Application of ant colony mixed algorithm in image enhancement

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Abstract

Image enhancement is a method of image processing to highlight some information and weaken or eliminate some irrelevant information in the image or transform the original image into an image which is more suitable for humans or machines to perform analytical processing by using some specific methods. Applying intelligent algorithm in image enhancement, this paper has proposed a mixed algorithm, namely the genetic-ant colony mixed algorithm based on genetic algorithm and ant colony algorithm and found the optimal combination point between these two algorithms by analyzing their time-speed curves. Then it designs the algorithm for image enhancement, including the image pre-processing, the computational steps of the early genetic algorithm, and the connection of genetic algorithm and ant colony algorithm according to certain conditions and the operations of the later ant colony algorithm. The experimental simulation result shows that the algorithm of this paper is superior to simple genetic algorithm or ant colony algorithm and it greatly improves the visual effects of the image, effectively supplements the weak information of the image and reduces the influence of image overexposure for ease of the subsequent image processing.

Keywords: genetic algorithm, ant colony algorithm, image enhancement

1 Introduction

The main purpose of image enhancement is to improve the image identification to make the image more propitious to observation and further analytical processing [1]. In general, it emphasizes or sharpens certain image features such as the edge, the outline, the contrast and the brightness to highlight the valuable information, suppress the unuseful information and improve the use value of the image. In other words, image enhancement is to make the processed image better than the original image under certain specific standard [2].

Most of the traditional image enhancement techniques process the image in the spatial domain. The spatial-domain processing methods are simple and easy to understand and many people work on the improvements in the enhancement methods such as the improved algorithms of histogram method and un-sharp masking, which have achieved some effects. With the continuous development of image enhancement techniques, various new methods emerge [3]. Such methods as Retinex model which simulates human visual system, fuzzy theory and neural network have been gradually used in image enhancement. Every method has its own advantages and disadvantages, including:

a) non-commonality of image enhancement algorithms;

b) selection of image quality evaluation criterion;

c) noise influence;

d) selection of the optimal parameters. As for (d), the selection of different parameters determines the final processing effects. The same method used in the image under different environments and backgrounds can have better enhancement effects with different parameters [4]. The algorithm has strong dependence, but its robustness is not high; therefore, it can not be used in practical applications. It is difficult to obtain better image enhancement effects on how to find the appropriate parameters and whether there is self-adaptive parameter selection method [5].

By integrating the advantages of genetic algorithm and ant colony algorithm in seeking the optimal solution problems, this paper has proposed the image enhancement method based on genetic-ant colony mixed algorithm. This algorithm has better solving efficiency and time efficiency and it can automatically find out the optimal value of the non-linear transformation function for every image. In the beginning of this algorithm, it adopts the operating steps of genetic algorithm. If the changes of the population fitness function value of the continuous 10 generations are within the error range, end the genetic algorithm and transform the current optimal solution to the matrix distribution of the initial pheromone concentration of ant colony algorithm. Then operate ant colony algorithm. After the algorithm ends, output the enhanced image. The algorithm of this paper can improve the image contrast, preserve the image detail information and enhance the dark and flat details of the image effectively and strengthen the visual effects of the enhanced image.

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2 Genetic algorithm and ant colony algorithm

2.1 BASIC GENETIC ALGORITHM

Genetic algorithm seeks the optimal solution of the problem through chromosome simulation and by simulating the evolution operation in chromosome. As a randomized algorithm, genetic algorithm simulates the natural evolution model such as crossover, selection, mutation, migration, local and neighborhood operations. In genetic algorithm, the solution is encoded as the chromosome of the biological individuals and the objective function of the problem corresponds to the fitness function of the biological individual. Start the computation from the population random initialization with N individuals; calculate the fitness of every individual; conduct such genetic operations as selection, crossover and mutation and generate the initial generation. Since the members of the new population are the excellent individuals of the last-generation population, the new population is superior to last generation in general. Likewise, repeat the iterations until it meets certain preset optimization criterion. In every generation, the fitness of the entire population will be evaluated and get the chromosome which is most suitable for the environment as the optimal solution by conducting multi-generation evolution on the biological population in the chromosome [6,7].

There are three genetic operations in genetic algorithm: selection, crossover and mutation and they are also the most commonly-used algorithms in the genetic algorithm.

2.1.1 Selection operation

Selection operation is to simulate the natural selection process and select excellent individuals from the current population to give them the opportunity to produce the next generation as parents according to the fitness of every individual and certain rules or methods. Selection will give the individuals with high fitness a bigger chance to produce the next generation while it gives a smaller chance for those with low fitness or it even eliminates those individuals. Selection reflects the survival of the fittest by Darwin [8].

2.2.2 Crossover operation

Crossover operation is the process to replace and reconstruct part of the structures of the gene strands of two selected parent individuals and produce new individuals. The purpose of crossover is to produce new individuals in the next generation and it is also the most important means for genetic algorithm to acquire new excellent individuals, suggesting the idea of information exchange [9]. The process of crossover operation is indicated in Figure 1.

2.2.3 Mutation operation

Mutation operation is to randomly select an individual from the population and randomly change the value of certain strand in the strand structures at a certain probability. As a local random search, mutation provides an opportunity for the production of new individuals and guarantees the effectiveness of genetic algorithm and the diversity of population by integrating with selection and crossover [10].

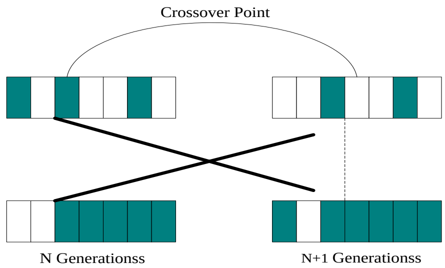


FIGURE 1 Crossover operation

The entire mutation operation is indicated in Figure 2.

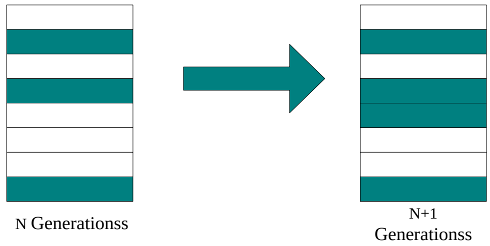


FIGURE 2 Mutation operation

The flowchart of basic genetic algorithm is indicated in Figure 3.

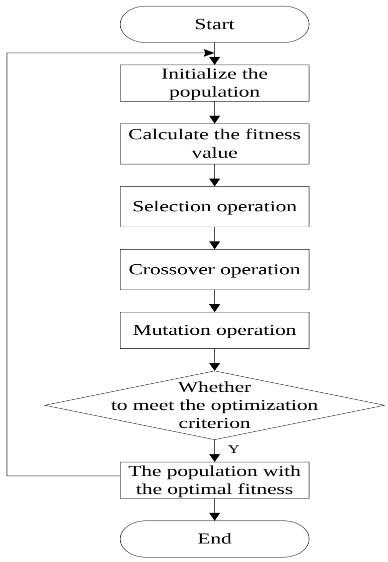


FIGURE 3 The flowchart of genetic algorithm

2.2 BASIC ANT COLONY ALGORITHM

Ant colony algorithm is a new colony intelligent heuristic bionic optimization and it was proposed by M. Dorigo, an Italian scholar in 1992 in his doctoral dissertation, where it was called ant colony system [11]. Ant colony system is used to solve travelling salesman problem (TSP) and it is suitable to settle the combinational optimization problems such as the vehicle routing problem (VRP) with its principle indicated in Figure 4.

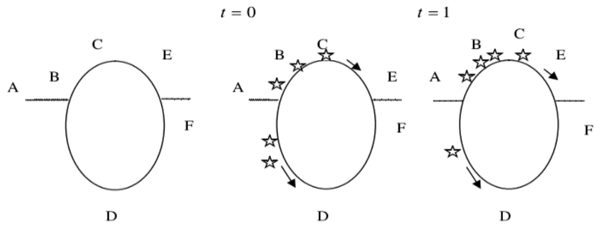


FIGURE 4 The principle of ant colony algorithm

In Figure 4, assuming that there are N ants searching food from cave A and it can be clearly seen from the principle of ant colony algorithm that there are two paths for the ants search food in the opposite end by passing the obstacles from cave A, namely A-B-C-E-F and A-B-D-E-F. These three figures clearly indicate the relationship between the two paths, namely that dAB is equal to dEF, but $dBDF$ is obviously larger than $dBCE$. Before all the ants start, the ants will randomly choose a path, as indicated in Figure 4b since there is no cumulative pheromone in the paths. However, as time passes, the ants will leave pheromone on the shorter path. Because $dBDF$ is obviously larger than $dBCE$, the pheromone concentration in BCE will be high. Therefore, more ants will choose this shorter path in Figure 4c and more pheromone will be released in this path, too. Under this circumstance, the pheromone of this path will be higher and higher and it will attract an increasing number of ants to choose this path, reflecting that ant colony algorithm has a strong positive feedback [12, 13].

Ant colony algorithm has made great process during the past decade of years since it was proposed by the Italian scholar. Ant colony algorithm has been used widely because of the following advantages: positive feedback mechanism, robustness, parallel, self-organization and ease to integrate with other methods [14].

Although ant colony algorithm has many advantages, it still has a lot of shortcomings because it was proposed not long ago. For example, it requires a long search time. It is slow in evolution and convergence. It is easy for the algorithm to stagnate and to have the pre-maturity phenomenon. In other words, after searching to a certain phase when all the individuals find the same solution, it won't further search the solution space and it is bad for finding more optimal solutions [15].

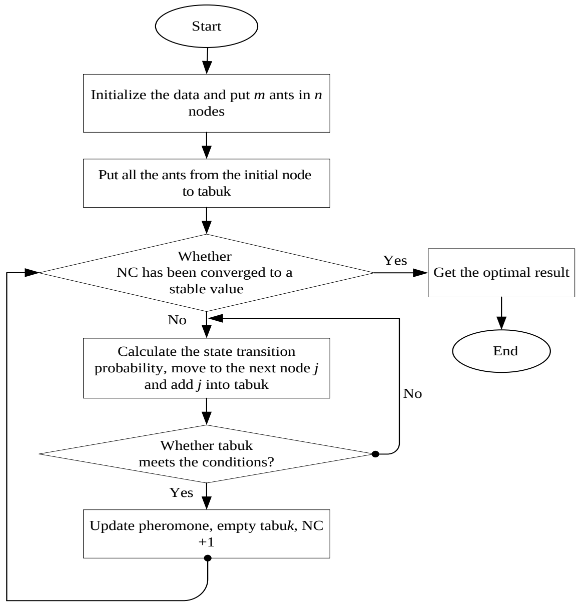


FIGURE 5 The basic procedures of ant colony algorithm

3 The integration of genetic algorithm and ant colony algorithm

Adopt the corresponding encoding scheme based on the practical problems of image enhancement. For digital image, its gray value is between 0-255; therefore, set the encoding systems of every chromosome as 8-bit binary coding and as for the genetic algorithm of image enhancement, set the population size between 100-200; the maximum genetic algebra between 200-2000; the mutation probability P_c=0.9 and the mutation probability P_m=0.1.

In the early genetic-ant colony mixed algorithm, operate genetic algorithm until it reaches the set terminal condition. Transform the current optimal solution seeked in the genetic algorithm as the distribution matrix of the initial pheromone in ant colony algorithm. Then operate ant colony algorithm until the optimal solution is seeked. The evaporation of the pheromone on one hand can prevent the search scope from being restricted in a local range; on the other hand, it can update the pheromone and enhance its learning according to the effects of the solution is seek.

In this paper, update the pheromone with Max-Min Ant-Colony Algorithm (MMAS). When setting the initial pheromone of ant colony algorithm, set the initial pheromone of every path as the maximum value $t_{\max}$ and the initial value τ_0 can be set as a fixed value 100. According to the distribution of the initial pheromone transformed by the previous genetic algorithm, we set the initial value of pheromone of resource i as:

$$\tau_i^s(t) = \tau_0 + \tau_i^G(t)\,, \tag{1}$$

where τ_0 is a constant of pheromone and it is formulated according to the specific problems, which is equal to $t_{\max}$

in MMAS. $\tau_i^G(t)$ is the pheromone value transformed by the second-optimal solution from the early genetic algorithm.

Then, randomly put *m* artificial ants in *n* pixel points and calculate the objective function value according to the distribution of every ant. Since genetic algorithm and ant colony algorithm are two different solution algorithm of the same problem in different phases, their objective function and fitness function are the same [16].

For every artificial ant *k*, G_k, is the unvisited node collection. S_k is the node collection which allows next visit according to the probability transfer formula. And $tabu_k$ is the search tabu table, suggesting the visited node collections.

$$C_{ij} = \begin{cases} \arg \quad \max_{j\in allowed} \{\tau(i,j)\eta^{\beta}(i,j)\}, & if \ q \le q_0 \\ 0, & otherwise \end{cases}, \quad (2)$$

where C_{ij} is a state variable and it is acquired from ant colony transfer formula; q_0 can take its value between [0,1] and when $q=(0,1]$, the ant colony randomly generates q in choosing the next pixel point. When q is smaller than or equal to q_0, choose the next shortest pixel point to transfer and when q is bigger than q_0, select according to:

$$p_{ij}^k(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^a[\eta_{ij}(t)]^{\beta}}{\sum_{s\subset allowed_k}[\tau_{ij}](t)]^a[\eta_{ij}(t)]^{\beta}}, & if \quad j \in allowed_k \\ 0 \quad , & otherwise \end{cases}, \quad (3)$$

where α is the heuristic factor of pheromone; β is the expected heuristic factor; $allowed_k$ is the pixel point which allows the next visit of the artifical ant *k* and $p_{ij}^k(t)$ is the probability that ant k moves from pixel point to pixel point *j* at the moment of *t* [17].

4 The basic steps of genetic-ant colony mixed algorithm faced to image enhancement

4.1 TYPICAL TRANSFORMATION FUNCTION

From the visual effects, the general input image may be darker, brighter or focusing the grayscale in certain area. For these different degraded images, we need different non-linear transformation. The following figure is several typical gray-scale transformation function figures with x-coordinate as the grayscale of the original image and y-coordinate as the enhanced grayscale [18].

Tubbs has proposed to realize the auto fitting of four transformation curves in Figure 6 by using the normalized non-complete Beta function and the normalized non-complete Beta function $T(u)$ is defined as:

$$T(u) = B^{-1}(a,\beta)\int t^{a-1}(1-t)^{\beta-1}dt, \qquad 0 < a,\beta < 10, \quad (4)$$

where $B(a,\beta)$ is Beta function.

$$B(\alpha,\beta) = \int_0^1 t^{\alpha-1}(1-t)^{\beta-1}dt. \quad (5)$$

With different α and β, the various transformation curves in Figure 6 can be obtained [19, 20].

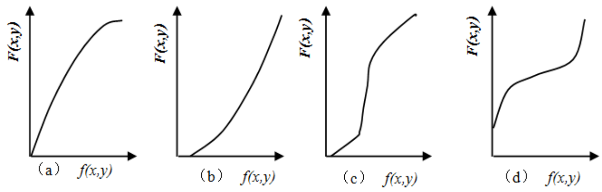


FIGURE 6 Four typical grayscale transformation functions: (a) Stretch the darker areas; (b) Stretch the brighter areas; (c) Stretch the middle area and compress the two sides; (d) Stretch the two sides and compress the middle area

4.2 THE PARAMETERS USE ANT COLONY MIXED ALGORITHM TO OPTIMIZE NON-LINEAR TRANSFORMATION FUNCTION

In the enhancement of every image, the design of the fitness function needs to take the global and the local of the image as well as the big structure and the small detail balance into consideration. This paper has adopted image quality evaluation criterion as the fitness function of the mixed algorithm, which is shown as follows:

$$Fitness(i) = -\frac{1}{n}\sum_{x=1}^{M}\sum_{y=1}^{N} f^2(x,y) - \left[\frac{1}{n}\sum_{x=1}^{M}\sum_{y=1}^{N} f(x,y)\right]^2, \quad (6)$$

where *M* are *N* are the width and height of the image respectively; *n=M*N* and *i* is a certain individual. The bigger value of *Fitness*(*i*) suggests that the image grayscale is distributed more uniformly; that the image contrast is higher and that the image quality is better.

This paper uses genetic-ant colony mixed algorithm to find out the optimal α and β in the non-linear transformation function automatically for every image. In this paper, the main steps are the operations of genetic algorithm and ant colony algorithm. Indicate the corresponding pixel points in the image with the grayscale matrix between 0-255.

Step 1: assume that the original image is $f(x,y)$ and $(x,y)\in\Omega$, Ω is the definitional domain of the image while the enhanced image is $f'(x,y)$ with $(x,y)\in\Omega$. Perform normalized processing on the grayscale image and transform it into the space of [0,1], namely

$$g(x,y) = [f(x,y) - L_{min}]/[L_{max} - L_{min}], \quad (7)$$

where L_{max} and L_{min} are the maximum and minimum image grayscales and it is obvious that $0 \le g(x,y) \le 1$.

Step 2: perform real number encoding on parameters α and β by using genetic-ant colony mixed algorithm. Every individual corresponds to non-linear transformation function T(u) with $0 \le u \le 1$ and process the grayscale image with non-linear transformation function:

$$g'(x,y)=T[g(x,y)], \text{ and } 0 \le g'(x,y) \le 1 \quad (8)$$

Step 3: make $T(u)$ as Equation (4) and output the image $f'(x,y)$ according to the value of $g'(x,y)$.

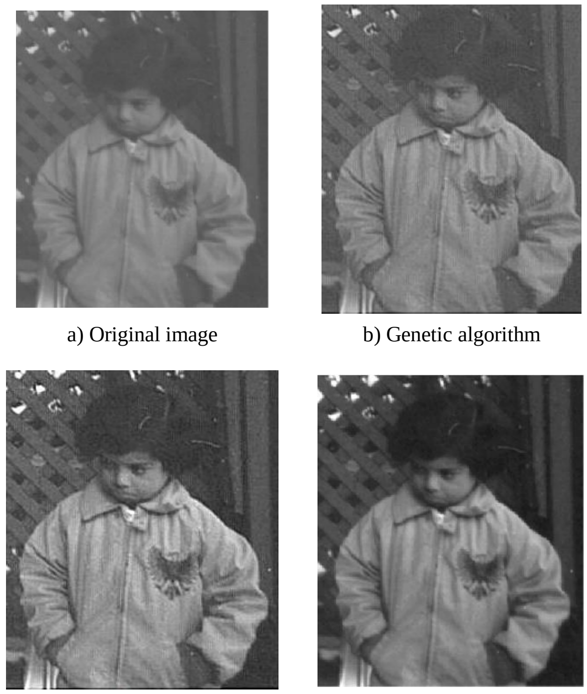
$$f'(x,y)=(L_{max}-L_{min})g'(x,y)+L_{min}, \quad (9)$$

Step 4: update the population with the mixed algorithm to get new population. Repeat the above steps until it reaches the maximum evolution generations or until it obtains more excellent individuals and output the individual with the current maximum fitness as the optimal solution.

5 Experimental results and analysis

The experiment selects the standard test image "pout girl" as the original image to conduct experimental analysis and to compare the enhancement effects by the algorithm of this paper with those by other enhancement algorithms. The run-time environment is Intel(R) Core(TM)2 CPU 1.33GHz, 2.5GB RAM, the operating system is Windows 7 and the run-time environment is Matlab R2012a.

For comparison's sake, compare the genetic-ant colony mixed algorithm of this paper with simple genetic algorithm and simple ant colony algorithm and set the same parameters. Set the algorithm parameters as follows: the population size of genetic algorithm: $g = n \times m$; the crossover probability $p_c = 0.9$; the mutation probability $p_m = 0.1$; the population size of ant colony algorithm $h = n \times m$; the heuristic factor of pheromone $\alpha = 3$; the expected heuristic factor $\beta = 1$ and the pheromone volatilization coefficient $\rho = 0.1$.



a) Original image b) Genetic algorithm

c) Ant colony algorithm d) Genetic-ant colony mixed algorithm

FIGURE 7 Comparison of image enhancements by different algorithms

TABLE 1 Comparison of enhancement effects by different algorithms

Enhancement methods	Mean	Mean square error	Contrast improvement factor
Original image	95.43	26.56	1.26
Genetic algorithm	108.38	41.32	1.39
Ant colony algorithm	123.61	53.71	1.54
Genetic-ant colony mixed algorithm	134.52	69.53	1.68

It can be seen from the above Figure 7 and Table 1 that the algorithm of this paper has the maximum corresponding mean square error and contrast improvement factor, suggesting that this algorithm has the most outstanding enhancement effects on image. Compared with the simple genetic algorithm and ant colony algorithm, the algorithm of this paper has excellent enhancement effects and clear image and it has preserved good brim outline, enhanced the image contrast, got more details and achieved better enhancement effects. Besides, this algorithm also has good processing effects on the image with insufficient or uneven lights.

6 Conclusions

This paper mainly investigates the applications of intelligent algorithm in image enhancement and it has also proposed a genetic-ant colony mixed algorithm with excellent comprehensive performance. The core of this algorithm is to control the design of the function and it controls the iterations by calculating the rate of evolution of the generation group in genetic algorithm to determine the time to integrate genetic algorithm and ant colony algorithm. Firstly, this algorithm transforms the results from genetic algorithm into the initial pheromone distribution in ant colony algorithm. Then it seeks the optimal solution by using ant colony algorithm. This algorithm has changed the mechanism of the initial value of ant colony algorithm and improved the search stability. In the meanwhile, it seeks the optimal solution by using such features of ant colony algorithm as parallel, positive feedback mechanism and high efficiency.

References

[1] Anand S, Kumari R S S, Thivya T, Jeeva S 2013 Sharpening Enhancement of Ultrasound Images Using Contourlet Transform *Optik – International Journal for Light and Electron Optics* **124**(21) 4789-92

[2] Samarasinha N H, Larson S M 2014 Image Enhancement Techniques for Quantitative Investigations of Morphological Features in Cometary Comae: A comparative study *Icarus* **239**(1) 168-85

[3] Zhao J, Chen Y, Feng H, Xu Z, Li Q 2014 Infrared Image Enhancement through Saliency Feature Analysis Based on Multi-Scale Decomposition *Infrared Physics & Technology* 62 86-93

[4] Khan M A U, Khan T M 2013 Fingerprint image Enhancement Using Data Driven Directional Filter Bank *Optik – International Journal for Light and Electron Optics* **124**(23) 6063-8

[5] Yeom E, Nam K H, Paeng D G, Lee S J 2014 Improvement of Ultrasound Speckle Image Velocimetry Using Image Enhancement Techniques *Ultrasonics* **54**(1) 205-16

[6] Kanan H R, Nazeri B 2014 Novel Image Steganography Scheme with High Embedding Capacity and Tunable Visual Image Quality Based on A Genetic Algorithm *Expert Systems with Applications* 41(14-15) 6123-30

[7] Chandwani V, Agrawal V, Nagar R 2014 Modeling Slump of Ready Mix Concrete Using Genetic Algorithms Assisted Training of Artificial Neural Networks *Expert Systems with Applications* **42**(2) 885-93

[8] Wikaisuksakul S 2014 A Multi-Objective Genetic Algorithm with Fuzzy C-Means for Automatic Data Clustering *Applied Soft Computing* 24 679-91

[9] Srinivas C, Reddy B R, Ramji K, Naveen R 2014 Sensitivity Analysis to Determine the Parameters of Genetic Algorithm for Machine Layout *Procedia Materials Science* 6 866-76

[10] Pehlivanoglu Y V 2014 Direct and Indirect Design Prediction in Genetic Algorithm for inverse Design Problems *Applied Soft Computing* 24 781-93

[11] Liao T W, Kuo R J, Hu J T L 2012 Hybrid Ant Colony Optimization Algorithms for Mixed Discrete – Continuous Optimization Problems *Applied Mathematics and Computation* **219**(6) 3241-52

[12] Kıran M S, Gündüz M, Baykan Ö K 2012 A novel Hybrid Algorithm Based on Particle Swarm and Ant Colony Optimization for Finding The Global Minimum *Applied Mathematics and Computation* **219**(4) 1515-21

[13] Yoo K S, Han S Y 2013 A Modified Ant Colony Optimization Algorithm for Dynamic Topology Optimization *Computers & Structures* 123 68-78

[14] Otero F E B, Freitas A A, Johnson C G 2012 Inducing decision Trees with An Ant Colony Optimization Algorithm *Applied Soft Computing* **12**(11) 3615-26

[15] Eroğlu Y, Seçkiner S U 2012 Design of Wind Farm Layout Using Ant Colony Algorithm *Renewable Energy* 44 53-62

[16] Romdhane L B, Chaabani Y, Zardi H, MARS Research Group 2013 A robust Ant Colony Optimization-Based Algorithm for Community Mining In Large Scale Oriented Social Graphs *Expert Systems with Applications* **40**(14) 5709-18

[17] Khan S, Baig A R, Shahzad W 2014 A Novel Ant Colony Optimization Based Single Path Hierarchical Classification Algorithm for Predicting Gene Ontology *Applied Soft Computing* 16 34-49

[18] Tharwat M, Mohamed N, Mongy T 2014 Image Enhancement Using MCNP5 Code and MATLAB in Neutron Radiography *Applied Radiation and Isotopes* 89 30-6

[19] Huang S C, Yeh C H 2013 Image Contrast Enhancement for Preserving Mean Brightness without Losing Image Features. *Engineering Applications of Artificial Intelligence* **26**(5-6) 1487-92

[20] Anand S, Kumari R S S, Jeeva S, Thivya T 2013 Directionlet transform Based Sharpening and Enhancement of Mammographic X-Ray Images *Biomedical Signal Processing and Control* **8**(4) 391-9

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