

WHITE PAPER

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**FORENSIC
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The scientific examination
of handwriting, documents
and fingerprints

Evaluation of WACOM'S Electronic Handwritten Signature Technology

by

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**with SignatureScope Software enhancements by
Wacom Global Signature Team**

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and

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EXECUTIVE SUMMARY

Research was undertaken to evaluate the examination and comparison of numerous signature features of ink on paper signatures and their electronic counterparts which were simultaneously captured using a Wacom STU-430 Signature Pad. The electronic signatures were captured and examined using Wacom SignatureScope software (v 1.29.1 and later versions) [1]. As a result of these evaluations we have formed the clear overall view that electronic handwritten signatures (“electronic signatures” for the purposes of this study) captured using Wacom STU-430 Signature Pads can be usefully examined by a professional forensic document examiner (“FDE”) using Wacom SignatureScope software with a view to addressing their genuineness or otherwise. Furthermore, for most features considered by us in the examinations and in the comparisons of the electronic signatures in this study, the information and value of that information is at least equivalent, and in many cases qualitatively and/or quantitatively superior, to that obtained from “traditional” examination procedures for the corresponding ink on paper signatures [2], [3].

Based on the outcome of this study, FDEs can be at least as confident of the results of a scientific comparative examination of a questioned signature and appropriate specimen signatures when electronic questioned and specimen signatures are captured on a Wacom STU-430 Signature Pad and examined using Wacom SignatureScope as when traditional examinations of ink on paper signatures are undertaken.

It is envisaged that on-going development of the technology (in conjunction with feedback from FDEs) would at least maintain but likely increase the advantage that examination of electronic signatures captured and interrogated using updated Wacom technologies has over the traditional methods of examining ink on paper signatures. Ideally, similar or appropriately adjusted research projects should be undertaken in the future using updated Wacom technologies to test this hypothesis.

It should be noted that this study has not included any other Wacom products or other firm’s technologies. It is recommended that further research be undertaken to test other electronic signature products.

1. INTRODUCTION

After initial encounters with much earlier versions of this software, it appeared to us that this type of software represented a potentially major advance in what could be determined by an FDE about the details of the act of handwriting, including of course signatures, but required research of the kind described in this White Paper. Most notable in the current software (and the most important of which were present in earlier versions) are the attributes described at points (a) to (d) below.

- (a) The ability to play back the track of the signature in real time (and related abilities to play back at reduced speeds) and most importantly having all the time related detail of the writing of a signature, that is the instantaneous speed at any point in the recorded digitised points in the signature. This is of key importance as one of the main indicators/symptoms of a non-genuine, simulation signature (that is an imitation "drawn" by another person or often loosely referred to as a "forgery") is frequently a much reduced speed of writing. With ink on paper signatures, the most an FDE can determine from microscope observation is a very qualitative description of speed. This would typically include a note that the ink line was produced hesitantly (possibly with some further descriptors of degree of hesitancy), moderately fluently or highly fluently (that is a qualitative determination of slow, medium or high writing speed). This is essentially determined by the degree of overall smoothness or otherwise of curved strokes with some influence of observations of the effects of varying pen pressure which often correlates with the direction of stroke. Until the advent of this type of technology, no retrospective numerical determination of the actual speed of the pen at any point in an existing signature and its variation across the signature could be made.
- (b) The ability to unravel the structure of complex handwriting formations, such as elaborate signatures in which the pen track repeatedly crosses over earlier written components of the signature. There are situations in which traditional examination techniques cannot unambiguously unravel the structure (that is the track that the pen travelled) and this can have a major impact on the ability of the FDE to determine the genuineness or otherwise of a questioned signature. With the electronic signature technology described in this White Paper, this difficulty is completely resolved.
- (c) Related to point (b) above, the ability to view the precise sequence and direction of all strokes in a signature. With traditional examination techniques, this information can sometimes (especially with ballpoint pen ink writings) but not always be determined, and often it cannot be determined (especially with fluid ink pen writings).
- (d) In more recent pen/pad developments over the last 12 years or so, the digitised pen/stylus track detection and analysis software (Wacom SignatureScope in the present study) allows tracking of the tip of the pen/stylus above the pad (typically to a height of up to about 10 mm). This "pen up" data allows a new dimension of

signature component examination by the FDE which is unavailable (or at best could only be hinted at from some indicators of pen direction at stroke endings and commencements) using traditional examination techniques. We have observed quite characteristic patterns of the pen track above the pad/document between ink strokes in these and other tests.

Our scientific evaluation of the use of the technology by direct comparison of the electronic signatures with simultaneously produced ink on paper signature counterparts has resulted in the findings outlined in this White Paper. Moreover we have accomplished this using (as best as we could) groups of signatures in one name containing questioned signatures produced by means that emulate what we encounter in day to day casework. We are not aware of any other study that has attempted to do this with Wacom or other manufacturers' electronic signature capture and/or analysis software.

2. PURPOSE OF THE STUDY

Wacom requested that FDS conduct a study to address the following two-part question:

Can electronic signatures written using Wacom's STU-430 Signature Pads be usefully examined by a professional forensic document examiner using Wacom SignatureScope software with a view to addressing their genuineness and, if so, how does it compare to the examination of ink on paper signatures?

3. EXPERIMENTAL DESIGN AND SAMPLE COLLECTION

In order to answer the question posed by Wacom, FDS had to undertake an extensive research project. A research proposal was devised by FDS (after consultation with an academic researcher) and ethics approval was obtained. Members of the FDS team were assigned roles: two primary examiners, two secondary examiners for peer review, and one analyst for compiling the study materials. The results were analysed and discussed in detail by the two primary examiners and the analyst so that final conclusions could be drawn from the study.

A vital part of this research was the use of an inking stylus (henceforth referred to as "pen"). This allows the writer to sign on paper placed on a Wacom digitising pad with an otherwise normal action ballpoint pen to produce an ink signature which is simultaneously captured electronically.

A pilot study was conducted (during 2015 and 2016) with a smaller sample of signatures than was used for the full study. The pilot study was very useful for refining the methodology for the full study to maximise efficiency and usefulness of the study.

For the full study (conducted during 2016 to 2018) the analyst collected many signatures from many volunteers using the Wacom STU-430 Signature Pad with the inking stylus and Wacom SignatureScope software. Signing forms were placed on the pad so that each signature collected had an ink on paper and electronic counterpart. Three extra signing forms were

placed between the subject signing form and the pad to provide a compliant writing surface. The analyst selected 15 signatures in each of six names (five questioned [being some combination of genuine, disguised and/or simulated by one of the other volunteers, in order to cover all possible explanations for an original questioned signature] and ten specimens) and signature packs were prepared containing the signatures to be examined, charts (showing enlarged images of the signatures) and signature examination, comparison and conclusion worksheets.

For signature packs in any given name, one primary examiner received the ink on paper signatures for examination, and the other primary examiner received the corresponding electronic signatures for examination (three signature packs each of ink on paper and of electronic signatures per primary examiner).

Ninety signatures were examined and reported on by each primary examiner (either as ink on paper signatures or the corresponding electronic signature). That is, a total of 180 individual signature examinations were undertaken (90 ink on paper and 90 electronic in total by the two primary examiners), each with a signature examination worksheet completed. Comparisons between the questioned signatures and the specimen signatures in the same name were then undertaken by the primary examiners. That is, 60 comparison exercises were undertaken in total by the two primary examiners (each exercise involving comparisons of one questioned signature with 10 specimen signatures in that name, there being six different signature names in total) and each with a signature comparison worksheet completed. Conclusions were then drawn by each primary examiner and recorded in a conclusion worksheet. The secondary examiners examined each signature independently from the primary examiner but with reference to the worksheets completed by the primary examiner. Any disagreement was discussed between the primary and secondary examiner until agreement was reached. This was to minimise the chances of any typographical errors in the worksheets and to minimise the potential of an “examiner effect”.

4. SUMMARY OF SIGNATURE EXAMINATION METHODOLOGY

A draft methodology for examining electronic signatures captured and examined using (specific) Wacom hardware and software (“the draft electronic signature examination methodology”) was developed by FDS and used during the pilot study (and was presented as a paper titled “Development of a Draft Methodology for Electronic Signature Examination using Wacom SignatureScope” at a meeting of the American Society of Questioned Document Examiners in August 2016 [4]. A further development of that draft methodology became the actual electronic signature examination methodology (“the electronic signature examination methodology”) used during this full study.

FDS is in the process of preparing scientific papers on the electronic signature examination methodology (as it was applied in the full study) and on the results of the full study for presentation at various conferences and potential publication. During the pilot and full studies, Wacom made several adjustments to SignatureScope software based on feedback from FDS. The result is a refined version of SignatureScope which has become even more attuned to the requirements of FDEs.

Much of the electronic signature examination methodology development was concerned with defining signature features in such a way that observations on electronic signatures and their ink on paper counterparts could be compared directly. In many instances, what at first sight might be considered as rather obvious signature/handwriting qualities in traditional examinations (such as fast or slow, heavy or light pen force [often, but incorrectly, termed “pressure”], degrees of variation of speed and of pressure, pen stops and pen lifts) took a lot of effort to define so that these qualitative (semi-quantitative) features in the ink on paper signatures could be directly compared with the detailed quantitative information that emanated from analysis of the electronic signatures using SignatureScope. These definitions are discussed in preliminary form in the draft electronic signature examination methodology paper and discussion of them will be included in the scientific papers on the electronic signature examination methodology and the full study [4].

The ink on paper signatures were examined and compared, following standard procedures for signature examinations (“standard signature examination methodology”) [2], [3].

Conclusions were then reached for the ink on paper and electronic signatures, with the conclusion expressed according to FDS’ nine point conclusion scale. That scale covers the whole gamut of unqualified, qualified and inconclusive results and closely correlates with the SWGDOC conclusion scale [5].

5. SUMMARY OF SIGNATURE FEATURES AND COMPARATIVE EXAMINATION POINTS EVALUATED

In brief, the signature features that were evaluated, where possible, either quantitatively and/or qualitatively, for both ink on paper signatures and electronic signatures are listed at points (a) to (i) below.

- (a) Pen “pressure” (actually the effects of pen force) and its variation across the signature.
- (b) Speed (“average” speed [for electronic signatures, the root mean square “RMS” speed is provided by SignatureScope] and variation in speed across the signature).
- (c) All determinable information about pen stops associated with each signature, including number, location and sequence.
- (d) All determinable information about pen stroke beginnings and endings (pen lifts) associated with each signature, including number, location and sequence.
- (e) Pen orientation.
- (f) Signature line smoothness.

- (g) Geometric location and orientation of the signature with respect to the signature line (which was present on the signing forms in approximately the same relative location as, and designed to approximately line up with, the signing line on the screen of the digitising pad that is stored with the electronic signature).
- (h) Geometric extent of the signature (overall width, height and area).
- (i) Pictorial features of the signature including (for electronic signatures) the pen up information.

There are multiple sub-features within most of those features listed above, so there were many more evaluated than just those signature features listed above.

These features were evaluated and their associated qualitative categorisations were compared between each ink on paper signature (determined by one examiner) and its corresponding electronic counterpart (determined by the other examiner).

The actual determination of whether each questioned signature was or was not written by the writer of the set of specimen signatures in that name was not central to this study but is of course of key importance in what we as examiners undertake professionally. The central issue in this study was the evaluation of any differences, including advantages or disadvantages of the particular signature medium (i.e., ink on paper or electronic) involved, between examinations of only ink on paper signatures and examinations of only their electronic signature counterparts.

6. SUMMARY OF EXAMINATION PROTOCOL

Using the standard signature examination methodology and electronic signature examination methodology document, the many defined signature features were evaluated qualitatively or quantitatively where possible (by separate examiners) based on each examiner's observations on the ink on paper signatures and on the corresponding electronic signatures. Each feature of a signature was evaluated by the particular examiner as being useful or not (or indeterminate/inapplicable) in the comparison process between each questioned signature and the specimen signatures in the same name, examined either as ink on paper or in electronic form. The usefulness factors described here and below are qualitative assessments by the examiners. For each questioned signature, each examiner's determination of whether each questioned signature was or was not, in their opinion, significantly different from the relevant set of specimen signatures was documented. Each examiner then recorded their conclusion as to whether the questioned signature was or was not written by the writer of the relevant specimens.

After the signature examination results had been documented by the primary examiners and peer reviewed by the secondary examiners, the results were initially assessed by the analyst and then were subjected to extensive discussions between the primary examiners and the analyst. The results of this analysis process were combined assessments as to:

- (a) the overall usefulness of each of the signature features in each ink on paper and electronic counterpart signature;
- (b) the overall usefulness of these features in the comparison process between each questioned signature and the relevant set of specimen signatures;
- (c) the determination of whether each feature was or was not significantly different between questioned and specimen signatures; and
- (d) whether either ink on paper signatures or their counterpart electronic signatures were deemed as more useful to examine in reaching an expert conclusion on the issue of genuineness or otherwise of each questioned signature.

An attempt was made to determine whether any differences in the feature categorisations, in the feature similarity/difference determinations and in the conclusions could be ascribed to the signature medium (i.e., ink on paper or electronic), to examiner effect and/or due to experimental set up effect. These combined assessments made it possible to answer the question that was the purpose of this study, stated in section 2.

7. SUMMARY OF RESULTS

The results in summary form are quite simple. Examinations based on electronic signatures were found either to have an advantage or were equivalent to examinations of ink on paper signatures. This was with respect to: examinations and comparisons of most signature features listed in section 5; determination of whether there was an overall significant difference in a questioned signature compared with the relevant specimen signatures; and in the determination of writer.

The only exceptions to this are pen orientation [(e) in section 5 above] and signature line smoothness [(f) in section 5], and possibly the geometric location/orientation and geometric extent factors [(g) and (h), respectively, in section 5].

Examiners were able to determine pen orientation, qualitatively, for a small number of the ink on paper signatures examined. This feature was not available in the data recorded by the devices used for this study. We understand that this and other additional data are available with some other electronic signature capture devices. (It should be noted that FDEs can only determine very approximately one of the three parameters of pen orientation being the “azimuthal angle” which is the orientation of the projection of the pen on the paper.)

With respect to signature line smoothness, the value of this parameter on its own is limited, especially taking account of its difficult to define nature and the effect of digitisation of electronic signatures.

With respect to geometric factors, ink on paper is only advantageous if the ink signature is taken as representing the ground truth of the actual pen tip movement. We have realised that there was a slight effect with the necessary experimental set up (especially the use of a stack of four signing forms “secured” to the digitising pad with small pieces of adhesive tape), in that in some

tests we undertook, it was evident there was very slight movement of the signing forms during the act of writing. Given that the electronic recording track of the pen could be regarded as a truer record of the pen's actual spatial movement, we now regard any differences in the recorded track between ink on paper and electronic signatures as neutral and an experimental artefact. By neutral we mean equivocal in terms of any advantage or disadvantage of examining electronic signatures compared with examining ink on paper signatures. We also regard them as being of little significance (except in spurring thought to further research and an improved experimental design) to the full study outlined here since they involve positional differences of the order of only up to about 1.5 millimetres and mostly much less. We are of the firm view that these very slight geometric differences between ink on paper and electronic signatures had no effect on the evaluations undertaken in this study.

Although in most cases the pictorial information analysis was equivalent in terms of revealing the structure of the ink on paper signatures and their electronic counterparts, there were many instances where the signature examination was significantly enhanced by having a record of a track of the pen above the signing form (and digitising pad) in the electronic signatures (that is the pen up data). In some instances, the track above the writing surface was not simply a continuation of the direction of the pen when it left the paper but patterns, such as loops and other significant changes of direction, were observed before the pen reached the paper surface again. In some cases, analysis of the electronic signature allowed examination of the pen up signature components that were not evident by projections of or interpolations between the end and start of the relevant parts of the ink line. Some of these pen up patterns in the specimen signatures of one person were quite characteristic of that person's (three spatial dimension) signature.

8. CONCLUSIONS

Electronic signatures written using Wacom's STU-430 signature pads can be usefully examined by a professional forensic document examiner using Wacom SignatureScope software with a view to addressing their genuineness. Furthermore, for most signature features considered by FDS in the examinations and in the comparisons of the electronic signatures in this study, the information and value of that information is at least equivalent, and in many cases qualitatively and/or quantitatively superior, to that obtained from traditional examination procedures for the corresponding ink on paper signatures.

Based on the outcome of this study, FDEs can be at least as confident of the results of a scientific comparative examination of a questioned signature and appropriate specimen signatures when electronic questioned and specimen signatures are captured on a Wacom STU-430 Signature Pad and examined using Wacom SignatureScope, as when traditional examinations of ink on paper signatures are undertaken.

9. FUTURE DEVELOPMENTS

We envisage that there will almost inevitably be future refinements of Wacom SignatureScope forensic analysis software, based on feedback from FDEs (including the authors of this paper). Different examiners may have different requirements of the program and their analysis of

signature features using it. Examples are some of the criteria which have been set (mostly as a result of feedback from the authors and ultimately set somewhat arbitrarily) for defining such electronic signature analysis features as "pen lift", "pen stop", "fast", "medium" and "slow" RMS speed. We also envisage that signature features that we have difficulty in categorising (in particular variability of speed and of "pressure" at every digitised point throughout the electronic signature) could fairly straightforwardly be provided to the forensic examiner by mathematical/statistical analysis of all of the recorded data for each signature or even for examiner selected parts of signatures. It should be noted that, for electronic signatures, variability of speed includes pen up components between strokes.

Detailed analysis of the position versus time record of the electronically recorded signatures has revealed hitherto undocumented (as far as we are aware) details of "normal" signatures. These include the observation that many signatures (and commencements of other separate strokes in signatures and handwriting) commence with a slight pause or very slow start (typically over a period of up to 35 milliseconds) before the pen accelerates towards its more normal writing speed. We also observed that turning points in cusp like features within a signature are associated with a pause that is measurable using this technology, typically of the order of up to 25 milliseconds. (It should be noted that a pen stroke that goes back on itself, i.e. a "retrace stroke", necessarily has the pen speed dropping to zero at the turning point.) However, it might have been expected that electronic signature analysis would reveal a close to instantaneous drop to or very close to zero speed at the captured digitised point(s) near the turning point. Our observations show a much longer pause or significant slowing down. We intend to undertake further research on this topic and especially on how the act of writing on sheets of paper secured to the digitising pad may or may not influence these pause times compared with signing directly on the digitising pad.

From the viewpoint of an FDE, the applicability of Wacom SignatureScope software to other manufacturers' dynamic electronic signature data would be a great bonus in allowing the FDE with access to the software to effectively examine electronic questioned signatures captured using a variety of technologies.

Significantly for the FDE, we now envisage in the near future a significant advance in overall forensic signature examination methodology. This would comprise, for both ink on paper signatures and electronic signatures, a combination of traditional methodology in examining signatures (where necessary modified as we have been required to do for the analysis of electronic signatures [4]) and on-going developments in both static and dynamic signature verification software, which could be used to provide statistical data on both geometric features and (where applicable) dynamic comparison points. Such verification software has been, and continues to be, developed by Wacom [6], [7]. We believe that this may result in a significant improvement in the means and reliability of scientifically examining signatures and handwriting, whether examined as ink on paper or as electronic signatures. The verification software, which has not been the subject of this study, would provide a large array of statistical data which we feel will be of significant assistance to the FDE. It would certainly be of assistance in quantifying (and, if necessary, showing summaries and pictorial illustrations of statistical assessments to the Court in a litigated matter on questioned signatures and/or handwriting)

those examination aspects that are currently almost always qualitative assessments. It should be noted that, importantly for FDEs, the verification software currently applies to geometric analysis of static signature images as well as to (dynamically captured) electronic signatures. Ideally, both examination by FDEs and verification software of questioned and specimen signatures should include both geometric and dynamic features.

We are also aware of significant developments in the FDE community/network in Europe. This relates in particular to the Institute of Criminalistics Prague, Czech Republic, a government supported program on the technical requirements (such as minimum hardware and software standards), procedures and development of tools for FDEs for the examination of electronic signatures (referred to by that group as digitally captured signatures [DCS]). Thus it embraces some of the work we have undertaken on this project but is generic in nature and intended to cover a wide range of manufacturers and technologies. We are hoping to liaise with this group in terms of the substantial work we have undertaken on the evaluation summarised in this White Paper and in particular in our current methodology, which is based on Wacom hardware and software as stated, but which, in principle, could be adapted to other technologies and generically.

As the conclusions regarding the signature comparative examinations were not a focus of the full study, in the future we would also like to explore further the issue raised in this study of examination of electronic signatures possibly contributing to the increased accuracy and/or confidence of conclusions reached by FDEs regarding the genuineness or otherwise of questioned signatures.

It is also important that we, in the future, explore what advantages, if any, there are in examining electronic (only) questioned signatures in relation to ink on paper (only) specimen signatures, or vice versa with respect to the signature medium, or some combination of electronic and ink on paper signatures.

REFERENCES

- 1 Signature Scope demonstration software (SDK):
<https://developer-docs.wacom.com/display/DevDocs/Signature+SDK+-+Signature+Scope>, accessed 31.01.2018 (note that the full version of SignatureScope, which FDS used for this study, is only provided by Wacom to *bona fide* forensic document examiners)
- 2 SWGDOC Standard for Examination of Handwritten Items
<http://www.swgdoc.org/images/documents/standards/>, accessed 31.01.2018
- 3 D. Ellen, (2006) *The Scientific Examination of Documents: methods and techniques*, 3rd Edition, CRC Press, Taylor & Francis Group, Boca Raton, FL

We consider this to be a concise introduction to the techniques used by forensic document examiners including the traditional examination of signatures and handwriting.

There are many other valuable texts on the subject, some of which are referenced within Ellen's book.

- 4 S. Strach, M. Novotny, A. Devlin, C. Graydon and P. Westwood, *Development of a Draft Methodology for Electronic Signature Examination using Wacom SignatureScope*, presented by A. Devlin at the 74th Annual General Meeting of the American Society of Questioned Document Examiners (ASQDE) in Pensacola Beach, Florida, USA (2016)
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ABOUT FDS AND THE AUTHORS

FDS is an independent forensic document examination laboratory with a team of examiners who use rigorous scientific analysis and examination techniques to establish the authenticity or otherwise of documents and to detect evidence of tampering or specific handling of documents and other items. We pride ourselves on our independence and impartiality, and strict quality assurance procedures. The majority of our work comprises examinations relating to questioned signatures.

Our case work arises out of civil, criminal and private matters including "forgery", fraud, identity theft, immigration, intellectual property, break and enter, arson, kidnapping, extortion, murder, probate, custody battles, divorce, drug importation, employment/labour disputes, unfair dismissal, debt recovery, insolvency, negligence, medical malpractice, personal injury, defamation, workplace safety, landlord/tenant disputes, worker's compensation, theft and assault.

Since 1999, FDS has been collaborating with Nick Mettyear and his team on the development of electronic signature capture and analysis technologies.

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Further details about FDS and our examiners can be found on our website (www.forensicdocument.com.au).