Handwritten Character Recognition for Automated Evaluation of Malaysian Primary Schoolers' Handwriting Readability

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ABSTRACT

Examinations are no longer obligatory for Lower Primary School children in Malaysia as they now would be assessed with PBD, a more objective classroom-based assessment. While it may reduce issues such as peer pressure and depression among children, however, PBD would also impose high workload to the teachers, which in itself could be another reason for less objective and inconsistent evaluation due to stress. Therefore, this study aims to explore the in-depth aspect of handwritten character recognition technique that will be able to evaluate the readability of students' handwriting based on the criteria established for a writing assessment. Results obtained from preliminary data analysis show that contour based feature, statistical features, structural features, and global transformation and moments features sets that are the techniques with the ability to extract all five (5) features of a handwritten word which match the criteria that measures handwriting readability that are size, space, slant, line quality, and formations.

Introduction

Reading, writing, counting and understanding have been identified by the Malaysian Ministry of Education (MOE) as the four basic skills (4M) which are necessary to be obtained by primary school attending pupils in Malaysia[1]. Therefore, in accordance of said objective, an initiative in a form of a classroom-based assessment which measures the 4M performance of the pupils has been proposed in place of the traditional examinations [2]. The nurturing of these skills starts right from the very beginning of the students learning process, which is when they enrolled in school at the age of seven years old.

To assess and evaluate the above skills for the first three years of schooling, MOE has further strategized to use classroom-based assessments (PBD) instead of examination-based, as an approach. This is in acknowledging few research findings such as [3] which stated that students have high stress level mainly due to pressure from examination-based assessments. In addition, in a survey involving 1,200 teachers by a national school support service in United Kingdom (UK), it was found that stresses involving anxiety and panic attacks had shown tremendous increase in almost 78% of primary schools over the past years.

Facing the immense pressure from the current education system which mandated children aged 7 and 11 to sit for national standardized tests, known as SATs, students were believed to overexert themselves in striving for the best result just so they could fit into the excellence narrative brought by the examination [4].

Hence, PBD, which is formative in nature shall be conducted continuously throughout the early learning years, with the evaluation results of each assessment shall be used to improve the attainment of the skills by each student through proper interventions. To ensure implementable and successful evaluations of the skills, standard evaluation schemes are provided to teachers in order to guide them during assignment of scores. However, despite having highlighted that better objective evaluation as the basis for PBD assessment, the objectivity of the evaluations could still be compromised as the teachers might be influenced by factors such as personal issues, biased judgement as well as selective favoritism [5]. Furthermore, with the usually large number of primary schoolers to be handled by teachers, PBD would also impose high workload to the teachers, which in itself could be another reason for less objective and inconsistent evaluations due to stress. The above, i.e., stress, has been highlighted in a study conducted by University of Missouri, which found that 93% of the 121 elementary school teachers who participated in the study were highly stressed due to the demands imposed by their profession [6]. Based on the outcome of the study, it was deduced that the primary source of stress came from the students, such as students with behavioural problems and difficulty in coping with their studies, earning them lower grades and poorer results.

Hence, aiming to resolve the issue of non-objectivity and inconsistency which could occur during a PBD's assessment evaluation, a study is formulated to conduct an in-depth investigation on how PBD evaluation could be executed in a fair and square manner with the help of information technology's techniques. In order to narrow down the breadth of the study, writing skills, in particular handwriting readability of first year primary schoolers has been chosen as the focus for investigation, and handwriting character recognition as the technology to be adopted. Even though there are many techniques already existed to recognize handwriting characters, none has been fully developed to recognize and assess the writing based on certain criteria, especially in Malaysia. This is because most research studies conducted were focusing more on interpreting what the computer has received into readable text such as [7], while none really looked into evaluating the recognized

handwritten characters according to certain criteria such as readability, especially for primary school pupils [8].

The further explain, the intended study, the next section shall present some backgrounds on handwriting issues pertaining to primary schoolers. The section will be followed by the methodology to be carried out for the study, and after that, the results and findings from review of literature on handwriting recognition that could be adopted by the study as solution for automated handwriting readability evaluation. The paper ends with a conclusion section and future plan of work.

Handwriting Skills and Primary Schoolers

2.1.   Recurring Concerns over the Current Education System

Assessing the writing skills of a child, especially one of a 7 years-old, may be perceived as an easy task as it requires them to write down very minimal letters or numbers that they have learnt. Regardless, this could be deemed a challenge for the teachers, especially when handling children who struggle with handwriting as they suffer some kind of writing problems. For instance, according to [9], the most common handwriting problems are poor formation of letters due to the awkward grasp of the pencil which may cause the unreadability of the child's handwriting. However, this is not an information that is knowledgeable to all teachers as they tend to focus more on the outcome instead of looking for the root cause which caused such outcomes. Thus, this could easily affect the way their teachers assess them, further demotivating them in cases of undeservingly earned low grades [10].

Compared to the previous decade, today's generations are much more progressive in terms of technological application, placing the educators at a disadvantage in the classroom due to their inability of integrating the use of technology which makes it harder to retain the attentiveness of the students in class [11]. Attaining students' interests in learning is one thing, keeping up with the highly intense demands of learning is another [6].

Today, information is within a hand's click but that is not the case with the out-of-date current education structure. Sticking to the strict discipline of learning from the outdated textbooks which further stifling the creative way of thinking among students, the existing practices of education could be perceived as failing to provide students the supports they needed to pursue their passions nor enhance their hidden potentials [12]. This is why technology should start being applied in schools as it helps students to gain information in a more advanced way, allowing them to experience an individualized learning and unleash their creativity, thus fulfilling their satisfactions and optimizing their daily productivity in school [11][12].

2.2.   Problems Faced by Children in Handwriting

Instead of a strictly examination-oriented assessment, pupils will now be assessed through different means such as observations, flash quizzes, group projects, essay writing and even drawings, depending on the teachers who will be in-charge of handling the classroom [13]. This is where the fundamental of this research lies on, the implementation of 4M-based assessment, an assessment which seeks to help pupils in nurturing their four basic skills; reading, writing, counting and understanding. Therefore, learning all of these, especially writing, is the most crucial element needed by a child prior to enrolling for school as it helps them to express themselves.

However, there are still cases of children aged 7 to 9 struggling to write on their own. According to [9], there are three common problems of handwriting among children that still could be fixed which causes the increasing level of stress and anxiety among them, especially when they are at school. One of them is difficulties in precisely differentiating letter shapes which triggers the confusion between letters of the similar shape such as lowercase a and e. Lowercase letters are especially harder to write than capital ones due to their smaller size with the addition of more curves and edges [14]. However, the more a child practices as he grows up, the more they are able to write steadily in a fluent rhythm. There are also problems with spacing which are required for Roman alphabets, written left to right. It takes children longer time to be able to tell the differences between the distances of each words before recreating them onto a paper as the spaces between letters also have to be considered [9][14].

Aside of the common problems faced by children, there are issues which may indirectly cause trouble with writing for them because when kids are struggling in writing, they may not only have a hard time with writing but they also have to put up with the difficulty of expressing their ideas by writing. This is a disorder which may be caused by dysgraphia, a learning issue which affects either one of the aspects or even both of them at once. Despite being able to speak their mind, children with dysgraphia often have to put up with the troubles of putting their thoughts into written word, even if they have a neat handwriting [6]. Other than the challenging expression of thoughts being written into words, dysgraphia also causes the disorganization of ideas among children as they could hardly write even simpler sentence structure, let alone interpret their proposition into written characters [15]. Thus causing all the ideas to be jumbled up due to the children's inability of converting them into scribbles of words.

Moreover, there are more to what causes the struggles of writing among children than merely dysgraphia such as hearing problems. Children with Attention Deficit Hyperactivity Disorder (ADHD) will hardly able to translate their thoughts into coherent words, perceivable by those who read what they have written [16]. It is inevitable that children with ADHD loathe writing due to the demanding act of writing which requires them to exert more forces to be able writing even just a single letter [16][17]. This is caused primarily by the limitations on their motor skills that developed much slower than their peers. However, that is no excuse to get discouraged as students with ADHD are still able to note down perfect sentences as long as they keep practising in the right way and focus more on what they intended to speak of [17].

2.3.　　Handwritten Character Recognition – The Architecture

Handwritten Character Recognition (HCR) is an optical recognition that converts documents written by hand into machine readable format, depending on the extraction of features and use of classifiers. For this technique, digital scanner will scan the various types of handwritten documents before transforming them into an ASCII code-like format. As shown in Figure 3, there are two categories in HCR which are on-line and off-line character recognition system. The former is for recognition that takes place while the characters are still being created, while the latter is for recognizing either handwritten documents or printed papers that are already captured and stored into the computer [18].
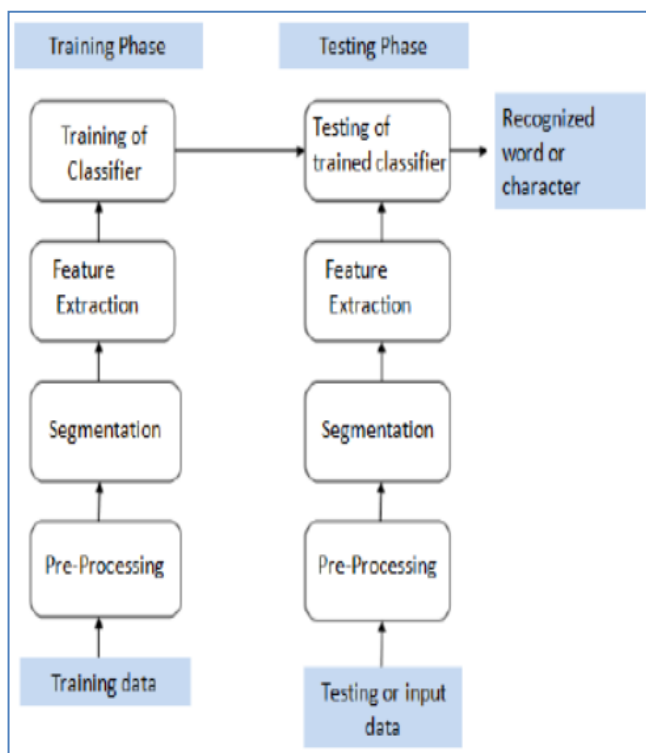
Figure 1. Block Diagram of HCR System

Features extraction is the most crucial phase in any recognition system as it enhances the rate of recognition by extracting all the important features of the scanned images which, in this case, comes in a form of the strokes containing distinctive information [18]. As there are many different categories that could be used to extract the feature which are statistical, structural and global transformation methods, therefore, the techniques used in extracting the attributes also vary according to unique features of the strokes in the raw data from the pre-processed coordinates [19].

The stage prior to feature extraction, segmentation, where the input images will be converted into individual characters depending on the types of segmentation, plays crucial role in classifying handwriting data. There are three types of segmentation [20]:

1.　　Line segmentation
a.　　Separates the lines from a paragraph, subdividing the paragraph of several lines into that of a single line
2.　　Word segmentation
a.　　Separates the words from a line, depending on the word spacing in-between as words will be separated by longer spaces while sub-words will be separated by shorter spaces due to the disconnection of characters to a subsequent character in a word
3.　　Character segmentation
a.　　Separates characters from a word, splitting them into individual characters

In addition to that, there are also variety of techniques which could be implemented for segmentation of characters such as segmenting based on vertical projection, segmenting based on thinning, segmenting based on ANN and many more [19]. Relying based on the sole fact that the thickness of the connecting strokes between the characters in a word will be lesser than the others, vertical projection is where two-dimensional information is diminished into that of one dimension.

Feature extraction is where features are extracted thus creating a feature vector, are divided into different categories which are statistical features, structural features and hybrid features, a combination of both features [21]. More explanation on feature extraction will be discussed in the later part of this paper, Section 4.2 The last stage before data is finally recognized is the classification step. The data set that has been gathered will be separated into two data sets, which are training and testing. To recognize an object or images, the tested features will be compared to those of the trained classes, given that training classes and model will be provided [21]. Furthermore, the presence of a training model is essential as it contains a set of instances where the correct output for every input has been prepared beforehand. Hence, classifier will be used in identifying an object based on the features before comparing them and saving them as the training models right after [19].

Research Methodology

With the interests of developing a handwriting recognition technique for evaluating handwriting readability of 7-years old primary schoolers in Malaysia, a research framework was designed for the study. As shown in Figure 1, the framework is divided into four (4) major activities consisting of preliminary data gathering, conceptual framework, data collection, image processing on sample data including the deduction of standard rules in writing which will be performed in feature extraction phase, evaluation of the result and lastly, research finalization.

However, for this paper, only the details of the preliminary data gathering and data collection components shall be shared as the study is still currently in the phase of data collection.

For this study, the preliminary data gathering phase will be divided into literature search and actual data collection.
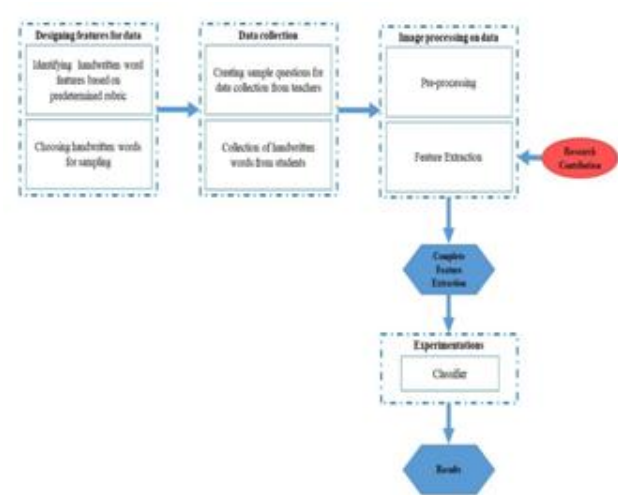
Figure 2. Proposed Research Framework

Literature search was conducted to find suitable handwriting recognition techniques that can be adopted and adapted for this study on handwriting readability.

Using several online search facilities such as IEEE Xplore Digital Library, ACM Digital Library, ScienceDirect and the like, more than 135 journals and papers of conference proceedings were downloaded while approximately 70 were referred to in this paper using the search terms such as "handwritten recognition", "handwriting readability", "standard metrics for handwriting readability" and "feature extraction techniques in recognizing handwriting".

The articles were then assigned to several groups such as according to techniques that they proposed, case studies that they used and others. The groups were then analysed for suitability to be incorporated into the design of the study's handwriting readability technique.

Figure 3. Sample Template in Capturing Students' Handwriting

On the other hand, for the actual data collection, draft of questions to be asked to the teachers who are involved in teaching handwriting to first year primary schoolers was prepared. The questions include inquiries such as the significance of mastering the skills of writing well at their young age, the importance of technology in assisting teachers during the assessment and helping the students in improving their handwriting. Besides, template to capture students' handwriting was also prepared as in Figure 3.

Results & Discussions

4.1. Handwriting Criteria and Types of Features Extracted

In assessing the readability of one's handwriting, standard criteria need to be established as to avoid the inconsistency in evaluation. In a study of issues regarding subjectivity of lecturers and standardizing the works of those of similar modules but from different courses, [22] stressed the importance of maintaining consistent standards in each evaluated work as different modules hold various ranges of students' group size. Due to the expanding size of the group, it becomes increasingly hard for lecturers to ensure that the consistency in assessing students could be attained [23] as different people have different perceptions and understandings. Hence, this is why it is essential that every educators abides by the standard criteria that is agreed upon by all as it reaffirms the validity of students' assessment results [24].

It is the same when it comes to the assessment of handwriting readability. Due to the subjective perception of teachers towards their students' handwriting, the need for an established set of writing criteria is extremely critical at this point. This is supported by [25] through their study in achieving consistency of a legibility assessment conducted globally. The key to that consistency was due to the list of standardized criteria that have been established beforehand of which all participating teachers must comply with. Table 1 shows the standard criteria that were typically looked into in most research studies, with regards to handwriting assessment.

Table 1. Criteria for Handwriting Assessment

CRITERIA / REFERENCE	SPACE	SLANT	GAP	HEIGHT	SIZE	FORMATIONS	TIME	ALIGNMENT	LINE QUALITY
[26]	/	/	/	/	X	X	X	X	X
[27]	/	/	/	X	/	X	X	X	X
[28]	/	/	X	X	/	X	X	X	/
[29]	/	/	/	X	/	/	X	X	X
[25]	/	X	X	X	/	/	/	X	X
[30]	/	/	/	X	/	/	X	X	X
[31]	/	X	/	X	/	X	X	X	X
[32]	X	X	X	X	X	X	/	X	X
[33]	X	/	X	X	/	/	/	/	X
[34], [35], [36]	X	X	X	X	X	X	X	X	/
[37]	X	/	X	X	/	X	X	X	/
[38]	/	/	X	X	/	/	X	/	/
[39], [40]	/	/	X	X	/	/	X	/	X
[41]	/	/	X	X	/	/	/	/	/
[42]	/	X	X	X	/	/	/	/	X
[43]	/	X	X	X	/	/	/	/	/
[44]	/	/	X	X	/	/	X	/	/
TOTAL 21	**14**	**12**	**5**	**1**	**15**	**11**	**6**	**8**	**10**

From the table above, every studies except for [32], [33], [34], [35], [36] and [37] agreed that adequate space in handwritten words is one of the most important criteria to be looked into when assessing how readable a handwritten word is. Furthermore, slant and formations of the handwritten words are also crucial in determining the readability of a handwriting as both of them are the few features that are mostly observed in an assessment, as shown in 12 and 11 total studies which referred to them respectively. Lastly, size, the most sought-after criteria in evaluating handwriting as 15 out of 21 studies seem to agree that size of handwriting is vital in determining the rate of readability of a handwriting is. To deduce, based on the comparison of criteria in assessing handwriting used by the research listed, focus on evaluating the readability of one's handwriting would definitely be on the size, space, slant as well as formations of the handwritten words, as shown in Table 1.

4.2. Feature Extraction – Purposes Behind the Technique

Handwriting recognition could be significantly used for variety of purposes, including measuring the rate of readability of one's handwriting, so is determining the right technique in extracting features for assessing handwriting. The selection of technique should match with the purpose of research study that is conducted due to the difference in ability of feature extraction in extracting specific features of different types of characters.

The right and precise use of feature extraction is crucial as it helps in generating accurate results as needed while achieving the intended objective of the study. However, prior to determining the proper feature extraction technique, the purpose of each handwritten character recognition technique shall be first analysed.

This assists a study in deciding which technique will be the most relevant for their research, especially one that concerns with evaluating the readability of a handwriting.

Table 2. Purpose of HCR and the Feature Extraction Technique Used

Purpose	Author	Feature Extraction Technique
To recognize handwritten words / characters	[45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64]	a) Multi-Level Local Phase Quantization descriptor b) Histogram of Gradient descriptor c) Gabor filters responses descriptor
		a) Statistical geometric components of straight lines (SGCSL)
		a) Discrete Cosine Transform b) Discrete Wavelet transform
		a) Box method b) Diagonal Distance c) Mean d) Gradient Operation e) Hybrid Features
		a) Gradient b) Structural c) Concavity
		Histogram of oriented gradients (HOG)
		a) Structural Features b) Regional Features c) Gradient Features Distance Transform Features
		a) LBP Features b) Directional Features c) Regional Features
		a) Statistical Approach b) Structural Approach c) Global transformations and moments
		d) Statistical Approach e) Structural Approach f) Gradient Feature Extraction g) Principle Component Analysis
		Structural Approach
		Statistical Approach
		a) Structural Approach b) Statistical Approach
To identify and authenticate the name of students	[65]	a) Modified direction Technique b) Gaussian Grid Technique
To determine cheque words	[66], [67], [68]	a) Statistical sets • Gravity center distance and pixel density • Ink crossings and profile features
To recognize handwriting in ancient transcripts	[69], [70]	Text line extraction
		Contour Based Features
	[71]	Histogram of oriented gradients (HOG)
To measure the legibility of a handwriting	[72]	Pattern Matching
To detect gender based on the written words	[73], [74]	Gabor filter bank
		Global features
To detect written digits	[75]	Histogram of oriented gradients (HOG

From the table above, it could be concluded that most of the feature extraction techniques are mainly used for recognizing handwritten words or characters. Furthermore, statistical and structural sets are the two most commonly approaches sought by most studies, such as [66], [67], [68], in extracting features of handwritten words. However, in terms of measuring readability of handwritten words, very few studies would ever approach the topic on a broader aspect. Even if there is, these studies are limited to observing the important criteria needed in assessing handwriting readability, such as [31], [32], [33], [34], [35], and [36]. Therefore, by reviewing the criteria of assessing handwriting readability along with the relevant feature extraction techniques as shown in Table 1 and 2, it helps in determining the precise criteria and techniques that shall be used in evaluating the readability of one's handwriting for this study.

4.3. Feature Extraction – Types of Character and theCriteria

For most literatures which studied handwriting, they have identified few unique features that enables the recognition of the handwritten document in a variety of language scripts. In a study by [76], a binary matrix that was originally measured 15×12 in size, obtained by performing binarization, was reshaped into that of 180×1 in size so that the optimum size for identified feature vector of the characters shall be extracted from the samples. Other than

that, the method of extracting structural features from the skeleton of a string of characters or a word in their image form, which included loops, junction points, lines which indicates the number of horizontal and vertical lines in the pre-processed image [77], and endpoints, was perceived as discriminative due to the minimum rate of error it could produce [55]. The features recognized will then be calculated before they were stored in a feature vector for classification purposes in the later step.

Another example of feature extraction of a statistical set is profiles features, a relative distance of the first ink pixel position from the border. They represent the shape details of a particular character which will then be separated into eight different directions with each having equally distributed stripes [66].

As one of the most commonly used features, the geometrical attributes of images captured will be illustrated by the structural features through the description of their local and global traits. Often, these features depended on the categories of the pattern that are to be classified. Features extracted for Arabic texts usually included strokes, the direction, the width and height of the strokes as well as the position of the dots in the Arabic letters [78]. Other than that, there are statistical features of which a statistical set from distribution of the local features will be derived. Prior to the deriving of the set, the spatial division of pixels will be analysed by taking every local feature at each pixel into account [19].

Table 3. Extraction of Features that Match the Criteria of Readable Handwriting from Different Types of Character with Relevant Feature Extraction Techniques

TYPE	STYLE	AUTHOR	TECHNIQUES	CRITERIA				
				SPACE	SLANT	SIZE	FORMATIONS	LINE QUALITY
Arabic	Cursive	[45]	a) Multi-Level Local Phase Quantization descriptor b) Histogram of Gradient descriptor c) Gabor filters responses descriptor	X	X	X	X	X
		[58]	Triangle Shape Feature	X	/	/	/	X
		[63]	a) Structural Approach b) Statistical Approach	/	/	/	/	/
		[46]	a) Statistical geometric components of straight lines (SGCSL)					
		[59], [64]	Structural Features					
Thailand		[65]	a) Modified direction Technique b) Gaussian Grid Technique					
• Arabic • English		[74]	Global features					
German		[69]	Text line extraction	X	X	X	/	/

Language		Ref	Features					
English		[70]	Contour Based Features	/	/	/	/	/
Gurmukhi		[52]	a) LBP Features b) Directional Features c) Regional Features	X	/	/	X	X
Devanagari		[51]	a) Structural Features b) Statistical Features c) Gradient Features d) Distance Transform Features	/	/	/	/	/
		[49]	a) Gradient b) Structural c) Concavity	/	/	/	/	X
• Gujarati • Bangla • Arabic		[50], [61], [71]	a) Histogram of oriented gradients (HOG	X	/	/	X	X
• Numerals • Thailand		[60], [75]						
English	Regular	[59] [48]	a) Hybrid of Box method, Diagonal Distance, Mean and Gradient Operation features	/	/	/	/	X
		[53]	a) Statistical b) Structural c) Global transformations and moments	/	/	/	/	/
		[55]	a) structural Approach	/	/	/	/	/
		[73]	a) Gabor filter bank	X	/	/	/	X
		[65]	a) Modified Direction Features (MDF)	/	/	/	/	/
Arabic		[47]	a) Discrete Cosine Transform b) Discrete Wavelet transform	X	/	/	X	X
		[57]	a) Statistical Feature b) Structural Feature	/	/	/	/	/
Malay		[66], [67], [68]	a) Statistical sets • Gravity center distance and pixel density • Ink crossings and profile features					
Devanagari		[54]	h) Statistical Approach i) Structural Approach j) Gradient Feature Extraction k) Principle Component Analysis					
Taiwan		[72]	a) Pattern Matching • Completion Time • Stroke Force • Stroke Velocity					
Urdu		[56]	Statistical Approach					
Chinese		[62]	a) Structural Approach b) Statistical Approach					

Table 3 shows the features extracted from different types of written which match the criteria in evaluating handwriting readability with each having used variety of feature extraction techniques. From the table, it could also be deduced that the most frequently used technique that will be the most compatible in extracting criteria for assessing handwriting readability are contour based features, statistical features, structural features, and global transformation and moments features sets[53][57][59][62][63][64]. Upon conclusion, these techniques are among those with the

ability to extract all five (5) features of a handwritten word which match the criteria of handwriting readability that are size, space, slant, line quality and formations.

Conclusion

This research aims to fulfil three research questions at the end of the study by achieving the research objectives. Firstly, in determining the right rubric necessary for handwriting readability assessmentof Year One pupils in Malaysia, an in-depth interview with primary school teachers will be conducted and a writing session will be held for Year One pupils. Secondly, in assessing theeffectiveness of Handwritten Character Recognition in capturing images and features of handwritten characters, existing methods are studied and planned into a structured literature review. Thirdly, a proposed alternative to objectivelyevaluate the handwriting readability of the pupilswill be developed based on the modified handwritten character recognition techniques. As of now, the research is focusing on extracting the features from the handwritten data sample of Year One pupils.

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