# E-BIOSIGN: STYLUS- AND FINGER-INPUT MULTI-DEVICE DATABASE FOR DYNAMIC SIGNATURE RECOGNITION

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## ABSTRACT

This paper describes the design, acquisition process and a baseline evaluation of e-BioSign, a new database of dynamic signature and handwriting. e-BioSign is comprised of 5 devices in total, three Wacom devices (DTU-500, DTU-530 and STU 1031) specifically designed to capture dynamic signatures and handwriting, and two Samsung general purpose tablets (Samsung Galaxy Note 10.1 and Samsung ATIV). For these two Samsung tablets data is collected using a pen stylus but also the finger to study the performance of signature verification in a mobile scenario. Data was collected in two sessions for 70 subjects, and includes dynamic information of the signature, the full name and number sequences. For signature and the full name skilled forgeries were also performed. A signature baseline evaluation is carried out for a predefined recognition system based on DTW, achieving a benchmark performance for each of the devices. The use of finger for signing achieves good results for the case of random forgeries (less than 1% EER), but the performance is degraded significantly for the case of skilled forgeries compared to the case using the pen stylus.

***Index Terms*—** Biometrics, dynamic signature, DTW, mobile devices

## 1. INTRODUCTION

The rapid rise of new devices such as smartphones or tablets, which make possible an interaction human-machine in a natural way through handwriting and gestures, is boosting the application of recognition schemes based on dynamic handwritten signature. Nowadays digital signature devices are spreading in the commercial sector to facilitate payments, also in banking to facilitate the digital storage of all the signed paperwork, and in many other sectors such as e-government, healthcare or education.

Traditionally dynamic signature recognition has been performed with a device specifically designed for that purpose using a specific pen stylus. However, there are many open questions regarding the application of signature recognition using devices such as smartphones with small touch displays and only able to acquire the signature using the finger. We consider this the "universal" case as no specific device is needed and everyone can have access to it.

In this sense, this paper describes the design, collection and baseline evaluation of a new database called e-BioSign for signature and handwriting recognition. The database is comprised of 70 users and data is collected in two sessions. The database is designed to collect data from five devices, three of them specifically developed for signature and handwriting applications (Wacom devices) and two general purpose tablets (Samsung tablets) that can collect data using a pen stylus but also the finger. These are some of the most common devices used in commercial, banking, and e-health applications nowadays, so research in the areas of inter-device and inter-tool (pen stylus and finger) recognition can be carried out. A baseline signature verification evaluation is carried out in order to obtain a benchmark performance for each device and writing tool using a reference system based on dynamic time warping (DTW). Also, this database will be made publicly available for research purposes.

There are a few available databases for dynamic signature verification research, being the most popular: MCYT [1] (2003), SVC [2] (2004), MyIDEA [3] (2005), Biosecure [4] (2007) or BiosecureID [5] (2007). These databases were collected with devices not in use nowadays in most cases and of course not considering mobile devices and signing with the finger. There is a recent work in this area [6] using new devices such as smatphones using both a pen stylus and the finger, but the database used is not publicly available for research. Also, no skilled forgeries were acquired in that work, while the present work also includes the case of skilled forgeries which is critical in this application.

The remainder of the paper is organized as follows. Section 2 describes the new database e-BioSign presented in this paper. Section 3 describes the pre-processing and feature extraction process. Section 4 reports the baseline evaluation carried out with e-BioSign database and finally, Section 5 draws the final conclusions and points out some lines for fu-


**Fig. 1**. Acquisition setup for e-BioSign database.

ture work.

## 2. E-BIOSIGN DATABASE DESCRIPTION

e-BioSign database is comprised of five capturing devices of dynamic signatures, three of them are specifically designed for capturing handwritten data (Wacom devices), while other two are general purpose tablets not designed for that specific task (Samsung tablets). Figure 1 shows an image of the setup used to capture the database, with all five capturing devices.

It is worth noting that the five devices were used with their own pen stylus, but in addition the two Samsung devices were also used with the finger. This will allow the study of the effect in recognition performance of the use of the same devices with a pen stylus and the finger. The same capturing protocol was used for all five devices, they were placed on a table and subjects were told to feel comfortable when writing on them, so small rotation of the devices were allowed.

The software for capturing the signatures and names was developed in the same way for all the devices in order to minimize the variability of the user during the capturing process. All devices had a rectangular area with an horizontal line in the bottom part, with two buttons “OK” and “Cancel” to press after writing if the sample was good or bad respectively. If the sample was not good, then it was repeated (See Fig. 1). A brief description of the devices used in e-BioSign is given next:

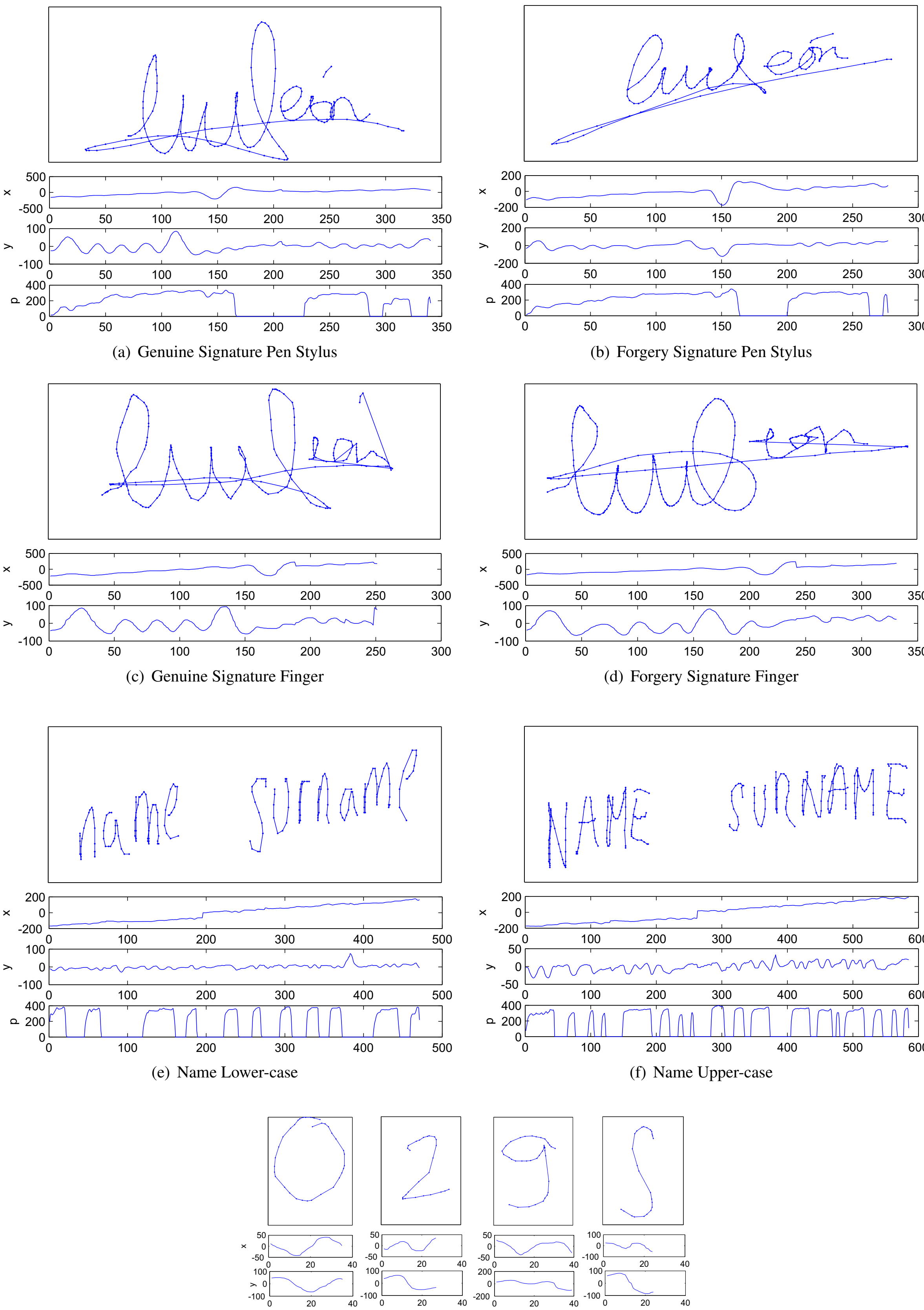
1. **WACOM STU-500**: 5-inch TFT-LCD B/W display, with VGA resolution of $640 \times 480$ pixels. It has a sampling rate of 200 Hz, and 512 pressure levels. This device gives a very natural feel of writing.

2. **WACOM STU-530**: Newer version of the previous. 5-inch TFT-LCD color display, with VGA resolution of $640 \times 480$ pixels. It has a sampling rate of 200 Hz, and 1024 pressure levels. This device allows safe transactions as it has an AES 256 bit / RSA 2048 bit data encryption embedded in the signature pads.

3. **WACOM DTU-1031**: This device has a larger 10.1-inch color LCD display, with a resolution of $1280 \times 800$ pixels. It has a sampling rate of 200 Hz, and 512 pressure levels. It also provides the same data encryption as the STU-530. It allows to visualize documents on the display before signing them.

4. **SAMSUNG ATIV 7**: This is a device with Windows 8 operative system (OS). It has a 11.6-inch LED display with a resolution of $1920 \times 1080$ pixels. It has 1024 pressure levels and regarding the sampling rate is not uniform as in the Wacom devices as it depends on the system time in this case. This tablet allows to use its own stylus or also the finger, but no pressure information is recorded in this last case.

5. **SAMSUNG GALAXY NOTE 10.1**: This is a device with Android OS. It has a 10.1-inch LCD display with a resolution of $1280 \times 800$ pixels. It has 1024 pressure levels and not uniform sampling rate. This device also allows to use its own stylus or the finger.



(a) Genuine Signature Pen Stylus

(b) Forgery Signature Pen Stylus

(c) Genuine Signature Finger

(d) Forgery Signature Finger

(e) Name Lower-case

(f) Name Upper-case

(g) Number Sequence

**Fig. 2**. Example of the data collected in e-BioSign database for Samsung Galaxy Note 10.1.

| | Block | Stylus | Finger |
|---|---|---|---|
| **Signature** | Gen. 1 | 2 (x5) | 2 (x2) |
| | Gen. 2 | 2 (x5) | 2 (x2) |
| | Forg. | 3 (x5) | 3 (x2) |
| **Full Name** | Gen. 1 | 1 (x5) | |
| | Forg. | 3 (only STU-530) | |
| **Full Name Capital Let.** | Gen. 2 | 1 (x5) | |
| | Forg. | 3 (only STU-530) | |
| **Number Sequence** | Gen. 1 | | 2 (x2) |
| | Gen. 2 | | 2 (x2) |

**Table 1**. Handwritten samples captured in e-BioSign Database per user in each of the two sessions.

Table 1 shows the number of samples captured for each user per session. As mentioned previously, the database was collected in two sessions with a time gap of at least three weeks between them. In each session there were three capturing blocks namely *Genuine 1*, *Genuine 2* and *Forgeries*. In *Genuine 1* block, two signatures plus the full name are performed for each device using their own pen stylus, and then two signatures and a number sequence comprised of numbers from 0 to 9 plus a random letter for the two Samsung devices with the finger. Next, *Genuine 2* block is recorded, which is comprised of the same information as *Genuine 1* block, but in this case the full name is written in capital letters. Finally, the last block *Forgeries* is performed, where each user carries out a forgery of the signatures of the three previous users in the database for each of the 5 devices using the stylus, and also with the finger for the two Samsung devices. Regarding forgeries of the full name, this is only performed for the Wacom STU-530 both for lower and upper case writing. In order to perform good forgeries, users are allowed to visualize a recording of the dynamic realization of the signature to forge for a few times.

In the second session, the procedure is identical, but the only difference is in the *Forgeries* block. In this case, users forge the same users as in session one, but this time a paper with the image of the signatures and names to forge is placed over the devices and they can trace the lines to perform the forgery. They are not allowed to see the recording of the signatures in this case. This will allow to study which of the two types of forgeries is more accurate.

In total there are 6,860 signatures, of which 3,920 are genuine samples and 2,940 are forgeries. From the total, 4,900 were performed with the stylus and 1,960 with the finger. There are a total of 2,240 handwritten names, of which 1,400 are genuine samples and 840 are forgeries (only for Wacom STU-530). Also, half of the samples are done with natural writing and the other half in capital letters. Finally, there are 1,120 genuine alphanumeric sequences carried out for the two Samsung devices using the finger.

The whole capturing process was supervised by an operator who explained all the steps that donors had to follow.

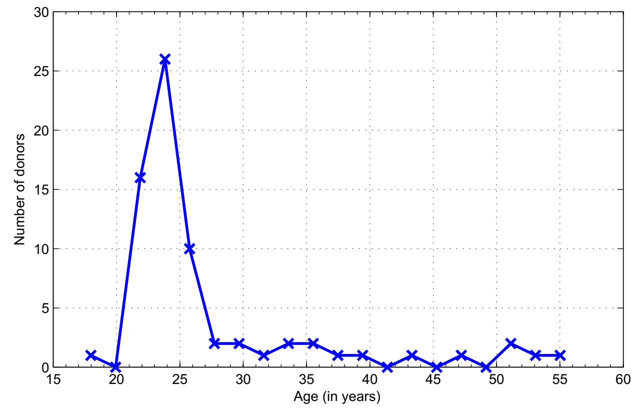



**Fig. 3**. Age distribution of e-BioSign Database.

| | |
|---|---|
| **Age distribution**<br>(17-21 / 22-27 / 28-38 / >39) | 11.4% / 67.1% /11.4% /10% |
| **Gender distribution**<br>(male / female) | 58.6% / 41.4% |
| **Handedness distribution**<br>(righthanded / lefthanded) | 88.6% / 11.4% |

**Table 2**. Population statistics of e-BioSign Database.

Therefore this is a multi-session and multi-device database with samples captured using a pen stylus and the fingertip for signature and handwritten data. Figure 2 shows examples of the data collected in e-BioSign for the Samsung Galaxy Note 10.1, as this device contains all types of information collected, i.e., signatures (genuine and forgeries) using the pen stylus and the finger, full name in lower and upper cases (only genuine as the forgeries were only performed with Wacom STU-530) and number sequences made with the finger. Figures 2(e) and 2(f) are just examples in order to not reveal the name of any user of the database. The rest of the samples are contained in the database. It is worth noting that data collected using the finger for Samsung Ativ and Galaxy Note 10.1 do not contain pressure information as this was not provided by these devices, and also there is no information of the trajectory ($X$ and $Y$ coordinates) when having a pen-up. For the case of using the pen stylus in the five devices the information of pressure and pen-up trajectories is available and has been used in the evaluation reported in this paper.

Figure 3 shows the statistics of the population of e-BioSign database. Regarding the age distribution, the majority of the subjects (67.1%) are between 22 and 27 years old, as the database was collected in a university environment. Then 11.4% are between 17 and 21 years old, also 11.4% are between 28 and 38 years old and 10% are above 39 years old. Table 2 shows the age distribution and also the gender and handedness distributions. The gender was designed to be as balanced as possible, having 58.6% of males and 41.4% of females. Regarding the handedness distribution, 88.6% of the population is righthanded.

## 3. SIGNATURE PRE-PROCESSING AND FEATURE EXTRACTION

This section and Section 4 describe the process of feature extraction and baseline evaluation carried out for the signature dataset comprised in e-BioSign database. The handwriting information (name and number sequences) will be evaluated in future works.

The pre-processing step consisted in removing the initial and final samples with no pressure, keeping this way only the information between the first and last pen-downs. Also, a step based on position normalization was performed by aligning the center of mass of each signature to a common coordinate.

The signature baseline system used to evaluate the baseline performance of e-BioSign database is based on previous works [7]. Dynamic time warping (DTW) algorithm is used as the classier, which allows to compute an elastic alignment between time sequences of different length, and obtain a distance measure.

This baseline system used in the evaluation of e-BioSign is based on a selection of time signals extracted from the *X*, *Y* and pressure signals, such as their first and second order derivatives, the velocity, the curvature radius, etc. This system was tuned on a different database, BioSecure [4, 8] in this case and it is applied to all the devices in e-BioSign to achieve a baseline evaluation of performance. It is worth noting that pressure information was not used for the two Samsung devices when signing with the fingertip as this information was not provided.

## 4. SIGNATURE BASELINE EVALUATION

### 4.1. Experimental Protocol

The experimental protocol was designed to obtain a baseline performance evaluation for each of the five devices using the pen stylus and also the two Samsung devices using the finger for signing. Only data collected during the first session was used to carry out this baseline evaluation. In this evaluation no user model has been trained, so the results are based on 1 to 1 signature comparisons. In this way, a leave-one-out approach was used with the four genuine signatures of each user in order to obtain 12 "genuine" scores per user. "Random forgery" scores (the case where a forger uses his own signature claiming to be a different user) are obtained by comparing the four genuine signatures to one signature sample of all the remaining users (69 in this case, and 276 scores per user). "Skilled forgery" scores are computed comparing the four genuine signatures with the 3 available skilled forgeries per user.

### 4.2. Evaluation Results

This section describes the baseline experimental results obtained for e-BioSign database using the reference system. Intra-device signature verification performance is reported in terms of equal error rates (EERs) in Table 3 and DET curves in Figure 4. Results are obtained for the five devices using a pen stylus, and for the two Samsung devices using the finger, for both scenarios of random and skilled forgeries.

The average EER performance for skilled forgeries is 10.60% and for random forgeries is 1.42%. It is interesting to see that the best results are achieved for the device Samsung Ativ using the pen stylus having 6.35% EER for skilled forgeries and 0.05% for random forgeries, being this a general purpose device and not specifically designed for signature applications as the Wacom devices. The second best results are achieved for the Wacom STU-530. Using the finger better results are achieved for the Samsung Ativ compared to the Samsung Note, obtaining EER results of 13.23% for skilled forgeries and 0.36% for random forgeries, which is a significant increment of the EER compared to the case using the pen stylus. The worst performance is achieved for the Wacom DTU-1031 with 13.81% EER for skilled forgeries and 4.70% EER for random forgeries.

As can be seen in Table 3 and Figure 4 for the case of skilled forgeries the two Samsung devices using the pen stylus achieve the best results together with the Wacom STU-530, while when using the finger achieve the worst performance together with the Wacom DTU-1031 (doubling the EER compared to the best cases). For random forgeries, the trends are different achieving very good results the Samsung devices using both the pen stylus and the finger, while the two devices achieving worst results are the Wacom STU-500 and DTU-1031.

## 5. CONCLUSIONS

This paper has presented the design, collection and baseline evaluation of the new database e-BioSign for signature and handwriting recognition. The database is comprised of 70 users and data is collected in two sessions. The database was designed to collect data from five devices, three of them specifically developed for signature and handwriting applications and two general purpose tablets that can collect data using a pen stylus and the finger. These are some of the most common devices used in commercial, banking, and e-health applications nowadays, so research in the areas of inter-device and inter-tool (pen stylus and finger) recognition can be carried out. This database will be made publicly available for research in the topic.

A baseline signature verification evaluation was conducted to obtain a benchmark performance for each device and writing tool using a reference system based on DTW. The best results were achieved for the Samsung Ativ device using the pen stylus for both skilled and random forgeries. The device achieving the worst results was the Wacom DTU-1031. A reason for this can be that a pointer we included in the display when writing which resulted to be a bit distracting, while the rest of the devices did not have this issue. Regarding the performance achieved when signing with the finger, very good results are achieved for the random forgeries, comparable to the results using the pen stylus, but the performance is degraded significantly for the case of skilled forgeries.

For future work, inter-device and inter-tool (pen stylus and finger) evaluations will be carried out. Also, handwriting information of the full name and number sequence will be taken into account for future research.

## 6. ACKNOWLEDGMENT

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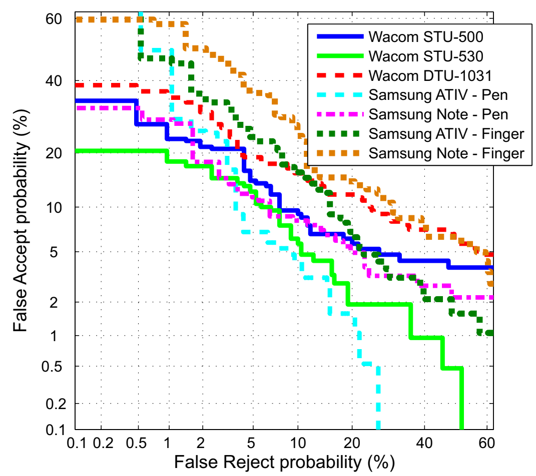
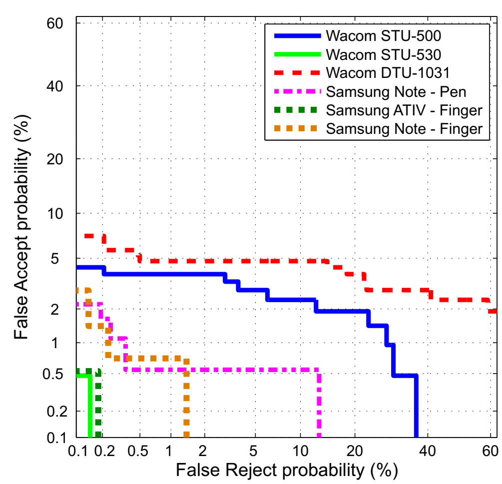
| | Device | Skilled (%) | Random (%) |
|---|---|---|---|
| Stylus | Wacom STU-500 | 9.52 | 3.33 |
| | Wacom STU-530 | 7.62 | 0.29 |
| | Wacom DTU-1031 | 13.81 | 4.70 |
| | Samsung ATIV 7 | **6.35** | **0.05** |
| | Samsung Galaxy Note 10.1 | 8.74 | 0.55 |
| Finger | Samsung ATIV 7 | **13.23** | **0.36** |
| | Samsung Galaxy Note 10.1 | 14.89 | 0.71 |

**Table 3**. Verification performance (EER in %) for each device and condition (pen stylus or finger) for random and skilled forgeries scenarios.




(a) Skilled Forgeries




(b) Random Forgeries

**Fig. 4**. DET curves results for the baseline signature evaluation of e-BioSign for the 5 devices using the pen stylus and the two Samsung using the finger, for both skilled forgeries and random forgeries scenarios.