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THE IMPLEMENTATION OF MEMETIC ALGORITHM ON IMAGE: A SURVEY

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Abstract: The growth of information technology is equal to the use of the algorithm. One of the most well-known algorithms is Memetic Algorithm (MA). MA is a part of the evolutionary algorithm and has been implemented on the most complex computational challenges. MA could be implemented in any field of research such as optimization, scheduling, prediction, image processing, image recognition, and many more. However, this research concerns the survey on the implementation of MA in image classification, image processing, and image recognition to find how many works are conducted related to MA and image. In this work, we use the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) method to survey another research about the implementation of MA, specifically on the image. The purpose of this survey is to determine the extent of the implementation of MA in image data. Finally, we found each 1 paper uses MA for image retrieval, 12 papers use MA for image processing and 18 papers use MA for image recognition and 2 papers use MA for image classification.

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1. INTRODUCTION

The Memetic algorithm represents one of the most distinctive and thriving research fields in evolutionary computation. The term memetic algorithm has been used widely to describe the enhancement of searching procedures based on individual or population approaches. Memetic algorithm refers to Baldwinian Evolutionary Algorithm, Lamarckian Evolutionary Algorithm, Cultural Algorithm, and Local Search Genetic Algorithm.

The memetic algorithm is a part of the evolutionary algorithm and has been implemented on the most complex computational challenge [1]. Memetic algorithm [2][3] is an enhancement of the evolutionary algorithm with local search separation [4]. This is a simple algorithm with reliable performance [5][6], provides solutions to many real problems with high accuracy [7][8][9].

Many things developed to address optimization problems caused by huge research fields, such as economic, biology, chemistry, physics, and many more. Many researchers use a memetic algorithm to address complex problems as graph partition, graph coloring, packing, and many other common problems. The newest applications implementation of memetic algorithm are artificial neural network [10], pattern recognition [11], robotic motion planning [12], beam orientation [13], circuit design [14], electric service restoration [15], medical expert systems [16], single scheduling machine [17], automatic scheduling [18], person scheduling [19], nurse rostering optimization [20], processors allocation [21], maintenance scheduling [22], VLSI design [23], clustering of gene expression profiles [24], feature/gene selection [25][26], and multi-class, multi-objective feature selection [27][28]. Generally, the MA flowchart is shown in figure 2 below.

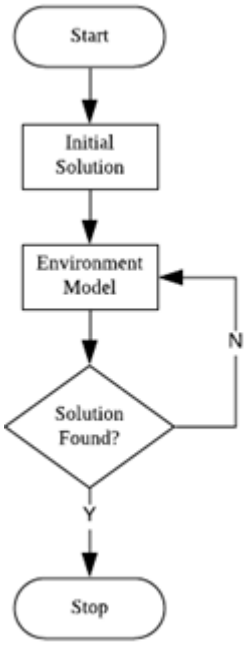

Figure 1. Local Seach

The MA is an enhancement of the evolutionary algorithm with local search separation [2][3]. This is a simple algorithm with reliable performance [29], provide solution of any real problems with high accuracy [30]. The MA is also an enhancement of the genetic algorithm (GA). GA runs a local search in parallel condition, therefore it will never be stuck in the local extreme. However, it has to verify the appropriate solution in every iteration so that it will increase processing time, which means this algorithm is slower than others. This weakness can be overcome by adding a local search feature hereinafter known as MA. The MA is a heuristic search method, a combination of genetic algorithm and separated local search method that can increase the quality of solution [31]. The local search feature in MA can be implemented before or after the selection process, crossover, and mutation. It is also useful to minimize search space. Below is the pseudocode of the memetic algorithm.

Begin
INITIALIZE population;
EVALUATE each candidate;
Repeat Until (TERMINATION CONDITION) Do
    SELECT parents;
    CROSSOVER to produce offspring;
    MUTATE offspring;
    IMPROVE offspring by Local Search;
    EVALUATE offspring;
    SELECET individual for next generation;
EndDo
End

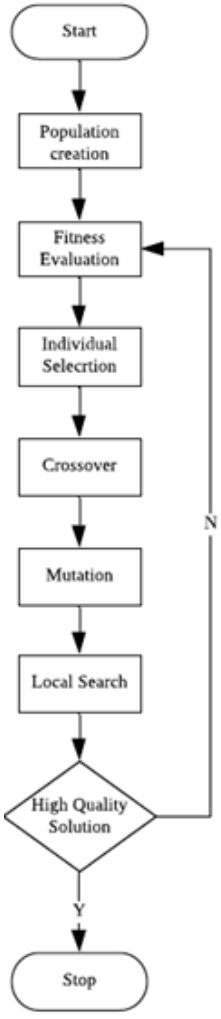

Figure 2. Memetic Algorithm

2. RESEARCH METHOD

We have surveyed several papers related to the implementation of the Memetic Algorithm (MA) then conducted a review using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) method [32]. This method has five stages, 1st is Defining Eligibility Criteria, 2nd is Defining Information Resources, 3rd is Literature Selection, 4th is Data Collection, and 5th is Data Item Selection.

To aim for the best selection result, those 5 stages must be done in sequence, make sure that every stage is well done before moving to the next stage. Repeat the previous stage if there are deficiencies.

2.1. Stage 1: Defining Eligibility Criteria

As defined in [36], the eligibility criteria are specified by Inclusion Criteria (IC). In this work, we defined the articles into three criteria, which are:

1) IC1: Original articles that are written in English.
2) IC2: Original articles that have been published from 2004 until 2021.
3) IC3: Original articles that analyze the implementation of MA on the image.

Thus this work surveys the articles that implement MA on the image, written in English, and published from 2004 until 2021.

2.2. Stage 2: Defining Information Resource

1) The articles can be found in online academics repositories such as Google Scholar, IEEE Xplore, ScienceDirect, and Springer Link.
2) In those online academic repositories, we will select the articles that appropriate to this work.

2.3. Stage 3: Literature Selection

1) Determining keywords. The 1st keyword is “memetics algorithm”, we use this keyword to know more about MA in general. The 2nd is “memetics algorithm and implementation”, we use this keyword because we want to know about MA and its implementation. The 3rd keyword is “memetics algorithm and image”, and we use it to know specifically about MA on the image. The 4th is “memetics algorithm and implementation and image”, and

we use this keyword to get some information about the implementation of MA on image data. The 5th keyword is “memetics and image”, this is almost the same as number 3, but we do not include the word “algorithm” to get information about memetics and images in general. The last keyword is “memetics and fingerprint”, we use this keyword because in future work, specifically, we will focus on the implementation of MA on fingerprint image datasets.

2) Select articles that are related to criteria by the title, abstract, and article’s keywords.
3) Articles that are not eliminated from the previous stage will be read, fully, or partially to define items' eligibility.

Only short-listed articles will be assessed to find the linkage to this work. These articles will be re-assessed by doing steps 3 to step 4 above.

2.4. Stage 4: Data Collection

We have created a data extraction form to collect data manually. From each keyword, this survey assesses 33,965 articles based on keywords “memetics algorithm”; 22,343 articles based on keywords “memetics algorithm and implementation”; 19,513 articles based on keyword “memetics algorithm and image”; 17,014 articles based on the keyword “memetics algorithm and implementation and image”, 19,149 articles based on the keyword “memetics and image”; and 1,156 articles based on the keyword “memetics and fingerprint”. The total of searched articles is 113,140.

Table 1. Data From Google Scholar

Source	**Keywords**	**Results**
Google Scholar	Memetics algorithm	23800
	Memetics algorithm and implementation	16600
	Memetics algorithm and image	16900
	Memetics algorithm and implementation and image	15500
	Memetics and image	17300
	Memetics and fingerprint	1051
Total		91150
Selected		6

Table 2. Data From IEEE Xplore

Source	Keywords	Results
IEEE Xplore	Memetics algorithm	1089
	Memetics algorithm and implementation	49
	Memetics algorithm and image	92
	Memetics algorithm and implementation and image	3
	Memetics and image	97
	Memetics and fingerprint	5
Total		1335
Selected		13

Table 3. Data From Science Direct

Source	Keywords	Results
Science Direct	Memetics algorithm	3353
	Memetics algorithm and implementation	2766
	Memetics algorithm and image	774
	Memetics algorithm and implementation and image	618
	Memetics and image	862
	Memetics and fingerprint	33
Total		8406
Selected		8

Table 4. Data From Springer Link

Source	Keywords	Results
Springer Link	Memetics algorithm	5723
	Memetics algorithm and implementation	2928
	Memetics algorithm and image	1747
	Memetics algorithm and implementation and image	893
	Memetics and image	890
	Memetics and fingerprint	68
Total		12249
Selected		6

2.5. Stage 5: Data Item Selection

Data are obtained from short-listed articles that explain the use or the implementation of the memetics algorithm. Finally, we decide and select 33 articles that are appropriate to the survey based on the titles, abstracts, keywords, and contents. The other papers are not included in the survey because they are not eligible in every selection stage (stage 1 to 4). Tables 1, 2, 3, and 4 show the data that have been collected from each source.

3. RESULT AND DISCUSSION

The research proposed to observe the implementation of Memetics Algorithms (MA) that have been done by other researchers. Based on this purpose, the research identifies many implementations of the MA shown in table 5.

Table 5 shows research papers that are focus on the method and implementation of MA. Most of them are from the journal and only four papers from the conference. Based on the 33 papers in table 5, we divide the implementation of the MA into four categories, image processing, image recognition, image classification, and image retrieval. 12 papers use MA for image processing, 18 papers use MA for image recognition, and every 2 papers use MA for image classification, and 1 paper use MA for image retrieval.

Table 5. Data From Springer Link

Title	Publication Type	Publication year
MA Image Enhancement…[33]	Journal	2019
Feature Selection…[34]	Journal	2019
An Enhanced…[35]	Journal	2019
Feature…[36]	Journal	2005
Evolutionary…[37]	Journal	2019
Sub-pixel…[38]	Journal	2015
Memetic algorithm…[39]	Journal	2017
Affinity Propagation…[40]	Conference	2010
A Memetic algorithm…[41]	Journal	2013
A Memetic Fingerprint…[42]	Journal	2007
Memetically…[43]	Journal	2012

An instantaneous…[44]	Journal	2004
Bacterial memetic…[45]	Journal	2016
Fully Automatic…[46]	Journal	2019
… Particle Gravitation….[47]	Journal	2015
Modified…[48]	Journal	2018
SAR…[49]	Journal	2005
A Flower….[50]	Conference	2018
High Resolution …[51]	Conference	2013
…binary image…[52]	Journal	2016
Automatic feature point…[53]	Conference	2015
Automatic SAR...[54]	Journal	2014
…for reconstructing …[55]	Journal	2016
…Pattern….[56]	Journal	2013
…Similarity measure…[31]	Journal	2017
...3D Protein…[57]	Journal	2020
For Handwritten…[58]	Journal	2017
..Filter design…[29]	Journal	2008
..binary image…[30]	Journal	2008
…face recognition…[59]	Journal	2009
A multi-objective…[60]	Journal	2005
A memetic…[61]	Journal	2010
Measuring Memetic…..[62]	Journal	2021

Papers included image processing papers with the scope of research about operations that are conducted on images with MA. The image recognition category consists of papers that use MA to identify and detect features in a digital image. The image classification category consists of papers that classify image and image retrieval consist of the papers that use MA to retrieve images based on its features.

At first, researchers suggest that this algorithm is only used for optimization such as scheduling problems and many more things refer to it. For image datasets, this algorithm can be implemented very well and provide an optimal solution. In this survey (on the researches between 2004 and 2021) we found that MA for image (recognition) is the most implemented. Generally, table 6 shows the implementation, method, and result.

Table 6. Several Implementations of Memetic algorithm, methods, and results

Author	Year	Implementation on	Methods	Results
Montazeri, et.al	2019	Image enhancement (image processing)	equalizing population of chromosomes with an array of integer to gray level then introduce fitness function to measure solutions quality	MA has higher value and quality solution, preserves brightness
Ghosh, et.al	2019	facial emotion recognition (image recognition)	Local search MA, use greedy and late hill-climbing base MA (LHCMA)	MA has the best performance in 17 of 30 cases, LHCMA performs better 66%
Bereta, M.	2018	Mitigates Baldwin effect and Lamarckian evolution (optimization)	Local search procedure of the genetic and memetic algorithm	Solve optimization problems and find an optimal solution
Welekar, et.al	2019	Recognize characters (image recognition)	An improvised local search of memetic algorithm	Using MA, research achieved efficiency, reduce memory consumption, enabling better utilization of available resources of processing systems.
Ghosh, et.al	2005	Recognize handwritten (image recognition)	multi-objective MA-based feature selection technique.	Improved recognition accuracy for an individual as well as for a combined feature vector.
Kumar, et.al	2019	Processing retinal fundus image (image processing)	Memetic differential evolution (MDE)	Achieves optimal solution, Integrated local search using DE algorithms enhances the search capability and reduces the number

				of generations to achieve the solution
Mu, et.al	2014	Detecting Community Structure in Complex Networks (prediction)	Memetic algorithm using local structural information (MA-LSI)	MA with LSI is superior to the original MA for network detection problems
Zhang, et.al	2015	Sub-Pixel Mapping (image recognition)	Sub-Pixel Mapping based on Memetic Algorithm	SMMA was implementing with hybrid memetic and DE. Algorithm tested on sub-pixel mapping remote sensing image
Zhang, et.al	2017	Image classification	MA-based un-supervised band selection method	Design new crossover and local search strategy. The method obtains high-quality band subsets
Zhu, et.al	2010	Image classification	Affinity Propagation based Memetic band selection (APMA),	The method improves performance and accelerates more compact subsets
Chi, et.al	2014	Learning large scale fuzzy cognitive maps (optimization)	Hybrid MA and neural network	The algorithm learns FCMs with 100 nodes efficient
Buck, et.al	2013	Matching spatial configuration in geographic information system (image recognition)	Combining evolutionary strategy on memetic algorithm	The original sketch location found with a longer running time
Sheng, et.al.	2007	Fingerprint matching (image recognition)	Memetic fingerprint matching without local improvement operation	This algorithm reduces several generations to find high-quality

				optimization problems
Haque, et.al	2017	Community detection (prediction)	Connected cohesion with memetic algorithm (CCMA)	Capture the largest and the most cohesive group in the network.
Pagacz, et.al	2010	Generalized minimum network problems (optimization)	Node oriented and greedy crossover to generate solutions, mutate probability with new solutions, and optimize with local improvement	The high-quality solution is achieved with small running times. Limited to the size of data.
Bhatt, et.al	2012	Matching sketches with a digital image (image recognition)	Extract information from sketch and digital images using automated memetic	Existing methods and commercial systems are poor compared to the proposed method
Fernande z, et.al	2004	Illumination correction (image processing)	Instantaneous Memetic Illumination Correction (IMIC)	The convergence of the algorithm is very fast and improves both in accuracy and variance of the results
Zhou, et.al	2016	Surface electromyograph y based hand motion recognition (image recognition)	Bacterial Memetic Algorithm with specific feature selection	The proposed method increases the 1% error rate experiments, and smaller than 2/3 reduction number of extracted features, it would reduce processing time.
Wan, et.al	2019	Remote sensing, multispectral imagery (image processing)	Fully automatic clustering using an adaptive multi-objective memetic algorithm (AMOMA)	The framework for fully automated remote sensing image clustering. This is a spatial structure that is

				utilized to find high-quality solutions.
Huang, et.al	2019	Image segmentation (image processing)	memetic particle gravitation optimization (MPGO) algorithm	MPGO outperforms k- means significantly in results
Huang, et.al	2015	Solving clustering problem (optimization)	Memetic gravitation search algorithm (MGSA)	Algorithm gets a better solution with computation time reduction. It is better than the original GSA algorithm and the Artificial bee colony algorithm.
Galvez, et.al	2018	Image reconstruction (optimization)	Modified self-adaptive firefly algorithm coupled with heuristics method for local search	Achieved unsatisfied solution, furthermore might improve the method in several ways.
Yang, et.al	2013	Image recognition on radar target	Using less sampling data to measure target accurately. proposing an MA optimizer that making more rapid convergence and shorter optimization time possible	Memetic reflectivity was superior to genetic and more accurate.
Ruiz, et.al	2018	Predicting energy consumption in buildings (optimization)	Adaptive search algorithm called "Cross-generational elitist selection, Heterogeneous recombination, and Cataclysmic mutation" (CHC).	The proposed method can be modified to produce a parallel memetic energy efficiency prediction proposal.
Nagi, et.al	2016	Image reconstruction (image processing)	Original memetic algorithm to compare experimental results on the algorithm based on 6 direction projections.	3 directions are faster than 6 directions in similar parameters.
Moscato, et.al	2007	Ordering microarray data (optimization)	Embedding tabu search procedure on evolutionary algorithm	Memetic has more time-consuming but consistent to

				improve initial solutions.
Matsui, et.al	2015	Augmented reality (image recognition)	extends hybrid meta-heuristics based on memetic and tabu search.	Choose a point selection feature to reduce computational time.
Li, et.al	2014	image enhancement (image processing)	Improving enhancement function to shrink and stretch image contourlet coefficient	Method tested on simulated and real images. The proposed method suppresses the speckle noise on the synthetic aperture radar image edges and texture
Gong, et.al	2016	Cross-cut shred document reconstruction (image processing)	Using splicing-driven memetic algorithm (SD-MA) with novel crossover, mutation operators, and an elitism-based local search strategy	The algorithm achieves stability for instances of 6 × 6 and 6 × 9 shreds. For 9 × 9 shreds, the improvement becomes more prominent
Bao, et.al	2013	Pattern search (image recognition)	PSO-PS (Particle swarm optimization -pattern search based on MA	Memetic is inferior to PSO. memetic consume much fewer fitness evaluations.
Alsmadi, M.K	2017	Similarity measurement (image recognition)	Use memetic to generate Content-based image retrieval (CBIR) system. And use memetic to measure similarity.	Memetic can discriminate color, shape, and image texture. System tested on different image queries. The proposed method outperforms the other systems
Ghosh, et.al	2017	Handwritten recognition	Proposes MA-based Wrapper-filter feature	Variety of accuracies in every execution due to the usage of

		(image recognition)	selection (FS) framework for handwritten recognition	random weights. An increase/decrease in recognition accuracies in virtue of feature reduction indicates the usefulness of the proposed method.
Dworak, et.al	2012	Cryptography	Proposed MASA-memetic algorithm using a standard simulated annealing algorithm to achieves high-quality solutions in less processing time with improving local search process.	MASA checks 130000–140000 fewer sub-keys than the previously proposed NGA.
Tirronen, et.al	2008	Defect detection in paper production (image processing)	Design digital filters with memetic differential evolution (MDE).	DE is better than an evolutionary strategy for accuracy
Botzheim, et.al	2012	Offline path planning of mobile robot (optimization)	Bacterial MA (BMA). Speed up the evolutionary process by combining BMA with local search.	The bacterial evolutionary algorithm (BEA) is faster than BMA. Several bacteria and their generation can improve high-quality solutions.
Aranha, et.al	2009	Financial portfolio optimization (prediction)	Three steps memetic tree-based genetic algorithm (MTGA), 1st introduce a new genome representing the problems. 2nd evaluates sub-trees, 3rd combines GA with a local optimization (memetic) step.	Generates a more understandable portfolio by removing assets that are not relevant.
Cabido, et.al	2012	Multiple object tracking on GPU (optimization)	Memetic algorithm particle filter (MAPF),	Solve high dimension problems and don’t suffer a

				lack of performance when the number of targets grows.
Gesu, et.al	2000 8	Image reconstruction (image processing)	Crossover is applied vertically or horizontally; mutation: operator locates white and black pixels randomly; compactness: algorithm is suitable to reconstruct objects.	The method is robust enough, through images satisfying a priori knowledge, like the hv-convex polyominoes constraint returned better results.
Caponio, et.al	2012	MA in engineering and design (optimization)	For offline optimization: Compare Fast Adaptive Memetic Algorithm (FAMA) with a pure GA and a simplex algorithm. For online optimization: compare FAMA with a pure GA only.	Pay attention to peculiarities of the specific optimization problem when designing MA. It could not be enough if we put it together with an evolutionary framework.
Feng, et.al	2016	Band selection for hyperspectral imagery (optimization)	Memetic solver for band selection and probabilistic memetic algorithm	Achieves better quality than the counterparts in training and testing accuracy. in the online search, the algorithm can adaptively balance the exploration and exploitation
Galinier, et.al	2011	Graph partitioning problem (optimization)	A memetic algorithm for graph partitioning (MAGP) algorithm	MAGP was able to reach or outperform a majority of the best former results.
Kielarova, et.al	2017	Optimization on Jewelry Design Applications (optimization)	General Regression Neural Network, Hybrid MA	Computational time: MA is 5,306 s and GA is 1,935 s. during the evolutionary process MA used five more

				computational times than the GA.
Kumar, et.al	2008	Face recognition (image recognition)	Proposes PCA-principal component analysis using MA. It can determine interesting regions in the search space and achieve that quickly find good solutions.	The proposed method is better to process recognition based on features selected
Liang, et.al	2015	body gamma knife stereotactic radiotherapy treatment planning (optimization)	memetic performs the optimization on relative dosimetric distribution.	Generates feasible treatment plan
Naveen, et.al	2016	Bankruptcy prediction (prediction)	Combining memetic to cuckoo search algorithm and particle swarm optimization algorithm.	Achieves better results in the case of WBC and Turkish bank with good accuracy .
Nguyen, et.al	2011	Time table problem (optimization)	Implement MA and GA then compare the results of those two algorithms.	MA and GA are tested on 6 instances collected from real-world data in 4 studying years of the University of Science. MA provides a better final solution
Ozcan, et.al	2006	Partial shape matching (image recognition)	MA with crossover, mutation, and hill-climbing operators; MA run was terminated when the correct solution was reached, or if the number of crossovers equals 500,000; Test was repeated 100 times	If the hill-climbing feature omitted algorithm performance unsatisfied; the algorithm is used; the advantages are: computationally efficient, space-efficient, fast, better

				than GA without hill climbing. successful for partial shape matching, even with a large database
Potti, et.al	2011	Very large scale integrated (VLSI) circuit floor-planning problem (optimization)	Parallelize memetic on Graphical Processing Units (GPU); compare parallel MA with an ordinary MA	General-purpose GPU (GPGPU) has good accelerated performance on larger population sizes
Radtke, et.al	2005	Feature extraction on pattern recognition (image recognition)	MOMA-Multi-objective Memetic Algorithm with IFE-intelligent feature extraction; IFE methodology assessed to generate representations for isolated handwritten digits.	Utilize MOGA approach for better convergence with a lower number of unique individual evaluations, the LS with the greedy first improvement strategy is most appropriate
Peralta, et.al	2017	Fingerprint matching (image recognition)	General decomposition on the matching algorithms based on minutiae	Asses the algorithm at the well-known big data framework ApacheHadoop and ApacheSpark with huge fingerprint data.
Peralta, et.al	2014	Fingerprint identification (image recognition)	Use a distributed framework for fingerprint matching with a reliable processing time.	With two sets of fingerprint data, synthetic and scanned, the system can compute 400000 data at a half-second rate.
Assiroj, et.al	2021	Fingerprint identification (image recognition)	Parallelize MA called HPCMA to process image fingerprint datasets.	HPCMA identifies fingerprints with high accuracy and speed.

According to table 6 above, the research analyzes the implementations of the memetic algorithm (MA) in various research fields. Most of the implementation of this algorithm is in image processing and image recognition, with various proposed methods. The amount is shown in Figure 3.

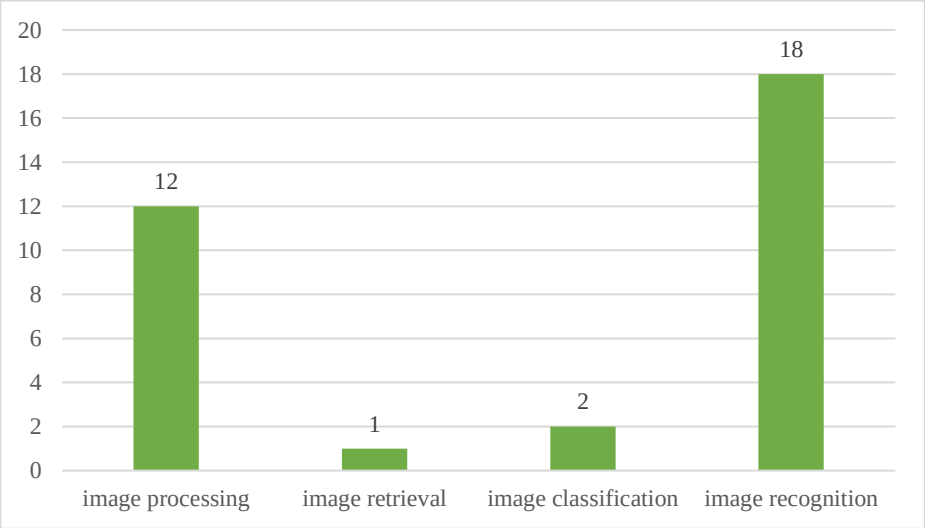

Figure 2. Memetic Algorithm

4. CONCLUSION

According to the survey that has been done, the MA implementation for image processing consists of 12 papers, 1 paper uses MA for retrieval, 2 papers use MA for image classification and the most is 18 papers use this algorithm for image recognition. In image processing, MA can distinguish colors, shapes, and image's texture. The result of this research could be a reference for future research about MA implementation that categorized into four, image processing, image classification, image retrieval, and image recognition. Some method has proposed for the novel of its implementation.

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CONFLICT OF INTERESTS

The author(s) declare that there is no conflict of interests.

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