www.ietdl.org

Published in IET Biometrics
Received on 7th February 2013
Revised on 15th July 2013
Accepted on 20th August 2013
doi: 10.1049/iet-bmt.2013.0022

ISSN 2047-4938

Assessment of methods for image recreation from signature time-series data

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Abstract: Human signatures are widely used for biometric authentication. For automatic online signature verification, rather than storing an image of the completed signature, data are represented in the form of a time series of pen position and status information allowing the extraction of temporal-based features. For visualisation purposes, signature images need to be recreated from time-series data. In this study, the authors investigate the accuracy and verification performance of a series of interpolation methods for recreating a signature image from the time-series data contained in two ISO/IEC data storage formats. The authors experiments investigate dynamic data stored at various sample rates and signature images recreated at differing resolutions. Their study indicates possible best practice in terms of image recreation method, recreated image resolution and temporal sample rate and assesses the effect on the accuracy of reconstructed signature data.

1 Introduction

Signature verification is a widely used form of biometric verification. Signature has a long usage history and is generally accepted by the public, especially because of familiarity of its use in the context of legally admissible authorisation of transactions and documents [1]. The analysis of the signature in many conventional scenarios relies upon visual inspection, assessing similarities between a model signature and the transactional signature under inspection. Applying automatic signature verification (ASV) to this process removes the potential subjectivity in this assessment. 'Static' ASV applies algorithmic techniques to the analysis of the signature image. However, current ASV systems increasingly go beyond this level of information by utilising the 'dynamic' or constructional aspects of signatures (e.g. pen velocities, time taken to sign and so on), the added richness of such 'hidden' features typically resulting in improved authentication performance [2–4]. Although techniques exist to infer dynamic data from a static image [5, 6] most signatures used in a dynamic ASV system are captured using a pen-based device, for example, a graphics tablet, personal digital assistant (PDA) or dedicated signature capture pad, which samples pen position, alongside other status 'channel values' such as pressure and pen tilts, at regular time periods during the signing process. ASV signature data is therefore commonly stored as a series of time-stamped channel values – indeed a recently published data interchange standard by ISO/IEC [7] mandates time-series data formats for use in biometric systems.

Although data can be effectively stored in a time-series format for use in any form of automatic system, there are many situations where there is a need to recreate the data into an image reproducing the original static signature for human visualisation. For example, a legal document (for instance, a driving license or passport) or banking scenario may require an image-based representation of a signature to be presented using data captured as part of a biometric system and stored in an efficient time-series format. The simplest recreation method is to linearly 'join-the-dots' of sample points representing drawn pen position, but this may not produce an optimal output in terms of fidelity to the original (i.e. the accuracy of the recreated image when compared against the original signature image).

There are a number of parameters that can affect the accuracy of a recreated static image including original sample rate of the dynamic data, the line drawing/data interpolation method and the recreated image resolution. Previous work [2, 8] has examined the effect of sample rate on dynamic signature verification systems with inconclusive outcomes as to performance implications. A study by Martinez-Diaz *et al.* [9] explored both the effect of sample rates and two data point interpolation techniques on on-line signature verification data, showing that lower sample rates can be utilised while optimising performance, and identifying that a linear interpolation of points in resampling a time-series signature representation produces the best biometric performance. With skilled forgeries, an equal error rate (EER) enhancement of 3–4% is noted using a combination of down-sampling followed by up-sampling of sample points. This work, however, was focused on the application of resampling solely within the dynamic domain.

As indicated, a recent initiative by ISO/IEC has been the development of data storage formats for biometric signature samples. Two standards have been defined which are described as follows:

- *ISO/IEC 19794-7 Signature/sign time-series data [7]:* This standard specifies several data interchange formats for signature data captured in the form of a multi-dimensional time series, using devices such as digitising tablets. The standard contains three different data formats: a full format for general use which stores the raw data captured by the input device; a compact format for use with smart cards and other tokens that does not require compression/decompression but conveys less information than the full format and a compression format capable of holding the same amount of information as the full format but in compressed form. The full format defined in this standard stored the 'raw' sample data from a capture device (e.g. a digitising tablet) as a sequence of time-stamped channel values. The channels to be stored are selectable according to the capture device with time, *x* position and *y* position being mandatory. Other channel values allowed are pressure, azimuth and elevation among others. The format caters to a wide variety of devices with specifications such as sample resolutions and ranges being defined and scaled as part of the format. This data format stores the sample points with a resolution of 2 bytes. Files generated using the full format have the potential to be large, especially when the file contains a signature that has a long signing time. This has implications for storage on platforms with relatively limited storage capacity such as smartcards. To alleviate this problem, the standard also contains both a compressed data format, which stores the same data as the full format by using a lossless compression data algorithm, and a 'compact format' which features less information by storing sample point data with a resolution of 1 byte. Fig. 1 depicts a signature data stored following 19794-7 full format.

  Fig. 2 shows a graphical representation of the data stored on a 19794-7 full format record, where the three time-series stored can be seen: pen *x* position, pen *y* position and pressure.
- *ISO/IEC 19794-11 Signature/sign processed dynamic data [10]:* This format stores features (dynamic events) relating to the signature time-series data rather than the raw data itself. The format uses a series of 'dynamic events' within the pen position and pressure streams. In this way, this data format represents an intelligent compression of the ISO/IEC 19794-7. These dynamic events are located at: (a) pen-down; (b) pen-up events and (c) at those sample points where the pen has changed direction either in the *x*- or *y*-planes, or there is an increasing pen pressure reversing to a decreasing pen pressure or vice versa. ISO/IEC 19794-11 stores a sequence of dynamic events representing the pen trajectory and pressure at each dynamic event point. On every dynamic event, the *x* and *y* position, pressure and time are stored along with the dynamic event type. Furthermore, a range of global data features are stored to complete the information about the signature such as: total signature time, *x*–*y*-pressure means, *x*–*y*-pressure standard deviation and a correlation coefficient. This standard also describes the mathematical definition of the dynamic events and overall data feature [10]. The resulting format aims to store enough information to enable an accurate representation of the sampled signature within a file of reduced storage size. Fig. 3 depicts a signature data stored following the 19794-11 data format

  Fig. 4 shows graphical representations of the data stored on a 19794-11 data format record. Depicted in this figure is the raw data which are normally stored using 19794-7 full format and the 19794-11 dynamic events:In this paper, we address several important questions regarding the storage of signatures in the standardised formats and the ability to transform the dynamic data back into an image for static comparison. The specific questions are 3-fold:

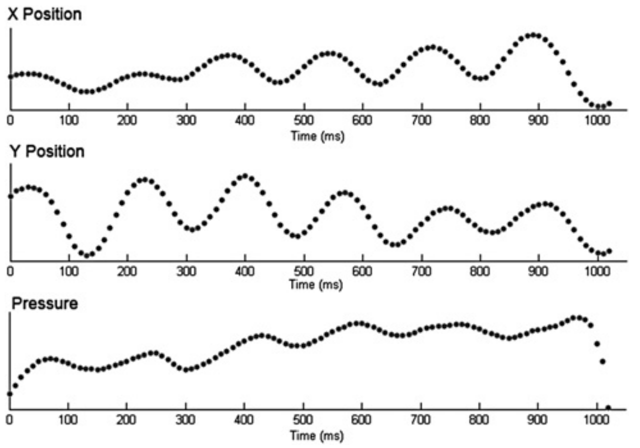

Fig. 2 *19794-7 Data sample points X, Y and pressure*

1. Investigate the best method to interpolate between time-sequenced sample data in forming an image. In

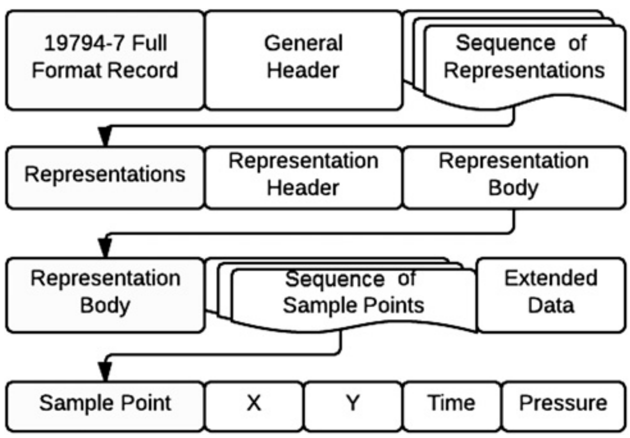

Fig. 1 *19794-7 Full format schema*

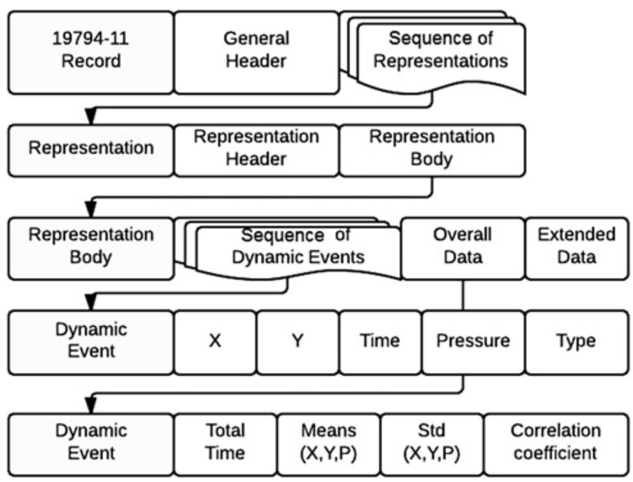

Fig. 3 *19794-11 Data format schema*

doi: 10.1049/iet-bmt.2013.0022

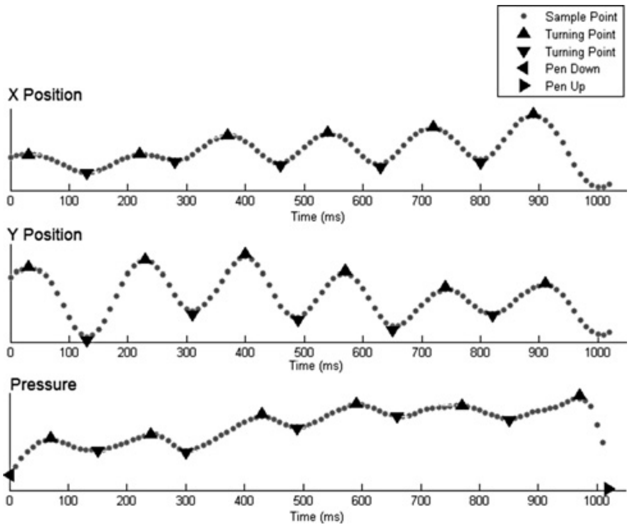

Fig. 4 *19794-11 dynamic events*

applying these techniques, we shall focus explicitly on 'fidelity/accuracy' assessment with respect to registration with the original image.

2. Investigate the effects of reducing the dynamic sample resolution and image recreation resolution on static verification performance using a commercial static signature verification engine.

3. Investigate the ability for data stored in the ISO/IEC 19794-11 formats to lead to accurate recreations of signature images in terms of static signature verification.

To answer these questions, we present the results of a series of experiments. In Section 2, we investigate the fidelity accuracy of a number of standard interpolation rates when used to convert dynamic data to static images. This is further investigated in Section 3 where we explore the effects on signature recreation fidelity of varying both the dynamic data sample rate and, separately, the image resolution of the recreated image using the best performing interpolation method. In Section 4, we apply our recreation methods to assess the fidelity accuracy of recreated signatures when dynamic data are stored in the ISO/IEC 19794-11 format as opposed to a stream of data points (as found in ISO/IEC 19794-7). Finally, in Section 5, we investigate the static signature verification performance (utility) of recreated samples when matched against original scanned images. As a whole, we form a series of best practice recommendations from our work.

2 Interpolation method fidelity assessment

The objective of this part of the investigation was to assess the similarity of images recreated from the time-stamped stored data with the original paper-based signature image produced by the signer. To facilitate this experiment, we used all 900 static signature images within the MCYT dataset [11] and their accompanying dynamic data (the MCYT time-series database is larger but for the purposes of our experiments we required both, the signature captured in a time-series format and the original paper-based drawn signature). In compiling this database, the subjects were asked to sign on a sheet of paper while the signature dynamic data was sampled at 100 Hz during signature execution to obtain the time-series data. The signatures on paper were subsequently scanned at a resolution of 600 dpi to obtain the original image. The time-series data was stored in a proprietary text format containing x, y, pen pressure, time and tilts for each sample point (similar to ISO/IEC 19794-7).

To recreate images from the time-series data a series of standard 'interpolation methods' [12, 13] were applied to form a line between individual sample points. The methods adopted were the following:

- *Linear interpolation (denoted as linear):* One of the simplest forms of interpolation, this method joins two known sample points by constructing a straight line between them. Consider two points ($x1$, $y1$) and ($x2$, $y2$). For a point x, where $x1 < x < x2$, the related y value at this point is given by

$$y = y1 + (y2 - y1)\frac{x - x1}{x2 - x1}$$

In forming a signature, this process is continued between pairs of sample point locations with values of x between $x1$ and $x2$, recognising that when the pen is lifted from the table surface no ink is drawn.

- *Nearest neighbour interpolation (nearest):* Another simple interpolation method whereby a y location value is associated with an x location between $x1$ and $x2$ ($x1 < x < x2$) is assigned to the nearest value of either $y1$ or $y2$. In this way, the resultant line exhibits a step function in the y-plane, rather than being a smooth line or curve between the points.
- *Cubic spline interpolation (spline):* A cubic spline uses a piecewise third-order polynomial interpolation of pen locations between the sample points (or knots). The shape of the spline will be determined to minimise the bending of the curve while passing through all the knots in the current section. If this fitting error is past a threshold then a new spline piece is added. As with the application of other interpolation methods, no ink is drawn when the sample points indicate a pen-up condition.
- *Piecewise cubic Hermite interpolation (PCH):* Another piecewise spline method, each piece is a third-order polynomial but expressed in Hermite form (function values and associated derivatives are defined at each sample point).

These interpolation methods were chosen as they are base implementations within the MATLAB environment and are widely used for interpolation solutions. Fig. 5 shows an example of a signature recreated using the five interpolation methods. As can be seen, there are clear performance deterioration issues with the spline and nearest interpolation method in relation to the other formation methods.

Owing to the complexity of some of the signatures, applying the spline and PCH interpolation method beyond separate signature strokes often results in poorly fitting curves. Owing to this, the pen coordinate streams were sub-divided according to the following criteria:

1. Pen coordinate streams have been sub-divided into each pen-down stroke, with a stroke defined as when the pen is in contact with the capture device surface during signature execution. Within a stream of data, a pen-up movement (when the pen is removed from the tablet surface) indicates the end of an individual stroke.

2. Pen coordinate streams are also sub-divided when a change in pen travel direction (either horizontally or vertically) has occurred within a pen stroke with pen travel direction

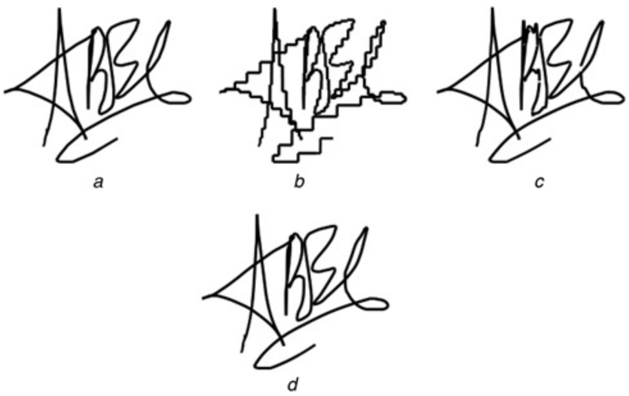

Fig. 5 *Examples of interpolation methods*

a Linear
b Nearest
c Spline
d PCH interpolation

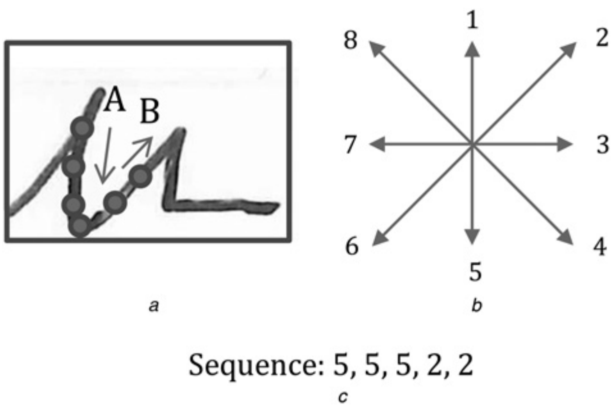

Fig. 6 *Chain code stroke segmentation*

a Sample ink trace
b Chain code directional identifiers
c Result chain code from ink trace shown in *a*

calculated by the angle between subsequent capture points. This angle is quantised to eight discrete points representing 45° divisions. Each of the eight points is given an identifier thereby enabling the construction of a chain code. A pen direction change (and hence a new stroke) is noted when the returned value from a quantised eight-point chain code differs from the previous returned value. Fig. 6 shows an example of this process. The directional identifiers in Fig. 6*b* are applied (in a quantised form) to the dynamic sample points of the signature shown in Fig. 6*a*. This forms a sequence shown in Fig. 6*c*. A new stroke (for the purposes of the spline application) is defined where the direction changes from 5 to 2.

Fig. 7 shows (a) the individual sample point locations within a signature, the application of the spline method (b) without and (c) with the chain code stroke break points. It can clearly be seen that the problems encountered by fitting a single curve to all the data in a signature are resolved when dividing the data into strokes. For the fidelity assessment, the spline and PCH interpolation methods have always been applied with this division of the signatures into strokes.

The thickness of the interpolated line was varied according to the pen pressure/force values stored within the time-series sample point, increasing in thickness linearly as the pressure increases thereby imitating normal pen drawing output (named variable-width interpolation in the following sections). A more simple one pixel width interpolation was also studied (named single-pixel width interpolation in the following sections). The recreated images were initially stored in a lossless Portable Network Graphics format at 500 dpi, although these high-resolution images were subsequently downscaled to 100 dpi (and beyond) for experimental purposes, reflecting typical end-use storage sizes within practical implementations.

Recreated images were matched against original scanned image using an affine registration technique. This meant that the recreated image could be subjected to rotation, scaling and shearing to identify the best registration fit between the two images.

Registration (and hence fidelity accuracy) errors were measured by finding the nearest scanned pixel to each recreated pixel with the two images once registered. Once each recreated pixel had been visited and the nearest distance was calculated, three statistics were produced – the mean Euclidean distance in pixels between the two images, the maximum distance in pixels between the two images and the percentage of pixels in the recreated image where there was a direct match (i.e. no distance between images). This process was conducted for all 900 static signatures and a mean taken on the results. This enabled a direct comparison between the recreation interpolation methods. Furthermore, the entire process was repeated for both single pixel-width interpolations and variable pixel-width interpolations. As the definition of fidelity is the assessment of representation accuracy between an original sample (in this case the pen-based signature on paper) and the stored sample we sought to select a method that enabled a simple distance-based metric to be derived between the two sources. Other methods could be employed to assess this distance such as those devised in recent work by Impedovo *et al.* [14, 15], however, our selected method provides a simple common baseline for fidelity assessment.

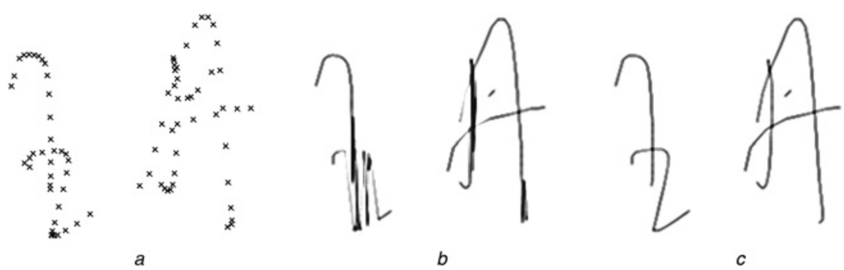

Fig. 7 *Example signature*

a Sample points, spline interpolation
b Without division into strokes
c With division into strokes

IET Biom., 2014, Vol. 3, Iss. 3, pp. 159–166
doi: 10.1049/iet-bmt.2013.0022

Table 1 Pixel registration distances using different reconstruction techniques – single-pixel width interpolation

Recreation method	Mean distance, pixels	% Direct match	Max distance, pixels
PCH	4.406	67.034	36.214
linear	4.656	66.700	37.163
smooth	4.863	65.065	39.089
nearest	5.232	52.002	40.240

Table 2 Pixel registration distances using different reconstruction techniques – variable-width interpolation

Recreation method	Mean distance, pixels	% Direct match	Max distance, pixels
linear	3.047	67.147	27.416
PCH	3.122	66.754	28.373
smooth	3.306	65.672	29.945
nearest	3.845	52.944	29.659

Table 1 shows the mean registration results across all 900 static images for the five recreation methods when the recreated signature was drawn as a single-pixel width interpolation. Although the performance is similar across all the methods, the table is ordered in terms of the best performing method by mean pixel match distance. PCH proved the closest match measured both by mean distance and percentage of direct match pixels.

Similar results are obtained from the recreated images with variable ink width (Table 2). The linear technique produced the best accuracy here with PCH being the second most accurate.

Owing to the high performance and stability (and hence generic applicability) across both single-pixel and variable width signature recreation, the PCH method was used in the remainder of the paper as the proven method for recreation.

3 Sample resolution performance assessment

In this section, the effects of sample rate (of dynamic data) and image resolution (of static data) are examined separately. Two down-sampling operations were conducted separately on the samples within each record:

1. The original data was sampled at 100 Hz. This was down-sampled to 75, 50 and 25 Hz by sample point removal (for the 50 and 25 Hz values) and interpolation of t, x and y and p channels (for the 75 Hz values). The PCH method (as the best interpolation method identified in Section 2) was used to plot each of the time-series sequences into a static image (with single-pixel width and, separately, variable width ink).
2. In a separate experiment, the recreated images were stored at 100, 75, 50 and 25 dpi.

In this way, it is possible to assess both the optimum sample rate and static recreation resolution with respect to storage size and fidelity.

Recreation accuracy was assessed again by registering the recreated image against the original scanned image and assessing the Euclidean distance between the nearest points on the image. Tables 3 and 4 show the fidelity distance results from the various sample rates and image resolutions employed, respectively.

The 100 dpi and 100 Hz sample rates are shown at the foot of each sub-table (shaded rows) and correspond to the result for PCH obtained in Section 2. In each case, it is interesting to note where a drop-off in fidelity accuracy occurs. In both cases, a reduction in sample rate has a larger effect on fidelity than image resolution reduction. This will be tested further with verification experimentation using these reduced resolution images, however, the above results indicate why it is critical to maintain a high sample rate (the results suggest that 50 Hz could be set as the lowest recommended sampling rate). However, the resolution of stored images maybe reduced without a loss in fidelity.

Table 3 Pixel registration distances using different sample rates – PCH generated

	Resampled resolution, Hz	Mean distance, pixels	% Direct match	Max distance, pixels
single width	25	7.612	46.755	52.169
	50	5.542	61.665	40.590
	75	5.041	64.854	38.900
	100	4.406	67.034	36.214
variable width	25	5.879	48.627	38.341
	50	4.034	63.146	29.728
	75	3.629	65.246	28.688
	100	3.122	66.754	28.373

Table 4 Pixel registration distances using different image resolutions – PCH generated

	Resampled resolution, dpi	Mean distance, pixels	% Direct match	Max distance, pixels
single width	25	5.019	62.220	39.515
	50	4.679	65.601	36.627
	75	4.541	66.305	37.052
	100	4.406	67.034	36.214
variable width	25	3.638	63.508	29.627
	50	3.346	66.323	27.679
	75	3.564	65.954	28.505
	100	3.122	66.754	28.373

doi: 10.1049/iet-bmt.2013.0022

This is of particular importance for storage capacity critical implementations.

4 Accuracy of ISO/IEC 19794-11 for static generation

An important aspect of ensuring that ISO/IEC 19794-11 may be adopted as a useful format for storing signature files is that fidelity and recognition accuracy is maintained even though not each sample point data are stored (as is the case with ISO/IEC 19794-7). To investigate the static recreation ability of ISO/IEC 19794-11 we have employed the same fidelity assessment method as used in Section 2 (PCH-based interpolation followed by an assessment of mean Euclidean error between a recreated and original image).

In preparation for these experiments, the MCYT dynamic files were converted into ISO/IEC 19794-11 files using the methodology described within [10] for locating key dynamic events, namely pen-ups, pen-downs, turning-points and pressure-reversal points. The x and y positions and pressure and time channel values were stored at these key events. From the resultant ISO/IEC 19794-11 files a static reconstruction was produced. This was achieved following the same procedure described in previous experiments using the PCH interpolation method. For this experiment, the information stored within ISO/IEC 19794-11 (i.e. the x, y and pressure values at the dynamic events) were used as input. Owing to the reduced number of data points in the sample, our hypothesis is that this will result in lower recreation accuracy (although a key consideration within the development of ISO/IEC 19794-11 was to maintain the performance characteristics of the samples). Samples were recreated with data at 100 Hz and at a resolution of 100 dpi to enable a direct comparison with the results obtained in Section 3.

Table 5 shows the results from this process for both single-pixel and variable width recreations. It is evident that the interpolation between the ISO/IEC 19794-11 dynamic events introduces significant fidelity distance errors within the recreated images in comparison with the 100 Hz, 100 dpi results contained in Tables 3 and 4, respectively (reproduced in Table 5 to enable a direct comparison).

These results indicate, as hypothesised, that directly forming static images from the ISO/IEC 19794-11 data files lead to inaccuracies in the static images.

To ascertain whether converting ISO/IEC 19794-11 files to 19794-7 files as an intermediary stage improves the fidelity result, the following experimental procedure was used. From the data stored within the ISO/IEC 19794-11 format, ISO/IEC 19794-7 data were interpolated following an enhanced methodology described in [14] and incorporated within the definition of dynamic events in the published version of the 19794-11 standard. The type of dynamic of event stored within 19794-11 allows the detection of constant value pen positions streams, thereby assisting interpolation methods, allowing the recreation of the raw data stored in the 19794-7 data format, whereas minimising the interpolation errors. This enhanced interpolation solves the specific problem of obtaining the raw data from the 19794-11 data format, but it cannot be used as a generalised interpolation method for recreation signature image from raw data and hence not used in a generic form as part of the static-to-dynamic recreation methods within this work. Also, as stated in Section 2, our goal was to use standard methods for this process rather than the bespoke method in [14].

As can be seen in Table 6, the results are more accurate than a straight conversion from the ISO/IEC 19794-11 (Table 5) but still less accurate than a direct conversion from the time-series data format (again reproduced from Tables 3 and 4 to enable a direct comparison).

5 Static recreation verification performance

The final experimentation was to assess the static verification performance of the recreated images. To achieve this, we used two independent engines labelled Method 1 and Method 2, respectively. Method 1 used pixel ink slant direction and shape envelopes [16] as features, whereas Method 2 uses a combination of polar and Cartesian features to describe the signature composition [17]. These methods were not optimised prior to use and were employed as common solutions to enable a direct comparison between the engines shown to produce good performance.

In training these systems, the number of training signatures used in each case was set to 3 and, separately, 5. We experimentally identified that a seven-signature training set had only a marginally better performance than a five-signature set with the additional overhead of extra training samples. In a scenario reproducing everyday use, the first n samples were used as training data (where n, as indicated, was either 3 or 5).

Table 5 Pixel registration distances of PCH generated static images from Part 11 data formats

Pixel recreation width	Mean distance, pixels	% Direct match	Max distance, pixels
single-pixel width using Part 11 data	8.085	42.940	55.440
single-pixel width (from Table 3)	4.406	67.034	36.214
variable width using Part 11 data	6.179	45.002	41.614
variable width (from Table 4)	3.122	66.754	28.373

Table 6 Pixel registration distances of PCH generated static images from Part 11 data formats interpolated to Part 7

Pixel recreation width	Mean distance, pixels	% Direct match	Max distance, pixels
single-pixel width	6.507	46.967	47.637
single-pixel width (from Table 3)	4.406	67.034	36.214
variable width	5.161	48.711	35.917
variable width (from Table 4)	3.122	66.754	28.373

IET Biom., 2014, Vol. 3, Iss. 3, pp. 159–166
doi: 10.1049/iet-bmt.2013.0022

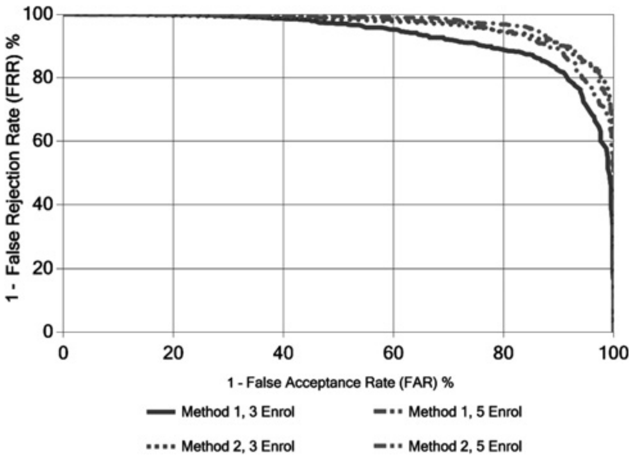

Fig. 8 *Verification performance of static against PCH recreated sample (100 Hz, 100 dpi) using the two verification methods*

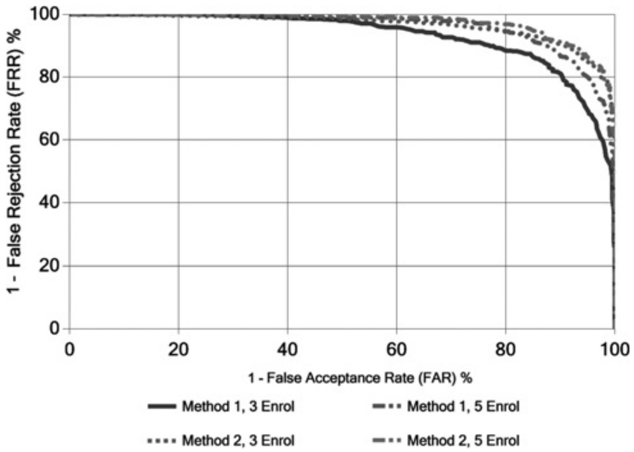

Fig. 10 *Verification performance of static against PCH recreated sample (100 Hz, 50 dpi)*

Fig. 8 shows the DET curve plot of the two methods when using scanned genuine samples and when verifying images recreated using PCH. Method 2, in this context, obtains better results than Method 1, with the latter being robust against the number of signatures taken for enrolment. The best results were when five samples were used with Method 2 with an EER of 9.03% (508 true positives, 57 false negatives, 45 false positives and 520 true negatives).

Fig. 9 shows the results when comparing static signatures against signature images recreated using PCH from signatures sampled at 50 Hz (a temporal down-scaling of 2:1) across the two methods and enrolment sample sizes. The lower simulated sampling rate used to generate this set of signature images does not seem to significantly affect the EER obtained with both comparison methods. This result shows how the sample rate limit of 50 Hz set from the previous results (Section 3) maintains enough information in order to perform good signatures comparisons. As with the results shown in Fig. 4, Method 2 with five enrolment samples produces the best results EER of 9.20% (508 true positive, 58 false negatives, 46 false positives and 520 true negatives).

Fig. 10 shows the effect of spatial down-sampling by using scanned samples for enrolment (as before) and PCH samples saved at 50 dpi. As above, this rate does not affect the EER obtained. A 50 dpi maintains enough information in order to perform good signature comparisons and confirms the findings within Section 3. Indeed, there is a slight improvement in performance with Method 2 again providing the best performance with five enrolment samples, this time resulting in an EER of 8.65% (508 true positives, 57 false negatives, 51 false positives and 524 true negatives).

Having established the superior performance of the five enrolment sample method, the final two experiments use this method solely. In these experiments, our aim is to establish the performance of recreated signatures (using the PCH method) where the data are originally stored in either a Part 11 or Part 7 format. Fig. 6 shows the DET plot results of this trail using the two signature verification methods.

Fig. 11 shows that for Method 1, the Part 11 recreations obtain almost identical EERs to the Part 7 recreations and that Part 11 is therefore a good alternative to store a dynamic signature in order to recreate and compare static signature images, although image recreations do not have the same degree of fidelity, as shown in the previous section. The former property does seem to be specific to individual signature engines as, for Method 2, the performance is considerably poorer for Part 11

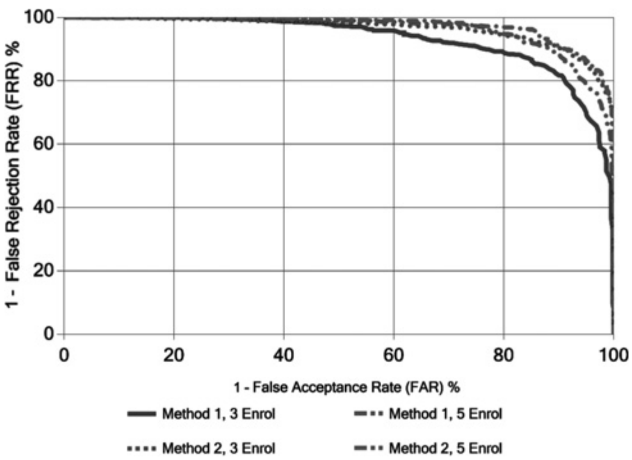

Fig. 9 *Verification performance of static against PCH recreated sample (50 Hz, 100 dpi)*

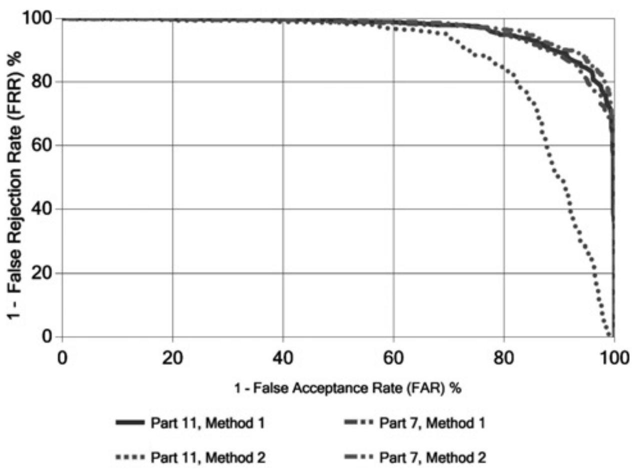

Fig. 11 *Verification performance of static against a) Part 11 and b) Part 7 verification*

reconstructions. The Part 11 storage format does, however, have the advantage of not storing all the online signature data with the enhanced security and storage benefits.

On examining the results it is interesting to note a number of factors when using these formats for data storage. Firstly, the performance does seem very signature system specific with Method 1 outperforming Method 2 in these instances. Secondly, the performance of Method 1 is very similar to the values obtained in earlier experiments thereby proving the usefulness of the ISO standards as a container for signatures data.

6 Conclusions

In this paper, we have examined a range of issues concerning the production of static signature images from dynamic data. Specifically, we have identified the best 'standard' method for interpolating between sample points and the effect of sample temporal and spatial resolution on the fidelity of the recreated image. We have also explored the use of two standardised data interchange formats to store temporal data and their ability to contain information to enable an accurate reconstruction of an image.

Verification performance has also been assessed using two popular static signature methods. These results show that the performance can be maintained with a reduction in temporal resolution in reconstruction. Although Part 7 storage performs comparatively, Part 11 reconstructions are sensitive to the particular static signature verification method being used.

This work highlights a range of best practice parameters for signature reconstructions and also shows the practicalities of adopting the ISO/IEC signature data formats for static signature comparison. Further work will explore the nature and sub-classification of static signature algorithms on the performance of Part 11 data storage.

7 Acknowledgments

This work has been funded in part by the Leverhulme Trust. The authors would also like to thank J. Ortega-Garcia and J. Fierrez-Aguilar for provision of the MCyT Signature Database.

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doi: 10.1049/iet-bmt.2013.0022