A Fuzzy Perception For Off-Line Handwritten Signature Verification

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Abstract. The purpose of this paper is the assessment of a family of shape factors for off-line signature verification. The initial method, suggested in [1], which extracts geometric features, is modified to assess the performance of verification in the general case of forgery. We contribute to the information coded by adapting the coding method to the image and by integrating a spatial distance into the shape factor definition. Moreover, we include the coding of an information related to the dynamic of the signature. To use these two types of information, we propose a fuzzy technique to combine and then obtain one kind of information. We evaluate this new coding operator with two types of forgery : random forgery and photocopy simulation with some adapted protocols.

1 Introduction

Financial and legal transactions imply the necessity of verifying the identity of the persons. This verification meets with two kinds of problems : identity usurpation or simulation of an usurpation. We note that this is a specific problem inherent to the notion of identity.

All verifications are carried out utilizing different attributes. A personal attribute such as a hand-written signature enables the verification of the identity of a person on paper documents. This is a universal attribute for which the achievement is independent of the level of knowledge. It is not anonymous, characterizes the individual, and presents a certain reliability.

However, several conditions can alter the morphology of the signature. These modifications can be caused (among other factors) by age, habits, psychological state of mind, and practical conditions. All these flaws in the act of signing produce uncertainties concerning the features of the signature.

There are several types of forgery including : random forgery (i.e., the signature of other database writers); simple forgery, with a totally different signature; forgery by transfer, obtained by transfer techniques; freehand forgery, made by a forger using visual memory. Verification is, therefore, a two-class pattern recognition problem that comes down to one question : " *Is the signature true ?* "

The verification in the case of random forgery remains an unsolved and critical issue. The generalization of the verification for all types of forgery is the most as difficult. Within this framework, defining the shape factor (i.e., pointing out the features of the signatures) is always a crucial point in the design of the verification system. Our approach is one of global recognition processes. The shape of the signature, whose geometric and dynamic signature properties are intrinsic characteristics of the writer, is preferred to the signature structure. A multi-scale approach leads us to the use of local as well as global geometric and dynamic signature properties. The aim is, of course, to obtain the highest possible efficiency and to generalize the verification of forgery.

In this paper, an improved method of extracting geometric features as suggested by R. Sabourin [1], is modified to assess the performance of verification in the general case of forgery. We contribute to the information coded by adapting the coding method to the image and by integrating a spatial distance into the shape factor definition. Moreover, we include the coding of an information related to the dynamics of the signature. To use these two types of information, we propose a fuzzy technique to combine and then obtain one kind of information. We evaluate this new coding operator with two types of forgery : random forgery and photocopy simulation.

2 The Shape Factor

The definition of a verification system needs the definition of a shape factor which allows the transformation from the image space to the feature vectors space. Thus, we should define a perception mechanism to obtain an appropriate transfer of pertinent information related to the discriminant features. To understand how we construct the shape factor, we should define the specific information of the problem. Then, we can specify its execution and evaluate its performance.

2.1 Problem Definition

To propose a solution for the signature verification problem, two sources of characteristics must be taken into account. The first one is the genuine signatures of a writer for whom a limited number of samples are possessed. The second one is the set of forgery that is a priori unknown.

Genuine signatures have different features in their line drawing that are copied with difficulty (i.e., harmony, height/width rate [2], or the rhythm of the writing gesture). This features set varies with time of day and month. A genuine signature can be defined as a harmonious space-time event where geometric notions, called static information and time notions, called dynamic information, were mixed. The dynamic notion cannot be directly used in an off-line approach. But Locard [6] has shown that the dynamic can be observed by gray levels in an image. In particular, light lines of the signature characterize a fast move with a low pressure during its realization, whereas dark lines express a slow trace with a higher pressure. So, gray levels of the image give an information about the dynamic of the writing action but not directly the real dynamic. We call this information “pseudo-dynamic” because it represents an indivisible combination of speed and pressure. This mix characterizes the essential difficulty in copying a signature, but also for verifying it [3].

Recognition complexity is all the more high as a large number of factors modify the signature trace. We can mention the teleological factor that conducts up to three categories of signature : formal (for notarial act), informal (service note), and fugitive (receipt). The context intensity is defined by the impact of the writing act. It comes in the attention and the rigour of the writing gesture. It conducts an important variability of the genuine signatures. Moreover, many factors like sickness, injuries, spatial or temporal constraints, and learning [4] or individual factors (i.e., age, sex, dominant hand, or educational knowledge level [5]) interact to shape the signatures. We also note the technical factors, such as the type of pen and paper, that also modify the shape of the signatures.

To show some of this variability, we present many signatures of a writer realized with the same pen and paper (Figure 1).

Fig. 1. Geometry of genuine signature

The features of genuine signatures are not sufficient to solve the verification problem and to define what kind of information should be used. Therefore, it is necessary to specify relevant characteristics of the forgery. The set of forgeries is a grouping of different categories that we can sort by their quality of copy. The forgery called freehand is the most difficult forgery to detect because its draw is very close to the genuine draw. Nevertheless, it presents some conflicts on the relative proportions of letters, spaces and alignments, and a loss of alternation in shadow (plain and loose). From a similar complexity, we distinguish the fawning or disguise forgery realized by the correct writer who wants to hide his identity. These draws are very similar to genuine signatures but with some distortions of letters, of the general axes [6], and, principally, some distortions in the dynamic of the gesture. Less complex, we find the optic-transfer forgery realized by a photocopier or other transfer process. These kinds of forgeries have the same draw as the genuine signatures but lack spontaneity with low gesture and uniform pressure. Last, the two easiest forgeries to detect are simple forgery (where the spelling of the signature is the same but the draw is fundamentally different) and random forgery (where the spelling and the draw are differents).

From this partial description of the forgeries, two major characteristics express the distortions between forgeries and genuine signatures. The set of characteristics is associated with the nature of forgeries and should be used for their detection. Table 1 indexes this set [7].

We note that the use of spelling is very discriminant for the detection of random forgery, but it is restricted to the elimination of this kind of forgery. To generalize the verification system, it is necessary to use the other characteristics. The static characteristics, as used by R. Sabourin [1] for the detection of random forgeries and for which we can extend the use to simple forgery, do not allow the elimination of other types of forgery (optic transfer forgery, freehand forgery,...). Moreover, the use of dynamic signature features allows just an adequate detection of optic transfer forgery and will contributes, in a smaller part, to the detection of freehand and servile forgeries. That is the generalization of a signature verification system implies the necessity to use the two types of characteristics.

In the definition of a tailor-made shape factor for general use, we must take into account the possibility of applying the verification system in multiple countries. So, the conception of the shape factor must be independent of the type of draw and must be text insensitive.

2.2 The Principle of the Shape Factor

To obtain a set of characteristics on the signature, while respecting the constraint of insensitivity for the text and the draw, Sabourin [8] has proposed an original method based on a multi-scale approach that collects a set of geometric characteristics. This set is then exploited by a vectorial discrimination.

Coding Technique The shape factor suggested, the so-called Shadow Code [9], was initially put forward by Burr to extract global characteristics out of hand-written characters. By extending the Shadow Code to the whole signature, Sabourin proposed the definition of the Extended Shadow Code as a global characteristic extractor for off-line hand-written signatures. This technique consists of projecting the signature information onto a bar mask lying on the binary signature image. The shape factor is made by the repetition of one basic pattern in a multi-scale approach (Figure 2).

Each pattern is made of three types of bars (i.e., vertical, horizontal, and cross bars where the two directions are taken into account). Each bar is made of a finite number of basic elements (pixels). A value expressing the characteristic of the coded signature is attributed to each basic element. The goal of this method is to make it possible to code several characteristics of the signature (e.g. position, orientation, gray levels). The projection principle used here is conventional in pattern recognition of written characters (Figure 3).

The interest such an approach is to offer different points of view on the signatures. Large bar masks give a global view where only the general characteristics are usable. A fine view gives a perception close to the text without being attached to the spelling. This technique eliminates the first step of segmentation in letters that have not been solved for hand-written signatures. It allows us to

Fig. 2. Multi scale shape factor

particularize one or more scales for the specific draws of a writer. Indeed, the scale of perception (fine or large) should be relativized to the inner volume of the signature of every writer.

The inconvenience of this coding method for hand-written signature images is the poor definition of the geometric characteristics of the signatures. This is why we have proposed, in [10], some modifications in the nature of the information in the coding and also in the method.

Distance coding The distance in coding allows us to code the proximity between the pixels of the signature and the mask bars. Thus, the farther from a bar a pixel is, the weaker its influence on this bar (Figure 3). Several points may be coded on the same pixel. To find the coding value, the maximum operator is chosen. This maximum value provides the shape of the pieces of the signature inside the pattern. For a large scale pattern, the coding signal provides the external shape of the signature that is close to the shape factor suggested by Nouboud[11]. The new pattern is more descriptive thanks to a multi-scale approach (Figure 3).

Pseudo-dynamic signature information To generalize an automatic off-line signature verification system, we should use geometric and pseudo-dynamic information on the signatures. The introduction of the distance in the coding tends to improve the shape factor because it takes taking into account the pertinent information necessary for hand-written signature verification in the geometric sense. Now, it becomes necessary to introduce the dynamic of the hand-written signature.

To use geometric and dynamic signature information, several methods can be used : a sequential, a parallel, or a simultaneous treatment. The sequential treatment needs to make the verification procedure on one type of information

Fig. 3. Projection principle

in order to verify the second. Two kinds of drawbacks are noted. Every type of forgery implies a verification with specific information like pseudo-dynamic, in the case of optic transfer forgery, and geometric with random forgery. Yet, the type of forgery is never known, so we cannot define the sequence of treatments to be used. Moreover, sequential treatments are longer than other analysis systems. It is for this reason, we generally prefer different kinds of architecture. The parallel treatment needs to construct two verification systems based on every type of information. The first one treats geometric signature information and the second treats pseudo-dynamic signature information. Then, it is necessary to combine the results from the two systems to obtain the final decision. This combination is hard to be define and the verification needs twice as many resources. A simultaneous verification needs the use of signature features which directly combine geometric and pseudo-dynamic signature information. For this, we should establish a combination operator that mixes the information from a heterogeneous nature. Yet, the pseudo-dynamic signature information is specific to each writer. So, it becomes very difficult to propose an analytical combination operator, but it is easier to give a logical qualification for which it should operate. This last comment induces the possibility of using the fuzzy technique.

To define a qualitative combination operator, we must make a qualitative analysis of pseudo-dynamic and geometric signature information.

First, to note the different qualification of the pseudo-dynamic signature information, we should analyze the different combinations of speed and pressure during the writing. We can dissociate three global components of a signature : the “pen down”, the “body”, and the “pen up” [12].

The “pen down” is an initial event where the writer puts his pen in place to begin or to resume again his gesture. This action is characterized by a low speed and a high pressure in a short time. The gray levels corresponding to this event are dark. After the “pen down”, the writing speed increases, whereas the pressure decreases, to reach a fluctuating medium level corresponding to the "body" of the signature that we can separate into plains and looses. Lastly, the "pen-up" is a part of the signature where the writer prepares himself to stop his gesture and finish his signature or to resume again in another position. "Pen-up" events are very fast with a decreasing pressure that gives clear gray levels in the signature. In addition, the passage between every event is gradual with the harmony of the gesture. This helps to qualify, in a continuous way, the pseudo-dynamic signature information.

These events have a relative importance in their repeatability in time. The "pen-down" is an important event because it is the starting point of the signature. The writer pays a particular attention at this moment because this starting point plays a role on the expression of his identity. The "body" is a succession of plains and looses, then it's a succession of acceleration and deceleration of the gesture where the attention of the writer is less important. During the "pen-up", the speed increases and the writer unfolds his attention. Then, it's a less important event due to its time repeatability. Sometimes, we note some degeneracy because the writer completely unfolds his attention in this part of the signature.

From this description and the order of importance of the different execution steps of the signature, we can define that the "pen-down" is a crucial event but it's less present. The "body" represents the major part of the geometry, but it seems to be certain for the dynamic. And last, since the "pen-up" is less certain in the geometry and the dynamic, then it's the less important event in the signature.

2.3 Combination operator

From this last linguistic description relating to the importance of the event and the notion of proximity usable to describe the geometric characteristics of the signature, a simultaneous coding can be defined. The relation between the characteristics and the coding can, for example, translate the importance of the events of the signature, but other relations can be expressed.

To realize this relation between the different notions of pseudo-dynamic ("pen down", "body", "pen up"), the proximity and the importance of the events, a fuzzy inference formulation appears to be well adapted.

To support this relation, we retain the most simple and the most known principle, the Mamdani [13] model which allows the integration of a linguistic formulation from the fuzzy characterization of geometric and pseudo-dynamic signature information.

Such a model requires a preliminary step of fuzzification or symbolization of the inputs. The obtained characterization should be defined on semantic fundamentals. In our case, the universe of discourse is a combination of speed and pressure, associated for the pseudo-dynamic, with some particular events ("pen down", "body", "pen up") corresponding to gray level ranges.

These three terms concern the gray level range of the signature. A threshold determines the edge between the gray levels of the signature and of the background. This threshold allows the placement of the three terms concerning the signature (i.e., "pen up", "body", "pen down") and a fourth term placed to represent the background. The linguistic terms are taken by trapezium to express an imprecise, but more certain, characterization of the terms. Simultaneously, we have chosen to traduce the notion of proximity by three linguistic terms ("close", "medium" and "far") in a distributed way so as to have a good definition of the level of proximity. The establishment of inference rules is intuitively done to express the relation of importance of the pseudo-dynamic events in the global analysis we have made, while taking into account the proximity notion that should stay a characteristic of the signature geometry. Thus, the "pen down"/"close" is considered as very important information, as is the "-body"/"close". These two combinations are associated to a "large" coding. A "pen up"/"close" is less important due to its low repeatability. Simultaneously, the "body" is essentially characterized by the proximity in order to keep the discrimination potential of random forgeries by traducing the geometry of the signature. Otherwise, the "pen down"/"far" and the "pen down"/"medium" are more important than a "body"/"far" or a "body"/"medium". Also, the "pen up" is considered less important than other notions in the same case of proximity. The linguistic definition of the inference rules which we gave can be expressed in an "IF-THEN" implication way.

IF the proximity is "far" and the pseudo-dynamic is "pen up" THEN the coding is "low".

IF the proximity is "close" and the pseudo-dynamic is "pen down" THEN the coding is "large".

Other combinations are derived from this extreme case and the notion of pseudo-dynamic is placed as an alteration of the notion of proximity. A point "close" is globally important. Yet, if the gray level of a point becomes light, it is less certain that it is so important for the signature then its interest decreases which implies the decrease of the coding. We have chosen the minimum and maximum for the operator of combination/projection, and the product of the inputs is accomplished by the minimum operator [13].

In this way, where many rules can be fired in a fuzzy model, the smoothing of the real behavior towards the behavior we want is allowed and many output terms can be activated. But, the coding on the bar mask needs a unique value. The defuzzification operator is obliged to aggregate the different output propositions in only one numerical value. It is done by the centroïd that provides a consensus on the final output. Figure 5 shows the fuzzy formulation of the coding operator.

3 Validation

To evaluate our tailor-made shape factor, we are using a standard signature database of 800 images completed by 20 writers (40 signatures per writer). Signatures were written on a white paper with a pilot fine liner pen in a 3 x 12 cm rectangle. Signatures were digitized to produce an image of constant size (512 x 128 pixels) and quantified in 256 gray levels. Every signature is moved so that its gravity center corresponds to the image center. This translation is allowed because it does not modify the characteristics we will use. Furthermore, the local variations of position, related to the gravity center, are reduced isotropically and allow only the use of the right characteristics.

3.1 Numerical Experiment : The Case of Random Forgeries

To evaluate the discriminant potential of each bar mask, we define a reference set and a test set for each writer and each bar mask. For a writer (class ω_1), his first 20 signatures have been attributed to the reference set and his last 20 ones to the test set. We introduce 5 signatures, chosen randomly from every other writer (class ω_2) within their first 20 signatures, for the reference set and a same operation is done for the test set but with their last 20 signatures.

For a correct evaluation of the discriminant power of each bar mask associated to our coding technique, we use a k nearest neighbors classifier with vote. This choice can be justified by the non-parametrical nature of the signature verification problem. Moreover, this classifier is often used in this kind of problem and provides the lower bound of the error with only one neighbor, if there is enough data [14]. An overall stage of evaluation consists of applying the protocol defined by Sabourin [9], on the same database.

Each discrimination produces two types of error reported in terms of type I [E_1, false rejection of genuine signatures] and type II [E_2, false acceptance of random forgeries] error rates evaluated for the 20 writers. The total error rate E_t of the test is expressed as the average of E_1 and E_2 which considers the same level of importance of each error type.

We can note that a statistical assessment is obtained by repeating this evaluation 25 times. By choosing different random forgeries, the final error rates are independent of the choice of forgeries.

To evaluate the performance of the coding process, we cannot directly use the entire quantity of information given by our coding technique in the discrimination system. The volume of information is reduced by describing the coding signals on the average. Some experiments, referenced in [12], show that the average of the coding signal gives the best performances. Then, the dimension of each characteristic vector space is given by the number of bar in each mask; as for example, R^6 for the mask a, and R^{276} for the mask o.

The results obtained are presented in table 2 and we can compare them to the results of Sabourin's method with the same database and protocol. In this case of random forgeries, our coding operator demonstrates better results than Sabourin's method for large bar masks such as mask a, h, b and f. For the largest bar mask a, the performance increases 40%. But, for fine bar masks, the performances are close to the Sabourin method results. Yet, we should relativized these last results because the dimension of the representation space is very large compared to the number of presented samples. Indeed, Bellman [14] defines this problem as a curse of dimensionality which is why it is very hard to prejudge the exact value of the performances if the number of samples increases. Nevertheless, we note that the global performance of our coding operator is better than Sabourin's for the discrimination of random forgeries by 23%, even if this method is made not only made for this kind of detection.

3.2 Numerical Experiments : The Case of Optic Transfer Forgeries

To evaluate the performance of our coding operator with this type of forgery, the problem is obtaining optic transfer forgeries because the database is not defined in this way. Thus, we apply an image treatment close to the photocopier optic operation. This operation can be viewed as a contrast modification that enforces the homogeneity of the signature gray levels. To achieve this, we propose the following look up table (Figure 4).

Fig. 4. Contrast modification look up table (LUT)

The factor δ allows us to define the rate of contrast modification. Its value can be directly associated to the photocopy quality or the difficulty level of detection. Indeed, the higher δ is, the closer a photocopy is to a genuine signature. Nevertheless, the geometry of the photocopy is the same as the genuine signature, whatever is the value of δ. Figure 6 shows a genuine signature and its photocopy with $\delta = 50\%$.

The last protocol cannot be used directly for the performance evaluation of optic transfer forgeries detection. The definition of the reference set from ω_1 and ω_2 is the same because we are not able to integrate all the types of optic transfer forgeries. On the other hand, the codification of the protocol focuses on the definition of the test set, which should now integrate many test signatures randomly chosen from the set ω_2 and transformed by the LUT. Then, we have not two kinds of affectation during the evaluation, but only one for the forgeries set.

That's why the error E_1 is replaced by an error E_{rec1} that characterizes the detection rate of genuine signatures. E_{rec1} should be maximum to define a good recognition of this type of forgeries. Simultaneously, E_2 should remain a minimum. Then, the evaluation of the performances, done by the nearest neighbor classifier, should be calculated by $E_t = \frac{(100-E_{rec1})+E_2}{2}$, where E_{rec1} is a success rate of detection of a genuine signature photocopied.

The evaluation of the capabilities of the coding operator, to show the difference between genuine signatures and their photocopies, is done by a nearest neighbor classifier with the last defined protocol. Moreover, this protocol is repeated twice with the different values of (75% and 50%). Table 3 shows the results of experiments with E_t and the values of E_{rec1} according to the values of δ.

These results show that the detection rate E_{rec1} with $\delta = 50\%$ is 7 - 27% and it demonstrates a good detection of photocopied random forgeries. The decrease of δ is directly observed by the increase in the detection rate from 27% to 45%.

The results are low, but not totally inadequate because the protocol used in this evaluation is directly issued from one of the random forgeries. Since the shape factor based on fuzzy inference rule is only able to do a small transformation of the coding signal because the geometry of the signatures is the same, the photocopies are naturally closer to genuine signatures than random forgeries. Indeed, random forgeries have different geometric characteristics. So, in the characteristic vector space, photocopies will be close to genuine signatures. A k nearest neighbors without distance rejection can yield only low performances. With the demonstration that photocopies, viewed by the shape factors, are effectively different from a genuine signature, we have defined a new protocol that integrates only 5 photocopies of genuine signatures (randomly chosen from the set ω_1) into the class of forgeries of the reference set. These 5 photocopies will to characterize a zone in the characteristics space to which photocopies can be attached.

The performances obtained from this second protocol are shown in table 4 with error rates E_t, and E_{rec1}, according to the value of δ. We note that the detection of photocopies becomes very interesting according to the value of E_{rec1}. With $\delta = 75\%$, the performances increase to the range of 48% to 68%. With $\delta = 50\%$, an increase to the range of 57% to 87% of photocopie detection is noted. This progression of the performances by the introduction of only five photocopie references shows that it is a local problem in the characteristic space. Consequently, the use of a classifier to make a verification decision should not be an extrapolator classifier such as classifier by compilation (e.g, Fuzzy C means, probability estimator,...).

Moreover, we can see that the performances are less dependent on the shape and the resolution of the bar masks than in the case of random forgeries. This is due to the nature of the gray level transformation. Because it is global and linear, the pertinence of the FESC is representative with large bar mask. We can found an equivalence with the performances of fine bar masks.

We note that the simulation of a photocopy is a particular case of optic transfer forgeries and another technique of copying will make more general modifications on signatures, both geometric and dynamic signature information. So, the shape factors can show better performances, with this case of modification, but they remain difficult.

4 Conclusion

We have shown that the use of geometric and pseudo-dynamic signature characteristics of signatures allows the increase of the performances of the verification in the case of random forgeries. These performances are better than those of the Extended Shadow Code. Moreover, it permits the treatment of other kinds of forgeries. By the acquisition of real forgeries of every type, we will be able to finetune the different parameters of our operators such as fuzzy membership functions and inference rules.

In future works, we will develop the step of multi-scale discrimination to operate on our shape factor in order to define a relevant decision from the different points of view of perception and the knowledge of verification problems given by samples of signatures in each scale.

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Table 1 : Difference level of characteristics

Pseudo-Dynamic characteristics	Servile	freehand	Optical	Simple	Random
Speed	1	3	1	3	3
Hesitation, mainquake	2	4	1	4	4
Retouch	3	4	1	4	4
Lack of loose	2	3	1	3	4
Uniform pressure	3	4	1	4	4
Geometric charateristics					
Shape of letters	3	3	4	1	1
Relative proportions of letters	2	3	4	1	1
Spacing	2	3	4	1	1
Alignments	2	3	4	1	1
Relative	2	4	4	1	1
Spelling	4	4	4	4	1

Table 2 : Results of coding methods with the nearest neighbor algorithm

1 *neighbor*	*a*	*h*	*b*	*i*	*c*	*j*	*d*	*k*	*e*	*l*	*f*	*g*	*m*	*n*	*o*
ESC	2.4	1.2	0.6	0.4	0.2	0.1	0.2	0.2	0.1	0.1	1.5	0.5	0.2	0.01	0.02
$FESC$	1.3	0.6	0.5	0.4	0.1	0.1	0.3	0.1	0.2	0.2	1.2	0.5	0.3	0.1	0.09

Table 3 : Results of FESC coding applied to photocopies

1 *neighbor*	*a*	*h*	*b*	*i*	*c*	*j*	*d*	*k*	*e*	*l*	*f*	*g*	*m*	*n*	*o*
$E_t, \delta(75\%)$	40	40	42	37	43	46	39	43	39	47	39	39	40	43	44
E_{rec1}	21	20	17	27	13	8.4	23	14	21	6.7	22	24	20	13	12
$E_t, \delta(50\%)$	32	31	33	27	38	42	27	34	30	45	31	30	20	13	12
E_{rec1}	38	40	36	47	25	16	47	32	40	9.5	40	42	38	27	24

Table 4 : Results of FESC coding applied to photocopies with some photocopies in reference sets

1 *neighbor*	*a*	*h*	*b*	*i*	*c*	*j*	*d*	*k*	*e*	*l*	*f*	*g*	*m*	*n*	*o*
$E_t, \delta(75\%)$	23	17	21	16	22	23	16	20	16	26	17	39	18	19	21
E_{rec1}	55	66	59	68	57	53	68	60	67	48	67	64	65	63	58
$E_t, \delta(50\%)$	15	9.5	13	8.7	14	16	16	9.7	9.7	21	8.2	9.1	11	12	14
E_{rec1}	72	82	75	84	73	68	87	81	81	58	85	83	79	76	73

Fig. 5. Fuzzy coding operator

Fig. 6. An example of genuine signature and its photocopie with a contrast factor of 50%