

Dynamic Signature Verification and the Human Biometric Sensor Interaction Model

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Abstract – This paper examines the application of the HBSI model to a range of dynamic signature verification capture digitizers. Behavioral biometrics (which considers the process by which a human performs a function) are inherently more complicated to analyze as they may contain a temporal modification as part of a valid capture interaction. In this study, a framework for the development of an HBSI model is outlined, based on two different signature digitizers. Both devices enabled the capture of both temporal data (dynamic) as well as an image of the completed (static) signature. Using this data, we propose a signature modality revision to the HBSI model with interaction errors classified into five categories. This study deals solely with genuine users, examining both correct and incorrect signature presentations.

Keywords: biometrics, dynamic signature verification, electronic signatures, HBSI

I. INTRODUCTION

Biometrics is the measurement and analysis of unique physical and/or behavioral characteristics commonly used as a means of verifying personal identity [1]. A physiological trait is a more stable physical characteristic, such as fingerprint, hand geometry, or face. A behavioral characteristic is a reflection of an individual's psychology [2]. The Human-Biometric Sensor Interaction (HBSI) model is used to categorize all possible errors that may occur during user interaction with biometric systems into six basic categories. The initial validation and subsequent testing of the model has been on physiological biometrics such as fingerprint (swipe and slap capture methods), iris and hand geometry. These physiological modalities tend to be more restrictive in their interaction possibilities. One drawback of the HBSI model was that it had not been validated against a behavioral biometric. This category of biometrics adds a particular challenge to the model – that is how to deal with that the interaction of the human and the sensor with a behavioral as well as a physiological component. This paper examines the development and adaptation of the Human-Biometric Sensor Interaction model for

behavioral biometrics, using Dynamic Signature Verification as a case study. This adapted model will aid future (behavior modality-focused) projects, as well as further research into dynamic signature verification. Figure 1 shows the latest version of the Human-Biometric Sensor Interaction model prior to this paper. It is possible that in one transaction more than one error can occur, however our method concentrates on the overall outcome of the signature process.

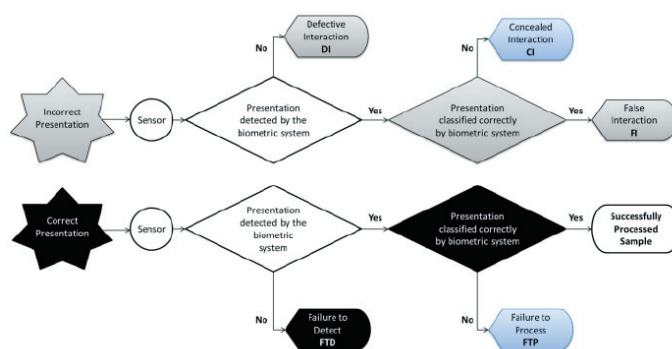


Figure 1: Current HBSI model

There are several inherent challenges with behavioral biometrics vis-à-vis physiological biometrics when examining the human interaction component. The first is that interaction between the human and the biometric sensor for a behavioral system will be more complex. Signing, speaking and typing are daily occurrences in a person's life. It is intrinsic that when presented with a pen and asked for a signature, a user will produce a good representation of their signature, because they know how to sign and they know what their completed signature is meant to look like. The same goes for voice recognition, and to some extent typing ability. Therefore, when something goes wrong with the presentation or utterance, the user can self-correct – for example they may stop signing because the pen doesn't work, or they will restart the utterance because of a problem with the telephone line. These self-determined corrections may be rarer when a user interacts with a physiological based sensor, such as a for hand

geometry machine. These behavioral components could cause an increase in the variability in the video interaction coding, which can make the HBSI analysis more complex and potentially unreliable.

Dynamic Signature Verification (DSV) is widely used as a means of biometric authentication and authorization [3]. Signature capture systems collect a variety of metrics such as minimum, maximum and average velocity in both the x and y dimensions, total time of pen up, pen down and direction, size, total pen distance, and others. These features are captured in real time as the user is writing to provide time stamped points of x/y coordinates along with pen pressure values in the z-direction. When deciding how to code the various Dynamic Signature Verification interactions, it is important to note how each potential interaction takes place. Each interaction encompasses the entire process from when the user first picks up the pen/stylus until the time that all writing is complete and the user has submitted their signature. To properly present a correct signature, users must be able to interact with any system or sensor they encounter. The first challenge is with the variety of different sensors that are available in the marketplace. The size and shape of the sensors are different, as are the pens. An individual may be familiar with signing on one type of digitizer, but will pause when a second type of digitizer does not provide the same type of feedback – for example, ink versus inkless. Furthermore, this sensor variability may compound the inherent variability within the signature itself. Even if you keep the sensor type constant, the writing of a signature can exhibit changes from one interaction to the next and can depend on a number of factors all related to the user. For example, the signature may vary based on the ceremony of the occasion. A person will possibly sign completely different if they are purchasing goods at a grocery store in comparison to when they sign for a home mortgage. The signature itself may also be different. Even if the ceremony is explained in order to remain constant, the user may still choose to abbreviate their name or not sign to the best of their ability. Although in a testing environment this user behavior is, to some extent, controlled, this variability needs to be acknowledged in the development of the model.

II. DEVELOPMENT OF THE HUMAN BIOMETRIC SENSOR INTERACTION MODEL FOR DSV

Taking into account the sensor and user variability, two different interaction flow charts are illustrated (Figures 2 and 3). The first signature capture sensor chosen was a back projected virtual ink device. Here the virtual ink (from the attached stylus) is displayed on a screen behind the writing surface. The majority of users are likely to be well acclimated with this device due to its common occurrence at point of sale areas. This type of digitizer can prompt user interaction errors; for example, latency. This is a measure of time delay that a system experiences, and could cause a negative reaction from the user. When latency is present, users may think that the sensor has stopped capturing their signature, thus prompting a resign. The second sensor chosen for the model development was a paper and ink device where the signer writes with a pen onto a paper surface with the pen leaving behind an ink trace as well as interacting with the sensor below the paper. A barrel-pen was used to write on the sheet of paper to give the

writer feedback on what their signature looks like. Although this removes the issue of latency from the user, new errors can occur such as faulty ink flow or the accidental push of the barrel button during the signing process. Based on these assumptions, two interaction flowcharts outlining possible decisions and outcomes are shown in Figures 2 and 3. These charts contain a series of location identifiers (labeled P_x and V_x respectively, where x is a unique numeric identifier) Where possible, examples in this section will relate back to the specific decision points in these figures.

There are five major interaction metrics or errors addressed in the new HBSI model. These errors stem from either a good presentation or a bad presentation and are defective interaction (DI), concealed interaction (CI), false interaction (FI), failure to process (FTP), and failure to detect (FTD). If none of these interaction errors occur with a correct presentation, the biometric sample is labeled as a successfully processed sample (SPS).

III. INCORRECT PRESENTATIONS

With reference to Figure 1, the types of HBSI errors within signatures deemed to be an incorrect presentation by the signer can lead to the following categories:

A. Defective Interactions

Defective interactions occur when the signature is deemed incorrect and no signature channel data is collected. In a paper and ink system, an incorrect signature is caused when the pen pressure is too light at all the sample points across the digitizer surface (below the pen-down threshold). No channel data is therefore collected, even though a partial ink trace may or may not be deposited on the paper. Within a virtual ink system no virtual ink is presented as a feedback to the signer. Another case is when an incorrect signature is donated and latency or other temporal errors in the attached hardware/software result in no samples being recorded. This error can apply to both paper and ink and virtual ink systems. The above scenarios are sensor-based issues, whereas the following cases relate to the user interaction. Illnesses such as Parkinson's or carpal tunnel may mean a sample cannot be given correctly – this will result in a DI. A DI can also occur if the user abandons the signature without any channel data being collected. With respect to interaction flow charts (Figures 2 and 3), all errors relate to when a signer halts the production of a signature (or is unable to start) and no data is collected. A “yes” from events V8 and P9 will lead to a DI if this scenario occurs.

B. Concealed Interactions

An error is classified as a concealed interaction when the signer donates an incorrect signature that is not detected by the system. A number of events can lead to a concealed interaction. Firstly P5/V5 or “User satisfied with signature production” in both signature systems will cause a concealed interaction if the signer is not satisfied with the signature being produced but does not abandon signature production (P8/V7=“no”). “Hardware latency problems,” (V2) “signature within signing bounds” (V3) and “pen pressure registered/ink dispersed correctly” (V4) will cause concealed interaction errors in a virtual ink digitizer if the

signer does not abandon the capture process even though visible system and signer out-of-bounds errors cause an erroneous signature to be displayed on the virtual screen. Also, in the case of a virtual ink digitizer, “hardware latency problems” and “signature within signing bounds” can lead to concealed interaction errors if the virtual ink feedback mirrors the latency and out-of-bounds recording error (i.e. delayed feedback and no display of out-of-bounds ink). “Ink dispersed correctly on paper” (P6) causes a concealed interaction if the signer does not abandon the capture process even though there are visible ink dispersal issues noted by the signer. “User abandoning donation” in P10 or V9 lead to concealed interactions if the signer abandons the capture process even though the signature is not complete.

C. False Interactions

False interactions occur when a signature, deemed incorrect or unrepresentative by the signer, has been donated with sample points being recorded. This incorrect nature of the presentation is detected by the system. There are several causes of false interactions, the first occurs when a signer uses a repetitive motion (repeating segments of signature) within a signing process caused by faulty ink-flow issues (paper and ink system) or insufficient pressure levels applied (virtual ink). The second cause of a false interaction is when a signer using a repetitive motion (repeating segments of signature) caused by a writing error introduced by the signer. Signers will also cause a false interaction by donating an unrepresentative/incomplete signature possibly due to bodily functions and reflexes such as sneezing, jolts, and twitches. False interactions can also be system specific, for example within a virtual ink system, a pen interface issue can occur (e.g. barrel button pressed during donation) causing channel data disruption which may cause a misrepresentation of a correct signature. This causes virtual ink feedback disruption. In both systems, at P5/V5, “User satisfied with signature production” will cause a false interaction if the signer is not satisfied with the signature being produced and abandons the signature production (P8/V7=“yes”). A false interaction will occur on both systems if the signer (or system) cancels the capture process following a signer modification of their standard signature with data having been collected (i.e. part of the signature has been signed), shown at P9 and V8. “Hardware latency problems,” (V2) “signature within signing bounds” (V3) and “pen pressure registered/ink dispersed correctly” (V4) will cause false interactions in a virtual ink digitizer if the signer abandons the capture process due to both system and signer out-of-bounds errors causing an erroneous signature to be displayed on the virtual screen. Also in a virtual ink digitizer, “hardware latency problems” (V2) and “signature within signing bounds” (V3) can lead to false interactions if the virtual ink feedback mirrors the latency and out-of-bounds recording error (i.e. delayed feedback and no display of out-of-bounds ink). In a paper and ink system, if the signer abandons the capture process due to ink dispersal issues it will also cause a false interaction. The majority of false interaction errors are created due to the decisions or judgments made by the signer at the time of donation.

IV. CORRECT PRESENTATIONS

Failure to detect (FTD), failure to process (FTP), and successfully processed samples (SPS) all constitute correct presentations.

A. Failure to Detect

Failure to detect errors occur when the signer has donated a signature that they have deemed acceptable, but the signature is not detected by the biometric system. Within a physical ink system, such an error will happen if a correct signature is donated, but the pen pressure used is too light at all sample points across the donated signature on the digitizer surface (below a pen-down threshold) but ink trace is left on the paper. A similar effect could be observed if the overlaid paper thickness caused insufficient downward pressure to be exerted on the digitizer surface. A failure to detect will also occur if a correct signature is donated, however latency (or other temporal recording errors) in the attached hardware/software results in no samples being recorded. This scenario applies to both virtual and real inking systems. A failure to detect will be achieved in the first decision of both flowcharts if data packets are not being recorded by the system.

B. Failure to Process

Failure to process errors arise when the signer has donated a signature that they have deemed acceptable. The signature has been detected by the biometric system but system errors cause the signature not to be an accurate representation of the donated signature. If a correct signature is donated but latency (or other temporal) errors in hardware/software result in partial or temporally distorted channel data being recorded it will be classified as a failure to process. An alternative case is where a correct signature is donated, but the start and/or end segments are missing in the recording process. This scenario can apply to both inking and virtual ink systems. In another case, a correct signature can be donated, however part of the signature has been signed outside the designated capture area. In the paper and ink system, this may occur if the boundary has not been clearly defined. In the virtual ink system, if ink is still displayed outside of a capture boundary then the failure to process will occur. Most likely, the ink will not be displayed outside of bounds so an incorrect presentation would occur. In either case, capture points will not be stored for out of bounds signature sample points.

Within a paper and ink system, a correct signature can be donated, however due to pressure variability within the signer’s action, it results in ink being deposited on the paper but in some areas the applied pressure was too low to register resulting in a partial capture of the signature deeming it a failure to process. Again, in a paper and ink system, a pen interface issue can occur (e.g. barrel button pressed during donation) causing channel data disruption which may cause a misrepresentation of a correct signature. Ink dispersal is not disrupted but it will still be classified as a failure to process. Both digitizer systems may be hindered by system performance and cause the system to miss certain parts of the signature input resulting in a failure to process error. This may be caused by the utilization of a machine with too low of a capability to record capture which would cause lag in processes and

therefore miss some of the input recorded during capture. In both digitizer systems, a failure to process will occur if the signature is signed out of bounds but the signer’s inking feedback indicates a correct presentation. In a paper and ink digitizer system, “pen pressure registered with system” (P4) relates to these issues. If the pressure is too low on a virtual ink system, the digitizer would not provide feedback from the virtual ink (hence it would be an incorrect presentation instead). In the case of paper and ink sig-

nature capture, if the outcome of “pen pressure registered with system” (P4) is “yes,” then it is assumed that correct pressure was recorded throughout the sample. If the outcome at P4 is “no,” then it will result in a failure to process if the drawn signature is acceptable to the signer. A failure to process may also occur at this decision due to a human interaction error such as touching the pen barrel button by accident which may cause the pressure channel capture state to not register during later processing.

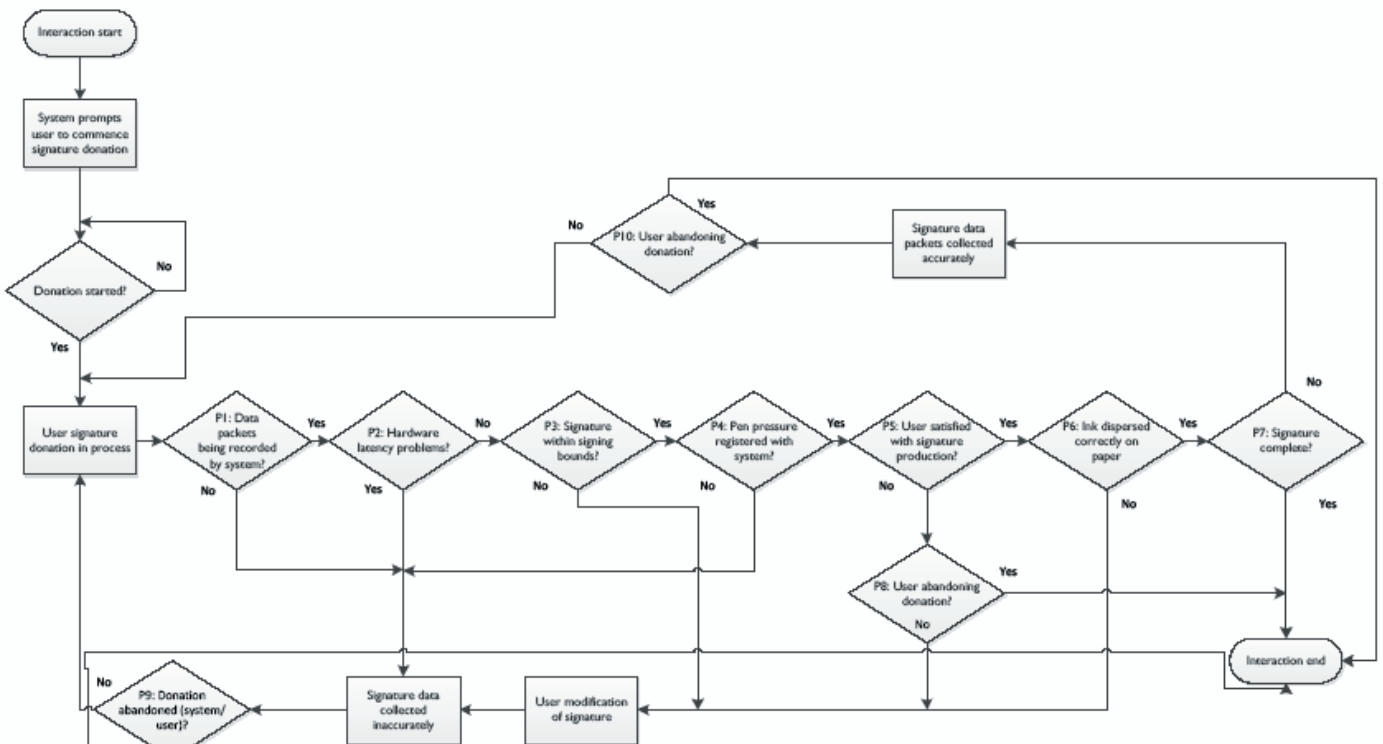


Figure 2: Interaction flow for paper and ink signature capture device

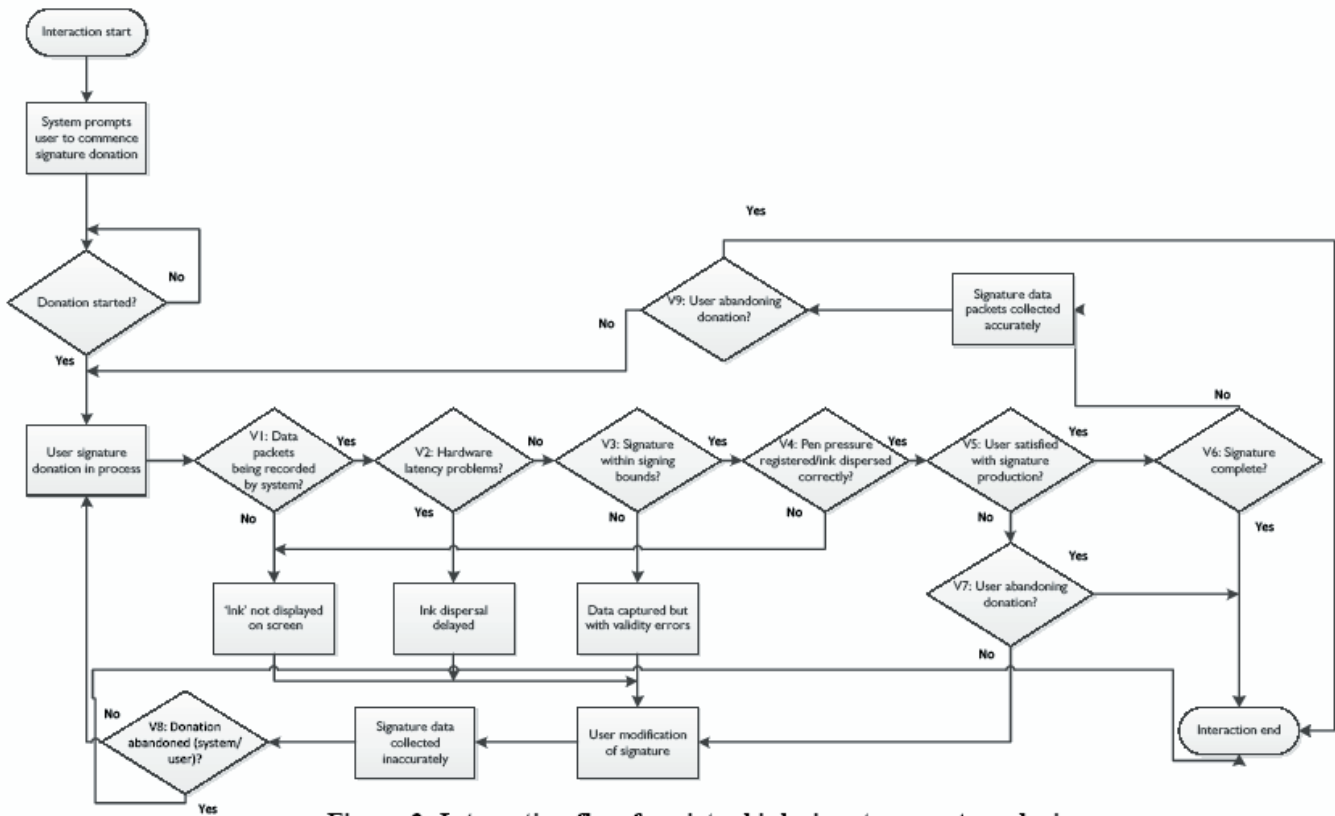


Figure 3: Interaction flow for virtual ink signature capture device

V. CONCLUSIONS

The development of the HBSI model for dynamic signature verification reveals the complexity of the potential interactions and the changes of those interactions when digitizers change, as well as when the ceremony changes. The findings in this paper are based strictly on the actions of genuine signers. Forgery poses an entirely different research topic that has been tested in a variety of different experiments so it has not been included in this study. Furthermore, Figures 2 and 3 have been defined in detail so that when the videos are coded, the inter-rater reliability of those coders is not compromised. Tables 1 and 2 summarize the various elements of the flow chart and HBSI errors.

Decision Point	Action	Outcome
V1	No	FTD
V2	Yes	FTP if feedback detached from sample capture, otherwise FI if abandoned, CI if not
V3	No	FTP if feedback detached from sample capture, otherwise FI if abandoned, CI if not
V4	No	FI if abandoned, CI if not
V5	No	FI/CI depending upon V7 outcome
V6	Yes	Successfully Processed Sample
V7	Yes	FI
V7	No	CI
V8	Yes	DI if no samples collected during interaction, FI otherwise
V9	Yes	CI

Table 2: Virtual Inking Device HBSI Errors

Decision Point	Action	Outcome
P1	No	FTD
P2	Yes	FTP
P3	No	FTP
P4	No	FTP
P5	No	FI/CI depending upon P8 outcome
P6	No	FI if abandoned, CI if not
P7	Yes	Successfully Processed Sample
P8	Yes	FI
P8	No	CI
P9	Yes	DI if no samples collected during interaction, FI otherwise

Table 1: Paper and Ink Device HBSI Errors

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VII. REFERENCES

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