00, will be computed.

	1	2	3	4	5	6	7	8	9	10
1	**0.96**	0.15	0.14	0.12	0.13	0.14	0.20	0.13	0.12	0.12
2	0.15	**0.95**	0.13	0.23	0.12	0.09	0.23	0.09	0.23	0.23
3	0.21	0.15	**0.93**	0.12	0.12	0.23	0.25	0.14	0.14	0.14
4	0.23	0.14	0.16	**0.91**	0.13	0.12	0.16	0.15	0.15	0.13
5	0.12	0.14	0.13	0.12	**0.97**	0.16	0.18	0.19	0.12	0.14
6	0.17	0.18	0.16	0.13	0.09	**0.92**	0.13	0.14	0.13	0.13
7	0.14	0.17	0.14	0.13	0.13	0.12	**0.91**	0.13	0.13	0.20
8	0.08	0.09	0.14	0.23	0.13	0.28	0.21	**0.89**	0.13	0.25
9	0.27	0.23	0.23	0.12	0.23	0.12	0.23	0.12	**0.94**	0.25
10	0.22	0.21	0.24	0.17	0.23	0.23	0.21	0.11	0.12	**0.92**

Conclusions and Discussion

The comparison algorithm works well for deep and complete striation marks. In practice these are striation marks in which the total width of the screwdriver is visible and which are rough enough. For the police in The Netherlands this might result in more cases being solved by automated comparison of toolmarks. Of course the program cannot be used for any striation mark. If the striation mark is very vague or only a part of the striation is visible, the computer might not select the right striation mark. However the aim of this research is to make comparing more efficient. If one has a large database, automatic comparison of toolmarks, might take a lot of time. This can be done in batch, or by using a computer with a higher computing speed. The final conclusion of the comparison has to be given by the toolmark examiner, and not by the computer.

This method could be extended for round surfaces like bullets by casting the bullet and flattening the cast under the microscope. However more research on this subject is required. This method is not suitable for automatic comparison of impression marks (on cartridge cases).

The future developments are implementation of this comparison algorithm in our program TRAX and making field tests with the Dutch police. Further we will do research on the automatic comparison on parts of striation marks and impression marks.

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