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TECHNICAL NOTE

Questioned Documents

Digitally Captured Signature solution errors revealed by calibration and testing: Two examples

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Abstract

Digitally Captured Signature (DCS) solutions consist of a hardware and a software component. Even though technical characteristics are almost always provided by the manufacturer, the implementation of a given solution may include errors and should be subject to examination. Furthermore, the non-intuitive relation between the exercised force (in Newtons) and the assigned values (arbitrary Pressure Levels) for the Force Channel data, as found in the standard collection of biometric data X for the X axis position, Y for the Y axis position, F for the pressure sensor values, and T for time, makes DCS solutions more difficult for companies to provide any such test or information, making the calibration of the Force Channel data a necessary step. In this paper, we present two real case deployments that proved to be problematic after thorough examination, one on the software component and the other on the hardware component. These problems were communicated to the providers of the specific DCS solutions and were corrected.

KEYWORDS
Digitally Captured Signature, digitizer, document analysis, force calibration, forensic science, zeta function

Highlights

- Data accuracy is fundamental in the examination of the authenticity of Digitally Captured Signatures.
- Calibration of force data of two deployed DCS systems found serious errors in accuracy and fidelity.
- Evaluation and calibration of DCS should be standard practice for DCS data interpretation.

1 | INTRODUCTION

Digitally Captured Signature (DCS) solutions have already been accepted globally as a valid alternative to pen and paper signatures, being adopted and deployed by the banking industry. The selection process for a commercially deployed solution rarely reflects the forensic concerns, aside from the "standard" solution characteristics which usually consist of resolution for X and Y axis parameters, frequency of event recording, and pressure levels captured, even though it is known that unnormalized force data values in the form of arbitrary pressure levels can be problematic in a forensic examination scenario [1].

DCS solutions are not only dependent on the nature of the hardware used (the digitizer and the stylus [1]) but also on the software that controls the procedure, with instances where the same hardware can provide different raw data based on the capturing software [2]. It is therefore necessary to thoroughly test a given commercial deployment forensically to confirm that the signature data is accurately recorded.

In this paper, we discuss the examination and evaluation of two commercially deployed solutions that had errors in their original form, which were discovered during their calibration by the authors, and which were then corrected by their providers. The first case refers to a hardware issue that was discovered during the calibration of the Force Channel data. The second case refers to a software issue that caused corrupted data capturing even though the hardware component was functioning according to specifications. For legal reasons, the hardware of the first case will be anonymized and referred to as Digitizer 1, with the testing software referred to as Software 1, and the software of the second case will be anonymized and referred to as Software 2.

2 | CASE 1: HARDWARE ERROR

2.1 | Method

In this deployment case, the authors were asked to investigate the suitability of Hardware 1 run with Software 1. Hardware 1 was an Electromagnetic Resonance (EMR) DCS solution. Part of the investigation involved the examination of the Force Channel data capturing capabilities and the calibration and normalization of this solution, according to the available method [1].

2.2 | Results

During calibration of the F Channel data, an error was detected; specifically when Force reached a specific value, a "anomaly" would appear in the assigned Pressure Level values (see Figure 1).

As can be seen in detail in Figure 2 and in the raw data in Table 1, there is a point in the ascending load calibration (Force = 0.821 N) and a different point in the descending load calibration (Force = 0.758 N) where a "anomaly" is observed. In the ascending load part, the assigned Pressure Level values fall from 790 for 0.798 N to 643 for 0.821 (when they should be only increasing), and for the descending load part, the assigned Pressure Level values jump from 640 for 0.774 N to 790 for 0.758 (when they should only be decreasing).

This is a serious problem because the same Pressure Level values are assigned to two different exercised force values, as observed in Figure 2 (e.g., for Pressure Level 700, there are two different Force values).

This error also affects the calculation of a Zeta Function for Hardware 1. DCS solutions provide the Force Channel data in arbitrary Pressure Levels; in order for those Pressure Levels to be comparable between different DCS solutions, it is necessary to calibrate the devices and calculate the Zeta Function, that is, the Function that calculates the assigned Pressure Levels from the exercised force, as described in the relevant literature [1]. From the Zeta Function, the inverse Zeta Function can then be calculated, which can provide the originally exercised force from the assigned Pressure Levels, thus normalizing the Force Channel data into Newtons. In this case, the assignment of the same Pressure Levels to more than one Force value renders the Zeta Function for Hardware 1 a non one-to-one function, which subsequently means that there can be no inverse Zeta Function calculated. Consequently, the assigned Pressure Levels cannot accurately be normalized into Force values in Newtons.

The authors communicated these findings to the manufacturer of the hardware, and after a series of tests with the authors, the firmware of the digitizer was identified as the source of the error, and it was updated to accommodate for this error (see Figure 3).

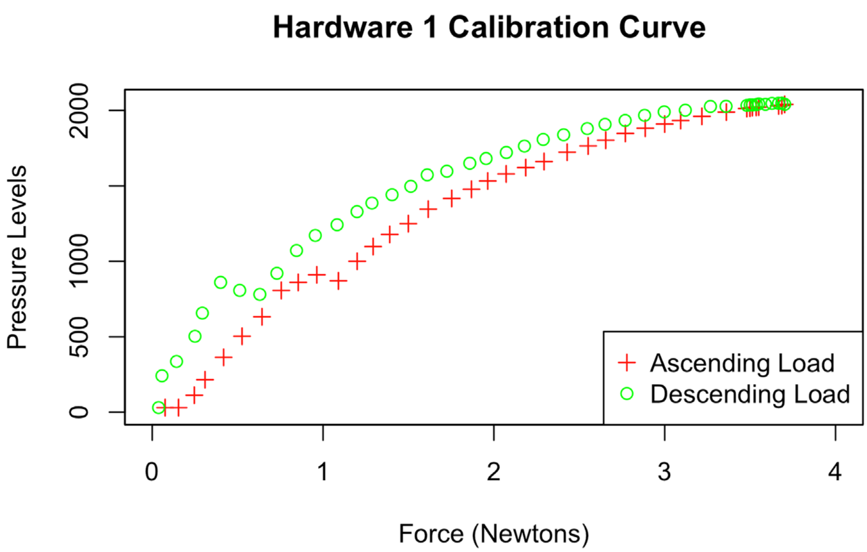

FIGURE 1 Hardware 1 calibration curve. It can be observed that both the ascending and descending load curves exhibit areas of abnormality (around the values of 1 N for the ascending and 0.7 N for the descending load), respectively.

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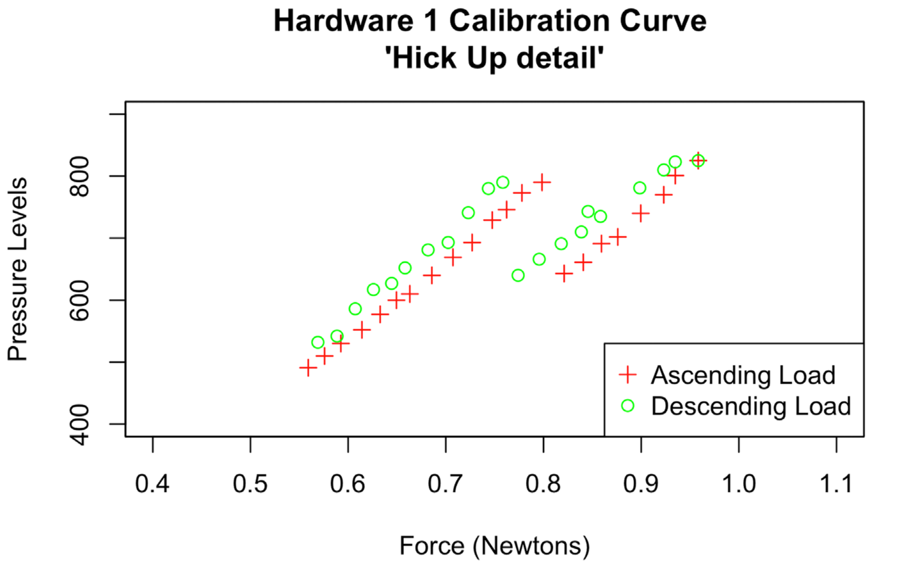


FIGURE 2 Detail of the “anomaly” section for both ascending and descending loads. These should be continuous lines following a pseudo-logarithmic rule.

TABLE 1 Portion of the force and assigned pressure level data that includes the “anomaly” error, both for the ascending and descending load.

Ascending force (N)	Assigned pressure levels	Descending force (N)	Assigned pressure levels
0.55917	491	0.958437	825
0.575847	510	0.934893	823
0.592524	530	0.923121	810
0.614106	552	0.898596	781
0.632745	577	0.845622	743
0.649422	600	0.858375	735
0.663156	610	0.838755	710
0.685719	640	0.818154	691
0.707301	669	0.795591	666
0.726921	693	0.774009	640
0.747522	729	0.758313	790
0.762237	746	0.743598	780
0.777933	773	0.722997	741
0.798534	790	0.702396	693
0.821097	643	0.681795	681
0.840717	661	0.658251	652
0.859356	691	0.644517	627
0.876033	702	0.625878	617
0.899577	740	0.607239	586
0.923121	770	0.5886	542
0.934893	801	0.56898	532

Note: The position where the error occurs is highlighted in red.

3 | CASE 2: SOFTWARE ERROR

3.1 | Method

In this deployment case, the suitability of a Samsung SM-P610 Galaxy S6 Lite (and the corresponding S pen stylus) was investigated for the purposes of capturing and recording biometric data within a banking environment (Figures 4 and 5). The (already deployed) software is identified as “Software 2” and was an Android application installed on the device. Furthermore, two additional applications were installed in the device for calibration and testing purposes, namely Namirial's GraphoSign App and IdeaStorm Labs' Stylusis App.

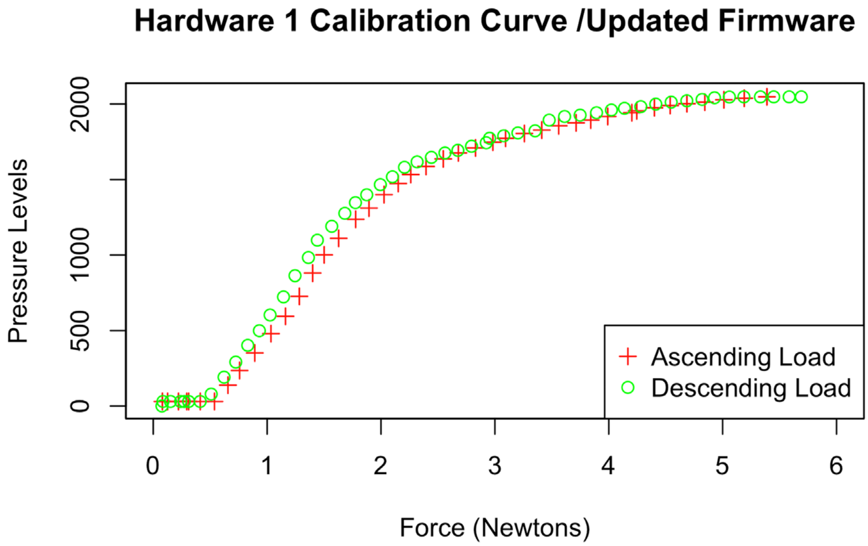


FIGURE 3 Calibration curve of Case 1 DCS solution, after the firmware update. No abnormalities can be observed.

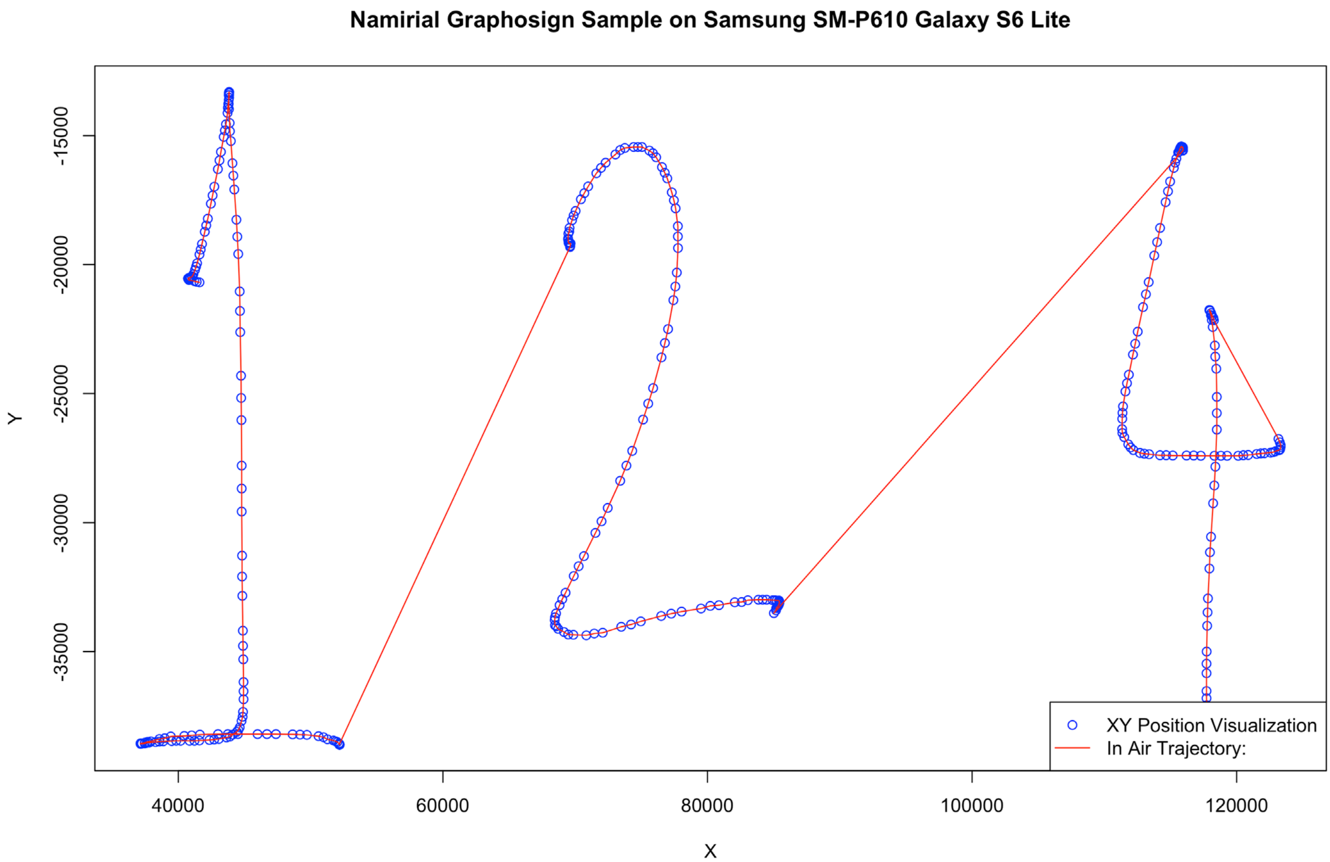


FIGURE 4 Presentation of test capturing on Samsung SM-P610 Galaxy S6 Lite through Software 2, and its stylus. The in-air movement of the stylus between the written numbers 1, 2, and 4 is not captured/visualized.

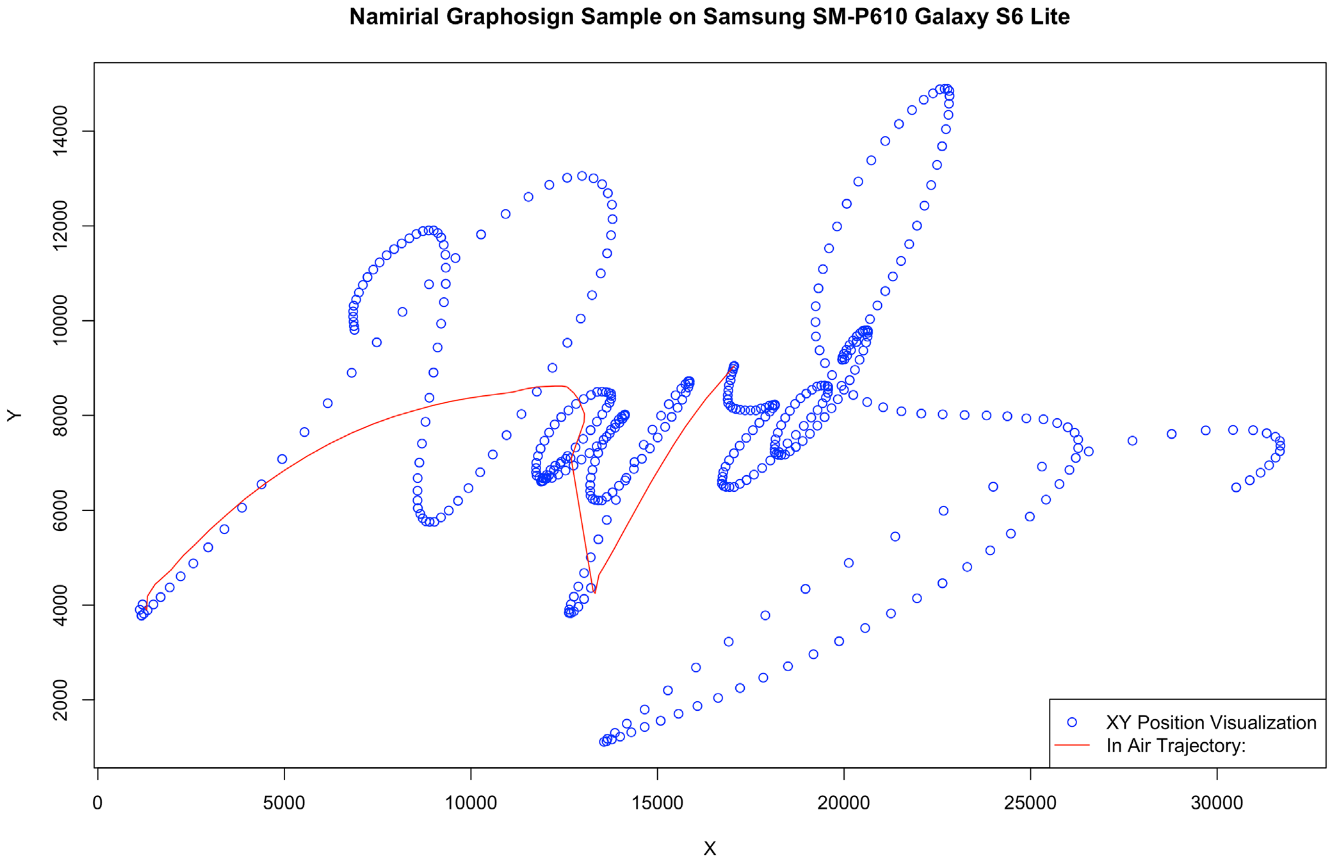


FIGURE 5 Presentation of test capturing on Samsung SM-P610 Galaxy S6 Lite through the Namirial Graphosign App, with its stylus. The capturing of the IAT of the stylus is presented in red color.

TABLE 2 List of compatible styli.

Device identifier	Device type
SP1	Samsung Galaxy Tab S6 Lite S Pen EJ-PP610BJEGU
UP4	Wacom UP61089A1 pen
UP5	Wacom UP6710 pen
LM1	LAMY AL-star black EMR pen Digital Writing
LTW1	LAMY safari twin pen all black EMR Digital Writing

3.2 | Results

During the initial testing and evaluation of the solution, two errors were detected. The Samsung SM-P610 Galaxy S6 Lite uses Wacom technology [3] for the stylus applications, and therefore other Wacom component styli are compatible. The compatible styli used for testing are mentioned in Table 2.

3.3 | Error 1: No capturing of in air trajectories

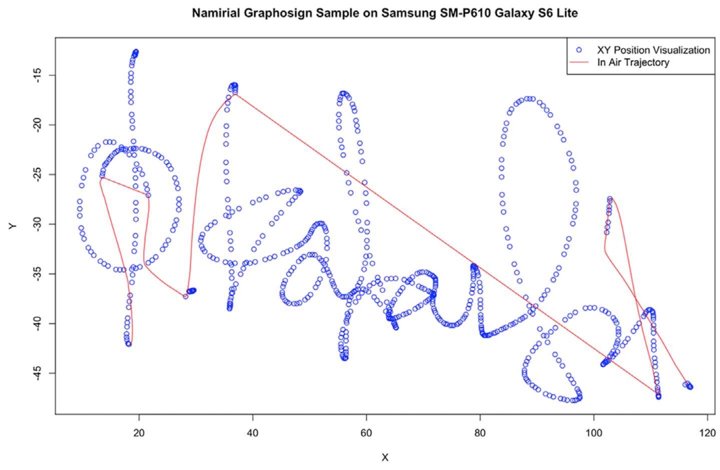
Testing and measurements that were conducted with Software 2 showed that the movement of the stylus on air (i.e., without the tip of the stylus being in contact with the glass surface of the digitizer), a.k.a. In Air Trajectories (IATs) was not captured, even though the digitizer technology of the hardware is EMR and supports it (Table 3). Further testing of the same device with the application Namirial GraphoSign App proved that the device and its stylus were able to capture IATs; therefore, it was deduced that the source of the problem was the software.

TABLE 3 Presentation and highlighting of the event of loss of events.

Sample point	Time (s)	X (mm)
137	0.761	42,310
138	0.765	42,240
139	0.774	42,080
140	0.782	42,000
141	5.772	55,760
142	5.776	55,740

Note: The biometric data shows a gap of almost 5 s between events 140 and 141 (due to the IAT of the stylus that was not captured).

As mentioned in the relevant international literature [4, 5], examination of the IATs is an important part of the process for the determination of the authenticity of a DCS, and capturing IATs constitutes one of the main advantages of EMR technology; therefore,



T	F
1.368	0
1.377	0
1.381	0
1.385	0
1.393	0
1.397	0
1.397	84.62
1.402	84.96
1.41	87.16
1.414	88.23

Presentation and visualization of a test DCS captured with Samsung SM-P610 Galaxy S6 Lite with Software 2 after the version update, with its stylus. The IAT of the stylus can be observed in red color.

Presentation of a segment of the captured biometric data of the same DCS (here data from T and F channels). Normal capturing of events 240-256 can be observed; these events correspond to an IAT of the stylus and can be seen to have 0 as a P% value.

FIGURE 6 Presentation of a DCS captured with Case 2 solution after the update. Both the XY plot and the (part of the) raw data show the recording of the pen position (XY) when in air (P = 0).

IATs should be captured (Figure 6). These findings were communicated to the software manufacturer and the error was corrected in a subsequent version update of Software 2.

3.4 | Error 2: Observation of discontinuity

During testing, discontinuity of the capturing of events with Software 2 was observed when the stylus remained static or slowed down. This situation is reflected not only in the captured data, exhibiting large segments of loss, but also in the visual feedback provided by the applications (see Figure 6).

Figure 7 depicts the visualization of a straight line executed in one stroke, that is, without lifting the tip of the stylus from the glass surface of the digitizer, as captured with Software 2 on Samsung SM-P610 Galaxy S6 Lite with its stylus. It can be observed that the segments appear as if without contact with the tip of the stylus. This artifact constitutes a big problem as the motion of the stylus during the execution of the signature movement is not faithfully captured

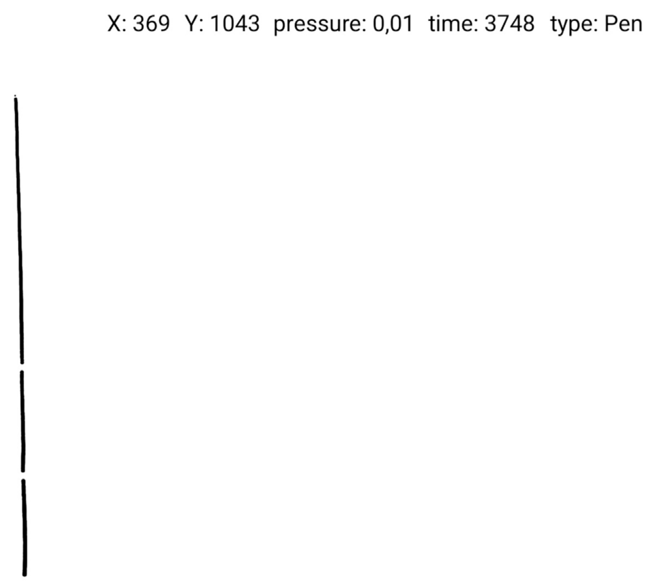


FIGURE 7 Visualization of a continuous line (in one stroke) that was captured and represented with breaks due to slow speed of execution, captured with Software 2.

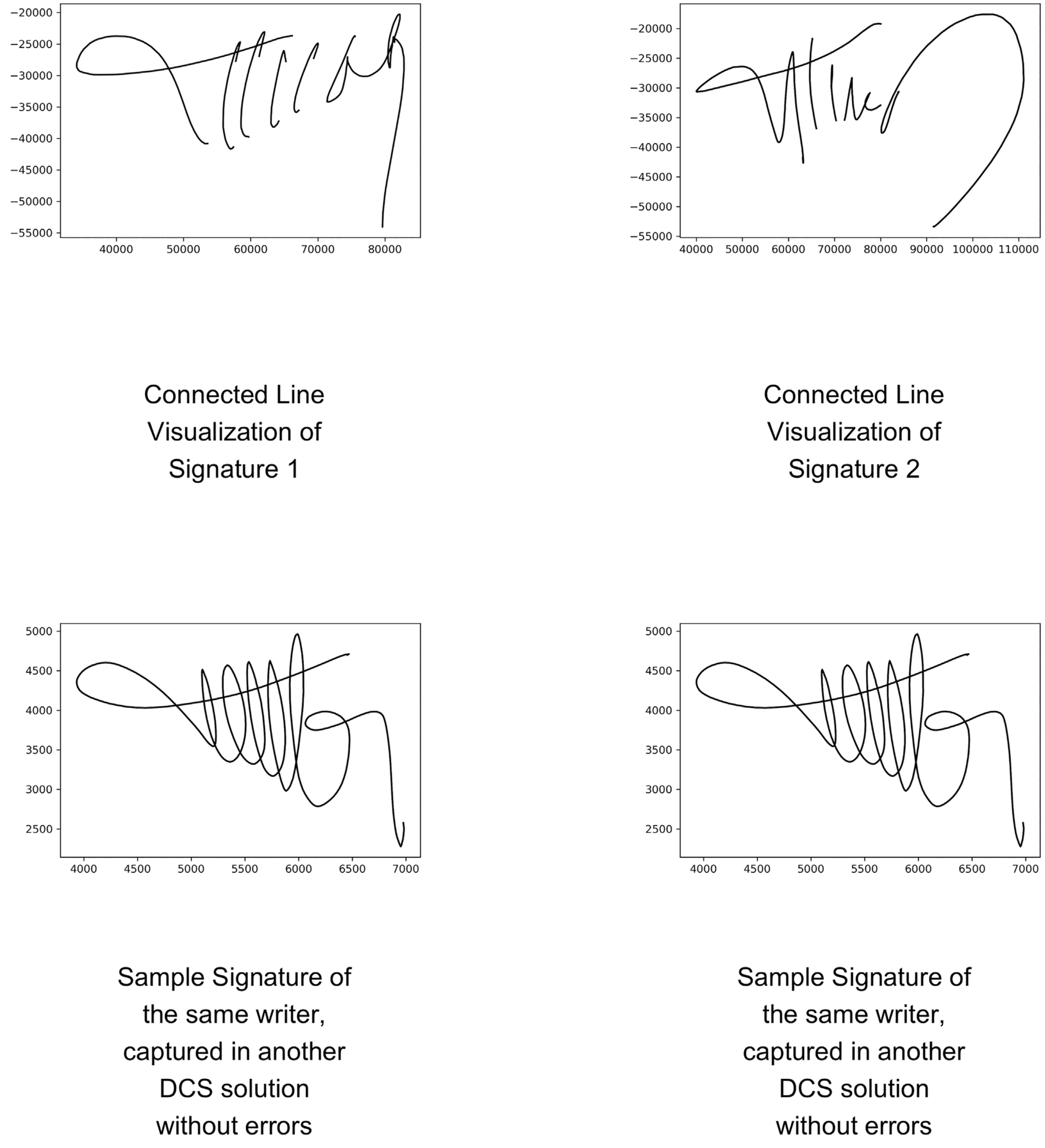


FIGURE 8 Examples of the error 2 of case 2 deployment. On the top row, two sample signatures captured with the problematic software are visualized in XY plots; on the bottom row, two sample signatures of the same writer captured with another DCS solution that has no errors. Discontinuity in the execution of the top row signatures can be observed in comparison with the bottom row continuous (one stroke) samples.

and represented in the data and cannot be accurately reconstructed from it.

The same phenomenon was observed during testing with volunteer writers executing their normal signature formation (see Figure 8).

As observed in Figure 8, two signatures of the same writer exhibit the discontinuity and appear as if executed in 5 and 6 strokes, respectively. This behavior is differentiated from the normal behavior of the writer who executes their normal signature in one stroke only, as can be observed from samples

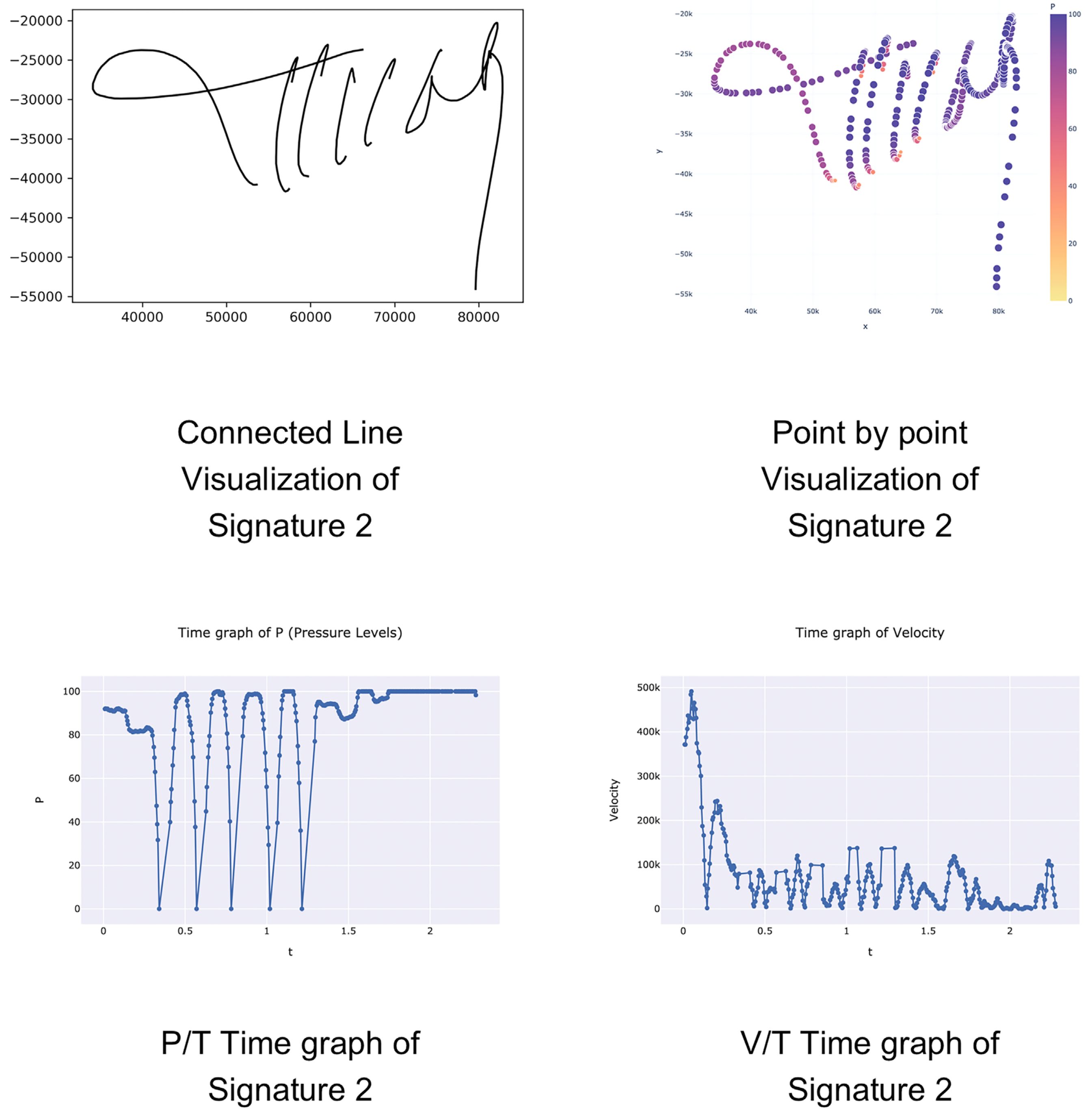


FIGURE 9 Visualization of the first sample signature with the problematic software. The missing data can be observed in the various representations.

captured with other solutions. The signature of the specific writer is executed in one stroke on paper as well, and therefore, these "breaks" in the continuity of the stroke are artifacts for the tested solution.

As can be observed on Figures 9 and 10, this solution not only does not record events whilst the stylus is slowing down, but also introduces zero Force artifacts in the data, creating the illusion of change of stroke number—which explains the large temporal gaps in the data. Apparently, Software 2 considers the stylus to have been removed from the active area and stops recording its positions.

Observation of these characteristics and the corresponding visualizations of the reference samples of the same writer prove that these findings cannot be attributed to the writer but are due to the software.

Repeated testing with Software 2 not only with a Samsung SM-P610 Galaxy S6 Lite stylus (S pen) but also with other Wacom Styli

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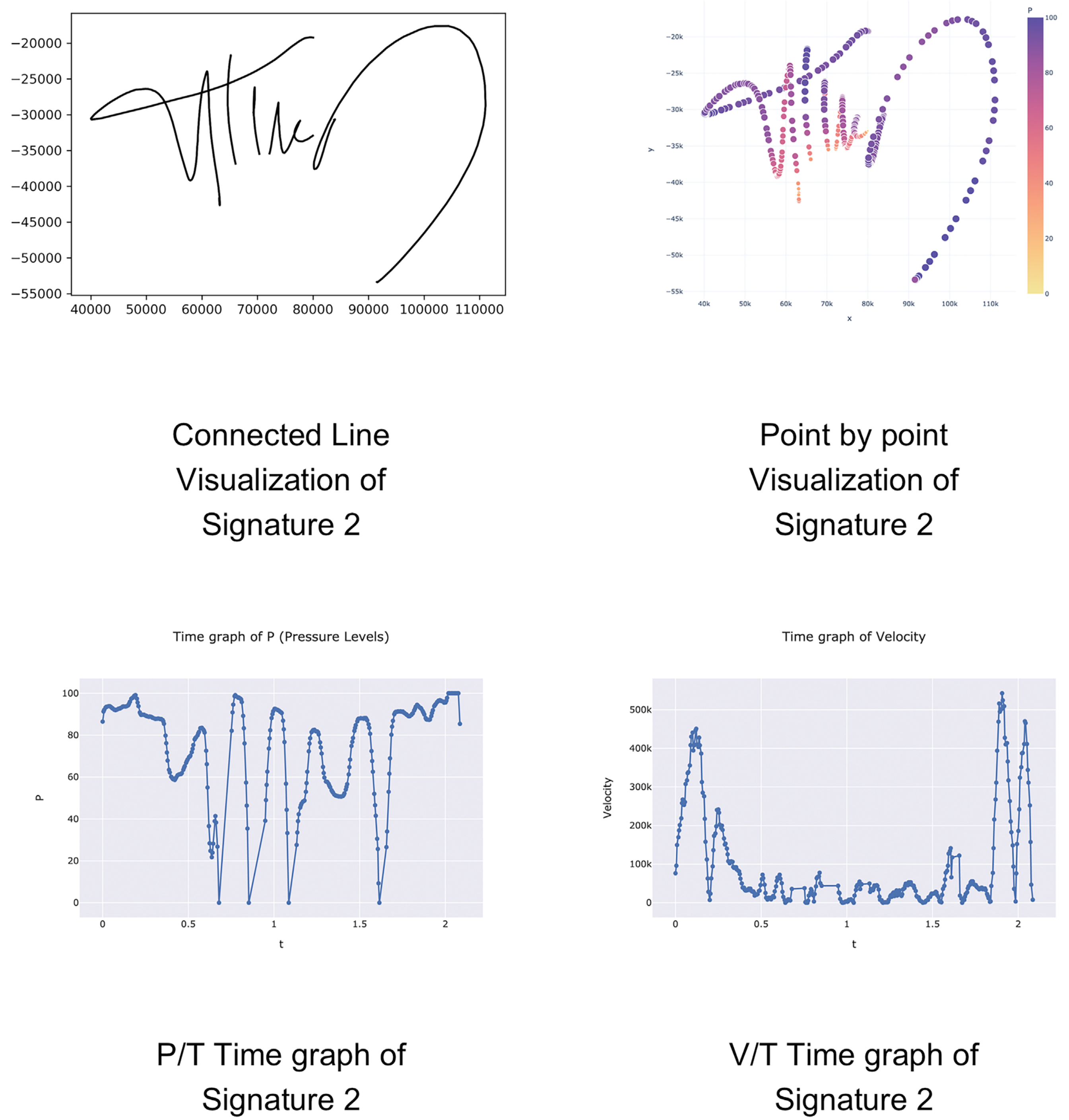

FIGURE 10 Visualization of the second sample signature with the problematic software. The missing data can be observed in the various representations.

(UP4, UP6, LM1, and LTW1) exhibited the same behavior, proving that the stylus was not the source of the error.

To determine the source of the problem, testing was carried out with software from a different manufacturer, and specifically App Graphosign, and this error was not observed. This finding pinpoints the source of the error to Software 2. This defect was also communicated to the software manufacturer and was corrected with the subsequent version of the app (see Figures 11 and 12).

3.5 | Error 3: Loss of events on T channel

The T channel shows a variable frequency of capturing events with a minimum value of 3 ms and a maximum value of 13 ms. This type of variable frequency is typical for standalone digitizers, as the clock used is that of the processor of the tablet (e.g., iPad Pro [1]). As a result of the errors mentioned previously, incidents of large gaps in time capturing were observed, with events captured

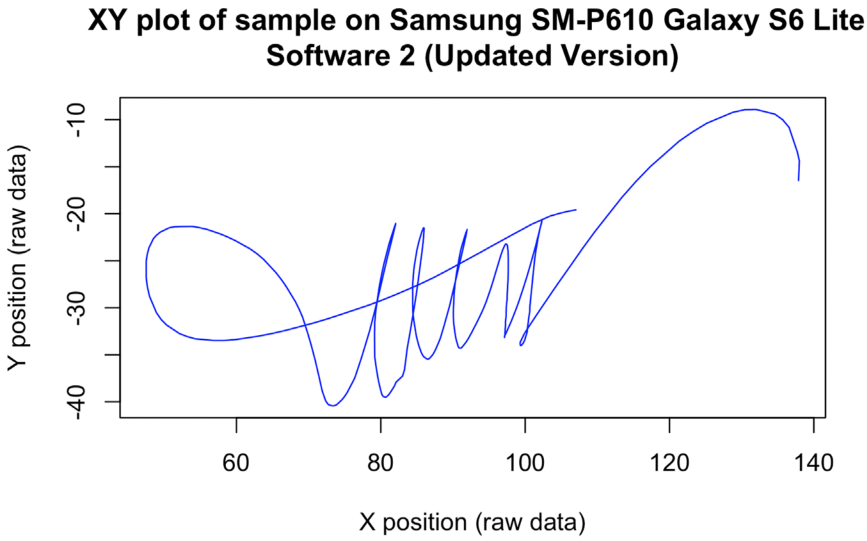

FIGURE 11 Signature captured with the updated version of Software 2—no discontinuity observed.

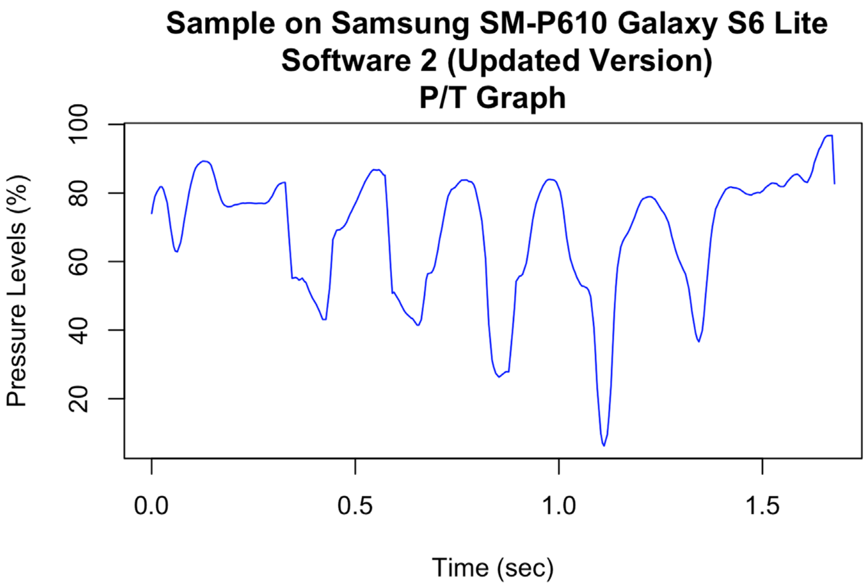

FIGURE 12 P/T Time Graph of signature from Figure 11—no discontinuity observed.

as far as 40 ms apart. This finding is not observed with the updated version of Software 2 that corrected the previously mentioned errors.

4 | DISCUSSION

The accuracy of the captured data in all data channels (X, Y, F, and T) is clearly a very important aspect in the forensic examination of the authenticity of DCS. As it is shown, the evaluation of the suitability of two already deployed DCS solutions and the calibration of the Force data channel led to the discovery of serious errors in the accuracy and fidelity of the captured data.

In the case of Hardware 1, the calibration revealed a serious error in the assignment of Pressure Levels that allowed the same value to be assigned for two different Force values, and hence not allowing a faithful visualization of the exercise Force, nor the calculation of the inverse Zeta Function (which would be required for the normalization of Pressure Level values to Newtons).

In the case of the Samsung SM-P610 Galaxy S6 Lite with Software 2, several errors were uncovered that may impact the validity of expert opinions on the authenticity of DCS.

It is already mentioned that not recording IATs hinders the application of the established scientific methodology for the determination of authenticity of biometric signature [4, 5]. Furthermore, the discontinuity error by default shows inadequate capturing of the handwriting motion and subsequent erroneous visualizations of the signing product.

In both examples, the evaluation and calibration of the deployed solution by forensic scientists was necessary to reveal

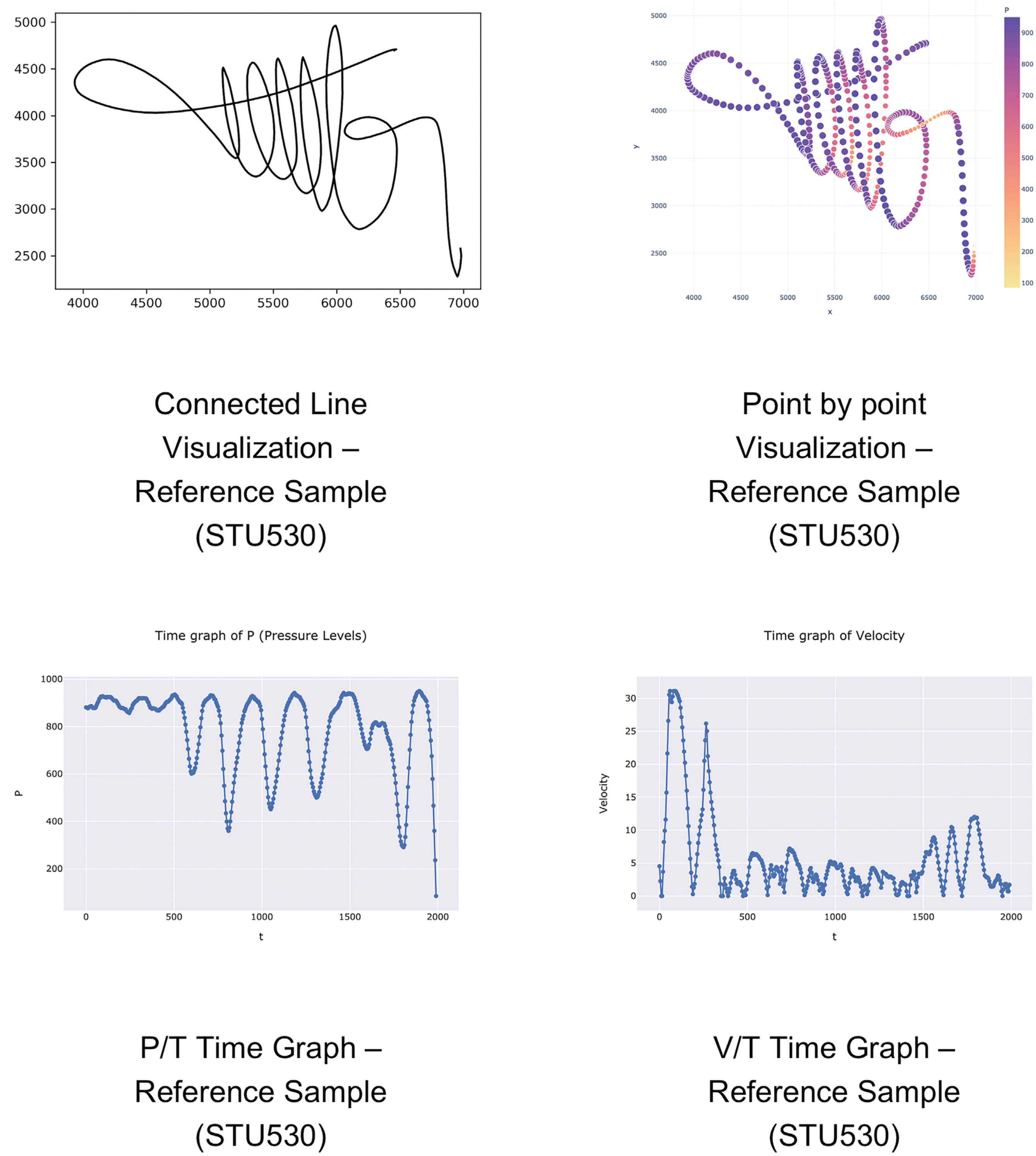

FIGURE 13 Visualization of one of the sample signatures of the same writer, with a properly functioning DCS solution.

aspects of its validity (or lack of). It is clear that this should be considered a standard practice in the deployment of DCS solutions (Figure 13), but more importantly, it should be clear that the investigation of the accuracy of a given deployed solution is necessary for the accurate interpretation of the captured DCS data from the forensic examiner. In the case of the Samsung SM-P610 Galaxy S6 Lite, the hardware itself was not malfunctioning, but Software 2 was; meaning that the inclusion of a trusted and tested hardware in a given DCS solution does not necessarily mean that the solution in its entirety is trusted (if it is not properly tested).

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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