Metaheuristic Optimization on Conventional Freeman Chain Code Extraction Algorithm for Handwritten Character Recognition

Muhammad A. Mohamad(✉), Habibollah Haron, and Haswadi Hasan

Faculty of Computing, Universiti Teknologi Malaysia, UTM, 81310 Johor Bahru, Johor, Malaysia
marif.utm@gmail.com, {habib,haswadi}@utm.my

Abstract. In Handwritten Character Recognition (HCR), interest in feature extraction has been on the increase with the abundance of algorithms derived to increase the accuracy of classification. In this paper, a metaheuristic approach for feature extraction technique in HCR based on Harmony Search Algorithm (HSA) was proposed. Freeman Chain Code (FCC) was used as data representation. However, the FCC representation is dependent on the route length and branch of the character node. To solve this problem, the metaheuristic approach via HSA was proposed to find the shortest route length and minimum computational time for HCR. At the end, comparison of the result with other metaheuristic approaches namely, Differential Equation (DE), Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and Ant Colony Optimization (ACO) was performed.

Keywords: Harmony search algorithm · Freeman chain code · Handwritten character recognition

1 Introduction

Handwritten Character Recognition (HCR) is the ability of a computer to receive and interpret intelligible handwritten input then to analyze many automated process system [1]. The major problem in HCR system is the variation of the handwriting styles, which can be completely different for different writers [2]. The objective of HCR is to implement user friendly computer assisted character representation that will allow successful extraction of characters from handwritten documents and to digitalize and translate the handwritten text into machine readable text. However, after many years of intensive investigation and research, the main goal of developing character recognition system still remains unachieved [3].

Generally, HCR can be divided into three stages namely preprocessing, feature extraction and classification. Preprocessing stage is to produce a clean character image that can be used directly and efficiently by the feature extraction stage. Feature extraction stage is to remove redundancy from data. Classification stage is to recognize characters or words. Nowadays different methods are in widespread use for character recognition.

Recognition accuracy of the image depends on the sensitivity of selected features. Hence, number of feature extraction methods can be found in the literature [4]. Feature

N.T. Nguyen et al. (Eds.): ACIIDS 2017, Part I, LNAI 10191, pp. 518–527, 2017.
DOI: 10.1007/978-3-319-54472-4_49

extraction can be defined as extracting the most representative information from the raw data, which minimizes the within class pattern variability while enhancing the between class pattern variability. For this purpose, a set of features are extracted for each class that helps distinguish it from other classes, while remaining invariant to characteristic differences within the class [5]. A good survey on feature extraction methods for character recognition can be found in [6].

This paper only concentrates on feature extraction stage of a HCR. Feature extraction stage in HCR is a very important field of the image processing and object recognition system because it is used by classifier to classify the data. The basic task of feature extraction and selection is to find out a group of the most effective features for classification that is by compressing from high dimensional feature space to low-dimensional feature space and to design classifier effectively [7]. Fundamental component of feature extraction is called features. As in many practical problems, it is often not easy to find those with most effective features [8]. This makes features extraction and selection as one of the most difficult and challenging tasks in pattern recognition system, data mining, and other fields.

There are many algorithms for feature extraction and selection. Recently, interest in feature extraction and selection has been on the increase with the abundance of algorithms derived. This algorithm can be classified into two namely heuristic and metaheuristic approaches. Many heuristic algorithms have been proposed in the literature for finding near–optimal solutions [9, 10]. GA is one of metaheuristic approach and has been widely used to solve feature extraction and selection problems [11–13].

In this paper, feature extraction and selection technique based on metaheuristic algorithm is explored using a Harmony Search Algorithm (HSA). HSA were applied successfully in many areas such as computer science, electrical engineering, civil Engineering, mechanical engineering and biomedical application. Summarization of application of HSA can be found in [4].

In this paper, Freeman chain code (FCC) is selected as the representation of a character image. FCC is one of the techniques representations based on the boundary extraction which useful for image processing, shape analysis and pattern recognition. Chain code representation gives a boundary of character image where those codes represent the direction of where is the location of the next pixel. Unfortunately, the study about FCC construction using one continuous route and minimizing the length of chain code to FCC from a thinned binary image (TBI) has not been widely explored. To solve this problem, metaheuristic methods are used to extract the FCC that is correctly representing the characters. Therefore, this paper proposed the HS-FCC extraction algorithm in handwritten character recognition.

This paper is organized as follows. Section 2 presents the related work. Section 3 describes the methodology. Section 4 describes the HS-FCC extraction algorithms proposed. Section 5 presents the parameter value setting. Section 5 describes the result and discussion and followed by a conclusion in Sect. 6.

2 Related Work

Chain code is one of the representations technique based on the boundary extraction which useful for image processing, shape analysis and pattern recognition. The first approach of chain code was introduced by Freeman in 1961 that is known as Freeman Chain Code (FCC) [14]. There are many kinds of chain code algorithms, which have been developed through extension of FCC and enhancement of chain code. Previous work in the literature about chain code representation can be found in [15–17]. There are two type of directions of chain code, namely 4-neighborhood and 8-neighborhood. This paper utilizes 8-neighbourhood in extraction of characters. The challenge of the chain-coding process would be very much on the way of the image would be traversing and the starting point of the traversing method [18]. A start point of a character will produce a different chain code direction even though is the same image. Randomly, the start point in a character is selected and then the best solution is searched.

Metaheuristic method is used for minimizing the length of the chain code. The main problem in representation characters using FCC is the length of the FCC that is depends on the starting point, the branching node and the revisited walk. To solve this problems, metaheuristic is used to generate the FCC which has the ability to produce FCC correctly in representing the characters.

In [19] the metaheuristic approach has been used in FCC extraction for HCR. The main problems in FCC representation technique as previously stated have been a motivation in using the metaheuristic approach to solve the problem. Thus, FCC extraction technique via metaheuristic approach i.e. Differential Evaluation (DE), Particle Swarm Optimization (PSO), Genetic Algorithm (GA), and Ant Colony Optimization (ACO) has been proposed. The proposed algorithms were used to extract the FCC from handwritten character image that is Thinned Binary Image (TBI). In the proposed algorithm, three solution representations were used in representing a character to minimize the FCC length namely character transformation into graph, graph is a solution representation, and metaheuristic approach. The role of the proposed algorithms is to minimize the objective function of the solution representation. The objective function is to express the quality of FCC solution and is defined as the number of nodes which the FCC must visit from the starting node until all of the nodes are visited. Then, using their particular characteristics, every approach tries to find a collection of good FCC solutions which minimize the FCC length. Route length and computation time were selected in this experiment because they are depending on starting point and automatically affected on the route length and how many time it needs to solve the chain code. This method enables them to extract and recognize such difficult character in relatively shorter computational time and route length. The proposed algorithm is evaluated based on route length and computation time. The result shows that in term of route length, PSO obtained the lowest compared to DE, ACO and GA. Meanwhile, for the computational time, DE obtained the fastest computation time compared to others.

Harmony search algorithm (HSA) is one of the recent metaheuristic that inspired from the musician performance that search for the better state of harmony [20]. To date, HSA has been applied to many engineering optimization problems including structural engineering [21–23], structural materials [24–26], hydraulics [27, 28], cost optimization

and construction management [29, 30], and structural vibration control [31]. Application of HSA in HCR that was implemented in [32] for recognition-based segmentation of online Arabic text was applied in the recognition stages instead of feature extraction phase using dominant point detection to extract the features. In contrast, in this paper HSA application was proposed to be applied in the feature extraction phase since as far as literature concern, HSA have not been implemented in feature extraction.

Therefore, in this paper the HS-FCC extraction algorithm is proposed in HCR that is harmony search (HS) algorithm is used for optimizing (minimize) the length of chain code. The proposed HS-FCC extraction algorithm is the similar study of application of metaheuristic (DE, PSO, GA and ACO) that was conducted by [19]. At the end of this study, the result in FCC extraction algorithms for HCR between the proposed metaheuristic algorithm (DE, PSO, GA and ACO) in [19] and the proposed HSA is compared.

3 Methodology

There are three stages in the proposed methodology. First, by using input character that is digitized, thinning is performed as pre-processing stage in the HCR. The output of TBI is a skeleton is used in feature extraction stage. This work applied thinning algorithm that is proposed by Engkamat [33] in extracting the FCC. Second, the representation of pattern is needed in the feature extraction stage. In this case, FCC is selected and is used to represent the character. Finally, the desired output of chain code is obtained. The proposed HS-FCC extraction methodology of HCR is shown in Fig. 1.

Fig. 1. The Proposed HS-FCC Extraction Algorithm

The experiments on the HSA algorithms are performed based on the chain code representation derived from established previous works of Centre of Excellent for Document Analysis and Recognition (CEDAR) dataset. The scope area is isolated handwritten on upper-case characters (A–Z). The pixel input of original CEDAR and its output TBI is 50×50 pixels.

4 Proposed HS-FCC Extraction Algorithm

The HS algorithm is used to extract the FCC from handwritten character image that is Thinned Binary Image (TBI) as shown in Fig. 2. A generation of FCC from a binary image can be modelled as a route of a graph problem. Initially, the binary image is transformed into a digraph which consists of vertices and edges. The vertices of the graph is taken from node which has only one neighbor and the node which have

neighbors more than two. In meantime, the edges of the graph are come from nodes which have two neighbors connecting the vertices from before. The lengths are obtained from the total number of nodes between two vertices. The complete graph can be seen in Fig. 3.

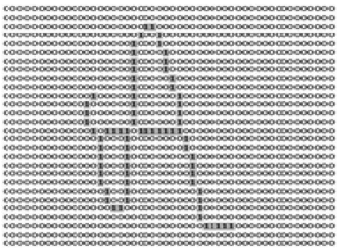

Fig. 2. Binary Image of "A" Handwritten Character

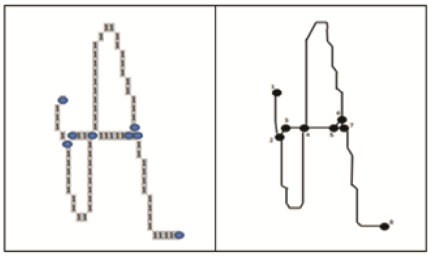

Fig. 3. Character Transformation of Fig. 2 into Graph

The proposed HS-FCC extraction algorithm uses a sequence of edges to represent the FCC solutions. The edge is used as the solution representation. An edge is derived and ended from the same node. Two different edges can be derived from the same node or can also ended in another same node too. Thus, one edge can visited twice and as a result the solution representation can have a complete tour since a revisit to the previous visited nodes is often needed. The objective function is defined as the number of nodes which the FCC must visit from the starting node until all of the nodes are visited (revisit is counted too). The HS-FCC extraction algorithm process is now summarized. The implementation of HS algorithm to generate the chain code as depict in Table 1.

Table 1. The Pseudocode Of HS-FCC Extraction Algorithm

The Pseudocode of HS-FCC Extraction Algorithm
Input data and settings parameter values
Clean image
Enumerate junction/end as nodes and interconnecting routes
Generate random node sequences.
Start HSA search with objective function()=path length
Initialize the harmony memory (HM)
Repeat
Improvise a new harmony from the HM
Update the HM
Until stopping criterion is archive

The algorithm work as follows:

1. Clean and break an image into paths
2. Enumerate junctions/end as nodes and interconnecting routes. At this point, generate chain code for corresponding route.
3. Find vertex by obtain list of junctions by testing neighbor population (i = 2).

4. Connecting between the junctions by testing each connected edges. Record the edge and junction at the other end.
5. Generate random node sequences for HSA memory initialization.
6. Start HSA with objective function() = path length. Assume the goal is to find the shortest route possible. Path length is the sequence of routes to reach all nodes.

5 Result and Discussion

This section describes the experimental results of the experiment. HSA is used to generate the continuous FCC which acts as the image features. The proposed HS-FCC extraction algorithm consists of 10 replications where each replication is 100 FCC solutions for every TBI. The result is analyzed by comparing result of the proposed metaheuristic HSA for extraction of FCC extraction with other metaheuristic algorithm [19] as shown in Table 2 and Fig. 4. The comparisons are based on route length and computation time.

Table 2. Comparison of Proposed HSA with Method by [19]

Algorithm	Route Length			Average Computation Time(s)
	Best	Average	Worst	
DE	2334.74	2.359.42	2.386.32	865.70
PSO	2247.79	2370.89	2391.77	2012.11
GA	2318.04	2334.63	2349.73	1144.58
ACO	2343.42	2354.92	2380.19	1126.33
HSA	1880.28	1915.88	1934.13	1.10

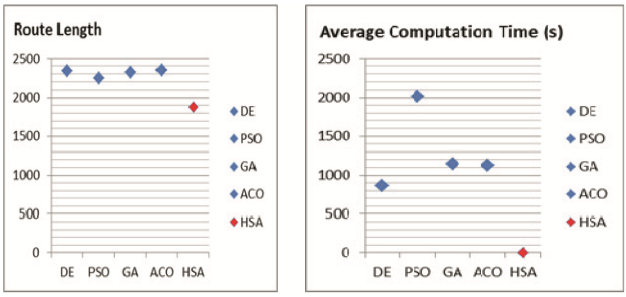

Fig. 4. Graph Comparison based on Route Length and Computation Time

Based on the result, the proposed HSA is better than other metaheuristic algorithm. HSA obtained the lowest in term of route length with 1880.28 compared to others. In addition, in term of computation time HSA is the fastest. To solve the whole thinned binary images, the proposed HSA only needs 1.10 s.

The efficiency of the HSA seem obvious by obtained the better performance compared to other metaheuristic technique. This is because of the ways of the HSA in handling the intensification and diversification. Diversification makes sure the search in

the parameter space can explore as many locations and regions as possible in an efficient and effective manner. It also ensures that the evolving system will not be trapped in biased local optima. On the other hand, the intensification intends to exploit the history and experience of the search process. It aims to ensure to speed up the convergence when necessary by reducing the randomness and limiting diversification. The optimal balance of diversification and intensification is required optimization process.

In the HSA, diversification is essentially controlled by the pitch adjustment and randomization. There are two subcomponents for diversification, which might be an important factor for the high efficiency of the HSA method. The first subcomponent of composing or generating new solutions, via randomization would be at least at the same level of efficiency as other algorithms by randomization. However, an additional subcomponent for HSA diversification is the pitch adjustment characterized. Pitch adjusting is carried out by adjusting the pitch in the given bandwidth by a small random amount relative to the existing pitch or solution from the harmony memory. Essentially, pitch adjusting is a refinement process of local solutions. Both memory considering and pitch adjusting ensure that the good local solutions are retained while the randomization and harmony memory considering will explore the global search space effectively. The randomization explores the search space more efficiently and effectively; while the pitch adjustment ensures that the newly generated solutions are good enough, or not too far away from existing good solutions.

The intensification is mainly represented in the HSA by the harmony memory accepting rate. A high harmony acceptance rate means the good solutions from the history/memory are more likely to be selected or inherited. This is equivalent to a certain degree of elitism. Obviously, if the acceptance rate is too low, the solutions will converge more slowly. As mentioned earlier, this intensification is enhanced by the controlled pitch adjustment. Such interactions between various components could be another important factor for the success of the HSA over other algorithms.

6 Conclusion

In this paper, metaheuristic approach via harmony search algorithm for feature extraction in handwritten character recognition namely HS-FCC extraction in handwritten character recognition is proposed. The proposed HS-FCC extraction algorithm is used to produce one continuous route and to minimize the length of FCC. This work is similar study of application of metaheuristic which are DE, PSO, GA and ACO was conducted by [19]. The proposed HSA algorithm implemented for FCC extraction use a similar solution representation and objective function calculated method same as algorithm proposed by [19]. The objective function is to express the quality of an FCC solution and is defined as the number of nodes which the FCC must visit from the starting node until all of the nodes are visited. Using the solution representation, by assume that one edge can be visited twice to assure that the solution representation can make a complete tour since a revisit to the previously visited node is often needed. Then using the particular characteristics of HSA, this approach tries to find a collection of good FCC solutions which minimize the FCC length. Route length and computation time were selected in

this experiment because they are depending on starting point and automatically affected on the route length and how many time it needs to solve the chain code. This method enables them to extract and recognize such difficult character in relatively shorter computational time and route length. The result of the proposed HSA was compared to the result of proposed method by [19] in term of FCC extraction in HCR based on route length and computation time.

The results show that, in term of route length, the proposed HSA obtained the lowest compared to the DE, PSO, GA and ACO proposed by [19]. Meanwhile in term of computational time, the proposed HSA also obtained the lowest means the HSA compute the fastest computation time in extracting the features compared to the DE, PSO, GA and ACO. The better performance of the HSA is controlling the optimal balance of diversification and intensification. In addition, the implementation of HSA is also easier. There is some evidence to suggest that HSA is less sensitive to the chosen parameters, which means that we do not have to fine-tune these parameters to get quality solutions. Furthermore, the HSA is a population-based metaheuristic, this means that multiple harmonics groups can be used in parallel. Proper parallelism usually leads to better implantation with higher efficiency. The good combination of parallelism with elitism as well as a fine balance of intensification and diversification is the key to the success of the HS algorithm, and in fact, to the success of any metaheuristic algorithms.

The resulting FCC will become the input to the classification stage. Every feature in chain code is fed to the classifier for recognition. The efficiency of FCC in the representation can be seen by the number of image characters that can be recognized. For future works, the HSA can be explored for enhancement by hybrid with other metaheuristic algorithm for instance, biogeography based optimization (BBO) and Particle Swarm Optimization (PSO). The advantages of characteristic of HSA make it very versatile to combine with other metaheuristic algorithms to produce hybrid metaheuristics and to apply in various applications.

Acknowledgment. The authors honorably appreciate to Ministry of High Education Malaysia (MOHE), Universiti Teknologi Malaysia (UTM), Research Management Centre (RMC) with grant vote number 4F860, Zamalah UTM and Soft Computing Research Group (SCRG) for their support.

References

1. Nasien, D., Haron, H., Yuhaniz, S.S.: Metaheuristics methods (GA & ACO) for minimizing the length of freeman chain code from handwritten isolated characters. World Acad. Sci. Eng. Technol. **62**, 230–235 (2010)
2. Patel, M., Thakkar, S.P.: Handwritten character recognition in english: a survey. Int. J. Adv. Res. Comput. Commun. Eng. **4**(2), 345–350 (2015)
3. Pithadia, N.J., Nimavat, V.D.: A review on feature extraction techniques for optical character recognition. Int. J. Innovative Res. Comput. Commun. Eng. **3**(2), 1263–1268 (2015)
4. Mohamad, M.A., Dewi, N., Hassan, H., Haron, H.: A review on feature extraction and feature selection for handwritten character recognition. Int. J. Adv. Comput. Sci. Appl. **6**(2), 204–212 (2015)

5. Oh, I.S., Lee, J.S., Suen, C.Y.: Analysis of class separation and combination of class-dependent features for handwriting recognition. IEEE Trans. Pattern Anal. Mach. Intell. **21**(10), 1089–1094 (1999)
6. Trier, D., Jain, A.K., Taxt, T.: Feature extraction method for character recognition - a survey. Pattern Recogn. **29**(4), 641–662 (1996)
7. Shi-Fei, D., Wei-Kuan, J., Chun-Yang, S., Zhong-Zhi, S.: Research of pattern feature extraction and selection. In: Proceedings of Machine Learning and Cybernetics. Kunming, China (2008)
8. Zhaoqi, B., Xuegong, Z.: Pattern recognition. In: 2nd Edition, Tsinghua University Press (2000)
9. Kwak, N., Choi, C.-H.: Input feature selection for classification problems. IEEE Trans. Neural Netw. **13**(1), 143–159 (2002)
10. Somol, P., Pudil, P., Kittler, J.: Fast branch and bound algorithms for optimal feature selection. IEEE Trans. Pattern Anal. Mach. Intell. **26**(7), 900–912 (2004)
11. Kudo, M., Sklansky, J.: Comparison of algorithms that select features for pattern recognition. Pattern Recogn. **33**(1), 25–41 (2000)
12. Oh, I.-S., Lee, J.-S., Moon, B.-R.: Hybrid genetic algorithms for feature selection. IEEE Trans. Pattern Anal. Mach. Intell. **26**(11), 1424–1437 (2004)
13. Cordella, L., De Stefano, C., Fontanella, F., Marrocco, C., Scotto di Freca, A.: Combining single class features for improving performance of a two stage classifier. In: 20th International Conference on Pattern Recognition (ICPR 2010), pp. 4352–4355 (2010)
14. Freeman, H.: Techniques for the digital computer analysis of chain-encoded arbitrary plane curves. In: Proceedings of Electron (1961)
15. Liu, Y.K., Zalik, B.: An efficient chain code with huffman coding. Pattern Recogn. **38**(4), 553–557 (2005)
16. Sánchez-Cruz, H., Bribiesca, E., Rodríguez-Dagnino, R.M.: Efficiency of chain code to represent binary objects. Pattern Recogn. **40**(6), 1660–1674 (2007)
17. Wulandhari, L.A., Haron, H.: The evolution and trend of chain code scheme. Graphics Vis. Image Process. **8**(3), 17–23 (2008)
18. Suliman, A., Shakil, A., Sulaiman, M.N., Othman, M., Wirza, R.: Hybrid of HMM and fuzzy logic for handwritten character recognition. In: Proceedings of Information Technology. Kuala Lumpur, Malaysia (2008)
19. Nasien, D., Haron, H., Yuhaniz, S.S., Najwa, A., Hassan, H.: Performance of metaheuristics technique in FreeMan chain code for handwritten characters recognition. Adv. Sci. Letters **4**(2), 270–274 (2011)
20. Erol, O.K., Eksin, I.: A new optimization method: big bang big crunch. Adv. Eng. Softw. **37**, 106–111 (2006)
21. Geem, Z.W., Kim, J.H., Loganathan, G.V.: A new heuristic optimization algorithm: harmony search. Simulation **76**, 60–68 (2001)
22. Lee, K.S., Geem, Z.W.: A new structural optimization method based on the harmony search algorithm. Comput. Struct. **82**, 781–798 (2004)
23. Saka, M.P.: Optimum geometry design of geodesic domes using harmony search algorithm. Adv. Struct. Eng. **10**(6), 595–606 (2007)
24. Degertekin, S.O.: Harmony search algorithm for optimum design of steel frame structures: a comparative study with other optimization methods. Struct. Eng. Mech. **29**(4), 391–410 (2008)
25. Saka, M.P.: Optimum design of steel sway frames to BS5950 using harmony search algorithm. J. Constr. Steel Res. **65**, 36–43 (2009)

26. Hasancebi, O.: Performance evaluation of metaheuristic search techniques in the optimum design of real size pin jointed structures. Comput. Struct. **87**, 284–302 (2009)
27. Degertekin, S.O., Hayalioglu, M.S., Gorgun, H.: Optimum design of geometrically non-linear steel frames with semi-rigid connections using a harmony search algorithm. Steel Compos. Struct. **9**(6), 535–555 (2009)
28. Erdal, F., Saka, M.P.: Harmony search based algorithm for the optimum design of grillage systems to LRFD-AISC. Struct. Multidiscip. O. **38**, 25–41 (2009)
29. Hasancebi, O., Carbas, S., Dogan, E., Erdal, F., Saka, M.P.: Comparison of non-deterministic search techniques in the optimum design of real size steel frames. Comput. Struct. **88**(17–18), 1033–1048 (2010)
30. Togan, V., Daloglu, A.T., Karadeniz, H.: Optimization of trusses under uncertainties with harmony search. Struct. Eng. Mech. **37**(5), 543–560 (2011)
31. Erdal, F., Dogan, E., Saka, M.P.: Optimum design of cellular beams using harmony search and particle swarm optimizers. J. Constr. Steel Res. **67**(2), 237–247 (2011)
32. Potrus, M.Y., Ngah, U.K.: A harmony search algorithm for recognition-based segmentation of online arabic text. In: Proceedings of International Conference on Engineering and Information Technology, pp. 205–210, 17–18 September 2012, Toronto, Canada (2012)
33. Engkamat, A.A.: Enhancement of parallel thinning algorithm for handwritten characters using neural network. M.Sc. Thesis, Universiti Teknologi Malaysia, November 2005