Artificial intelligence-based Karawo motif formation using genetic algorithm

Mukhlisulfatih Latief[1], Syahrul[2], Abdul Muis Mappalotteng[3]
[1]Department of Informatics Engineering, Faculty of Engineering, Gorontalo State University, Gorontalo, Indonesia
[2]Department of Informatics and Computer Engineering Education, Faculty of Engineering, Makassar State University, Makassar, Indonesia
[3]Department of Technology and Vocational Education, Faculty of Engineering, Makassar State University, Makassar, Indonesia

Article Info

Article history:

Received Nov 1, 2023
Revised Dec 30, 2023
Accepted Jan 11, 2024

Keywords:

Arithmetic transformation
Artificial intelligence
Boolean transformation
Genetic algorithm
Geometric transformation
Karawo motif

ABSTRACT

This research explores the application of artificial intelligence in generating Karawo motifs, a traditional Indonesian pattern. The research involves collecting a dataset of existing Karawo motifs and utilizing genetic algorithms to evolve and create novel pattern variations. The generated motifs are evaluated based on their adherence to traditional design principles and aesthetic appeal. The formation of Karawo motifs begins with randomly selecting image data from a database. Then, the selection of transformation treatments is performed by optimizing the fitness function within the genetic algorithm. The applied types of transformations include geometric transformations, Boolean transformations, and arithmetic transformations. The outlined genetic algorithm steps include determining the fitness function, performing its evaluation, selecting fitness values, applying crossover, implementing mutation, managing survivor selection, and terminating iterations. The results indicate that the developed system is capable of creating diverse and appealing Karawo motif patterns, showcasing the potential of combining traditional artistry with artificial intelligence. This study has the potential to expand the possibilities of Karawo motif design and contribute to the preservation and promotion of Indonesian cultural heritage.

Corresponding Author:

Mukhlisulfatih Latief
Department of Informatics Engineering, Faculty of Engineering, Gorontalo State University
Gorontalo, Indonesia
Email: mukhlis@ung.ac.id

1. INTRODUCTION

Karawo is a traditional motif or pattern originating from Indonesia, specifically the Gorontalo region. The Karawo motif is characterized by intricate geometric patterns and captivating color combinations, making it a prominent feature in traditional woven fabrics like songket, sarongs, and other indigenous textiles [1]. The manual creation of Karawo motifs by skilled artisans remains the current practice [2]. This process demands precision, time, and a profound understanding of geometric patterns and harmonious color compositions. The intricate nature of Karawo motif creation makes it challenging to automate, hindering improvements in production efficiency.

In recent years, artificial intelligence (AI) has made significant strides, with genetic algorithms emerging as a promising method successfully employed in diverse fields, including art and design [3]–[5]. Genetic algorithms leverage the principles of natural selection to explore optimal solutions within complex search spaces [6]–[16]. In the realm of Karawo motif design, genetic algorithms offer the potential to generate novel, authentic, and aesthetically pleasing patterns.

Genetic algorithms, known for their optimization capabilities, are particularly well-suited for navigating complex design spaces. Given that Karawo motifs involve a combination of geometric, Boolean, and arithmetic transformations, creating a complex design space, genetic algorithm efficiently optimizes these combinations to meet desired design criteria [17]–[19]. Genetic algorithms strength lies in exploring vast and intricate solution spaces, making it suitable for the diverse variations inherent in Karawo motifs. Operating on a population-based approach, genetic algorithms aligns with the evolutionary principles found in traditional art, where motifs evolve through variation and natural selection. Moreover, genetic algorithms adaptability to uncertainty and design preference variations makes it a robust choice for handling the dynamic nature of artistic preferences. Its adaptive nature and ability to handle changes in the design environment further contribute to its suitability for exploring and enhancing the creativity of Karawo motif patterns. In summary, the selection of genetic algorithm reflects a desire to leverage evolutionary optimization methods to achieve diverse and aesthetically appealing Karawo motif designs.

Previous studies have addressed engaging teenagers with traditional Karawo textiles, producing contemporary ornamental fabrics by blending traditional and urban influences [1]. Designs, inspired by Bili’u wedding dresses and modern icons, align with teenagers’ preferences, emphasizing dynamism, energy, uniqueness, and fashion-forwardness. This research highlights Karawo’s potential to sustain traditional textiles. Another study explores craftsmen proficiently applying Karawo motifs to garments, showcasing their skill in the learning process stages [2]. Additionally, a separate study introduces a novel design method, interactive genetic algorithm with individual fuzzy interval fitness (IGA-BPFIF), incorporating user preferences in alternative pattern creation, contributing to traditional pattern preservation. Experiments demonstrate IGA-BPFIF’s effectiveness, collectively offering insights into traditional motifs and innovative design methods, enriching the intersection of tradition, technology, and creativity [4].

While research on applying AI to art and design has been conducted, the utilization of genetic algorithms for crafting Karawo motifs remains relatively limited. This study addresses this gap by developing a system that utilizes AI through the genetic algorithm method to create Karawo motifs. In the genetic algorithm applied in this research, a thorough exploration is conducted to search for the optimal fitness function and weight values essential for shaping the Karawo motif pattern. This involves a systematic investigation into various combinations of fitness criteria and corresponding weights. The fitness function serves as a critical benchmark, assessing the effectiveness of each potential solution in generating high-quality Karawo motifs. Through the iterative nature of genetic processes such as selection, crossover, and mutation, the algorithm fine-tunes these weight values. The ultimate goal is to achieve an optimal combination that enhances the overall aesthetic and structural qualities of the Karawo motifs, ensuring a meticulous and well-calibrated approach to motif formation.

The anticipated outcome of this research is to contribute to the advancement of automated techniques for crafting Karawo motifs using artificial intelligence. The implementation of genetic algorithms is poised to yield diverse and authentic motifs, maintaining the unique characteristics and individuality of Karawo designs. Furthermore, this research is expected to create new avenues for integrating AI into the traditional craft industry of Indonesia.

2. METHOD

This research endeavors to create an automated system dedicated to the generation of Karawo motifs through the implementation of artificial intelligence, specifically employing the genetic algorithm method. The proposed methodology involves several crucial steps that contribute to the development and enhancement of the Karawo motif creation process. These key steps encompass:

2.1. Data collection

In this research, 30 images of Karawo motifs are employed, subjected to diverse transformation treatments for the generation of novel pattern motifs. The visual representation of Karawo motifs can be observed in Figure 1. These images serve as the foundation for exploring and creating innovative pattern variations through the application of transformation techniques.

2.2. Application of genetic algorithm

The application of the genetic algorithm involves determining the optimal values for transformations on the Karawo motif image, encompassing geometric, arithmetic, and Boolean transformations. Guided by genetic principles through iterative processes, the algorithm systematically explores and refines these values across generations. It aims to identify the most effective combination that enhances the visual aspects of the Karawo motif image. The specific values for geometric, arithmetic, and Boolean transformations within the genetic algorithm are presented in Tables 1 to 3.

Figure 1. 30 images of Karawo motifs

Table 1. Values for geometric transformations in the genetic algorithm

Value in the genetic algorithm	Type of geometric transformation
1	Rotation 45°
2	Translation
3	Horizontal flip
4 and 0	Vertical flip

Table 2. Values for Boolean transformations in the genetic algorithm

Value in the Boolean algorithm	Type of Boolean transformation
0 and 1	NOT
2	XOR
3	AND
4	OR

Table 3. Values for arithmetic transformations in the genetic algorithm

Value in the arithmetic algorithm	Type of arithmetic transformation
0 and 1	Multiply
2 and 3	Add
4	Subtract

In the application of the genetic algorithm to the Karawo motif image, several key steps are meticulously followed. First, the fitness function is determined, setting the criteria for the evaluation process.

Subsequently, the fitness function is rigorously evaluated, assessing the effectiveness of the selected parameters. Following this, the genetic algorithm undergoes a fitness value selection phase, where the most promising candidates are chosen for further evolution. The process then proceeds to crossover, introducing genetic recombination to diversify the solution space. Mutation follows, introducing small random changes to enhance exploration. The survivor selection or replacement process carefully manages the retention of individuals for the next generation. Finally, the iterative process continues until the termination criteria are met, ensuring the algorithm converges to an optimal solution or a predefined endpoint [20]–[24].

2.2.1. Determining the fitness function

Determining the fitness function is a critical step in the application of the genetic algorithm to the Karawo motif image. The fitness function used serves as a pivotal criterion for evaluating the effectiveness of the selected parameters and guiding the evolutionary process. By defining and implementing a robust fitness function, the algorithm can systematically assess and enhance the quality of generated motifs. The fitness function used is as (1) [25]:

$$f = w_1 * x - w_2 * y \tag{1}$$

where:
f is the fitness function,
w_1 is the weight for the first image,
x is the transformation treatment value for the first image,
w_2 is the weight for the second image,
y is the transformation treatment value for the second image.

In this process, the first and second images are different. Both of these images are randomly selected from the database. The values of w_1 and w_2 are determined through trial and error to obtain the optimal selection of geometric transformation types. In this process, the value of w_1 is set to 0.2, while the value of w_2 is set to 0.3. For the fitness function, it is determined that the search for the optimum value uses the maximum function. Therefore, the fitness function can be rewritten as (2) [25]:

$$f_{max} = 0{,}2 * x - 0{,}4 * y \tag{2}$$

where:
f_{max} is the maximum fitness function,
x is the transformation treatment value for the first image,
y is the transformation treatment value for the second image.

2.2.2. Performing fitness function evaluation

In this transformative process, random numbers are generated to determine the values of the transformation treatment for both the first image (x) and the second image (y). These randomly generated values play a crucial role in shaping the fitness function. The equation used for fitness function evaluation incorporates these values, providing a quantitative measure to assess the efficacy of the transformation treatments and guide the optimization process. The equation used for fitness function evaluation is as (3) to (5) [26]-[29]:

$$x = (max\_x - min\_x) * rand(1{,}1) + min\_x \tag{3}$$

$$y = (max\_y - min\_y) * rand(1{,}1) + min\_y \tag{4}$$

$$f(x, y) = 0{,}2 * x - 0{,}4 * y \tag{5}$$

where:
x is the transformation treatment value for the first image,
y is the transformation treatment value for the second image,
min_x is 0, max_x is 3 (transformation treatment values range from 0 to 3),
min_y is 0, max_y is 3 (transformation treatment values range from 0 to 3),
$rand$ is a random number between 0 and 1,
$f(x, y)$ is the fitness function.

2.2.3. Fitness value selection
In the iterative generation of random numbers for fitness function evaluation, the process is repeated four times, producing a set of four fitness values. These values are then systematically sorted, and the maximum value, denoted as f_{max}, is identified. This method ensures a comprehensive exploration of fitness values, facilitating the selection of the most optimal candidate for further steps in the genetic algorithm [30].

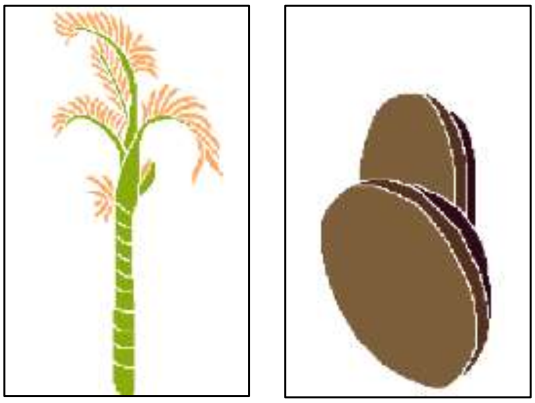
2.2.4. Crossover
In the process of fitness function evaluation, the transformation treatment values (x and y) are crossed over to obtain the best composition of values. This step is a critical part of the genetic algorithm, where genetic recombination is performed to create potential variations and enhance the quality of solutions. By obtaining the best composition of values through the crossover process, the genetic algorithm can generate more unique and optimal Karawo motif patterns [31].

2.2.5. Mutation
During the mutation process, a gene replacement occurs, involving the generation of a random number for one of the transformation treatment values for both the first image (x) and the second image (y). This stochastic modification introduces variability in the genetic makeup, contributing to the exploration of novel patterns within the Karawo motif. The random replacement of genes enhances the algorithm's ability to adapt and discover unique combinations of transformation treatments [32].

2.2.6. Survivor selection or replacement process
Following the generation of random numbers in the mutation process, N chromosomes are carefully chosen from the combination of the previous population. These selected N chromosomes are designated as the population for the subsequent iteration or cycle of the genetic algorithm. This strategic selection process ensures the retention of promising genetic material, facilitating the continuity of the algorithm's evolution toward optimal solutions [33].

2.2.7. Termination of iterations
The iteration will stop when the specified number of cycles is reached. In this study, a cycle value of 10 is used. When the iteration stops, the optimum fitness value is obtained. This value represents the transformation treatment values that will be applied to each image [34].

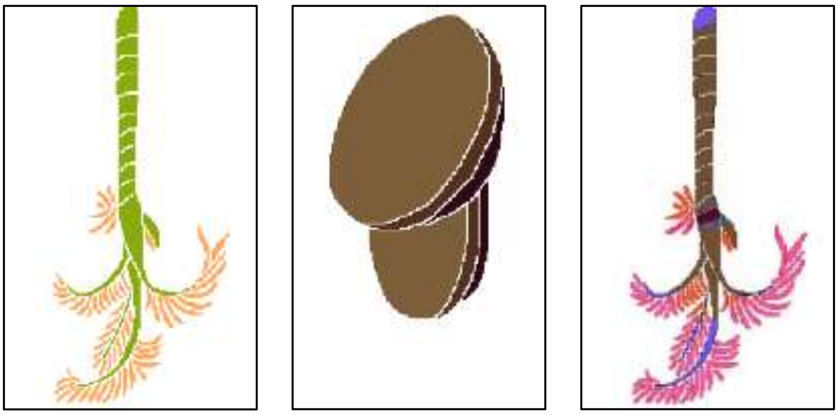
3. RESULTS AND DISCUSSION
This study utilizes three types of transformations in the formation of Karawo motifs, namely geometric transformations, Boolean transformations, and arithmetic transformations. Geometric transformations used include translation, rotation, horizontal flip, and vertical flip. Boolean transformations used include AND, OR, NOT, and XOR. The arithmetic transformations used are Add, Subtract, and Multiply. The formation of Karawo motifs begins with randomly selecting two images. The randomly selected images are shown in Figure 2, with the first random image in Figure 2(a) and the second random image in Figure 2(b).



(a) (b)

Figure 2. Two randomly selected images (a) first image and (b) second image

In the random generation process, the generated values for geometric transformation treatments from the genetic algorithm are 4, 4, 4, and 4. The performed transformations include a vertical flip on the first image, a vertical flip on the second image, followed by an OR and Subtract transformation. The results of the transformations on the two selected images are shown in Figure 3, with a vertical flip applied to the first image in Figure 3(a), a vertical flip applied to the second image in Figure 3(b), and a logical OR and subtract operation performed on Figure 3(a) and 3(b) in Figure 3(c).



(a) (b) (c)

Figure 3. Transformation results on two images; (a) vertical flip on the first image, (b) vertical flip on the second image, and (c) OR and subtract on images a and b

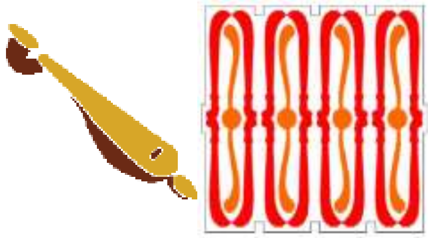
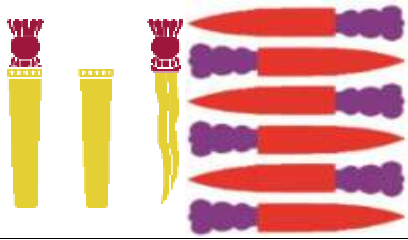
Table 4 illustrates various outcomes of the Karawo motif formation process. These results offer a comprehensive overview of the diversity and visual appeal achieved through the application of the genetic algorithm. The table serves as a visual representation of the algorithm’s effectiveness in generating distinct Karawo motifs.

In this study, a Karawo motif generation system using genetic algorithms has been successfully developed. The formation of Karawo motifs begins with randomly selecting image data from a database. Then, the selection of transformation treatments is performed by optimizing the fitness function within the genetic algorithm. The applied types of transformations include geometric transformations, Boolean transformations, and arithmetic transformations. For future development of the Karawo motif generation system, the authors suggest further enhancements to the genetic algorithm and transformation treatments to generate more diverse Karawo motif patterns.

On the other hand, a study aimed at developing contemporary ornamental textiles of Karawo for teenagers revealed that the existing ornamental designs have not attracted teenagers, possibly due to the lack of appeal [1]. The experimental research produced contemporary ornamental textiles by combining traditional and urban culture, resulting in designs that meet teenagers’ preferences for dynamic, energetic, unique, and fashionable styles. Another research focused on the application of traditional Gorontalo motifs in clothing [2]. The study used a qualitative method to investigate the learning process and application of Karawo motifs by craftsmen. The craftsmen successfully applied Karawo motifs to various traditional garments, demonstrating the stages of preparation, learning, and evaluation. Lastly, a novel design method using an interactive genetic algorithm with individual fuzzy interval fitness was introduced to create alternative complex patterns [4]. The study emphasized the integration of quantitative rules of aesthetic evaluation and user cognition through a surrogate model based on the error backpropagation neural network. This approach effectively designed innovative patterns matching users’ preferences and contributed to the heritage of traditional national patterns.

The comparison of the research outcomes highlights several key challenges for future investigations on Karawo motifs. First and foremost is the imperative to diversify motifs and transformations, ensuring a broader spectrum of creative outputs. Secondly, there is a need to develop more interactive systems, especially in response to teenage preferences, as demonstrated by the second research. Balancing the integration of traditional heritage with innovative techniques, as seen in the third study, poses another challenge for future endeavors. Advancements in algorithm sophistication, including efficiency and handling increased complexity, represent an ongoing challenge. Collaboration with traditional industries and communities is essential for practical implementation and sustainability. Lastly, enhancing user involvement, feedback mechanisms, and evaluation processes will be critical in refining and advancing Karawo motif generation systems. Addressing these challenges will contribute to the continued evolution of Karawo motifs, combining tradition with innovation and meeting the preferences of diverse user groups.

Table 4. Several results of Karawo motif formation

No	Type of transformation	Original image	Transformation result
1	Flip horizontal rotation 45° AND Add		
2	Flip horizontal flip vertical AND Add		
3	Flip vertical flip vertical OR Subtract		

4. CONCLUSION

In this study, a Karawo motif generation system using genetic algorithms has been successfully developed. The formation of Karawo motifs begins with randomly selecting image data from a database. Then, the selection of transformation treatments is performed by optimizing the fitness function within the genetic algorithm. The applied types of transformations include geometric transformations, Boolean transformations, and arithmetic transformations. For future development of the Karawo motif generation system, the authors suggest further enhancements to the genetic algorithm and transformation treatments to generate more diverse Karawo motif patterns.

ACKNOWLEDGEMENTS

The author expresses gratitude to Gorontalo State University and Makassar State University for their support in this research.

REFERENCES

[1] I. Mohamad, S. Dangkua, S. N. Botutihe, and A. Lahinta, "Designing contemporary karawo motifs for teenagers," *Journal of Arts and Humanities (JAH)*, vol. 7, no. 8, pp. 30–37, 2018, doi: 10.18533/journal.v7i8.1452.

[2] H. Hasdiana, U. Naini, I. Mohamad, and N. Malanua, "Engineering design of traditional Gorontalo motif for learning Karawo Embroidery," in *Proceedings of the 1st International Conference on Education Social Sciences and Humanities (ICESSHum 2019)*, 2019. doi: 10.2991/icesshum-19.2019.53.

[3] D. G. T. Meranggi, N. Yudistira, and Y. A. Sari, "Batik classification using convolutional neural network with data improvements," *International Journal on Informatics Visualization*, vol. 6, no. 1, pp. 6–11, 2022, doi: 10.30630/joiv.6.1.716.

[4] J. Lv, M. Zhu, W. Pan, and X. Liu, "Interactive genetic algorithm oriented toward the novel design of traditional patterns," *Information (Switzerland)*, vol. 10, no. 2, 2019, doi: 10.3390/info10020036.

[5] A. E. Minarno, M. Y. Hasanuddin, and Y. Azhar, "batik images retrieval using pre-trained model and K-Nearest neighbor," *International Journal on Informatics Visualization*, vol. 7, no. 1, pp. 115–121, 2023, doi: 10.30630/joiv.7.1.1299.

[6] R. S. Samosir, E. Abdurachman, F. L. Gaol, and B. S. Sabarguna, "Brain tumor segmentation using double density dual tree complex wavelet transform combined with convolutional neural network and genetic algorithm," *IAES International Journal of Artificial Intelligence (IJ-AI)*, vol. 11, no. 4, pp. 1373–1383, 2022, doi: 10.11591/ijai.v11.i4.pp1373-1383.

[7] A. S. Al-Zoubi, A. A. Amaireh, and N. I. Dib, "Comparative and comprehensive study of linear antenna arrays' synthesis," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 12, no. 3, pp. 2645–2654, 2022, doi: 10.11591/ijece.v12i3.pp2645-2654.

[8] A. Alzahrani and M. A. A. Bhuiyan, "Feature selection for urban land cover classification employing genetic algorithm," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 11, no. 2, pp. 793–802, 2022, doi: 10.11591/eei.v11i2.3399.

[9] M. E. A. A. Tharwat, M. F. M. Fudzee, S. Kasim, A. A. Ramli, and M. K. Ali, "Multi-objective NSGA-II based community detection using dynamical evolution social network," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 11, no. 5, pp. 4502–4512, 2021, doi: 10.11591/ijece.v11i5.pp4502-4512.

[10] B. Warsito, R. Santoso, and H. Yasin, "Metaheuristic optimization in neural network model for seasonal data," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 19, no. 6, pp. 1892–1901, 2021, doi: 10.12928/TELKOMNIKA.v19i6.20409.

[11] R. A. Nugroho, A. S. Nugraha, A. Al Rasyid, and F. W. Rahayu, "Improvement on KNN using genetic algorithm and combined feature extraction to identify COVID-19 sufferers based on CT scan image," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 19, no. 5, pp. 1581–1587, 2021, doi: 10.12928/TELKOMNIKA.v19i5.18535.

[12] R. A. Gangurde and B. Kumar, "Biogeography optimization algorithm based next web page prediction using weblog and web content features," *IAES International Journal of Artificial Intelligence (IJ_AI)*, vol. 9, no. 2, pp. 327–335, 2020, doi: 10.11591/ijai.v9.i2.pp327-335.

[13] J. Revathi, J. Anitha, and D. J. Hemanth, "Training feedforward neural network using genetic algorithm to diagnose left ventricular hypertrophy," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 18, no. 3, pp. 1285–1291, 2020, doi: 10.12928/TELKOMNIKA.v18i3.15225.

[14] Z. F. Hussain *et al.*, "A new model for iris data set classification based on linear support vector machine parameter's optimization," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 10, no. 1, pp. 1079–1084, 2020, doi: 10.11591/ijece.v10i1.pp1079-1084.

[15] A. B. Alnajjar *et al.*, "Wireless sensor network optimization using genetic algorithm," *Journal of Robotics and Control (JRC)*, vol. 3, no. 6, pp. 827–835, Jan. 2022, doi: 10.18196/jrc.v3i6.16526.

[16] S. Oh, J. Yoon, Y. Choi, Y. A. Jung, and J. Kim, "Genetic algorithm for the optimization of a building power consumption prediction model," *Electronics 2022*, 11, 3591, 2022, doi: 10.3390/electronics11213591.

[17] A. Alharbi and M. Alghahtani, "Using genetic algorithm and ELM neural networks for feature extraction and classification of type 2-Diabetes Mellitus," *Applied Artificial Intelligence 2019*, vol. 33, no. 4, pp. 311–328, 2019, doi: 10.1080/08839514.2018.1560545.

[18] J. Tang and Y. Deng, "Artificial intelligence system detection in english teaching based on heuristic genetic algorithm," *Computational Intelligence and Neuroscience*, vol. 2022, 2022, doi: 10.1155/2022/3082779.

[19] A. Rezaeipanah and M. Mojarad, "Modeling the scheduling problem in cellular manufacturing systems using genetic algorithm as an efficient meta-heuristic approach," *Journal of Artificial Intelligence and Technology*, vol. 1, no. 4, pp. 228-234, 2021, doi: 10.37965/jait.2021.0018.

[20] X. Jiang, M. Brown, Z. Hu, and H.-R. Cheong, "Covid-19 diagnosis by gray-level cooccurrence matrix and genetic algorithm," *EAI Endorsed Transactions on e-Learning*, vol. 8, no. 1, p. e2, Aug. 2022, doi: 10.4108/eetel.v8i1.2344.

[21] Q. Zhang, D. Deng, W. Dai, J. Li, and X. Jin, "Optimization of culture conditions for diferentiation of melon based on artifcial neural network and genetic algorithm," *Scientific Reports*, 10:3524, 2020. doi: 10.1038/s41598-020-60278-x.

[22] H. Iima and Y. Hazama, "Genetic algorithm with machine learning to estimate the optimal objective function values of subproblems," *ISMSI*, 2022, doi: 10.1145/3533050.3533051.

[23] P. Ramyaa and B. Karthik, "An optimal feature subset selection by using genetic algorithm for an effective text classification," *Journal of Algebraic Statistics*, vol. 13, no. 2, p. 2318-2326, 2022.

[24] I. A. Doush and A. Sawalha, "Automatic music composition using genetic algorithm and artificial neural networks," *Malaysian Journal of Computer Science*, vol. 33, no. 1, pp. 35–51, 2020, doi: 10.22452/mjcs.vol33no1.3.

[25] M. J. Arshad, M. Umair, S. Munawar, N. Naveed, and H. Naeem, "Improving cloud data encryption using customized genetic algorithm," *International Journal of Intelligent Systems and Applications*, vol. 12, no. 6, pp. 46–63, Dec. 2020, doi: 10.5815/ijisa.2020.06.04.

[26] A. Yadav, B. B. V. S. V. Prasad, R. K. Mojjada, K. K. Kothamasu, and D. Joshi, "Application of artificial neural network and genetic algorithm based artificial neural network models for river flow prediction," *Revue d'Intelligence Artificielle*, vol. 34, no. 6, pp. 745-751, 2020, doi: 10.18280/ria.340608.

[27] M. Rostami, K. Berahmand, and S. Forouzandeh, "A novel community detection based genetic algorithm for feature selection," *Journal of Big Data*, vol. 8, no. 2, 2021. doi: 10.1186/s40537-020-00398-3.

[28] P. C. Jennings, S. Lysgaard, J. S. Hummelshøj, T. Vegge, and T. Bligaard, "Genetic algorithms for computational materials discovery accelerated by machine learning," *npj Computational Materials*, vol. 5, no. 1, 2019, doi: 10.1038/s41524-019-0181-4.

[29] C. Kallab, S. Haddad, and J. Sayah, "Flexible traceable generic genetic algorithm," *Open Journal of Applied Sciences*, vol. 12, pp. 877-891. 2022, doi: 10.4236/ojapps.2022.126060.

[30] H. A. Shehadeh, H. M. J. Mustafa, and M. Tubishat, "A hybrid genetic algorithm and sperm swarm optimization (HGASSO) for multimodal functions," *International Journal of Applied Metaheuristic Computing*, vol. 13, Issue 1, 2022, doi: 10.4018/IJAMC.292507.

[31] N. Ghaffarian and M. Hamedi, "Optimization of rubber compound design process using artificial neural network and genetic algorithm," *International Journal of Engineering, Transactions B: Applications*, vol. 33, no. 11, pp. 2319–2326, 2020, doi: 10.5829/ije.2020.33.11b.22.

[32] D. Yang, Z. Yu, H. Yuan, and Y. Cui, "An improved genetic algorithm and its application in neural network adversarial attack," *PLoS ONE*, vol. 17, no. 5 May, p. e0267970, May 2022, doi: 10.1371/journal.pone.0267970.

[33] C. M. Louis, N. Handayani, T. Aprilliana, A. A. Polim, A. Boediono, and I. Sini, "Genetic algorithm–assisted machine learning for clinical pregnancy prediction in in vitro fertilization," *AJOG Global Reports*, vol. 3, no. 1, p. 100133, Feb. 2023, doi: 10.1016/j.xagr.2022.100133.

[34] H. Wang, "research on the application of genetic algorithm in physical education," *Journal of Mathematics*, vol. 2022, 2022, doi: 10.1155/2022/8477945.

BIOGRAPHIES OF AUTHORS

Mukhlisulfatih Latief doctoral student at Makassar State University. He is currently an associate professor at Informatics Department in Gorontalo State university, Gorontalo, Indonesia. His research includes machine learning, data mining, and programming. He can be contacted at email: mukhlis@ung.ac.id.

Syahrul he is a professor of informatics and computer engineering education, Makassar State University, Makassar, Indonesia. Her research interests are in evaluation and vacational education. He can be contacted at email: syahrul@unm.ac.id.

Abdul Muis Mappalotteng he is a doctor of technology and vocational education, Makassar State University, Makassar, Indonesia. Her research interests are in computer and electronics. He can be contacted at email: abdulmuism@unm.ac.id.