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Conducting a Forensic Examination of Electronically Captured Signatures

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The Uniform Electronic Transactions Act (UETA–1999) gave electronic signatures the same legal weight, as original (hand-made) signatures. As a result, a proliferation of signature capture devices has entered the market place. One of the most commonly used capture devices is the electronic signature tablet, which acquires electronic versions of signatures executed as part of a transaction. Typically, these electronic representations of a signature are embedded (or associated with) the document requiring the signature in such a way as to prevent tampering. Research conducted by the author for Topaz Systems, Inc. (a leading producer of electronic signature tablets and software) and studies necessitated by actual casework, have shown that signatures captured at a rate of 100Hz or faster contain sufficient detail and fidelity to arrive at reliable forensic conclusions as to authorship. In addition, Microsoft Excel™ can be used to produce very accurate graphical plots from the captured raw data.

Introduction

Electronically-captured signatures are used in all types of business environments. Some of these include signatures on point-of-sale-terminals, insurance policy transactions, medical records, and stock transfers. All of these signatures have the potential to be disputed and fall into the domain of the forensic document examiner (or whoever else is willing to render an opinion as to authorship). This author has worked with the engineers and developers at Topaz (one of the world's leading producers of signature capture devices) for more than a decade and actually provided research and input into the development of forensic tools that can be used by the Questioned Document community to evaluate and compare questioned and known signatures that have been electronically-captured. Dr. Tomlinson Rauscher, Vice President of Software Engineering at Topaz, stated in a 2010 presentation at the Southwestern Association of Forensic Document Examiners Meeting that, for several years, Topaz has continued to experience increasing sales, and market acceptance of digitally captured signatures. There is little doubt that electronic signature pads are becoming a routine part of business transactions. The purpose of this paper is twofold: to provide some insight into how a forensic examination of electronic signatures should be conducted and to provide the results of a study which was undertaken to determine the accuracy of the signatures that are captured on a typical Topaz tablet.

Electronic Signature Tablets

Nearly all electronic signature tablets capture a signature as if it were being written on a sheet of graph paper. They do this by looking at the location of the stylus within the Cartesian coordinates as it is moved over the surface. A snapshot of the stylus locations is recorded in regular small increments of time—typically between 1/400th (very high resolution) to 1/100th of a second (standard). Less than 3% of electronic capture pads also record changes in pressure, and most of those 3% are tablets used for digital artwork, such as Wacom Tablets™.The vast majority of electronic signature capture pads like those used for commercial transactions record x-y position and timing data only.

The Topaz tablet that was utilized in my experiments (model T-S751-HSB) begins recording when the stylus makes contact with enough pressure to activate the circuitry. It digitizes the pen position at a very high rate internally in order to provide highly precise timing accuracy and consistency from sample-to-sample. It continues to record hand movement on the tablet surface until the stylus pressure decreases below a certain threshold or it leaves the tablet, at the conclusion of the signature. Because pressure variations typically happen several times in the execution of a normal signature, there are usually a number of "strokes" that it records. These "strokes" are simply pen-lifts or places on a signature where the pressure decreased for an instant and then reapplied. Although there is no quantitative pressure information captured, the locations of the pen-lifts and/or extremely light pressure in the signature are precisely positioned and can provide extremely valuable forensic evidence. Because the (x-y) data points from the captured signature are recorded sequentially, it is also possible to determine the movement of the hand as it creates each stroke, dots 'I's, crosses 'T's, and moves through highly-complex, cursive type signatures.

The Anatomy of Captured "RAW" Signature Data

Topaz tablets and the required operating software capture the signature data in a secure format provided by the software application. This data may also be associated with or embedded in the transaction documents in some encrypted/compressed format by the end user. Because the raw data contains information that is needed to "reconstruct the signature" as well as other information that can be used as part of a forensic handwriting examination, it is critical that the forensic document examiner utilize this raw signature data so that they can determine the number of x-y pairs that were captured, the x-y coordinates of the stylus obtained at the tablet/software capture rate, the number of individual "strokes" that comprise the signature, the starting position of each of the strokes, and the date and time of capture. In my studies and in actual casework involving questioned electronically captured signatures, I was able to use extracted raw signature data. In this format, the data could be analyzed using standard spreadsheet functions and graphing capabilities. In situations where only the secure data is available, however, Topaz provides two software applications for forensic signature examinations—SigAnalyze™ and SigCompare™. These tools can be used to obtain a "full resolution" plot of a signature captured with a Topaz system and all of the critical data needed to perform a valid handwriting comparison. In addition, SigAnalyze™ displays the number of data pairs contained in each "stroke" and the time used to execute the strokes.

In my analyses using raw signature data, the x-y data pairs are usually obvious. One could laboriously count the number of these pairs, but this is not necessary because there is a field within the SIG data that already holds this value. Another field often holds the number of individual strokes in the signature and a series of values that tell which x-y pair starts each of the new strokes.

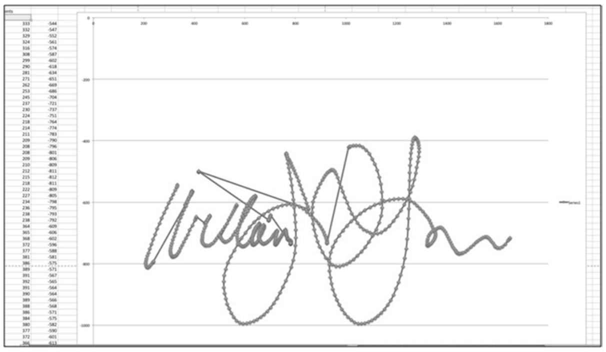
If you take a case involving electronically-captured signatures, the client may think it is only necessary to provide the graphic representations of the questioned captured signatures for (what would be thought of as) a traditional signature comparison. There are several reasons why you absolutely need to do your analysis based on the raw signature data, however. The three most important pieces of evidence contained in the raw signature data that might be difficult or impossible to deduce from the examination of an original signature are:

1. The segment (stroke) timings to an accuracy of 1/100th of a second or greater
2. The precise acceleration and deceleration of the hand as it created the signature; and
3. The exact sequence of strokes including when the i-dots were placed in relation to the other letters, exactly how retraces are formed, and how complex, highly-cursive signatures are created

Although the resolution of a digitally captured signature is certainly less than that of an original (analog) ink-made signature, there is information that can be extracted from the raw signature data that could never be exactly known in a traditional signature comparison. So, while it is true that some detail is inevitably lost in a digitally captured signature, there is also a gain in information that can assist in the determination of authenticity—but ONLY if you are working with the raw signature data.

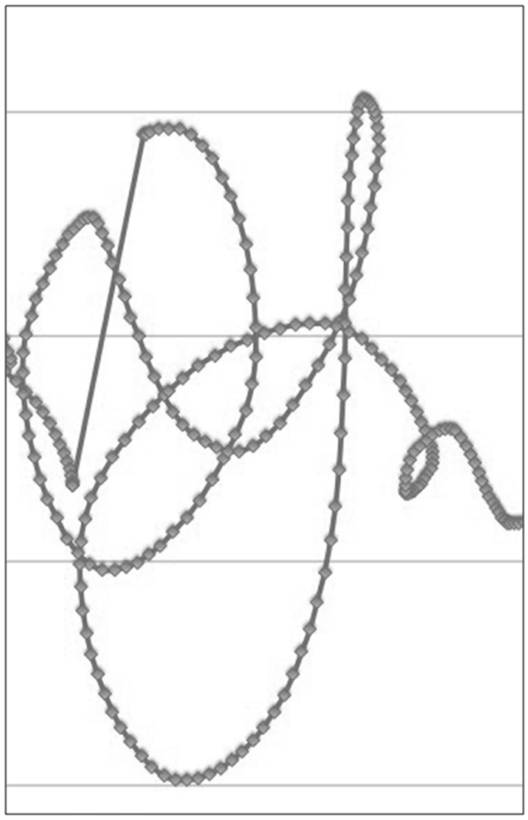
Importing the Raw Signature Data into Excel

When working with the raw (extracted) signature data I found it useful to import the x-y pairs in the signature data into an Excel™ Spreadsheet. In my research study I have found that Excel can produce a high quality representation of the original signature that can be a near perfect overlay of the original. In addition, all of the forensic analytical data contained in the raw signature data can be extracted and usually represented graphically to assist in your analysis. If it is not possible to obtain the extracted raw signature file (or if one does not wish to setup a spreadsheet for each case) SigAnalyze™ will provide the same information. Below is a chart created in Excel showing a plot of my signature using the data pairs in this *raw signature data*:



The small size of the graph on this 8.5 x 11 in. page does not begin to show all of the underlying information. It does, however, show a very accurate representation of the signature I executed on the tablet and also the points in time when my hand was "flying through the air" to place i-dots and move from the middle initial to the last name (the straight lines are the movements in the air, above the tablet). The enlargement below is cropped and enlarged from the last stroke of the "J" to the end of the first "n" in order to highlight the distribution of data points.

In the cropped and enlarged view shown at upper right, much more information about the dynamics of the signature can be obtained. This is one of my "speed" signatures where my last name is actually written as "Fl (loop) n." The straight line on the left is the "air" movement from the end of my middle initial "J" to the top of the "F." The spacing of the data-points is directly proportional to the speed of the strokes. The wider the spacing, the faster the hand was moving. Look at the spacing of the data points in my signature above and see how logical the acceleration movements are—acceleration on the long strokes, but slowing down to make the turns. Just as on a racetrack the tighter the turn the slower the hand has to move to execute it. This could not be more clearly illustrated than in this plot! As a result of actual casework and the research I have conducted, I have found these segment timings to be much different between genuine and forged signatures.



There are other data analyses that can be made from the raw signature data once imported into Excel and there are also forensic tools available from Topaz in the form of the software packages, SigCompare TM and SigAnalyze ™. The typical spreadsheet I use to perform a detailed analysis looks something like this:

X	Y			Distance
463	**522**			
463	**522**	463	-522	
463	**522**	463	-522	0.000
463	**523**	463	-522	0.000
463	**524**	463	-523	1.000
462	**526**	463	-524	1.000
461	**529**	462	-526	2.236
458	**535**	461	-529	3.162
454	**543**	458	-535	6.708
449	**552**	454	-543	8.944
		449	-552	10.296

With the above calculations I can easily produce acceleration plots that graph the moment-by-moment changes in writing speed. As you will see below, these plots show a much different pattern in genuine signatures versus simulations or tracings.

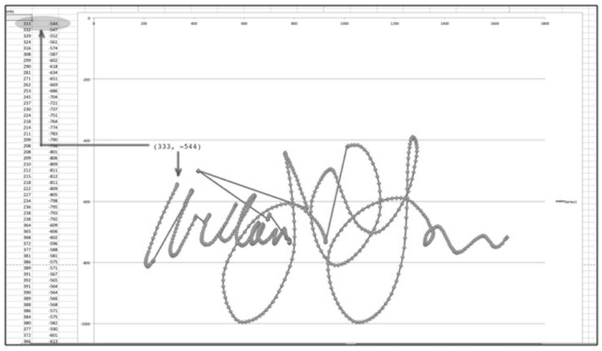
Using Excel to Analyze a Raw Signature Data

The five columns of data in the Excel spreadsheet pictured on the previous page represent all of the information needed to plot a representation of the written signature and make an acceleration/deceleration graph that shows changes in pen speed as the signature was being executed.

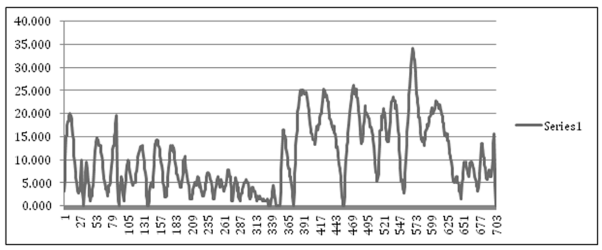
The two columns of data on the left have been imported directly into Excel from the *raw signature data* and represent the (x-y) signature pairs that were captured. In order for the signature to plot in Excel in the proper orientation it is necessary to change the sign of the y-data. The next two columns serve to copy the data in column "A" to column C with the formula **"=a4…etc."** starting in C4 and from column B to column D with the formula **"=b4*-1 …etc"** starting in D4. These two formulas are then dragged to the bottom of the x-y data pairs.

In order to determine how fast the hand was moving at any instant in time, it is necessary to calculate how far the stylus moved in any 1/100th of a second. To do these calculations, we need to look at how far the hand moved along the x-axis plus how far it moved along the y-axis in each 1/100th of a second interval. As an example, if we are starting on a street corner and walk 3 blocks west, turn, and walk 2 blocks south, and take one minute for the journey, we are walking at a rate of 5 blocks per minute. The hand, however, is not restricted to following the right-angle grid pattern but rather, moves directly from point to point. In our walking analogy, we would be following an avenue that cuts directly from our starting point to our ending point rather than making one right-angle turn. Pythagoras showed us long ago that the length of the diagonal of a right triangle is calculated using the formula—in Excel format this is typed as: **"SQRT(a^2 +b^2)"**

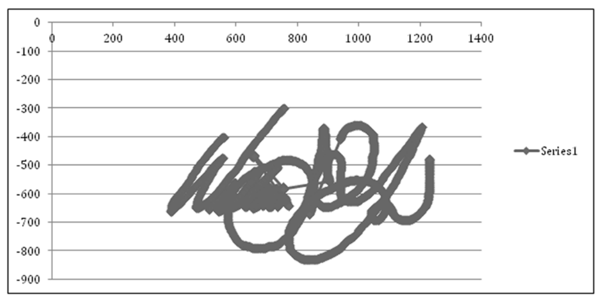
In the spreadsheet starting in E5 the formula **"=SQRT((b4-b5)^2+(c4-c5)^2)"** will provide the distance the hand moved from the first x-y pair of coordinates to the second x-y pair of coordinates. Because the result of the subtraction is squared, the actual distance traveled will always be a positive value. This formula is then dragged to the bottom of the data pairs just like the earlier formulas. One other step is needed before this data can be accurately converted to an acceleration graph—the six "air-movements" in the example signature have to be backed out of the values in column "E." There are two ways to find these six values: 1) determine how many data pairs are in each stroke (the bottom of the *raw signature data* will tell you that) and start counting down from the first data pair until you reach the first "air-movement" or 2) you can simply look for values that are orders of magnitude larger than the others in column "e." For instance, a typical value in the "E" distance-column might vary from 0 to 30 if it is a true "stylus-on-pad" movement. The air movements will often have values in the 200-300 range. Scrolling down the "E" column will reveal these 6 outliers pretty quickly. When the "air-movements" are located, write down their location and value and then manually change them to zero in the spreadsheet. The reason this is done is that the "air-movement" values are so high that if they are included in the plot, they overwhelm the true movements and skew the scale of the graph so much that it becomes hard to see the actual acceleration/deceleration changes.



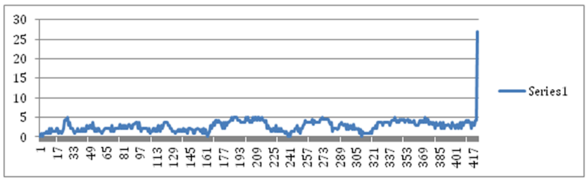
A Signature Plot of a naturally executed genuine signature



The acceleration/deceleration plot for the above "naturally-made" signature



The plot of a simulated signature



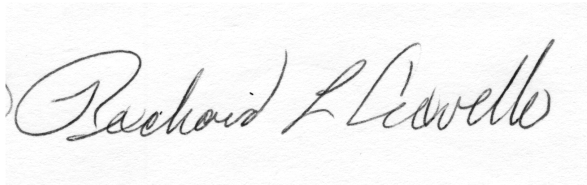
The Acceleration/Deceleration plot for the above simulated signature:

It is obvious from the acceleration plot of a simulated signature above that the hundred years of Questioned Document text books that have mentioned a "slow, drawing effect" as an indicator of forgery were absolutely correct. The difference for a forensic analyst performing an evaluation of an electronically-captured signature, however, is that this slow drawing effect does not have to be inferred from the appearance of the writing line—it can be quantitatively proven from the captured data.

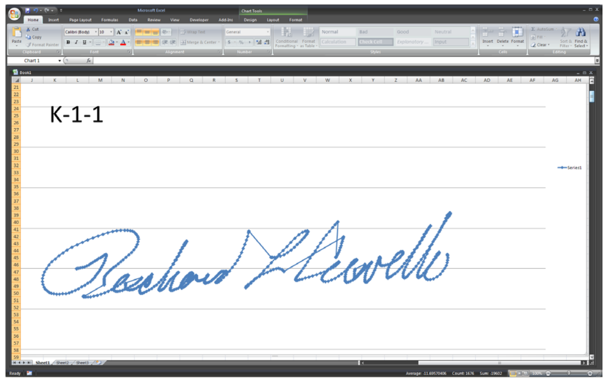
An acceleration plot of the naturally made signature above shows a variation in speed from 0 to 35 units. More accurately, the plot shows the distance the hand traveled every 1/100th of a second (or whatever the capture rate was for this particular tablet/software system). Obviously, the greater the distance traveled the faster the hand had to be moving. From the signatures I have evaluated in this study, a range of 0 to about 40 distance units is about average for a genuinely made signature. The simulations, however, show a much more narrow distance range. In the simulated signature example, the distance varies by only 0 to 5 units (except for the final stroke where the forger's hand "flew" off of the tablet). A look at the number of underlying data-pairs also shows that the simulation took about 3-times longer to execute than a genuine signature of this writer (7 seconds versus 22 seconds for the simulation).

Evaluating the Accuracy of the Signature Captures

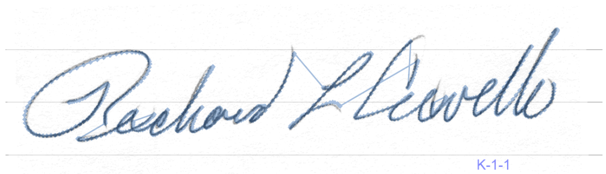
In order to test how accurately the digital versions of signatures (or, more precisely, the Excel plots of the captured signatures), mimic the corresponding ink-made signatures I asked 13 document examiners and trainees attending a SWAFDE meeting to provide exemplars of their signatures. All of the exemplars were captured on a Topaz tablet using Topaz SigPlus® software.[1] The electronic and ink signatures were captured simultaneously by laying a sheet of tablet paper over the capture pad and using a stylus that had a ballpoint pen in its tip (this is a stylus option offered by Topaz). In this way, normal ink-made signatures and their digital analogs were recorded together.



An ink-made signature, K-1-1, written on a Topaz tablet



The Excel plot of the same signature



An overlay of the ink and electronic signature

between the original ink versions and the Excel plotted versions was consistently as portrayed in the above example. In other words, there was a very high level of agreement between the ink and electronic versions of the signatures.

Discussion

Electronic signatures are now in general use for

[1]Because the forensic calculations used to determine the overall time expended by the writer to execute the signature as well as the individual stroke-timings will be depend on the capture rate — the number of pixels per second represented in the raw signature data must be obtained from the end user, or. by utilizing Topaz SigAnalyze™ software.

the purpose of conducting business transactions and entering into contracts. U.S. Courts have consistently held that they are as acceptable as ink signatures for these purposes[2]. The commercial use of electronic signatures ensures that they will, at some point, become questioned by one of the parties. The author has, in fact, had two such cases in the last year.

The purpose of this study was to determine how well the techniques, developed by the author, functioned to accurately reproduce and forensically analyze the signatures that were signed on an electronic signature tablet. The study has shown that almost no graphical data is lost when a tablet is capturing data at 1/100th of a second or greater. In addition, the acceleration and deceleration of the hand can be ascertained with an accuracy based on the frequency of the capturing tablet (typically between 1/100th and 1/400th of a second) rather than being inferred from observation of the strokes. Because the position of the hand is typically recorded at a minimum of every 1/100th of a second, pauses and hesitations (classically found in simulated forgeries) present themselves as multiple data points clustered at the same location. Because the clock associated with the tablet captures this information, it is possible to show not only that there was a pause, but also for exactly the amount of time it *lasted*.

Document examiners will also know how long it took to execute an entire signature, each of the signature segments within the signature, and the exact sequence of strokes (something that can be very difficult to unravel in a complex, cursive type signature).

Of equal importance in a forensic signature analysis, of course, is the ability to differentiate between a genuine and forged version of an electronically captured signature. This study has confirmed that attempts to simulate or trace a genuine signature on an electronic capture device result in Excel plots showing the same indications of tremor, patching and hesitations as have been used for more than 100 years to ascertain the genuineness of a signature.

Because the data pairs are captured sequentially, very subtle differences in signatures that would normally be difficult or impossible to determine—like the sequence in which "i-dots" are made or the direction "t's" are crossed—can be absolutely established. Because the amount of time used to execute the strokes is captured, a questioned signature that is relatively complex, has good agreement with the knowns, and was made as a series of rapid strokes (rather than slowly drawn movements) would certainly be, at least indicative of, genuineness.

Conclusions

Because the printed-on-paper versions of digitally captured signatures may be prepared at a much lower resolution than that contained in the raw signature data, it is absolutely necessary for the forensic document examiner to be working from this data. Since the timing information is equally important in arriving at valid conclusions as to authorship, it should be part of your standard procedures to find out what time interval has taken place between each of the recorded x-y pairs To put it another way, how many pixel locations are being recorded as data every second.

It appears that the tools and techniques developed over the years by forensic document examiners to authenticate handwriting can be put to use in the examination of electronically captured signatures as well. The new toolbox, however, will also have to contain examination protocols for importing and plotting signature data files. This study has validated my method of transforming Topaz Systems raw signature data into signature representations that provide both the observable features needed for a traditional signature examination as well as hard data on the signature dynamics and sequence of strokes.

[2]See "Notes" at the end of this paper for important legal decisions affecting electronic signatures.

Notes and Resources

1. In the U.S. electronic signatures are covered under the Uniform Electronic Transactions Act (UETA – 1999) http://esignrecords.files.wordpress.com/ 2009/ 03/ueta.pdf

2. See also: Electronic Signatures in Global and National Commerce (ESIGN) law (2000)http://www.rkmc.com Electronic_ Signatures_in_Global_and_National_ Commerce_Act_ESIGN_FAQs_and_ Resource_Links.htm

3. Anderson vs. Bell, Utah, June 22, 2010. Wherein a candidate running for political office used nominating petition signatures that were captured on an electronic signature pad. The court ruled that the validity of the signatures could not be challenged solely on the basis that they were obtained electronically. ***"An electronic signature is sufficient to satisfy the Election Code."***

4. http://esignrecords.org/category legal-matters/

5. Electronic signatures are currently being used in a multitude of commercial applications. Some of these include[3]:

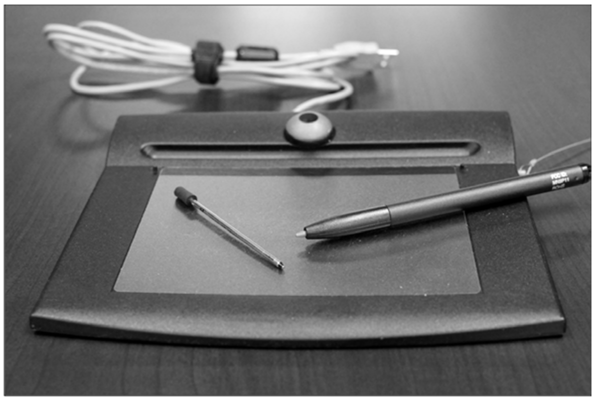
   a. Insurance and Worksite Marketing
   b. Government Agencies
   c. Loan, Escrow, and Leasing Services
   d. Banks and Credit Union Signature Cards
   e. Medical Facilities
   f. Pharmacies
   g. Application Service Providers
   h. Pharmaceutical Companies
   i. Human Resource Applications

6. On November 3, 2011 Federal Judge Tom S. Lee of the United States District Court, Southern District of Mississippi, Jackson Division ruled that the forensic examination of electronically captured signatures had met the Daubert requirements and refused to grant a defense motion to exclude or limit my testimony. The case citation is: ***American Family Life Assurance Company of Columbus vs. Glenda Biles, et al.***

7. In order to accurately determine the speed, acceleration, deceleration, and stroke timings of a captured signature it is necessary to find out what time interval is represented in the sequential data pairs. Topaz certifies the conversion rate and sampling interval of their hardware devices. In actual casework, however, it is likely that an examiner will have to obtain both the certified hardware information from Topaz and determine if the company using the tablets has made any custom software adjustments. Topaz may be able to assist a forensic examiner on both fronts.

8. Claims 11 and 14 in US Patent #6,307,955 describe how Topaz Systems manages the accuracy of the timings related to their hardware and provides software tools to cross check these timings to a computer system clock running the capture software. Use of a certification stamp to ensure timing accuracy is also described.

9. A list of patents in the Topaz eSign patent portfolio can be found at http://www.topazsystems.com/Information/legal.htm#patents



A Topaz Model T-S751-HSB Signature Capture Tablet.

This is the type of tablet that is in widespread use as a capture device in many industries and the model that was used in the research conducted for this paper. The normal plastic stylus (non-writing) point is shown on the right. The ballpoint pen insert, with the yellow band, is shown to the left. Topaz also provides Tablets

[3]Source, Topaz Systems, Inc., 650 Cochran St., Suite 6, Simi Valley, CA 93065

that include interactive LCD display devices which utilize electronic inking.

The screen capture below is from Topaz's SigAnalyze™ program, version 1.11. Topaz has advised me that they are currently working on enhancing this software to provide additional display and analysis options for document examiners.