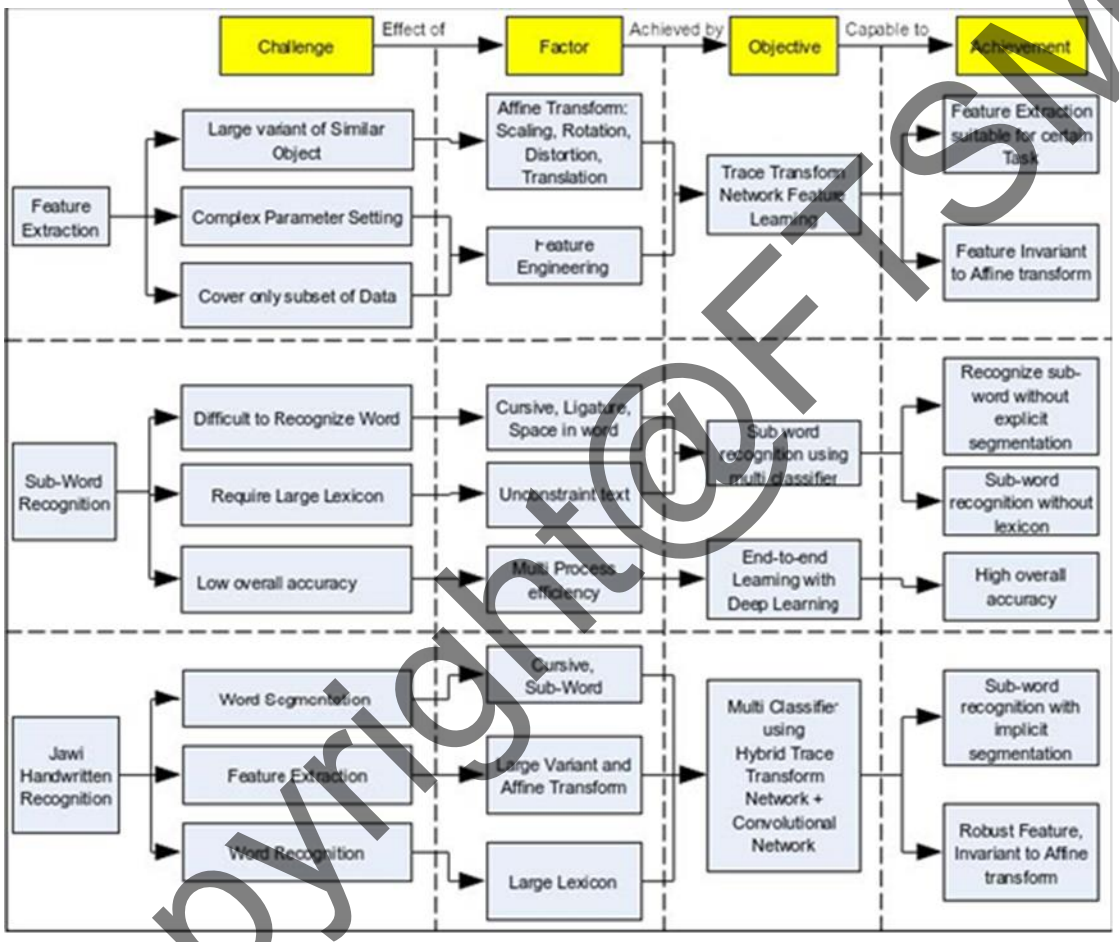
Skim Geran Penyelidikan Fundamental (FRGS)
Laporan Teknik
Status Laporan Teknik: Dijana Urusetia CRIM



PICTURE RELATED TO THE RESEARCH PROJECT

PROJECT TITLE: Trace Transform Feature Learning for Offline Jawi Handwritten Recognition
PROJECT CODE: FRGS/1/2016/ICT02/UKM/01/1

PROFIL PENYELIDIKAN SKIM GERAN PENYELIDIKAN SKIM GERAN PENYELIDIKAN FUNDAMENTAL (FRGS)

JAWI SUBWORD HANDWRITTEN RECOGNITION USING MULTIMODAL SHARED REPRESENTATION

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Field:/FASA1/2016/Information And Communication Technology/UKM

ABSTRACT

Jawi handwritten subword recognition still an open problem. Previous researchers use separated components, or single modalities (e.g., text or images) with explicit or implicit segmentation, or only using suitable small size lexicon data to learn features over single modalities. Improvement in each component didn't translate directly to the improvement of Jawi handwritten subword recognition accuracy. This research proposes the Deep learning (DL) algorithm to learn features over multiple modalities. In particular, we demonstrate cross modality feature learning, where better features for one modality (e.g., images) can be learned if multiple modalities (e.g., images and text) are present at feature learning time. Using additional layer of structure prediction, implicit segmentation approach using DL algorithm with end to end learning solve the recognition of Jawi subword images. Because of lack of Jawi image data, structure prediction (SP) learning will have limited lexicon and by using multimodal shared representation (MSR) approach, SP learnings are handled by predict missing modality of jawi image by using modality from jawi text learned from corpus. Jawi text content with labeling image training of jawi subword are transform into MSR. Using character level model of jawi text to represent the subword relation in form of combination of character in MSR. Jawi images are recognize using convolution neural network (ConvNet) to provides candidate of character which position and relation are learned from MSR which will present the candidate subword recognized. The output of this proposed approach will improve the performance of Jawi subword recognition without manually define the rules with expensive prior knowledge and easily applied to script similar to Jawi such as Arabic, Farsi, Urdu and Pashto. The usage of multimodal input will make the MSR usable for other tasks which benefit the researcher in document analysis and recognition, computer vision and natural language processing.

1. INTRODUCTION

1.0 RESEARCH STRUCTURE

The research structure as depicted in Figure 1 composed of three main components. The objectives were formulate as followed:

1. To propose Trace Transform Network feature learning.
2. To propose lexicon-free Multi-Classifier Jawi Handwritten sub-word recognition
3. To propose Hybrid Trace Transform Network with Convolutional Network features learning for multi-classifier Jawi handwritten sub-word recognition

The achievement of these objectives as shown in figure 1 reflex the contribution of this research.

Three major focus of this research are identified and shown in research structure. First, Feature Extraction which is major component in handwriting recognition. Second, Sub word recognition is which is unique problem of Jawi and other Arabic scripts descendant. Third is solving the main domain problem in Jawi handwritten recognition.

1.1 Features Extraction

The features extraction has the challenges represent the similar object, which has large variant because of the effect affine transformation. This affine transformation including scaling, rotation, distortion and translation. This factor happen because handwriting have variance of medium and writer with different style of writing. Previous research try to handle this problem with features engineering but facing the challenges of complex parameter setting to get robust features. However, even with lots of tuning parameter and evaluation, its only cover subset of data and performance is consider sub par. Therefore, this research propose the Trace Transform Network feature learning. Feature learning extract features from object for optimize for certain task. Using Trace Transform which invariant to affine transformation, feature learning adjust the parameter of Trace Transform to get better parameter according to data thus cover whole subset of data and has generalization capabilities.

1.2 Sub word recognition

Sub word recognition is second focus of this research. This problem cause by nature factor of Jawi scripts which are cursive, has ligature, overlap between character in words and contains space inside the word because of disconnected type of characters. Therefore, instead try isolated and recognise word, the Jawi research focus on sub word recognition and handle word recognition as post-processing. These factors cause word recognition challenges in Jawi handwritten recognition.

Previous Jawi handwritten recognizer using analytical approach try to solve sub word recognition, however facing bigger problem of character recognition which is cause lost information and lower overall accuracy. holistic approach facing problem with large possible lexicon class which causing lower classification result.

Furthermore, large lexicons are requires because un-constraint nature of Jawi handwritten. It further complicate the word recognition.Therefore, this research focus of solving the sub word recognition problem instead of the word recognition and handle word recognition as the next task after sub word recognition.

Previous research propose multiple stages processing and component to overcome this problem. However, each of the component are isolated and evaluate independently thus in-effect and has low overall accuracy of word recognition. This research propose end-to-end learning using Deep Learning approach using multi-classifier. It remove the requirement to do explicit segmentation and improve system parameter from pre-processing until post-processing.

1.3 Jawi Handwritten Recognition

Finally, this research conducted to overcome Jawi handwriting domain problems as it have historical and sentimental value. Jawi handwritten is cursive and has large variance of writing style its require robust word segmentation, features extraction and word recognition. This research propose the robust recognizer by propose robust feature extraction using hybrid feature learning and multi classifier to produce robust Jawi handwritten sub word recognizer. The state-of-the-art Convolutional Network feature learning which is robust local features combine with Trace Transform Network which is global feature learning will handle affine transformation and adversarial problems to better handle variance of Jawi handwritten.

2. RESEARCH METHODOLOGY

2.0 EXPERIMENT DESIGN

The experimental design is an experimental layout that undertaken by the authors to allows the final output to be analysed and formulated throughout this study. Figure 2 illustrates the experimental design that divided into two main phases; the investigation phase and implementation phase. Each phase has several tasks that are then consolidated into a systematic module. Two initial modules, namely the identification problem and literature review are in the investigation phase.

2.1 Investigation Stages

In this stage, the domain problems are identified and analyzed, and the solutions are proposed based on improvement on previous research and the state-of-the-art approach. Investigations on domain and subjects are conducted in the early phase of the study. In this phase, the background of problems, trends and issues around the domain of issues are explored to get an overview of the research to be made. Factors that lead to problems are also structured. This overview is useful for identifying the subject or topic to explore. Based on the overview, the problem statement and the next research objective are specific. After that, theoretical framework, the importance of the study and the scope of the study are also be formulated. Among the important topics being explored are the general outline of offline Jawi handwritten recognition,

strategies in the text recognition system, issues surrounding previous research, feature extraction with feature engineering and feature learning, recognition strategy, deep learning overview and trace transform features.

2.2 Implementation Stage

This phase contains implementation based on experimental design formulated in this research. This stage will discuss about data collection and pre-processing, performance evaluation and Research tools. Following section will discuss detail implementation of Feature learning using Trace Transform Network, sub word recognition using Multi classifier, Hybrid Trace Transform Network with Convolutional Network. Finally, Evaluation of the result, discussion and analysis.

It also means each experiment in each module will be measured and its performance will be analysed. A detailed discussion of each of these modules is included in each section. However, the summary is as follows:

i. Development of Trace Transform Network Feature Learning. In this module, Feature Learning type of Trace Transform Feature are developed based on work on Weight Trace Transform (Srisuk et al. 2006) and inspire by Deep Learning approach in Convolutional Network. Trace Transform Network consist of Trace functional layer which similar with Convolutional layer. This layer will produce feature map in form of sinogram. Diametrical function will act as sub sampling process similar with pooling layer in Convolutional Network. This module were run using algorithm based on (Shin et al. 2008) which uses by Mohammad Faidzul Nasrudin (2010) to generate suitable Trace transform features for Jawi handwritten. This algorithm generate object signature of Jawi handwritten image using equation in (1).

$$\mathrm{II}(f) = \Phi[P[T[f(r, \theta, t)]]] \quad (1)$$

The algorithm for this module given bellow (Anton, 2019):

1. Define 3 parameter of Trace transform:

   t, distance between subsequent point in each trace line

   p, distance between trace line in image

   ϕ, number of trace lines generate in full circle (360 degree).

2. Select the function T, P, and Φ

3. For each ϕ, calculate the trace function, $T = [(r,,)]$to generate trace transform image.

4. Calculate the diametric function, $P = [[(r,,t)]]$ to produce object signatures features which generate based on trace line row.

ii. Multi Classifier implementation using only one fully connected network (FCN) classifier for targeted whole sub word in dataset. This multi-classifier used to recognize sub-word (Jawi sub-word recognizer) without explicitly segmented the character from sub-word but instead using implicit approach where character in sub-word recognize by each of sequence of classifier. The classifier will semantically try segmented the sub-word into characters. The classification component of the Jawi sub-word recognizer, consist of input layer, which an output from features learning layers following ReLu, hidden layer and final ReLu non-linearity. The last output layer will consist of fix size of classifier with regard to dataset maximum characters sequence in sub word. Jawi dataset standard maximum length of characters sequence in sub-word is 7. Each classifier target 51 class of jawi letter and symbols. The length classifier to further validate the correct output and improve the semantic capability of features learning implicitly segment the letter in sub-word.

Using multi-classifier Jawi handwritten recognition will recognize the sub-word by predicting the input length and provides correct sequence of letter using each classifier to determine probability of letter in that position of sequence. Given power of data representation of feature learning with multi-classifier each letter are implicitly, classified into sub-words.

iii. Hybrid Trace Transform Network with Convolutional Network explained to discuss the combination both approach which has its own strength. The advance research on Convolutional Network will multiple approaches and architecture, and implementation so it can be use as bases and improved with robust and invariant feature capabilities of Trace Transform Network will improve overall performance of Multi classifier Jawi handwritten sub-word recognition.

3. LITERATURE REVIEW

Jawi is subset of Arabic writing used to write Malay language with additional character to support non-existence phoneme of Malay language. There is tremendous amount of unexplored Jawi historical handwritten manuscripts which yet to studied because require Jawi expert which are very limited. Therefore, digitalization and further processing will simplify the information retrieval of manuscripts. There are lot of research on Jawi handwritten recognition (Nasrudin et.al, 2010), most of the research are conducted on limited lexicon and still shown relative low accuracy. Therefore, the Jawi handwritten recognition still considered open problem. The problem consists of lots variant of writing style, ligature, dialect and the low quality of the manuscripts images (Yahya et. al, 2010).

Previous research of Jawi handwritten recognizer contains multiple component handle each steps of process in order to recognize the sub-word (Omar 2000, Manaf 2000, Heryanto et al. 2008, Heryanto 2019, Redika et al. 2008, Nasrudin 2010). This

approach depend on high performance of each component and which most of the time, improvement of one component not necessary improve overall performance of the application. The training process mostly only improve classification components.

Most of the approach can be categories into explicit segmentation and implicit segmentation. Explicit segmentation (Lorigo and Govindaraju, 2006). The explicit segmentation requires more component in order to segment the raw image of sub-word into character, but mostly false positive result mostly affect the overall performance of systems. Whereas the implicit segmentation provides imaginary segmentation which mostly focus on overall sub-word recognition without concentrated on the correctness of segmentation of character but rather on sub-word overall performance. Its sometimes more robust on false positive recognition as whole performance are the priority.

State of the arts of handwritten recognition consist of major components of pre-processing, features extraction, classifier post-processing components. Most of the approach only suitable for limited lexicon. The training approach mostly on character level because word level training requires more training samples.

The robustness of the features extraction play major roles to the overall handwritten recognition performances, as the features extraction output will be the inputs for classifier which produces the end products of the handwritten recognition. But, the problem faced as the features extraction mostly only sensitive to specific subset of training data and loose its generative capabilities to more broad variant of testing data. It's because the features extraction is handcrafted and predicted suitable theoretically with the object to recognized.

Handcrafted features or feature engineering require extensive parameter tuning in order to able to handle variant of sample. Simple variant of writing style, ligature, and affine transformation of the data will lead to confusing output to classifiers, which lead to worst overall performance of the handwritten recognizers. As the component are independent the improvement at training level on classifier not propagate to features extraction as the features extraction are hand tuned. Previous Jawi Research using feature engineering of geometrical features (Omar, 2000, Manaf 2002, Heryanto et al. 2008, Heryanto 2019, Redika et al, 2008, Nasrudin 2010, Azmi 2013), but not really perform well for variant of Jawi writing scripts.

Using Convolutional Network as Learning features proven to be successful in handwritten recognition and recently object recognition (Krizhevsky, et. al, 2014). Learning features optimize the data representation of specific tasks. The features parameter are optimized by learning the features end to end with data. Given the advance of Deep learning architecture which were layer of neural could be stacked more than 2 layer and able to represent the features space of object target (Hinton et. al, 2006), this achieved with improvement in backpropagation learning method with dropout and rectified linear unit which improve learning for multiple layer without overfitting or under fitting the network model (Srivastava et. al, 2014).

4. FINDINGS

This research proposes three main objectives, first the use of Deep Learning approach where training is conducted end-to-end from input to class output, which enable the improvement of each Jawi handwritten recognition component to improve overall performance. Secondly, the use of Trace Transform Network as feature learning to address the features engineering approach by optimizing the data representation through end-to-end training of the parameters from raw input data to target class. This feature learning are more robust to Affine Transformations compared to the state-of-the-arts Convolutional Networks feature learning. Lastly, in order to recognize sub-word, this research proposes a multi-classifier approach, which implicitly segments the sub-word into sequences of characters. The classifiers consists of one sub-word length classifier and seven character classifiers. This approach is lexicon-free to address absent of lexicon data. This research also proposes a hybrid of Trace Transform Network with Convolutional Network feature learning with the advantage of combined robustness of global and local features of the respective networks to further improves the overall performance of the recognizer. Experiments conducted on a Jawi handwritten standard dataset showed an accuracy of up to 93.10% and suggest that the approach used is superior to state-of-the-art methods of Jawi handwriting recognition.

5. CONCLUSION

Based on the motivation and issue found the Jawi handwritten research problems which based described by research structure in Figure 1, the Jawi handwritten problem can be solve with end-to-end learning using deep learning approach which enable to classify the sub word into sequences of character by implicitly segment the character inside the sub word using robust representation of features learning.

The improvement in Trace transform feature from feature engineering approach to feature engineering approach, significantly improve the recognition performance of Jawi handwritten recognition compare to previous state-of-the-art. The feature learning approach improve the parameter of feature based end-to-end training from input image sub word to sequence of character classified.

The evaluation on features learning strategy of Trace Transform shown that each weight in trace line or angle has effect on features learning capabilities. Depend on parameter and task to handle this strategies still open to evaluate which one is suitable for given task as it depend on task to handles. In context of Jawi handwritten recognition, using trace line weight or the angle weight is more suitable because combination of weight in trace line and causing more free parameter which require more training data.

Multi-classifier approach try to solve problem in Jawi domain where lexicon available is limited However Jawi historical manuscript is unconstraint with large possible lexicon required. by providing sequence of character as output which is similar with the

analytical approach result but still using holistic approach, enable further improvement when the lexicon is available. the architecture choice using deep learning approach enable to extends the network with improvement of injection of prior knowledge or adding the structure predictor to improve the sequence combination.

This research try to produce the new state-of-the-art Jawi handwritten recognizer by hybrid the best local feature learning with extensive research using Convolutional Network with propose Trace Transform Network Global Feature Learning combine with multi classifier. This approach open large of possibility of improvement with more dataset available, improvement on architecture, adding structure predictor and extend with multi modal share representation with Jawi text to improve character sequence combination and produce correct Jawi text not only in sub word level, but further to word, phrase and sentences which enable information retrieval on Jawi historical manuscripts.

The uniqueness of this study lies in the introduction of Trace transform Network features learning which will act as robust global features. This research explore more on the strategy of Trace Transform as feature learning which not explorer by previous research, which are following:

1. The uses of trace function weight not only on trace line but on angle and combination of both which enable more variant of feature representation of the image for given task.
2. Multi classifier approach shown that possible using feed forward neural network to handle sequence problem in Jawi sub-word recognitions.
3. The feature learning using Deep learning approach with end-to-end learning which enabled the combination with existing state-of-the-art architecture and techniques.

ACHIEVEMENT

1. Name of articles/manuscripts/book published

RELATED PUBLICATION	
1	Laporan Penyelidikan: Jawi subword handwritten recognition using multimodal shared representation: data preparation; Khairuddin Omar, Anton Heryanto, Mohammad Faidzul Nasrudin, Azizi Abdullah, Siti Norul Huda Sheikh Abdullah, Zamri Murah, & Abdul Aziz Azri.;Intelligent Collaboration; 2017
2	Laporan Penyelidikan; Pengecaman Bentuk Huruf Jawi Berasaskan Khat Arab Menggunakan Rangkaian Neural Berasaskan Algoritma Rambatan Balik; Fatimah Adnan & Khairuddin Omar; PTA-FTSM-2017-030; 2017

3	Laporan Penyelidikan: Pengecaman Huruf Arab Menggunakan Teknik Rangkaian Neural; Nur Suriza Syazwany Ahmad Nizam & dan Khairuddin Omar; Intelligent Collaboration; 2017
4	Laporan Penyelidikan: Pengecaman Huruf Jawi Tunggal Menggunakan Pengelas Perambat Balik;Abdul Aziz Azri & dan Khairuddin Omar; Intelligent Collaboration; 2017
5	Jurnal: Sitti Rachmawati Yahya, Khairuddin Omar, Siti Norul Huda Sheikh Abdullah, Ali Sophian; International Journal on Advanced Science, Engineering and Information Technology; 2018
6	Jurnal: Anton Heryanto, Khairuddin Omar, Faidzul Nasruddin; International Journal on Advanced Science, Engineering and Information Technology;2018
7	Laporan Penyelidikan: Khairuddin Omar, Anton Heryanto, Mohammad Faidzul Nasrudin, Azizi Abdullah, Siti Norul Huda Sheikh Abdullah & Mohd Zamri Murah; LP-FTSM-2019-002; 2019

2. Title of paper presentations (international/local)

1. THE 4TH INTERNATIONAL MULTI-CONFERENCE ON ARTIFICIAL INTELLIGENCE TECHNOLOGY (M-CAIT 2018), Fakulti Teknologi dan Sains Maklumat, UKM,01/11/2018-03/11/2018;

3. Talent

PhD Student

1. ANTON HERYANTO(P52862) - finished

2. RAMI SALAH EDDIN YOUSIF SIHWAIL(P91206) - ongoing

Master Student (GRA)

1. ABBAS SALIMI BIN ZAINI (P80692) – finished

REFERENCES

Azmi, M. S., Nasrudin, M. F., Omar, K., Ahmad, C. W. S. B. C. W., & Ghazali, K. W. M. 2013. Exploiting features from triangle geometry for digit recognition. In *2013 International Conference on Control, Decision and Information Technologies, CoDIT 2013* (pp. 876-880). [6689658] DOI: 10.1109/CoDIT.2013.6689658

Heryanto, A., 2019. Jawi Handwritten sub-word recognition based on Trace Transform Network. Ph.D thesis, Universiti Kebangsaan Malaysia.

Heryanto, A., Nasrudin, M. F., & Omar, K. 2008. "Offline Jawi handwritten recognizer using hybrid artificial neural networks and dynamic programming," in Information Technology, 2008. ITSim 2008. International Symposium, vol.2, no., pp.1-6, (26-28 Aug. 2008)

Fiscus, J. G. 1997. A post-processing system to yield reduced error word rates: Recognizer output voting error reduction (ROVER). In IEEE Workshop on Automatic Speech Recognition and Understanding, pages 347–354.

Geng, Xin, Zhou, Zhi-Hua, & Kate Smith-Miles. Automatic age estimation based on facial aging patterns. TPAMI, 29(12):2234–2240, 2007.

Hinton, G. E., Osindero, S. & Teh, Y.-W., 2006. “A fast learning algorithm for deep belief nets.” Neural Comp. 18, 1527–1554.

Järvelin, K & Kekäläinen, J. 2002 Cumulated Gaon-Based Evaluation of IR Techniques. ACM Transactions on Information Systems (TOIS) 20, 422-446.

Kanungo, S., Duda S., & Srinivas Y. 1999. “A Structure Model for Evaluating Information Systems Effectiveness”. System Research and Bahavioral Science, Vol. 16, pp 495-518.

Krizhevsky, A., Sutskever, I. & Hinton, G. 2012. “ImageNet classification with deep convolutional neural networks.” In Proc. Advances in Neural Information Processing Systems 25 1090–1098.

Lorigo, L. M., & Govindaraju, V., 2006. Offline Arabic Handwriting Recognition: A Survey. IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 28 No. 5 (2006) 712–724

Levenshtein, V. I. 1966. Binary codes capable of correcting deletions, insertions, and reversals. Soviet Physics Doklady, 10:707–710

Manaf, M. 2002. “Jawi Handwritten Text Recognition Using Recurrent Bama Neural Networks (in Malay),” PhD Thesis, Universiti Kebangsaan Malaysia.

Manning, C.; Raghavan, P.; and Sch¨utze, H. 2008. Introduction to information retrieval. Cambridge: Cambridge University Press.

Nasrudin. M. F., 2010. Offline Jawi Handwritten Recognition using Trace Transform (in Malay). Ph.D. thesis, Universiti Kebangsaan Malaysia.

Nasrudin, M. F., M. Petrou, L. Kotoulas, 2010. "Jawi Character Recognition Using the Trace Transform," in Computer Graphics, Imaging and Visualization (CGIV), 2010 Seventh International Conference, vol., no., pp.151-156, (7-10 Aug. 2010)

Omar, K, 2000. “Jawi Handwritten Text Recognition Using Multi-Level Classifier (in Malay),” PhD Thesis, Universiti Putra Malaysia.

Redika, R., Omar, K., Nasrudin, M. F., 2008. "Handwritten Jawi words recognition using Hidden Markov Models," in Information Technology, 2008. ITSim 2008. International Symposium, vol.2, no., pp.1-5, (26-28 Aug. 2008)

Shin, B., Cha, E., Cho, K., Klette, R. & Woo, Y. 2008. Effective feature extraction by trace transform for insect footprint recognition. ” in 3rd International Conference on BioInspired Computing: Theories and Applications. IEEE, sep 2008, pp. 97 – 102.

Srisuk, S., Petrou, M., Kurutach, W. & Kadyrov, A. 2006. A face authentication system using the trace transform 8: 50–61.

Srivastava, N., Hinton, G., Krizhevsky, A., Sutskever, I. & Salakhutdinov, R., 2014. Dropout: a simple way to prevent neural networks from overfitting. J. Machine Learning Res.15, 1929–1958.

Yahya, Sitti Rachmawati, S.N.H. Sheikh Abdullah, K. Omar, M.S. Zakaria, & C.Y. Liong, 2010. “Review on Image Enhancement Methods of Old Manuscript with the Damaged Background.” International Journal on Electrical Engineering and Informatics. 2(1): 1-14. ISSN 2085-6830.

Yates, Baeza, Ricardo and Ribeiro-Neto, Berthier. 1999. Modern Information Retrieval. ACM Press, New York. Addison-Wesley.