OBECTIVE

The objective of the present work is to evaluate the performance of ASTIS, specifically its ability to retrieve a sole pattern in the database.

EXPERIMENTAL CONDITIONS

MATERIAL USED

The codification of all the pictures used in this project was made on a network of 6 computers:

- 3 Dell Optiplex 755, Intel® Core™ Duo 3 GHz, 3.23 GO RAM
- 3 Dell Optiplex 754, Intel® Core™ Duo 2.13 GHz, 1.99 GO RAM

All the comparisons, were made on a Dell Optiplex 754, Intel® Core™ Duo 2.13 GHz, 1.99 GO RAM.

The version of the different compounds of ASTIS used in this work is the follow:

- Retina NN – 118;
- HM Intelli 121 P;
- Matcher x3 651.

DATA USED

Reference data:

A pictures collection of 200 shoeprints (inked impressions) was first made. It builds up a reference collection on which all the comparisons will be carried out. This reference collection is composed uniquely of right and complete shoeprints each with a different general pattern. All shoeprints pictures were standardized (orientation correction, suppression of artifacts like label or ink marks, optimization of the background homogeneity, cropping the picture around the shoeprint, reduction of the resolution from 400 to 45 dpi (initial magnification 1:1 of the shoeprint is conserved) and saving as bitmap 8 bit files).

Preliminary tests have that the resolution of pictures has an important impact on the accuracy of the codification made by ASTIS. The resolutions tested were 30, 45, 60 and 75 dpi. However, present limitations of the system concerning size of templates and databases required to find a compromise between the quality of the codification and the number of data the system is able to use. That's why the resolution of 45 dpi has finally been chosen allowing working with 250 entities (200 references pictures + 50 query data).

Query data:

From the 200 shoeprints in the reference database, 50 shoes were used to make a second print. These new prints were then used to create several query data sets.

A set of 50 pictures of right and compete shoeprints was created. From this first set of query data, several sets of pictures have been generated:

- 4 sets of 50 images of rotated shoeprints. (Rotation angles are ± 10° and ±20°);
- 4 sets of 50 images of rescaled shoeprints. (Size variations are ± 10% and ±20%);

- 50 images of translated shoeprints. Prints were translated by adding 100 pixels on the top and the left side of the original images (see figure 9, page 24 of the report);
- 2 sets of 50 partials shoeprints. A set of “50% partial shoeprints” representing the top half part of the original shoeprint images and a set of “25% partial shoeprints” representing the top left quarter of the original shoeprint images.
- From the set of “50% partial shoeprints”, 6 sets of 50 images of rotated and partial shoeprints have been made. The angles of rotation applied are: 10°, 20°, 30°, 60°, 90° and 180°. Note that a wider range of angles was tested because a partial shoetrack is more likely to be misorientated than a complete shoeprint.
- 3 sets of 50 noised shoeprints images. Noise is added by superposing the shoeprint on a textured background after having deleted the initial white background on Photoshop. Textured backgrounds used are; a picture of a wooden floor, another of a paved surface and a last of concrete with small peddles (see figure 11, page 25 of the report).

A set of 50 images of left whole shoeprints was also made from the left soles.

Finally, a set of 20 shoe tracks was created. Dusty shoe tracks were made on a PVC surface and transferred on a black gelatine sheet. The images of the gelatine sheets compose the set.

All query data were standardized, as were the reference data.

METHODOLOGY

Each reference or query image is automatically codified using ASTIS encoder. The 200 reference imprints and a set of query pictures are imported to constitute a database. Then, using the batch process, each query entity is compared to the whole database. The list of candidates obtained for each search is then analysed and the position of the corresponding reference is noted, as well as his comparison score. During this last task, query data (tracks) appearing in the list of candidates are ignored. Only reference entities are taken into account.

The performance of the system is essentially measured with the CMC method (*Cumulativ Match Characteristic*). It consists in determining the probability the correct match are given among the *n* first percent of the list of the candidates reviewed. The relative score is also calculated from the score of comparison of each correct match as follow:

$$\text{Relative score} = \frac{\text{comparison score of the query shoeprint and his matching reference shoeprint}}{\text{comparison score of the query shoeprint and itselves}}$$

Two particular and important global conditions of the experiments must be mentioned:

- The default parameters of the retina have been conserved for the codification of all the data used in this work (contrast threshold: 12, sensitivity: 70; ripple: 59; aggression: 40).
- The automatic codification (pattern recognition) of shoeprints was not corrected or improved by a manual intervention. The component ASTIS- Composer wasn’t used at all in this work.

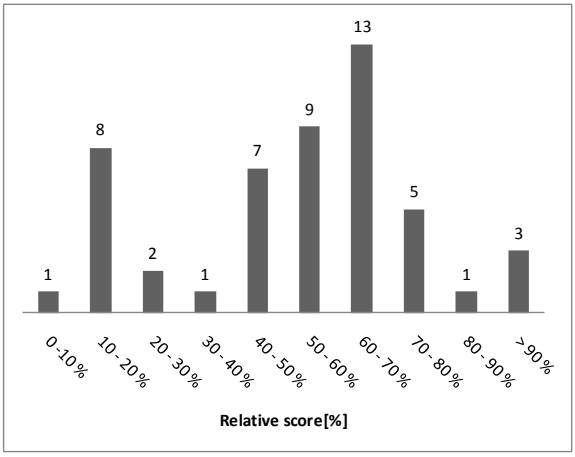
RESULTS

REPRODUCTIBILITY OF THE CODIFICATION STAGE

For this experiment, 50 reference print (same images) were encoded a second time and compared to the 200 shoeprints database.

The codification made by ASTIS of exactly the same shoeprint's pictures isn't totally reproducible. Essentially small but sometimes important and always multiple differences can be observed between each couple of corresponding images.

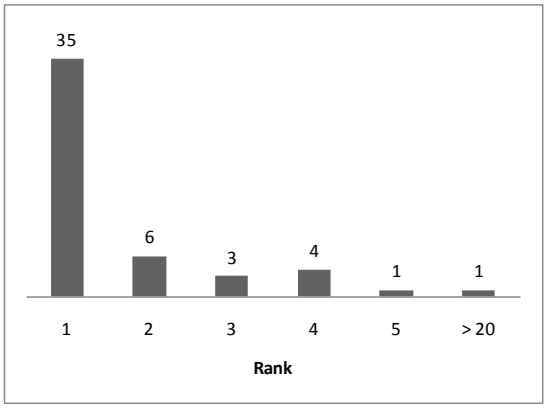
About the comparisons, if we look only the rank of the correct match, the unreproducibility of the encoding stage doesn't seem to have any influence on the performance of the system. Indeed, the system gives the correct match at the first place for all the 50 researches. However, effects can be observed if we look at the relative score of each correct match. As we can see in the graphic n°1, the relative score obtained are rather weak knowing that it's exactly the same shoeprint's picture that are compared here. If the codification was reproducible, relative scores of 100% should be obtained for each correct match.



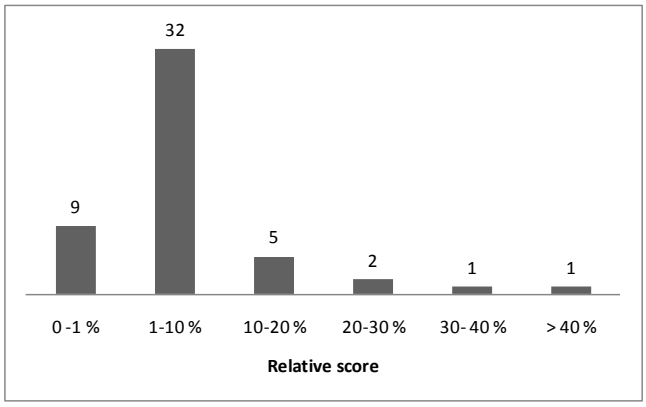
Graph 1 – Distribution of the correct matches according to their relative score

COMPLETE RIGHT SHOEPRINTS

The results obtained by retrieving the position in the list of the candidates and the relative score of the correct match from each of the 50 researches are presented in graphs n°2 and 3 below.



Graph 2 – Distribution of the correct matches according to their rank



Graph 3 – Distribution of the correct matches according to their relative score

Concerning the position of the correct matches, the system is able to give, at the first place, the right reference in 35 of the 50 searches. So 70 % of correct matches are in the 0.5 first percent of the list of the 200 candidates. Furthermore, in only one case, the system wasn't able to give the right response in the five first positions (exception finding at the 32th place).

Looking at the relative score of each correct match, we can observe that it falls down dramatically. The great majority of the relative score are smaller than 10 % and even in 9 cases smaller than 1 %!

ROTATED, RESCALED AND TRANSLATED SHOEPRINTS

The results obtained by comparing to the collection of 200 references shoeprints the 4 sets of rotated shoeprints, the 4 sets of scaled shoeprints and finally the 50 pictures with translated shoeprints are presented in the chart 1 below in the form of CMC.

		Correct match [%]								
Candidates reviewed [%]	**Ranks**	**No modified prints ***	**Rotated prints**				**Scaled prints**				**Translated print**
			+ 20°	**+ 10°**	**- 10°**	**- 20°**	**+ 20%**	**+ 10%**	**- 10%**	**- 20%**	
0.5	**1**	70	42	48	56	42	34	60	46	42	42
1	**1 -2**	82	58	66	64	50	46	64	58	58	52
2	**1 – 4**	96	76	80	78	74	66	82	72	74	72
5	**1 – 10**	98	82	88	92	82	86	94	90	82	88
10	**1 – 20**	98	92	92	98	88	90	96	96	90	92
20	**1 – 40**	100	94	98	100	94	96	100	98	96	94

Chart 1 – Percent of correct match according to the percent of the list of the candidates reviewed. * Results obtained in the precedent experiment but present in the CMC form.

We can see that all the transformations applied to the query data have a significant impact on the comparison's performance of ASTIS. Indeed, the results obtained from the set of rotated, scaled or translated shoeprints are smaller than the ones obtained previously with no modified shoeprints.

Better results are obtained with these two sets: -10° rotated shoeprints and +10% resized shoeprints. They are also the only sets from which the system is able to give 100% of the corresponding reference in the first 20% of the list of the candidates, (i.e. the top 40 candidates).

However the results obtained from the scaled and rotated shoeprints are a little surprising, knowing that the transformations apply for these two groups of data should normally be accepted by the system.

PARTIAL SHOEPRINTS, ROTATED OR NOT

The results obtained, by comparing to the collection of 200 references shoeprints, the 2 sets of partial prints as well as the 6 sets of partial and rotated shoeprints are presented in the chart n°2 below in the form of CMC.

Concerning partial prints without any rotation, we can see that the results obtained from the set of 50% partial prints are rather good in comparison to the results obtained from the set of whole shoeprints. On the other hand, weaker results are obtained from the set of 25 % partial shoeprints. With this set of data, the system give the right answer in the first place in only 40% of the researches (20/50 researches).

Candidates reviewed [%]	Ranks	Correct match [%]								
		Partial prints		Rotated partial prints (50%)						Left prints
		25 %	50 %	10 °	20 °	30°	60°	90°	180°	
0.5	**1**	40	64	26	28	8	0	0	6	28
1	**1 -2**	50	78	36	46	20	2	0	12	30
2	**1 – 4**	62	89	56	56	26	6	0	16	44
5	**1 - 10**	76	96	78	74	44	10	6	26	60
10	**1 - 20**	88	96	84	82	62	14	12	40	72
20	**1 - 40**	94	98	88	88	72	22	28	54	82

Chart 2 – Percent of correct match according to the percent of the list of the candidates reviewed.

The performances of ASTIS are still weaker when rotations are applied on partial prints even with the smallest angles tested. With partial prints turned with an angle of +10° and +20°, the system gives the correct match at the first place in respectively 26 and 28% of the searches and is able to place the correct match in the four first places of the list of the candidates in only a little majority of the searches (56%). Results obtain with the 30° rotated partial shoeprints are weaker but the worst results are obtained with the sets of 60° and 90° rotated partial prints. The system doesn't seem able to work with these last sets of data. The reference shoeprints corresponding to the query prints are often observed over the 100th rank and even one time at the 199th place. The system seems to place the correct match randomly, supplying the corresponding reference in the 40 first ranks in less than 30% of the searches. Slightly better results are obtained with the set of 180° rotated partial shoeprints. Some query data share elements of symmetries with their corresponding references, what can explain this improvement of the performances of ASTIS.

Note finally that some comparisons failed with the sets of 90° and 180° rotated partial shoeprints, a message of error appearing during the process ("out of memory"). Solution was found with the set of 90° inclined data by reducing the number of entities in the database (deletion in the database of query data whose comparison previously made a success) but no solution was found with the set of 180° rotated partial shoeprints. Even by reducing the database to 201 entities (200 references and 1 query data), the comparison failed with 13 pictures.

LEFT SHOEPRINTS

The results obtained, by comparing the 50 left complete shoeprints to the collection of 200 right references shoeprints, are presented in the chart n°2 above.

The results obtained in this experiment show the capacity of ASTIS to make correct correspondences between right and left shoeprints isn't still optimum. The system gives the right match at the first place in only 28% of the researches and in the 4 first places in little less than 50% of the researches. The reasons explaining why some couples of matching shoeprints are given in the first places in the list of candidates and other not, couldn't be identified. At the first sight, the sharing of elements of symmetries between the matching shoeprints doesn't seem to be as important as we could believe. But this should be investigated deeper.

NOISED SHOEPRINTS

The three surfaces (see original report p. 25) used as background in this experiment produced elements of codification (curves, circles and lines) besides the elements produced by the shoeprint patterns. The number of these "erroneous elements" is particularly important with the background n°3, certainly the most complex of the three backgrounds. This last one produces a lot of arcs and circles on all the pictures. The accuracy of ASTIS to encode shoeprint pattern over a complex backgrounds doesn't seem significantly worst than with homogenous background shoeprint picture. The presence of textured background only seems to add "erroneous elements" but it doesn't affect significantly the shoeprint recognition.

Results obtained by comparing each of the 3 sets of noised shoeprint to the collection of reference shoeprints are showed in the chart n°3 below. It's important to remind here that the codification of the query pictures hasn't been corrected or improved using ASTIS – *Composer*.

Candidates reviewed [%]	Ranks	Correct match [%]			
		Noised prints			Tracks
		Background 1	Background 2	Background 3	
0.5	**1**	34	44	20	20
1	**1 -2**	44	52	24	35
2	**1 – 4**	58	70	36	35
5	**1 - 10**	74	76	52	55
10	**1 - 20**	86	94	56	60
20	**1 - 40**	96	98	64	80

Chart 3 – Percent of correct match according to the percent of the list of the candidates reviewed.

Textured background behind the shoeprint has an important influence on the performance of ASTIS. Logically, this influence is as important as the background interact in the codification of the picture (produce irrelevant information). The system is still able to find a match when the query picture is almost totally covered by codification elements produced by the background.

As with the sets of 90° and 180° rotated partial prints, some comparisons failed in the test using the set of background n°3 noised prints. Those comparisons were made with success by reducing the number of entities in the database. However one comparison always failed even when reducing the database to 201 entities.

SHOE TRACKS

The objective was to obtain data similar to the one treated by the forensic services. However, most of the tracks produced in this work can be judged as good, even as very good quality for tracks. Some are equally of poor quality but judged as exploitable because the general pattern is still recognizable. All the pictures contain more or less noised background produced by dust on the deposition surface.

In most cases, codification of the shoe track patterns is good even when the contrast with background is weak. However tracks codification seems less accurate than shoeprint codification (less complete) and codification of the shoe tracks with poor quality is problematic (fragmentary,

false interpretation of pattern borders, lot of artifacts …). Generally, many "erroneous codifications elements" are observed inside the shoe track patterns and in the background of the pictures.

Results obtained by comparing the 20 shoe tracks in the database of 200 shoeprints are in the chart n°3 above. The correct match rate at the first place is only of 20%. The system was also unable to give the right candidate in the 40 first places of the list of candidates in 20% of cases. Note that this last test is based on a restricted number of query data (20 tracks).

GLOBAL DISCUSSION OF THE RESULTS

Factors influencing result have not been strictly identified. On one hand because of the misunderstanding of the complex processes and comparison's algorithms hiding inside ASTIS and secondly because of the multiple sources of variation existing between the reference and query data and produced by the choice to use and compare several impressions of same sources. That is why the interpretation of results mainly limited to the study of the position, in the list of the candidates, of the corresponding reference shoeprint.

The results obtained in the multiple experiments show that, in optimum conditions (comparisons between complete and standardized data), the system is able to give at the first rank the correct match in 70% of cases. This rate is 96% looking at the first 2% of the list of the candidates. However, all variation factors tested in this work have shown to have generally a significant impact on the performance of the system. It brings to light the necessity:

- To standardize the data to reduce maximally the variations like orientation, size, contrast, quality, position of the print in the image, …
- To correct and improve manually the automatic codification of pictures in particular when information analyzed is poor like with the tracks, or when a textured background interacts in the codification.

CONCLUSION AND PERSPECTIVES

The results obtained in this work can be judged as encouraging knowing a first beta version was used here and many improvements will come. The experimental conditions applied, the choice of resolution of 45 dpi for the picture used and to not modify manually the automatic codification did certainly have an important impact on the result too. Next tests with new versions of ASTIS and using the whole potential of the system will most probably give much better results.

The evaluation of ASTIS made in this work is most certainly not complete! Other tests must be carried out, notably:

- On the data codification accuracy and its optimization ;
- With ASTIS – Composer, a component absolutely not used in this work but which seems powerful and essential in the ASTIS performance optimization;
- With shoe tracks, poor quality data and 3D data (molding of tracks);

- With a much more important number of data. In this work, the system was tested on 250 database pictures but the current databases used in the forensic services usually count several thousand of data.

Out of the results obtained in this work, numerous improvements have to be brought to ASTIS before it can be used by the forensic services, in particular, about the process duration of ASTIS (codification, importation and comparison) and about the present size limitations of the system (template and database). At last, the current version of the system doesn't allow integrating contextual and descriptive information accompanying each track or shoeprint image. Information like date of the imprint, owner of the shoes, case number, size or mark of the shoes, case information, are essential not only for the chain of custody but also for the exploitation of the system in a police service.