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.
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;
    SELECT 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.

| 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.

| 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             |
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.
| Author          | Year | Implementation                      | 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 |
| Authors   | Year | Title                                                                 | Method Description                                                                 |
|----------|------|----------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Mu, et.al| 2014 | Detecting Community Structure in Complex Networks (prediction)        | Memetic algorithm using local structural information (MA-LSI)                      |
| Zhang, et.al | 2015 | Sub-Pixel Mapping (image recognition)                                  | Sub-Pixel Mapping based on Memetic Algorithm                                       |
| Zhang, et.al | 2017 | Image classification                                                   | MA-based un-supervised band selection method                                        |
| Zhu, et.al| 2010 | Image classification                                                   | Affinity Propagation based Memetic band selection (APMA),                          |
| Chi, et.al| 2014 | Learning large scale fuzzy cognitive maps (optimization)               | Hybrid MA and neural network                                                       |
| Buck, et.al | 2013 | Matching spatial configuration in geographic information system (image recognition) | Combining evolutionary strategy on memetic algorithm                               |
| Sheng, et.al | 2007 | Fingerprint matching (image recognition)                               | Memetic fingerprint matching without local improvement operation                   |

- **Mu, et.al 2014**: Detecting Community Structure in Complex Networks. Memetic algorithm using local structural information (MA-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 was implemented 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.
- **Zhu, et.al 2010**: Image classification. Affinity Propagation based Memetic band selection (APMA).
- **Chi, et.al 2014**: Learning large scale fuzzy cognitive maps (optimization). Hybrid MA and neural network.
- **Buck, et.al 2013**: Matching spatial configuration in geographic information system (image recognition). Combining evolutionary strategy on memetic algorithm.
- **Sheng, et.al 2007**: Fingerprint matching (image recognition). Memetic fingerprint matching without local improvement operation.

This algorithm reduces several generations to find high-quality solutions.
| Author(s)       | Year | Category                              | Approach                                            | Challenges                                                                 |
|-----------------|------|---------------------------------------|----------------------------------------------------|---------------------------------------------------------------------------|
| 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 |
| Fernandez, 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 |
| Authors          | Year | Title                                                                 | Method                                                                 | Details                                                                 |
|------------------|------|----------------------------------------------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------|
| 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 |
| Authors | Year | Field | Methodology | Result/Impact |
|---------|------|-------|-------------|--------------|
| Matsui, et.al | 2015 | Augmented reality (image recognition) | Extends hybrid meta-heuristics based on memetic and tabu search. | Improve initial solutions. |
| Li, et.al | 2014 | Image enhancement (image processing) | Improving enhancement function to shrink and stretch image contourlet coefficient | Choose a point selection feature to reduce computational time. |
| 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 $6 \times 6$ and $6 \times 9$ shreds. For $9 \times 9$ 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 achieve 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), 1\textsuperscript{st} introduce a new genome representing the problems. 2\textsuperscript{nd} evaluates sub-trees, 3\textsuperscript{rd} 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
| Author(s) | Year | Field of Study | Description | Notes |
|----------|------|----------------|-------------|-------|
| Gesu, et al | 2000 | 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 |
| Researcher, Year | Field/Problem | Description |
|-----------------|--------------|-------------|
| 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) | 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 computational times than the GA. |
| 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 | than GA without hill climbing. successful for partial shape matching, even with a large database 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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