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Pen Pressure: An Important Tool in Online Signature Verification

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Abstract

Over the years, many different methods and software have been developed to distinguish between genuine and forged signature verification. Automatic verification of online signature has been a compelling task with greater practical applications. This paper focuses on the pen pressure and other pen dynamics to differentiate between a forged and a genuine signature. Pen pressure is the force applied by the fingers in the process of writing and it is one of the many characteristics which the forensic experts use for comparison. Other pen dynamics like velocities, forces, varying orientation of the pen, and the way in which a signer grasps a pen are also an important in examination process. Traditional offline verification systems are replaced by automatic online verification systems in the commercial market, as these systems are more reliable, less time consuming, accurate, precise, and needs less efforts. The present review represents the importance of pen pressure, different online signature verification techniques based on pen pressure and other features in differentiating genuine and forged signature.

Key-Words: *Online verification, pen pressure, signature, handwriting, forgery, forensic science.*

Introduction

Pattern recognition has been a widely used tool in forensic science, from analysis of unknown compounds to individual personal identification. The identity of a person can be verified or determined through pattern recognition of various biometric traits such as palm print, iris, fingerprint, retina, face, odour, ear, gait pattern, signature, voice recognition, hand vein, or genetic information like DNA. The biometric traits range from various individual physical characteristics (such as face, iris, fingerprint) to behavioural attributes (such as handwriting or signature) [1, 12].

In forensic handwriting and signature examination, experts compare the characteristic writing features of the questioned handwriting with the control specimens. Handwriting is an acquired skill, a task which takes place by coordination of nervous and muscular system. It is also known as a neuro-muscular task. Handwriting of every individual is unique and it changes during our lifetime with experiences and learning. Handwriting identification is based on the principle that, while handwriting within a language tends to be alike to the degree that we can meaningfully read it, there are individual features that distinguish one person's writing from that of another. Just as no two people are exactly alike, the handwriting of no two people are exactly alike in their combination of characteristics. There are, of course, natural variations within the handwriting of each individual. these variations must be closely and

carefully studied by the examiner, so that he can distinguish between what is a "variation" and what is a "difference".

A technological revolution has affected the world of writing in these recent years. Most companies today need to have lower costs for archiving and transmission of document and in the same time it was posed the security question. The answer has been the digital biometric signature: Biometrics is actually the science of using digital technologies to identify a human being based on the individual's unique measurable biological characteristic. Applied to handwriting, biometrics enable the comparison between digital signatures in order to avoid falsification and disclaimer [3].

In this present study importance of one of the individual characteristics of handwriting are shown i.e. PEN PRESSURE. Pen pressure is the force or pressure applied by the fingers of an individual during writing. The heavy pressure applied on the paper cause indentations behind the paper [3]. It has been mentioned in the literature that natural pen pressure variations are an integral part of an individual's signature. The variations are individual to such an extent that it is highly unlikely to have two authors with well-developed signatures of normal length with the same pressure patterns. Besides, the pressure patterns of a well-developed signature of normal length are extremely difficult to duplicate in the forged signature. Signature verification computer systems using pen pressure as an identifying characteristic were developed since 1970s. However, normal course of business signatures were mostly written on pieces of paper and pressure patterns of the signatures could not be easily recorded or converted from the paper to be examined [1].

Questioned document examiners pay more attention to individual characteristics other than pen pressure like slant, letter formation, pen lifts, embellishments, movement, form, height proportion, spacing, connections, speed, etc. They give less importance to pen pressure which is also one of the unique individual characteristics of handwriting. Similarly, a forger while doing forgery pay more attention to formation of letters, connections, slant and other individual characteristics but give less or no attention to pressure points. The examiner and forger both forget that pen pressure is also one of the most important individual characteristic of handwriting which can be used to differentiate between genuine and forged document or signatures.

A handwritten signature is biologically linked to a specific individual. Modern forensic document examiners commonly compare a suspect signature with several examples of known valid signatures. They look for signs of forgery which include: Signatures written at a speed which is significantly slower than the genuine signatures; frequent change of the grasp of the writing implement; rounded line endings and beginnings; poor line quality with hesitant and shake of the line; retracing and patching; and stops in places where the writing should be free.

Genuine Signatures and Writing

Genuine signatures are naturally written signatures that a writer develops as a personal identifier [10]. They are the combination of writing characters which are consistent with natural conditions surrounding the signed document. Authentic writer writes freely or subconsciously because he/she has been

signing his signatures for years. Authentic signature is rapid, smooth, rhythmic, carelessness or obvious corrections are normally seen. Authentic writer has no fear of being accused as a forger does [14].

Characteristics

- Rapid.
- Rhythmic
- Obvious corrections are normally seen
- Introduce certain other forms
- Smooth
- Flowering ending stroke
- Natural free flowing Appearance

Forged Signature and Writing

Forgery is an attempt made by a person to defraud another by falsely making or altering a signature or writing. Forgery basically means making a false document with intend to defraud [14].

Characteristics

- Unnatural appearance
- Lack of individuality
- Slowly written
- Study attention to the formation of letters
- Blunt beginning and ending strokes
- Lack of rhythm
- Appearance of being drawn

Pen Pressure

Pen pressure is the amount of pressure exerted on the pen point and is the result of the rhythmical contraction and relaxation of muscles during the act of writing. It is the force exerted by the pen on the paper during writing which appears to be a discriminating parameter between individual writers [1]. Person identification on the basis of normal hand-writing samples becomes easy and improved if the pen-force signal is known. Thus, pen pressure signal is an important source of information in handwriting or signature verification systems. Osborn stated the importance of pen pressure in signature identification. He expressed that "a delicate, inconspicuous, and almost wholly unconscious variation in line quality, weight of stroke, location of emphasis, smoothness of line and manual skill that has high identifying value. As shown in the "quality of line," and especially the location and character of emphasis or unconscious shading, the variation in this feature is one of the most important evidences of genuineness and forgery" [3,10].

Those who write with heavy pressure are slow writers. Illiterate persons ordinarily write with heavy pressure. Every individual have different pen pressure habits in their handwriting, so this feature is very useful to detect different forgeries e.g. carbon paper forgeries etc. The variations in pen pressure are usually manifested in the contrast of darkness and lightness of the ink stroke. However, the nature of the ink and the absorbance of the paper surface may hinder the examination. In addition, the pen pressure pattern of the entire writing could hardly been visualized by tradition photographic and lightening techniques [3].

There are number of methods discovered to measure pen force. Sometimes, it is measured by using transducer in writing

instrument or under the writing surface so so that its time function can be noted. In forensic handwriting analysis, pen force can also be measured from the static properties of the handwriting, i.e., paper characteristic, trace thickness and depth. Other methods which use different pen dynamics are also available [4,5].

Handwriting Attributes (Features)

Features are quantitative measurements that can be obtained from a handwriting sample in order to obtain a meaningful characterization of the writing style. These features can be obtained from the entire document, or from a paragraph, line or a word. Generally two types of features are considered i.e. conventional features and computational features.

Conventional features are the handwriting attributes that are commonly used by the forensic experts in document examination. These features are obtained from handwriting by visual and microscopic examination. Software like FISH (Forensic Information System of Handwriting) are also used to narrow down the search. Computational features are those that have known software/hardware techniques for their extraction. They can be determined algorithmically, e.g., by software operating on a scanned image of the handwriting. Computational features can be divided into macro and micro-features, depending on whether they pertain globally to the entire handwritten sample, e.g., darkness, or are extracted locally, e.g., contour variations [16].

Different Methods of Pen Pressure Examination

Research on various computerized methods for online signature verification has been reported. There are number of software available which can be used for this purpose. Various machine learning algorithms has also been developed for examining scanned paper documents.

Examination of Scanned Documents

Software for recognizing handwritten scanned documents has many applications in the field of forensic. Different machine learning algorithm are used for the purpose of examination. In case of scanned image examination, scanned images are mostly stored as grey scale image of discrete pixels, which can later be converted to a pure black and white image by binarization algorithm [16].

Namirial GrafoCerta method

Speed and pen pressure are two important individual characteristic of handwriting and a research was carried out to explain the correlation between pen pressure and speed. It was found that all people have had more difficulty in slowing their movement rather than accelerating. In all the slowed signature there are more pauses, more fragmentation of shape and more overhead movements, furthermore people put into words their difficulty. Index of deceleration goes from 3,60% to 84,37%, index of acceleration goes from 6,25 % to 277,97% . This research was done to find out if there is a constant correspondence between speed and pressure, if pressure always lightened in acceleration and if it always make heavy in deceleration. In this paper correlation between pressure and speed is exposed [3].

Dynamic Handwriting Features

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In the study it was investigate if computer-measured dynamic features (duration, size, velocity, jerk, and pen pressure) differ

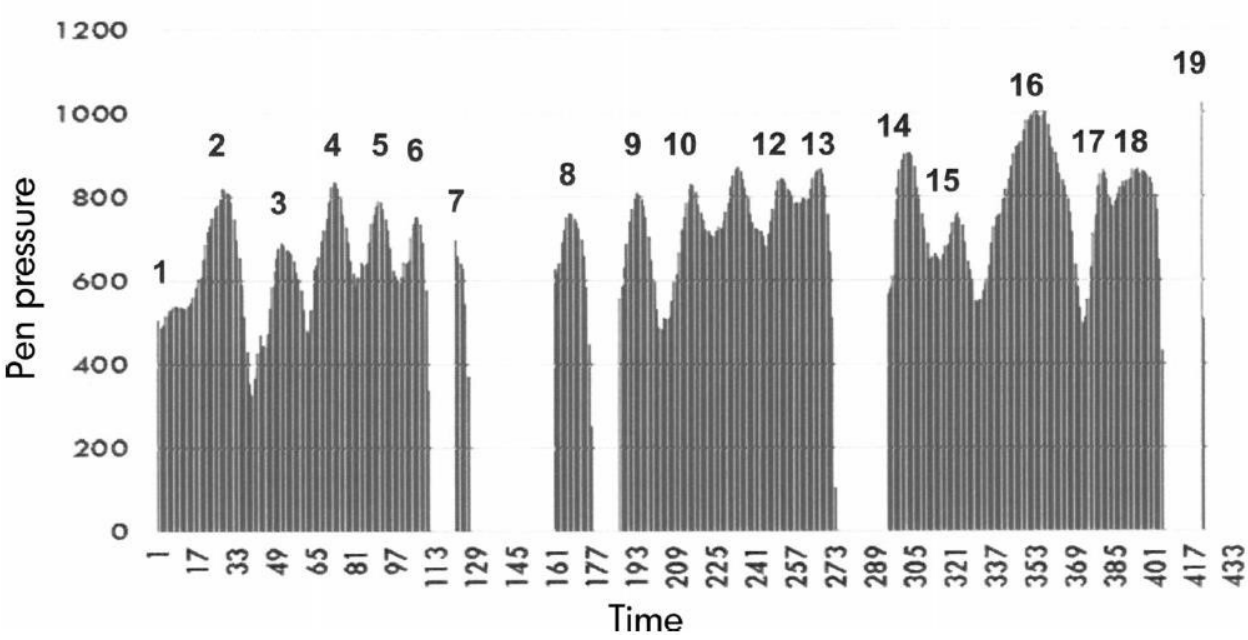

Figure-1: Graph of pen pressure versus time of a signature (numerals illustrates the relationship between the peaks and stroke segments) [1].

between genuine and simulated signatures. Stroke duration, velocity, and pen pressure were found to discriminate between genuine and simulated signatures regardless of the simulator's own style of signature or the style of signature being simulated. The results shows that the dynamic handwriting features, indicate that the style of the simulator's own signature and the style of signature being simulated can impact the characteristics of handwriting movements for simulations. Thus, the normal writing style of the simulator had a significant effect on the writing dynamics for the simulated signatures. Writer style characteristics might therefore need to be taken into consideration as potentially significant when evaluating signature features with a view to forming opinions regarding authenticity [10].

Developing A Prototype for Pen Pressure Patterns

Through this experiment a prototype was derived using simple mathematical treatment of the pen pressure data recorded by a digital pen movement recording device. Pearson's correlation coefficient was used to compare the data of the pen pressure patterns. The prototype could be used as a complementary technique to improve the objectivity of signature examination and also has a good potential to be developed as a tool for automated signature identification. In addition, the establishment of the relationship between the stroke segments and peaks in the pressure patterns graph allows the

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comparison of signatures with variation in structures. In this study, the treatment of the pen pressure data using Pearson's correlation coefficient provides an objective means to determine the degree of matching between two signatures, which could be used for the identification and elimination of common authorship [1].

Hidden Signature method

Hidden Signature method describe a proposition for replacing the template signatures with the hidden signature—an artificial signature which is created by minimizing the mean misalignment between itself and the signatures from the enrollment set. The hidden signature opens a number of new possibilities for signature analysis. Statistical properties of the hidden signature were applied to normalize the error signal of the verified signature and to use the misalignment on the normalized errors as a verification basis. A satisfying error rates that allow creating an on-line system, ready for operating in a real-world environment is achieved.
Dynamic time warping (DTW) is used to form a misalignment score between the verified signature and a set of template signatures [2].

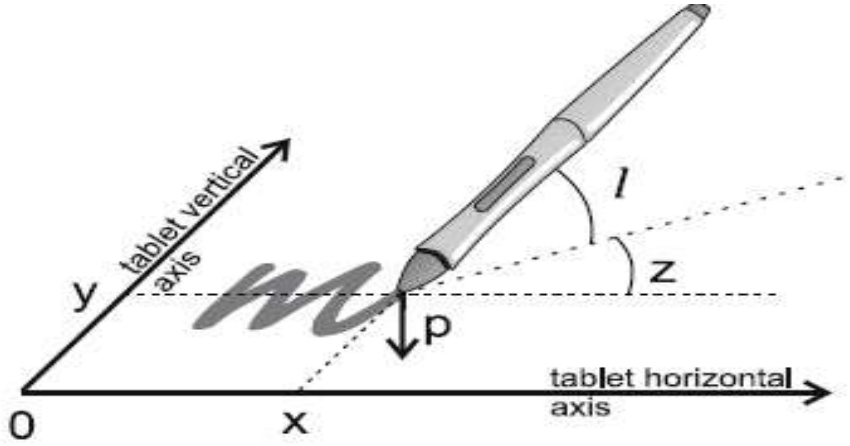

Figure-2: Signature on-line acquisition by Wacom Intuos (WACOM,2015) [2].

Slant and Size Transformation method

In this method a theory was tested that on-line adaptations to the rescaling of visual feedback are better described by the neuromotor noise theory of Van Gemmert and Van Galen than by traditional chronometric approaches. According to this processing demand that is reflected in deteriorated signal-to noise ratios (SNRs) in the neuromotor system is equivalent to a change in scaling factor of slant or size. At the behavioural level, deteriorated SNRs will result in less fluent writing, which can be compensated by applying a biomechanical noise- filtering strategy of increased limb stiffness. This strategy will lead to increased axial pen force, and, with higher degrees of difficulty, to a loss of movement speed. Results revealed decrements in writing fluency together with increments in axial pen force and increments in movement time when compensations to the feedback transformations coincided with the more difficult task conditions. These findings

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contrast with the traditional resource theory (Kahneman, 1973) in which chronometric measures alone indicate increased processing demands [5].

Frictional Coefficient and Control of pen pressure

The study was aimed at using a computer simulation to show that the effects of sliding and static friction may be subtle but can significantly alter the dynamics of pen control. These simulations lead to hypotheses on human strategies which may reduce the disruptive effects of friction. Specifically, it is proposed that subtle modulations in the general level of normal force are necessary if the relative pen dynamics are to remain stable across changes in pen speed. Empirical data was collected from 11 adult subjects writing repetitions of a series of words in different script sizes, at different speeds and on different surfaces. Axial pen pressure was recorded in synchrony with x, y position information. The resulting pressure records are used to explore some hypotheses of previous researchers on pressure variability, as well as the hypotheses developed from the computer simulations. Finally a theoretical model is presented of a 'perceptual instrument' that may serve to explain the sensitivity apparent amongst competent writers in the modulation of pen pressure [7].

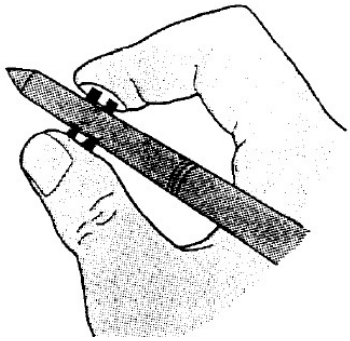

Figure-3: Control of pen - pressure(7)

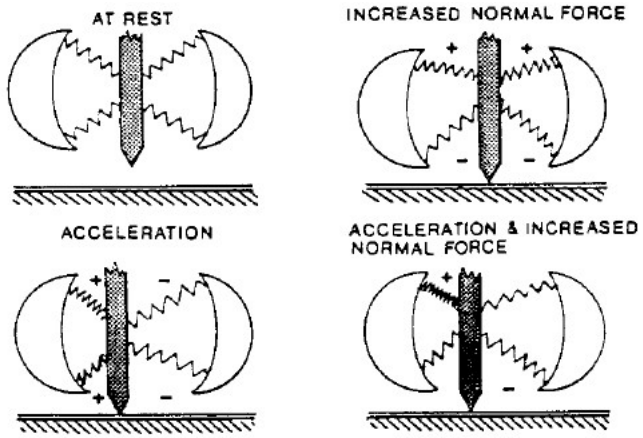

Figure-4: A model for perception of frictional effects [7].

Interval-valued symbolic features

It proposes a new method of representing online signatures by interval-valued symbolic features. Concept of writer-dependent threshold is exploited and the concept of feature-dependent threshold to achieve remarkable reduction in equal error rate is introduced. Extensive experimentations are conducted to evaluate the performance of the proposed methods by projecting features onto Eigenspace and Fisherspace. The results of the extensive experiments reveal that the proposed representation scheme is simple and efficient, has achieved a considerable reduction in EER, and thus outperforms several other contemporary models. In this research global features of online signatures are used to form an interval-valued feature vectors. Methods on symbolic representation are proposed for signature verification and recognition [8].

Vishvjit S. Nalwa, describe a robust, reliable, and elastic local-shape-based model for handwritten on-line curves. Biased and weighted harmonic mean is considered as a graceful mechanism or tool of combining errors from multiple models. A successfully tested signature verification algorithm is also described. This approach rely primarily on the detailed shape of a signature for its automatic verification and breaks the tradition of relying primarily on pen dynamics [6].
The usefulness of pen dynamics during on-line signature production in automatic on-line signature verification must be investigated. Such dynamics might include not only velocities and forces, but also the varying orientation of the pen, and the way in which a signer grasps a pen.

Correlation between Spectral Coherence and Time-domain

It helped to investigate the spectral coherence and time-domain correlation between pen pressure (axial pen force, APF) and several kinematic variables in drawing simple patterns and in writing cursive script. Findings show that overall coherence is low (< 0.5) and decreases with pattern complexity, attaining its lowest value in cursive script. Looking at subjects separately, it is found that only in a small minority of writers" biomechanical coupling" between force and displacement takes place in cursive handwriting, as indicated by moderate to high negative overall correlations. The majority of subjects displays low coherence and correlation between kinematics and APF. However, APF patterns in cursive script reveal a moderate to high replicatability, giving support to the notion of a" centrally" controlled pen pressure. A motor task demanding mechanical impedance control, such as handwriting, apparently introduces a complexity that is not easily explained in terms of a passive mass-spring model of skeleto-muscular movement [4].

Every individual has a unique handwriting characteristic. An examiner uses these unique characteristics to differentiate a forged document from a genuine. There are number of different methods discovered to measure pen pressure in handwriting verification. Different pen dynamics and handwriting features are used to differentiate between genuine and forged handwriting. In the following table shows combination of different techniques, computer software and statistical parameters used to examine pen pressure and other pen dynamics as a tool to

differentiate between genuine and forger handwriting/signature.

There is a great demand of on-line signature/handwriting verification systems in the commercial market. These automatic

Discussion

verification systems have the potential to replace the traditional verification systems done manually

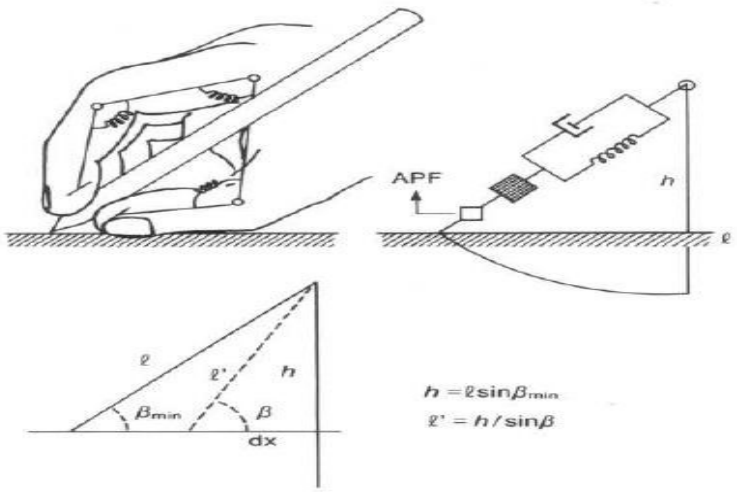

Figure-5: Biochemical model relating planar movement to axial pen pressure (h is fixed height of hinge, l is distance from hinge to pen tip, β is current pen angle, βmin is minimum angle for surface contact, dx is current distance between pen tip and the normal) [4].

PEN PRESSURE MEASURING METHODS			
S.No.	**BASIS**	**COMPUTER SOFTWARE USED**	**MODEL & STATISTICAL PARAMETERS**
1	Dynamic handwriting features	• Wacom Intuos 3 digitizer tablet • MovAlyzeR Version 4.1 • Wacom inking pen	• ANOVA • Tukey's HSD test
2	Slant and size transformations	• Calcomp 9000 digitizer tablet • VAX-workstation 310 software	ANOVA
3	Measure of frictional coefficient and control of pen pressure	• Quest Micropad pressure sensitive pad • Acorn BBC microcomputer • Pen with force transducer within barrel	Pearson correlation
4	Interval-valued symbolic features	• Digitizer tablet • digitizer pen	• Dynamic Time Warping(DYW) • Hidden Markov Model(HMM) • Support Vector Machine(SVM) • Neural Network • MCYT-Signature subcorpus database
5	Replacing Template signature with Hidden signature	WACOM, 2015 digitizer tablet	• Dynamic Time Warping(DYW) • Hidden Markov Model(HMM) • Support Vector Machine(SVM) • Neural Network • MCYT-online database
6	Digital biometric signature	• Wacom tablet LCD STU-520 • Namirial "Firma Grafocerta" software	
7	Spectral coherence & time-domain correlation between pen pressure & other kinematic variables	• Calcomp 9000 digitizer tablet • PDP 11/45 Computer • Digitizer pen • VAX Station 2000 computer • Fortran-77 software	• Spectral coherence • Fourier transform

8	Prototype using mathematical treatment of pen pressure patterns	• Wacom Intuos 4,5 Pro Inking pen • Wacom Intuos Pro medium digitizer tablet • MovAlyzeR version 6	Pearson correlation coefficient

Table-1: Different pen pressure measuring methods

Conclusion

In manual verification by a expert there are few drawbacks associated with human nature like tiredness and absent-mindedness which may influence the verification ability. In online verification by using a digitizer tablet and a pen to record samples pen pressure and pen dynamics are the mostly considered and examined to verify the samples. It was found that pen pressure which is an important individual characteristic of handwriting was found more in simulated samples or forgeries. The variations in pen pressure are usually manifested in the contrast of darkness and lightness of the ink stroke. However, the nature of the ink and the absorbance of the paper surface may hinder the examination. In addition, the pen pressure pattern of the entire writing could hardly been visualized by tradition photographic technique. This limitation of offline verification is overcome by online verification systems through which pen pressure pattern of the entire signature can be visualized and compared in a graphical form. Further investigation on the usefulness of pen during online signature production in automatic online signature verification must be done. Such dynamics might include not only velocities and forces, but also the varying orientation of the pen, and the way in which a signer grasps a pen. Pen pressure can be a useful parameter in discriminating between genuine signatures and forgeries. In order to advance the use of pen pressure and other pen dynamic features in the forensic environment there is a need to develop pressure measurement techniques.

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