Online Signature Slant Feature Identification Algorithm

MOHD RAZIF SHAMSUDDIN, AZLINAH MOHAMED
Faculty of Information Technology and Quantitative Sciences
Universiti Teknologi MARA
40450 Shah Alam
MALAYSIA
razif@feizar.net, azlinah@tmsk.uitm.edu.my
http://www.tmsk.uitm.edu.my

Abstract: - According to the American National Science and Technology Council (NSTC), the first signature recognition system was developed in 1965. Then the research continued in 1970 focusing on the potential of geometric characteristic of a signature rather than dynamic characteristic. Nowadays, signature is a commonly used identification procedure. Everyone would be required having a signature for authorization and other important tasks that needs identification. Thus, signature has become one of a method to represent its writer uniquely. Signature has many hidden features that are difficult to extract. Some of the identified features that a signature should have are slanting, baseline, proportion and size. This paper covers the area of signature slant identification. Signatures are captured using a tablet and saved in a digitized format of *x* and *y* values. Then it is filtered and calculated for its angle and degree. In the end the signature will be classified to its slant category. A slant algorithm is created and coded into a functional system. An experiment consisting of 50 signatures are tested and the finding shows the angle and degree of the slant in every signature. The result is then tested for its accuracy with an available 10 sample of created proofed signatures. The result shows a favorable accuracy of 80% correct slant identification. The creation of this algorithm would be able to give some degree of contribution in the area of signature recognition.

Key-Words: - Slant, Slant Recognition, Signature Recognition, Online Signature, Curved Stroke, Curved Slant

1 Introduction

Signature is the most personal graphic movement a person created on a paper [1]. Nowadays, it has been a common form of authentication in this digital age. Signature is captured electronically to be used for many reasons. Electronic signature may be used to authorize transaction or it may be used for security reasons. It has been known that federal agency in Washington has been promoted to use digital signature in electronic filing of information [2]. Thus a numerous signature recognition instruments are accessible in this rapid growing world of knowledge.

People have known to capture signature in forms or paper and digitized the image in order to extract the hidden features contained inside one's signature. These were known as off-line signature recognition. The signature is scanned from raw paper and transformed into image data. The image will be converted into grayscale in order to ease the identification of the signature. Values of black colored pixels are marked as '1' and white pixels are marked as '0'. These data will then be used in various feature extraction functions depending on the need of the system. Refer to figure 1 for the offline signature capturing flow.

However, this paper will represent on-line signature identification. In on-line signature identification a tablet instrument are available in order to extract the signature information more accurately.

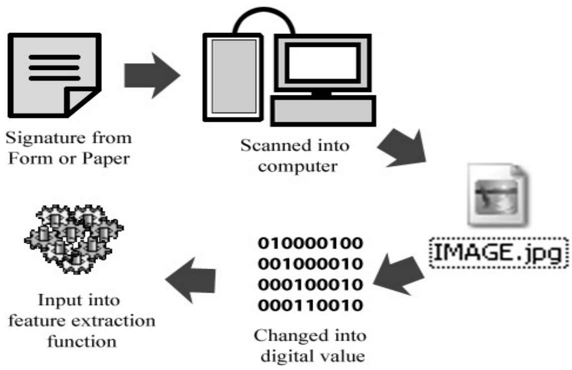


Fig. 1 Off-line signature capturing flow

Signature data can be captured on-line in x and y values in a form of continuous coordinates. These continuous coordinates will be mapped into a grid and represent how the signature should look like. Refer to figure 2 for the on-line signature capturing flow that will be discussed further in the next section. There are many hidden features contained in a person signature which some of them are very hard to extract.

Slanting is chosen to be extracted in this paper as it is one of the important features a signature should have. A signature usually will have a slant which can be rightward, upward or leftward.

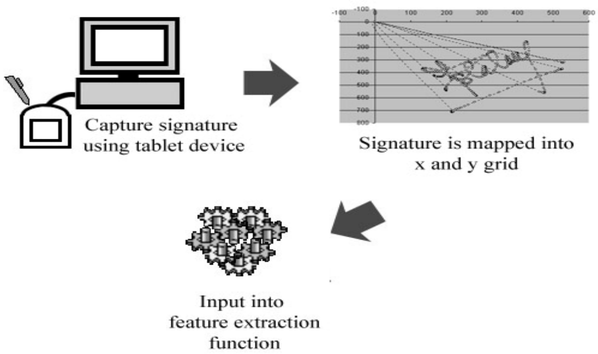


Fig. 2 On-line signature capturing flow

The objective of this paper is to design an algorithm to identify the angle and degree of a signature slant using on-line recognition and classify it into three categories. Section 2 of this paper will discuss a bit of slant features and signature related research works that have previously made by others. Consequently, in section 3 the approach that has been used will be explained. Section 4 would discuss the experiment tested on 50 signatures and its results would be reported. The last section would provide suggestion for further improvement and recommendation.

2 Signature Slanting

A signature has many hidden features; some of them are size, proportion, spacing, alignment to baseline, progression, form and slant. The first four of these features are categorized as static features while the last three is categorized as pseudo dynamic features [3]. According to Oliveira, pseudo dynamic features contain rich element of signature feature as it is directly related to the signature strokes. The slant of writing is referred to the direction of the letter slope from the baseline. Loopy writing slant is measured from the apex at the highest point of the letter to where the lines cross near the baseline [1]. Please refer to figure 3 for examples.

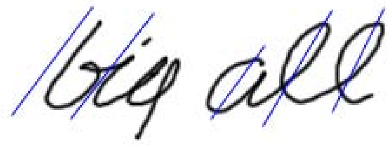
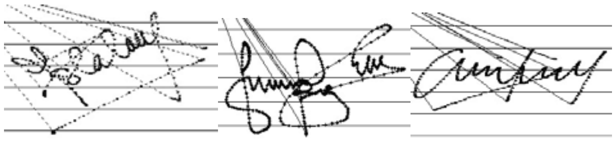


Fig. 3 Slant measurement

In figure 4(a), we can distinguish the angle of the stroke of the signature slope is inclining leftward thus making this signature categorized as leftward slant.



(a) (b) (c)

Fig. 4: Signature left slant (a), vertical slant (b), right slant (c)

Meanwhile, in figure 4(b), the signature slant is mostly vertical. Figure 4(c) shows the signature slant to the right. Slant measurement is easy to distinguish from its long strokes but easily misinterpreted from the curved loops. There is no general range of degree to classify signature slant, but a simple rule can be made to distinguish between the three categories of slant, that is, degree between 60° to 85° can be considered as rightward slant meanwhile degree between 95° to 120° is considered as leftward slant. Meanwhile slant between 86° to 94° is considered as upright. The range of upright slant is determined because it is very hard to obtain an upright slant degree of exactly 90°.

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3 Associated Study

There have been many signature recognition studies since pattern recognition is introduced. The first subsystem in off-line recognition systems was segmentation. According to [4] the existing research has utilized many different approaches for segmentation in handwriting recognition. He argues that there are only a few researches on off-line signature recognition that have been made unlike online signature recognition which is widespread [5]. The author also states that offline signature lack any form of dynamic information. Signature feature such as number of stroke and the speed of writing cannot be captured because of its several limitations.

Online signature verification methodologies can be categorized into two types, one is parametric approach and the other is functional approach. In functional approach a very straightforward technique is usually taken as time independent function [9]. Each of the original point of the signature is used for verification. There are many methods of on-line recognition based on parametric approach [6]. In this approach the enrollment data size and computation is very small.

The preprocessing stage in off-line recognition is Gaussian smoothing, size normalization, translation, rotation and slant normalization [7]. There are two types of features that can be obtained during on-line recognition that is static feature such as maximum, minimum, average of writing speed, curvature measurement and length. Meanwhile, the dynamic features are the evolution of given parameter as function of time [9].

4 Approach & Methodology

4.1 Prototype Development

A Slant Identification System (SIS) Prototype is developed to test the algorithm. There are two major phases that was employed in this research methodology, specifically defined as prototype development and conducting experiment. This research will focus on recognizing the features of the signature instead of the character

4.1.1 Data Acquisition

The Genius MousePen 8”× 6” tablet with cordless wheel is used in this research. The tablet is capable of sampling data at 1024-level pressure sensitivity for all kind of shape and thickness. Figure 5 shows an example of the tablet used. The Genius MousePen started capturing samples when the pen tip touches the tablet which is connected to the computer.

Fig. 5: Genius MousePen 8”× 6” tablet

Figure 6 shows how the raw data is captured using the tablet. As the pen moves toward the right, the x point value will increase. Meanwhile if the pen moves in a higher position, the y value will decrease. The wide size of the tablet allows freedom of creating the signature by providing enough space for the signer. Data are captured in *y* and *x* position and mapped into grid in sequence. The next step is to group all significant points that can form one stroke. Next, all possible strokes will be accumulated and categorized.

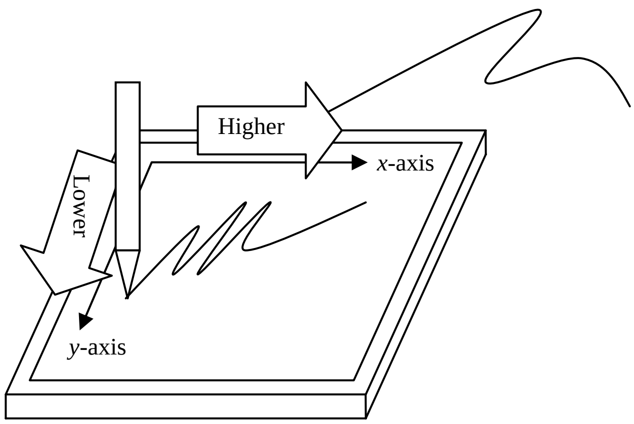


Fig. 6: Raw data captured from tablet

4.1.2 Data Filtering

In this phase, the position points are counted from when the pen touches the tablet until it is lifted up or when the angle of the connecting points changed within certain made rules as shown in table 1. If the amount of x and y points accumulated is less then 10 then the connecting points of data will be discarded from the process of extracting features, otherwise it will be stored in a list of possible slants.

In the end of the filtering stage, an accumulated list of raw unprocessed slant is acquired. This can increase processing speed where only the possible set points of data, which can form a slant, will be processed.

As shown in figure 7 a part of stroke in the ‘h’ character of the given signature shows an accepted stroke during the filtering process. This is due to the fact that the stroke contains more than ten points. Data filtering is done to avoid getting small samples of short strokes. These short strokes can affect the categorization output of the slant algorithm afterwards and must be discarded.

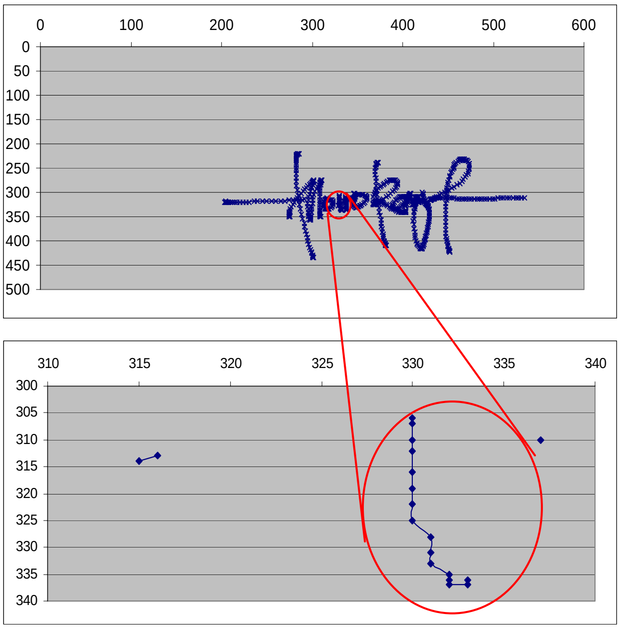


Fig. 7 Filtering stroke points

4.1.3 Feature Extraction

After the filtering steps, slant points are extracted from the accumulated slants list during the filtering stage in a form of x- and y-axis values. Two algorithms were proposed in this research to extract the slant features. The first feature to be extracted is the angle of the slant which is determined by mathematical function based on the value of first and last point of extracted slant. The angle will determine whether the slant attributes is left slant, right slant or upright slant (vertical). From the angle, the degree can be acquired by a mathematical function of (3). The entire accumulated slant list will be calculated for its angle and degree. The slant will then be categorized for their attributes as explained earlier. The dominating attributes will be selected as the global slant of the signature that will determine the overall signature slant.

5 Slanting Algorithm

5.1 Signature Data Attributes

The raw data acquired from tablet (Genius MousePen) consists of two dimensional series data of *x* and *y*:

$(xi, yi) \in R$
$i = 0,1,2,3,4,5,6,7,8,\ldots\ldots.,I$

Where $(xi, yi) \in R$ is the pen position referred to the *x*- and *y*-axis. At the starting point of the data *i* value will be equal to zero. The raw data gathered from the tablet shows that the smaller value in *y*-axis stand as the higher position of a stroke, and otherwise a higher value depict a lower position of a stroke. For *x*-axis, the higher value is towards the right side.

5.2 Design

From the acquired two dimensional series of *x* and *y* data, the possible slant is identified starting from the pen touches the tablet to when the pen is lifted up or when the direction of the slant changes between two points. Slant direction has been identified to be 8 possible directions as shown in figure 7

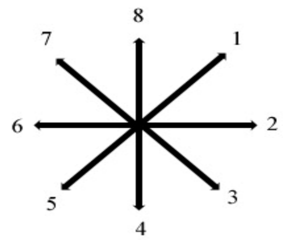


Fig. 7 Eight possible angle of slant

All these directions would be computed for the difference value of current point and the previous point:

Let point a $= (X_a, Y_a)$
point a-1 $= (X_{a-1}, Y_{a-1})$

Difference points $d(x) = (X_a - X_{a-1})$ (1)

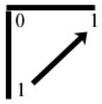
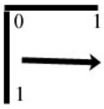
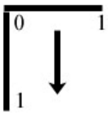
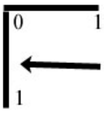
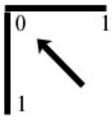
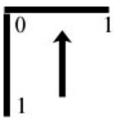
Difference points $d(y) = (Y_a - Y_{a-1})$ (2)

When the difference value is acquired, the direction of the slant can be identified.

5.2.1 Position & Direction

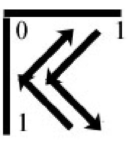
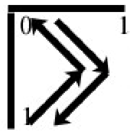
From the identified difference value, the slant is computed into 8 possible directions. The direction of the slant can be determined by analyzing the values whether it is lower than zero, higher than zero or equal to zero. Please refer to table 1 for better understandings of the point direction and direction rules.

Table 1: Possible Point Direction and Rules

No	Point Directon	Rules
1		WHEN d(y) is lower than zero AND d(x) is higher than zero THEN stroke is Right Up
2		WHEN d(y) is equal to zero AND d(x) is higher than zero THEN stroke is Right
3		WHEN d(y) is higher than zero AND d(x) is higher than zero THEN stroke is Down Right
4		WHEN d(y) is higher than zero AND d(x) is equal to zero THEN stroke is Down
5		WHEN d(y) is higher than zero AND d(x) is lower than zero THEN stroke is Down Left
6		WHEN d(y) is equal to zero AND d(x) is lower than zero THEN stroke is Left
7		WHEN d(y) is lower than zero AND d(x) is lower than zero THEN stroke is Left Up
8		WHEN d(y) is equal to zero AND d(x) is lower than zero THEN stroke is Up

When the direction is calculated, and if it is the first connecting point, it will be stored in temporary flag to keep track of its current direction. The next direction will be compared to the flag direction to detect any changes of direction. If the direction changes, it will calculate the number of points accumulated. If the accumulated point is more than 10, it will be accepted. Otherwise it will be discarded and a new point will be calculated, if it is not the end of the point list.

Table 2: Accepted direction change for curvy strokes

No	Direction Change	Rules
1		WHEN prevDir is equal to 7 AND curDir is equal to 1 THEN continue Or WHEN prevDir is equal to 5 AND curDir is equal to 3 THEN continue
2		WHEN prevDir is equal to 1 AND curDir is equal to 7 THEN continue Or WHEN prevDir is equal to 3 AND curDir is equal to 5 THEN continue

A number of direction change can be accepted due to slant of 'C', inverted 'C' or 'S' shaped strokes which is a bit curvy. The direction changes that are accepted as one stroke is as depicted in table 2.

As for any direction change to the left (6) and right (2). The stroke will still accumulate unless the significance of left and right is too big. This is done in order to avoid jagged edge of a stroke.

The entire possible slant stroke derived from the rules will be stored in a list of slant strokes. The acquired strokes is not yet been analyzed for its angle and degree. All the start point and end point of the strokes that have been gathered is used to calculate the angle and degree.

5.2.2 Angle Degree and Calculation

When the accumulated slant are acquired, the angle and degree are calculated using atan2, which is a two-argument function that computes the arctangent of y / x given y and x, but with a range of $(-\pi,\pi]$.

$$\text{Angle} = \text{atan2}(d(y)/d(x)) \qquad (3)$$

In this paper c++ programming language is used to apply this algorithm into the SIS prototype as c++ atan2 function calculates the arctangent of the two variables y and x. It is similar to calculating the arctangent of y/x, except that the signs of both arguments are used to determine the quadrant of the result. This is because atan2 finds the counterclockwise angle in radians between the x-axis and the vector (x, y) in two-dimensional Euclidian space. This function is applied as it is useful to find the direction from one point to another.

The degree of each two points is calculated by the equation in (4) since angle will be positive when measured counterclockwise and negative when measured clockwise.

$$\text{Degree, } \theta = (\text{Angle} \times 180) / \pi \qquad (4)$$

$$\text{Where } \pi = 3.142, \text{ radians} = \text{Degree} (\pi /180)$$

Therefore the degree for each pen position depends on the value of angle direction. The actual degree, θ is based on position and directions of each two point position are given by:

ΔD, Right & Up, $\theta = \theta$ WHERE $dy<0$ AND $dx>0$

ΔD, Right & Down, $\theta = 360 - \theta$ WHERE $dy>0$ AND $dx>0$

Δ D, Left & Up, $\theta = 180 - \theta$ WHERE $dy<0$ AND $dx<0$

Δ D, Left & Down, $\theta = 180 + \theta$ WHERE $dy>0$ AND $dx<0$

The degree of each slant will be calculated and classified into its category.

5.2.3 Slant Classification

According to [10], strictly determined classification of stroke in terms of category such as right, upright and left does not exist at all due to the variation of handwriting. He also mentioned that the predetermination of slope measurement is hard, very time consuming and prone to subjectivity.

For the purpose of this study, an objective measure of slant will be categorized as discussed earlier, and the range of left, right and upright is denoted as:

Degree, $\theta \in \{0° - 180°\}$
$60° > \theta > 85°$ } Degree, θ = right slant
$86° > \theta > 94°$ } Degree, θ = upright slant
$95° > \theta > 120°$ } Degree, θ = left slant

Once the slant is sorted out, the dominating slant category is selected as a global slant.

5.3 Application of the Slant Algorithm

In order to accomplish the objective of this study, a development of slant algorithm is required. In order to realize the development of the slant algorithm, a systematic plan and design is constructed as a guideline to the research. This section will explain the design flow and development of the slant feature recognition algorithm. The process of creating the slant algorithm will be explained in detail by using figures, and flowcharts.

5.3.1 Algorithm Process Flow

As explained earlier, the flow of the algorithm started by acquiring the raw data of the signature in *x* and *y* values. The connection of these values will form the signature when mapped to the signature grid.

These values are then analyzed using predefines rules to extract the slant stroke. Please refer to table 1 and table 2 for the extraction rule. The extraction of the stroke process can also be addressed as the filtering process. This is because, during the extraction process, only long strokes with more than 10 points will be accepted and used.

After the filtering process is finished, the entire slant stroke is calculated for its angle and degree. The calculation of degree is made using the equation (4). Then, the angle and degree of the stroke will be classified to its category. The process will repeat itself until the entire filtered stroke is determined for its degree and categorized to its group. Finally, the algorithm will check the most dominant category of the slant in order to classify the overall signature slant category.

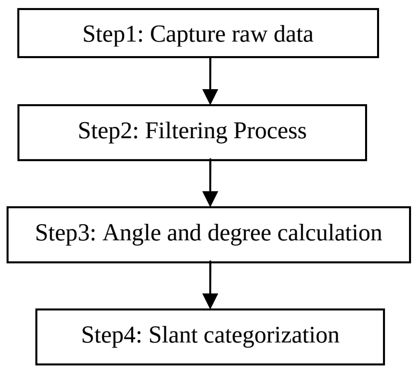


Fig. 8 Algorithm Process Flow

The process flow is best summarized using the flowchart in figure 8. The process flow of the algorithm is divided to four major steps.

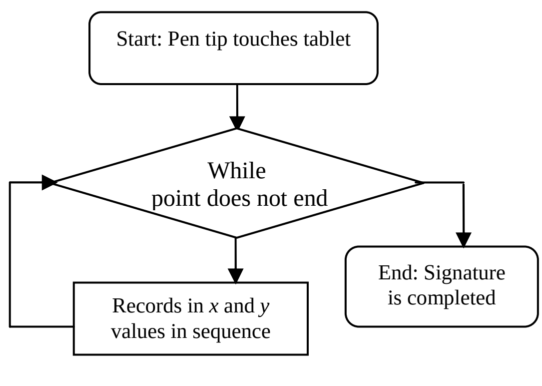


Fig. 9: Step 1 Process Flow

In order to fully understand the algorithm process flow, the algorithm process flow is broken down to four main processes. The first phase is depicted in the process flow in figure 9. During the first phase, it is shown that the x, and y points is recorded until the signature ends.

The acquired raw data of x and y values is used to represent the signature form. As the x values increases, it shows the movement of the signature stroke from left to the right. Meanwhile as the y values increases, it shows the signature stroke is moving downward. This happens as the data representation of the tablet recorded a higher y value as the stroke moves to the bottom part of the tablet.

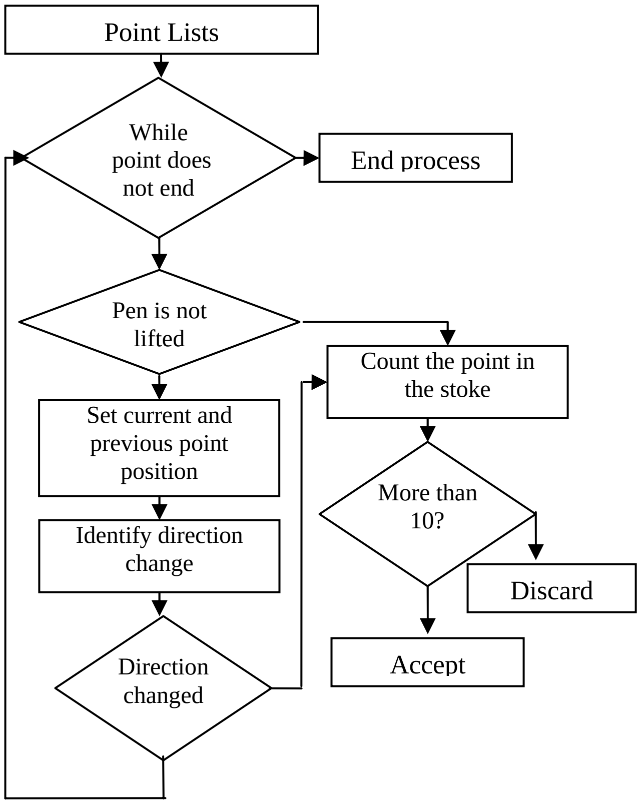


Fig. 10: Step 2 Process Flow

After completing the first step, the entire signature x and y values is filtered to acquire a slant stroke suitable for slant angle, degree and categorization process. The process flow of the filtering step is best described using the flowchart in figure 10.

As the filtered process is finished, a slant stroke list will be acquired. Nevertheless, the slant angle and degree is not yet calculated. In order to classify the slant category, the angle and degree information of the entire slant list is needed. The entire slant list is calculated for its angle and degree in the third step as depicted in figure 11.

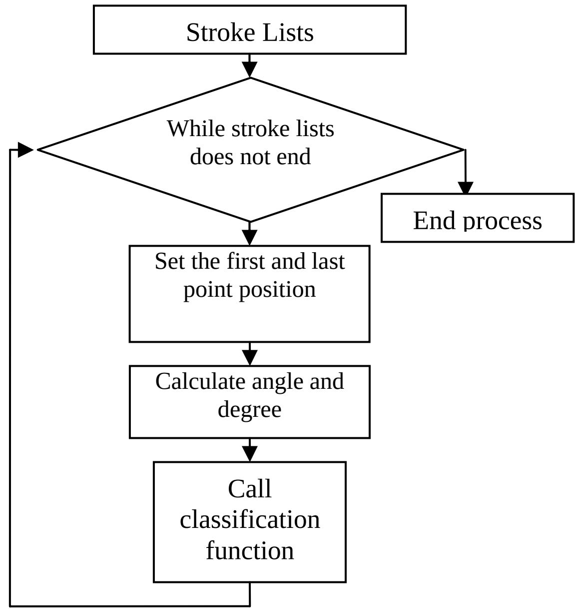


Fig. 11: Step 3 Process Flow

In the third step, the entire filtered slant list is calculated for its angle and degree. The process will end when the entire stroke is determined for its angle and degree.

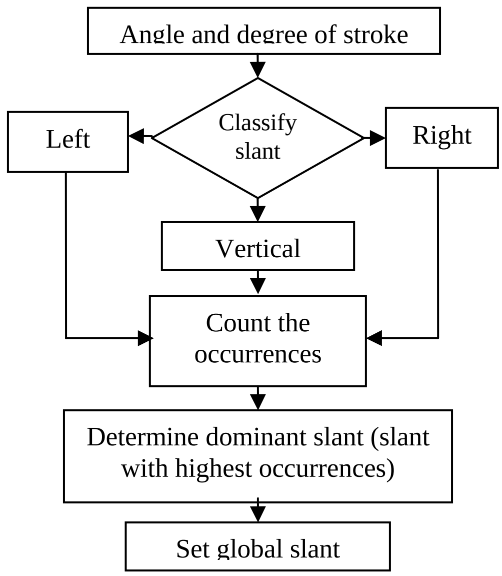


Fig. 12: Step 4 Process Flow

This is followed by the final step. In the final step, the stroke is classified for its slant category and segregated to its group. The occurrence of each category is recorded in order to identify the dominant category. In the end the signature slant will be classified according to the most dominant category. This is described in the flowchart in figure 12 below.

6 Results and Findings

The results are tested with desired range and the results are as in table 3:

Table 3: Result 1

No	Right	Up	Left	Local	θ°	Global	Max	Min
1	3	0	0	Right	74	Right	74	62
2	6	2	0	Right	77	Right	83	65
3	3	1	2	Left	115	Right	77	74
4	6	0	0	Right	65	Right	81	61
5	4	0	0	Right	82	Right	82	64
6	2	3	0	Up	88	Up	95	88
7	5	3	0	Right	73	Right	80	61
8	0	0	1	Left	99	Left	99	99
9	5	3	2	Right	70	Right	81	70
10	6	3	0	Right	62	Right	82	62
11	4	1	2	Right	79	Right	81	64
12	5	1	0	Right	62	Right	79	62
13	5	3	0	Up	84	Right	83	69
14	2	0	0	Right	83	Right	83	71
15	0	3	0	Up	85	Up	91	85
16	3	4	1	Up	87	Up	90	85
17	2	0	0	Right	67	Right	67	65
18	1	0	0	Right	67	Right	67	67
19	Undetected							
20	0	1	0	Up	96	Up	96	96
21	5	2	0	Up	84	Right	78	63
22	2	2	4	Right	63	Left	113	100
23	1	3	2	Up	91	Up	92	87
24	1	1	0	Right	62	Equal RU		
25	2	1	3	Left	119	Left	119	97
26	4	0	0	Right	77	Right	81	61
27	2	0	0	Right	79	Right	79	65
28	0	1	0	Up	91	Up	91	91
29	2	2	2	Right	63	Equal All		
30	4	1	2	Right	74	Right	80	68
31	3	1	2	Left	98	Right	71	63
32	2	1	2	Right	82	Equal LR		
33	9	1	2	Right	60	Right	83	66
34	2	0	0	Right	74	Right	82	74
35	4	7	2	Up	95	Up	95	84
36	2	0	1	Right	76	Right	76	63
37	10	1	5	Up	90	Right	80	63
38	1	1	1	Up	92	Equal All		
39	9	5	4	Right	67	Right	78	66
40	4	1	2	Left	101	Right	76	61
41	5	3	3	Right	78	Right	80	70
42	4	2	1	Up	89	Right	75	62
43	3	2	1	Right	74	Right	83	73
44	2	2	4	Left	104	Left	117	100
45	1	0	1	Right	68	Equal LR		
46	4	2	2	Right	70	Right	83	61
47	10	2	3	Right	74	Right	82	65
48	1	1	0	Right	75	Equal RU		
49	1	1	3	Up	86	Left	111	103
50	6	2	5	Right	80	Right	82	67

The result of the acquired slant looks promising as the result shows 98% signature can be identified for its slant. From all 50 signature analyzed, 49 signature slant are detectable and only one signature did not produce any results. In order to get better result, the algorithm is modified for the range of the stroke degree and number of accepted points in one stroke. The values are modified as follows.

While Points must be more than 6;
Degree, θ ϵ {0° - 180°}
50° > θ > 85° } Degree, θ = right slant
86° > θ > 94° } Degree, θ = upright slant
95° > θ >130° } Degree, θ = left slant

The algorithm is tested again with the same signature, and changes are depicted as in table 4

Table 4: Changes in Result 2

No	Right	Up	Left	Local	θ°	Global	Max	Min
1	3	0	1	Right	74	Right	74	62
2	12	5	5	Right	77	Right	83	54
3	6	2	3	Left	115	Right	80	60
4	18	4	4	Right	65	Right	83	51
.	…	…	…	…	…	…	..	..
18	1	1	2	Up	92	Left	116	101
19	3	0	0	Right	60	Right	78	60
20	2	1	0	Up	96	Right	69	53
21	10	2	1	Up	84	Right	82	51
.	…	…	…	…	…	…	..	..
48	4	2	0	Right	75	Right	75	59
49	3	1	5	Right	53	Left	111	102
50	8	3	8	Right	80	Equal LR		

The results have shown an increasing number of strokes detected in every signature. Some strokes that is not identifiable before is attained and classified. As we can see signature number 19 slants is identifiable when the range of rule is changed. However, the new results have affected several slant classification change from the earlier results. We can see the changes in signature 50. This may due to the increasing number of stokes identified. The algorithm is then tested with 10 created proofed samples. The result of the 10 samples is predefined before it is tested with the algorithm. Table 5 shows the indicator of the 10 signature predefined proofed samples.

Table 5: 10 Predefined proofed samples.

Signature 1	Right
Signature 2	Right
Signature 3	Left
Signature 4	Left
Signature 5	Left
Signature 6	Right
Signature 7	Up
Signature 8	Up
Signature 9	Right
Signature 10	Up

After acquiring the 10 proofed samples, the algorithm is tested and the results are as shown in table 6.

Table 6: Result of 10 created proofed samples

No	Right	Up	Left	Local	Θ°	Global	Max	Min
1	6	1	1	Right	74°	Right	75°	64°
2	5	0	0	Right	66°	Right	80°	60°
3	4	4	6	Left	99°	Left	118°	99°
4	1	4	12	Left	104°	Left	118°	98°
5	7	5	4	Right	79°	Right	81°	62°
6	13	2	1	Right	57°	Right	83°	65°
7	3	7	3	up	92°	Up	96°	84°
8	2	2	1	Mixed	87°	-	-	-
9	7	2	0	Right	78°	Right	78°	61°
10	7	9	3	Right	75°	Up	96°	89°

The result shows a favorable accuracy of 80% correct slant identification. This is identified when eight out of ten signatures is able to be identified for its correct slant feature.

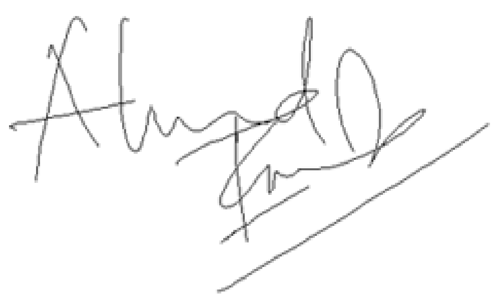


Fig. 13: Signature 5

Signature 5 shown in figure 13 shows a complex signature that may looks like a left slant. Due to the high sensitivity of the slant identification algorithm, it is categorized as a right slant. Meanwhile signature 8 as shown in figure 14 is predefined as a vertical slant. The algorithm result shows the same amount of Right and vertical slant thus making it impossible for the algorithm to determine the dominating slant. This setback may be enhance in adding new rules or applying advanced technique such as fuzzy inference or neuro fuzzy inference for the classification of the signature slant.

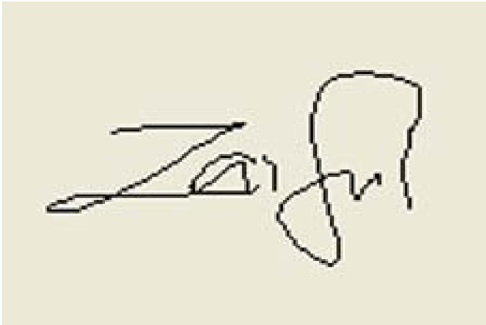


Fig. 14: Signature 8

7 Recommendation

Upon the successful creation of the slant algorithm, the slant feature of the signature is able to be identified. As, explained earlier, the understanding of how the slant is identified is very important. The slant of the signature is identified by performing several steps. Firstly the signature raw data is captured in x and y values, then it is filtered to acquire the slant strokes. After acquiring all the slant strokes, angle and degree of all the strokes is calculated. Then the stroke is classified with its slant category. Finally, the signature slant is categorized by identifying the dominant slant classification. The slant algorithm is carefully designed and developed.

This paper has contributed a way to identify signature slant. The algorithm was successfully tested by the SIS prototype. The SIS prototype is able to extract stroke and classify its slant from a sample signature.

Although the result looks promising, the SIS prototype needs to be calibrated for the best result. The most appropriate range and points to be considered is yet to be determined. Many new techniques can be applied in order to enhance this flaw such as fuzzy inference and neural network to adapt the best range value of the classification of slant. It is hoped this paper can contribute some knowledge in signature recognition.

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