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ARTICLE

A NOVEL JAVA MACAQUE ALGORIHTM FOR TRAVELLING SALESMAN PROLEM

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ABSTRACT

Abstract: *The natural evolution is originated from the principle of nature and it is completely based on the Charles Darwin theory "survival of the fittest". The naturally inspired algorithms are efficiently used for solving the real-world problems are motivating. This paper proposes the new java macaque algorithm based on the social behavior of the java macaque monkey. The behavior of the java macaque monkey is analyzed differently from the existing algorithm. Hence, the Java Macaque algorithm has the ability to solve the real-world optimization in an efficient way. In order to verify the efficiency of the proposed algorithm, the experimentation was performed with standard test- bed of Travelling Salesman Problem (TSP). Experimentation results clearly illustrate the consistency of the proposed algorithm over the existing algorithm like genetic algorithm (GA), particle swarm optimization (PSO) and ant colony optimization (ACO).*

KEY WORDS
Natural-inspired algorithm, JMA, java macaque, optimization algorithm, TSP, GA, PSO, ACO.

INTRODUCTION

Natural-inspired Optimization Algorithms are become quite popular because of its simplicity and flexibility for solving large-scale optimization problem [1]. Most optimization problem remains unsolved or poorly solved, by the exact solving methods. In the last few decades, natural computing [2] has stood out as the essential technique for solving the complex real-world problems. Generally, the Natural-inspired algorithm [3,4] is the combination of the imitated process in nature and also inspired from nature. The Natural-inspired optimization algorithms are broadly divided into two categories such as Evolutionary Algorithms (EAs) and Swarm Intelligence (SI). The evolutionary algorithms are effective for solving the discrete optimization problem whereas the continuous problems are solved by swarm intelligence. But the wide optimization problems (M. Wagner, 2013) are intriguing because the main objective is to find the optimal arrangement, ordering or selection process. In particular, the famous evolutionary algorithms are the genetic algorithm, genetic programming, evolutionary strategies and evolutionary programming [5,6,7,8]. Similarly, the popular swarm intelligences are ant colony optimization [9], particle swarm optimization [10], clonal selection algorithm [11], cuckoo search [12], bat algorithm [13] etc.

RELATED WORK

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In the literature, there are several algorithms for solving the combinatorial optimization problem. But the most dominant optimization algorithm is the genetic algorithm and particle swarm optimization. The Genetic algorithm is introduced by John Holland [5] which operates on the behavior of evolution process. The basic unit of the genetic algorithm is called as chromosomes or genotype of the genome that can be an optimal solution to the problem called phenotype. However, the primary contrast of the GA is crossover and mutation which play the vital role in exploitation and exploration of the search process. The PSO was introduced by Kennedy and Eberhart [14]. The basic principle of PSO is "collective intelligence" to find the candidate solution in the search space. It is also population (called swarm) based algorithm with the basic entity as particle [15,16]. Both the GA and PSO are widely used in the literature for solving the optimization problem [17,18, 19].

There are many natural inspired optimization algorithms [20] which are inspired by natural evolution and swarm optimization. Similarly, the social behavior of the monkey is also considered as the important natural inspired algorithm. Zhao and Tang [21] introduced the monkey algorithm (MA) based on the mountain-climbing process of monkeys. The main process of MA is climb-process, watch-jump process and somersault process. In the monkey algorithm, the random process is used for generating the initialization process which is followed by the climbing process used to search for the local optimal solution. Finally, the somersault process is employed for updating the current position. Zheng [22] has proposed the improved monkey algorithm with chaotic search method for initialization process and also introduced two parameters such as evolutionary speed factor and aggregation degree. The evolutionary speed factor is utilized to dynamically change the step length of each monkey in climb process whereas the aggregation degree dynamically modifies the eyesight and somersault distance of monkeys.

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J.C. Bansal et al. [23] proposed Spider Monkey Algorithm (SMO) based on the promising behavior of monkey which holds well for the local search space problem. Sandeep et al suggested the fitness based position update for the Spider Monkey Algorithm that enriches the convergence rate. Even though, the algorithm shows its significance in local search process but lacks in the global search process. Menga and Pana [24] have proposed the Monkey King Evolution (MKE) algorithm based on the action of monkey king in the Chinese mythological novel. MKE algorithm is based on the transformation of monkey king into the

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small monkey to solve the tough problem. The solution of the small monkey can be given as feedback solution to the monkey king. The basic ideology for exploitation is achieved by small monkey whereas the remaining monkeys in the population are used for exploration. Hence, this motivates our research to develop the natural- inspired algorithm which adopts well for both local and global search process.

SOCIAL BEHAVIOUR OF JAVA MACAQUE MONKEY

In this section, section 2.1 explains the Social behavior of Java Macaque Monkey and section 2.2 explains about our Proposed Java Macaque Monkey Algorithm.

Java Macaque Monkey is an important primitive which lives in the social structure. The male and female java macaque are shown in [Fig.1] and [Fig. 2]. and it has 95% gene similarity when compared with human being [25]. The important characteristics of the human such as joy, fear, violent, loyal and dedication are often seen in java macaque are shown in [Fig.3, 4, 5,6 and 7].

Fig. 1: Male with moustache.

Fig. 2: Female with beard.

It follows the social hierarchy structure among the java macaque individuals. The high-ranking java macaque dominates the low order JM individuals for accessing the food and resources. Usually, the java macaque lives in a group of 20-60 individuals with the average lifespan of 40 years [26]. There are many groups that found in the same environment but each group tries to dominate over their region of living.

Fig. 3: Joy.

Fig. 4: Fear.

Fig. 5: Violent.

Fig. 6: Loyal.

Fig. 7: Dedication to offspring.

Fig. 8: Group behavior of java macaque monkey.

[Fig. 8] clearly demonstrate the group behavior of java macaque monkeys and each group has their social hierarchy among the individuals [26]. The dominant individual of the group is called as "Alpha Male" which also means as the leader of the group. Each group is majorly subdivided into two division such as dominant and non-dominant. Dominants are the higher rank individuals in the population which lives at the top of the social hierarchy while the Non-dominant are at the bottom of the social hierarchy. It is noteworthy that the advantages of the dominant are more access to resources, high power and social protection when compared with another non-dominant individual. So, the non-dominant has only less access to food and other resources. But apart from the dominant and non-dominant, in general, the male java macaque dominant over the female individuals. The learning method of java macaque is depending on the environments circumstances. [Fig.9, 10] shows the social learning of individuals such as playing, Fighting and learning from the elders.

Fig. 9: Playing.

Fig. 10: Fighting.

The next important stages of JM culture are the reproduction. The reproduction is always depending on the social hierarchy of the individuals (i.e.) the male or female JM selects their partner based on the social rank [27]. Especially, during the reproduction time, the male java macaque sends the secret signal towards the female JM by making special noise and raising the eyebrow as presented in [Fig.11].

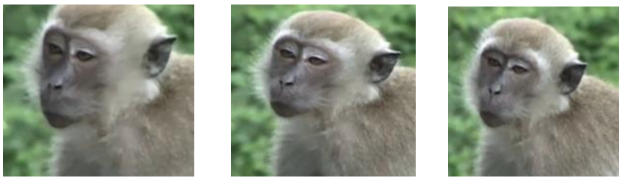

Fig. 11: Raising the eye brow.

In every group, the number of female individuals is higher in comparison with male (http://animaldiversity.org/accounts/Macaca_fascicularis/). So, each male has the relationship with the maximum of 3 female java macaque in the group. Then the new born java macaque has the social status depends on the parent's social ranks. In detail, the child born for the dominant rank individuals in the group has given importance when compared with individuals in the group [28]. In the same manner, the child of low-rank individuals is given less importance and consider as low-ranked individuals in the group. Generally, the children learn from the dominant female of the group. Thus, the newborn java macaque is protected by the other individuals from the group (i.e.) mother or other JM of the same social order as displayed in [Fig.12].

Fig. 12: Protection of new born java macaque monkey.

Engelhardt and Pfeifer [27] the major challenge for the alpha male is to protect their group and also find the suitable environment for finding the food and shelter. It also has to concentrate the behavior of the other individuals within the group and solve the dispute among the individuals as shown in [Fig.13]. The alpha male has more right to food resource of the group. The newborn male and female java macaque reach the sexual maturity in 4 and 3 years respectively. The male JM which reaches the sexual maturity has forced to leave the group and it is called as "stray male".

Fig. 13: Alpha Male solve the dispute among individuals.

The stray male has to search for another group for their protection. In order to join a new group, stray have only two ways (i.e.) either defeat the alpha male of the group or sexually attract the female JM of the group. If the stray male defeats the alpha male of the group then it became the new alpha male of the group and defeated alpha male has to leave the group and become stray male. But in most cases, the stray male attracts the female JM and that female JM convince other group members to add the stray male into the group. The fittest male java macaque has the right to become the alpha male of the group. The important factors which influence the dominance hierarchy of the java monkeys are age, size and Fighting

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techniques. Hence, the lower ranking java macaque can become the higher ranking alpha male by improving the size and Fighting skills. The learning or cultural behavior is one of the special characters of the java macaque among other non-human primates. There are different types of learning pattern are followed among the java monkeys. Mostly the learning process is based on the circumstances of the environment and also the behavior of the other monkeys within the group. Especially, the grooming process is maintained among the female within the group as exposed in [Fig.14]. The lower ranking female monkeys are used to groom the higher ranking female java macaque in order to increase the access to food and protection.

The communication and perception of the java macaque genus are the facial expressions, vocalization, and body gesture. On the other hand, the chemical (olfactory) and physical signal are the main modes of communication among the java macaque monkeys.

Fig. 14: Grooming.

PROPOSED JAVA MACAQUE ALGORITHM

The Java Macaque Algorithm (JMA) was inspired by the social behavior of java monkeys which falls under the categories of Natural-inspired Algorithm. The intelligent and social behavior of the java macaque monkeys with multi-group population motivates the authors to develop new Java Macaque Algorithm. Hence, the Fig.15 clearly demonstrates the life-cycle of java macaque monkey suits well for solving the large-scale optimization and engineering problem. The proposed JMA is one among the naturally inspired algorithm with the feature like adaptive and self-organization. The java monkey exhibits adaptive social behavior which often responds according to the environmental changes and also has the dynamic process which maintains the global order emerging from the local interaction among the java monkeys in the group.

Java Macaque Algorithm (JMA)

Step 1: [Begin] Initialize n number of groups and individuals.

Step 2: [Evaluation] Evaluate the fitness value (i.e.) social rank of every individual in each group and fittest is "Alpha Male".

Step 3: [Reproduction] Generate the new individuals for each group

- a. [Selection] select the two individuals from each group based on their social rank or fitness value.
- b. [Reproduction] create the new individual using the reproduction process (CROSSOVER).

Step 4: [Evaluation of Children] Evaluate the fitness value of newly generated individuals.

- a. [Stray Male] If the fitness value of the individuals is > 3/4 of Alpha male then become Stray male.
- b. [Female] Remaining individuals in children are female which stays in the same group.

Step 5: [Male Replacement] Stray Male find the suitable group using fitness value.

- a. If stray male fitness value > alpha male then become alpha male.
- b. Else if stray male fitness value > fitness value of the higher-ranking male then become higher ranking individual.
- c. Else if stray male is removed.

Step 6: [Learning] Improves the behavior of the individual from the surrounding and other individuals in the group.

Step 7: [Termination] Maintain the group size with new population and Repeat the above of the certain number of generation.

Initialization

Initialization is the important process of the java macaque algorithm which generate the 'n' number of groups and 'm' number individuals or macaque per group. The initialization process begins with the minimum number of individuals per group (i.e.) group size at initialization process is 20 individuals. But the maximum number of individuals for each group is 60.

Evaluation of fitness value

The fitness value of the individuals is calculated for all the individuals. The individuals with best fitness value for each group is called as "Alpha male". The alpha male is the leader of the group which dominated

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other individuals. The average fitness value of each group is utilized for dividing the group into two major subdivision such as "Dominant" and "Non-dominant". The individuals which have fitness value above then the average fitness value is called as "Dominant". The dominants are high fitness individuals or high social rank individuals of the group. On the other hand, the lower ranking individuals of the group are Non-dominant. Further, the dominant and non-dominant are classified into male and female based on the region fitness value using hashing method. From this region, the individual with maximum fitness is considered as male and remaining individuals are female. After this, the Average fitness value of dominant and non-dominant are calculated.

Reproduction

The new individuals are created by selecting the parent of same social rank. The parent selection procedure is based on the social hierarchy of the java macaque. Then the new individuals are generated by the combination of the both parent behavior. The probability of male to participate in reproduction is only 3% in one generation whereas the female has the probability of 1% respectively. The survival of the new offspring is based on the social ranking of the parent.

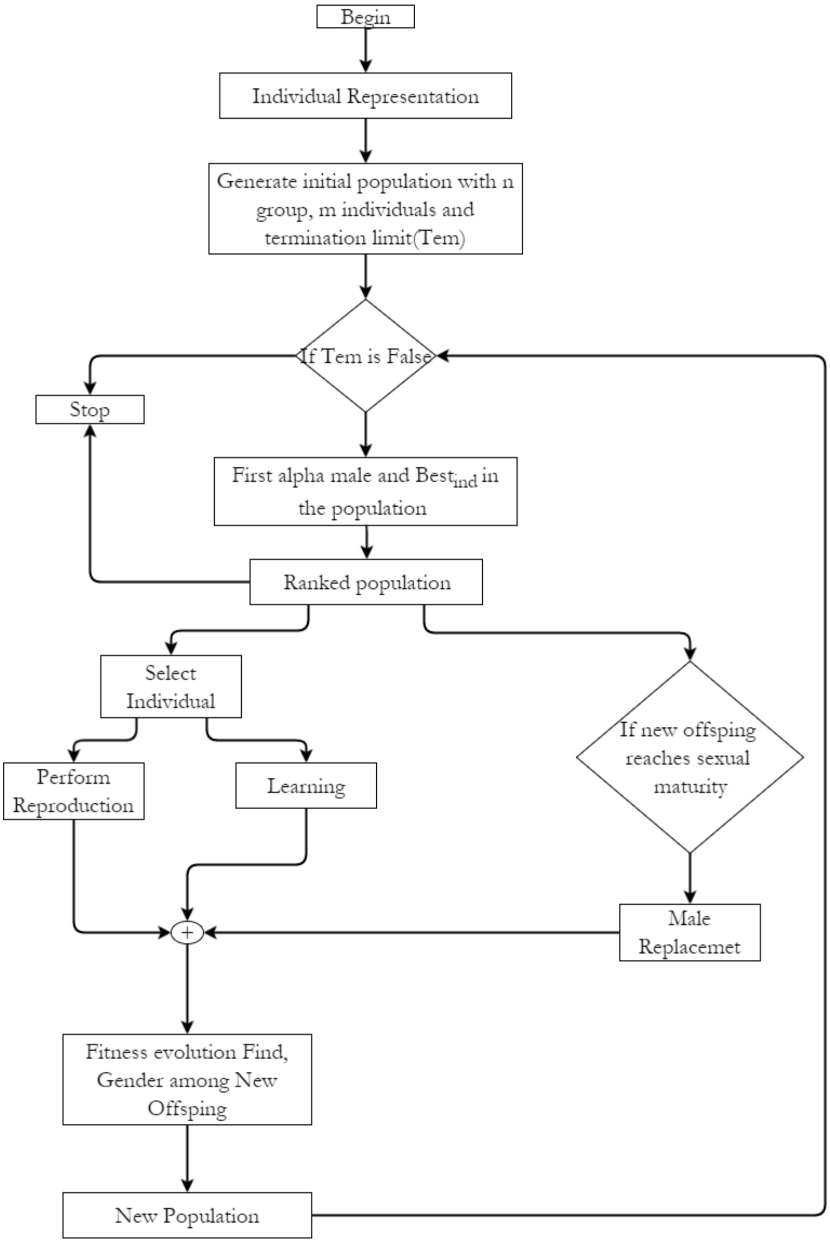

Fig. 15: Flowchart of Java Macaque Algorithm.

Fitness evaluation of new individuals

The newly generated individuals are evaluated using the fitness function. The fitness value of the male in the new offspring if greater than the 3/4 of Alpha male, then it became stray male. The female individuals of the group are protected by the alpha male and other dominant individuals of the group but the stray males are sexually matured male which has been forced to leave the group.

Male replacement

The stray male has to find the appropriate group for leaving by using its fitness value. If the fitness value of the stray male is higher than the fitness of alpha male of any group, then it became the alpha male of the group Then if the fitness value matches the average fitness value of dominant of any group it becomes the dominant individual of the group. On the other hand, the stray male has the chance to become the non-dominant individual of the group if the fitness value is higher than the average fitness value of the non-dominant. In some cases, if the stray does not suit for any group has been eliminated from the population.

Learning

Learning is considered as the important stages of the newly generated individuals which learn from the surrounding and environment. The learning procedure of the newly generated individuals is mainly depending upon the behavior of the dominated individuals of the same group. The grooming is the special kind of learning activity which takes place between higher and lower ranking females.

Termination

The population of each group is maintained by eliminating the male and female of the group with the new population and the above process is repeated until the generation limit is reached. The initial population of the JMA is generated using the random population initialization technique. But the multi-group based population plays an important role in solving the travelling salesman problem efficiently. Further, the group is subdivided into male and female.

The individuals in the population are ranking according to the fitness value in the population. Then the social ranking based selection process is used for selecting parents for reproduction. Meanwhile, the new offspring which reaches the sexual maturity called 'stray male' are forced to leave the nodal group. Then the stray male has to find the suitable group using male replacement process. Finally, all the individuals in the group have undergone the learning process from the surrounding and environment.

RESULTS

The significance of the proposed Java Macaque algorithm is demonstrated using the travelling salesman problem (TSP). The Travelling salesman problem is one of the most important optimization problems for the researchers has been chosen as the test bed. Naturally, the TSP belong the class of NP-hard problem and act as the testbed for the new optimization algorithm. Hence, the instances eil51, st70, eil101 and ch130 are chosen as the test dataset which is obtained from the standard library of TSPLIB [24].

Therefore, the fitness function (Fit) for the proposed algorithm has been calculated using:

$$Fit = \min\left\{\left(\sum_{j=1}^{P} dist(C_i, C_{i+1})\right) + dist(C_P, C_1)\right\}$$

Whereas,

- P refers to the number of cities in the individual,
- $dist(C_i, C_{i+1})$ Refers the distance between two cities C_i and C_{i+1},
- $dist(C_P, C_1)$ Refers to the distance between last city and first city during return after the tour.

The standard experimental setup for the proposed JMA: the number of groups (n=5) with the population size of (m=60) and executed up to 100 generations and the initial population of each group were generated randomly. The performance of the proposed algorithm is compared with the Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO). Each algorithm was run on each instance 25 times and hence the best among the 25 runs are considered for analysis and validation purposes.

Parameter for performance assessment

As stated earlier, the efficiency of the proposed self-organized GA is demonstrated against classical GA techniques with the help of a set of standard assessment factors such as convergence rate, error rate, average convergence rate and convergence diversity, which is briefed as follows:

Convergence rate: Convergence rate of an individual in the population is defined as the percentage of fitness value obtained by the individual in accordance with the optimal fitness value. It can be formulated as follows:

$$convergencerate(\%) = 1 - \frac{Fitness - optimalfitness}{optimalfitness} \times 100$$

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Average convergence: Average convergence rate can be defined as the average percentage of fitness value of the individual w.r.t to the optimal fitness value. It can be expressed as follows:

$$Avg.conv.(\%) = 1 - \frac{averagefitness - optimalfitness}{optimalfitness} \times 100$$

Error rate: Error rate of an individual is defined as the percentage of the difference between fitness obtained by the individual and optimal fitness value. It can be given as:

$$Errorrate(\%) = \frac{Fitness - optimalfitness}{optimalfitness} \times 100$$

These above assessment criteria form a strong base for demonstrating the performance of the proposed JMA in the related domain and hence adopted by most of the researchers in the related domain. By following the same, this research also uses the same for validating the performance of the intended research.

DISCUSSION

The computational result of the experimentation is illustrated in [Table 1]. Thus, the experimentation is directed to evaluate the performance of the proposed JMA with another existing GA, PSO and ACO. For instance, the sample instance eil51 may be taken for discussion. From the [Table 1] the best convergence rate for GA is 81.54%, PSO is 77.58% and ACO 90.82% but the convergence rate of JMA is 100% of the

Table 1: Computation result for GA, PSO, ACO and JMA

S.No	TSP Instance	Technique	Optimum value	Fitness		Convergence rate (%)	Error rate (%)	Average Convergence (%)
				Best	Average			
1	eil51	GA	426	522.44	790.66	81.54	18.46	14.40
		PSO		549.09	686.44	77.58	22.42	38.86
		ACO		469.09	616.44	90.82	9.18	55.30
		JVM		426.00	485.84	100.00	0.00	85.95
2	pr76	GA	108159	131092.80	200955.99	82.51	17.49	14.20
		PSO		136082.80	175945.99	79.48	20.52	37.33
		ACO		121425.45	156599.77	89.07	10.93	55.21
		JVM		108159.00	127534.83	100.00	0.00	82.09
3	pr144	GA	58537	71188.74	111140.30	82.23	17.77	10.14
		PSO		75189.00	95839.30	77.85	22.15	36.28
		ACO		65421.63	85103.84	89.48	10.52	54.62
		JVM		59083.15	70469.88	99.08	0.92	79.61
4	tsp225	GA	3919	4944.16	7533.00	79.27	20.73	7.78
		PSO		5255.16	6494.82	74.57	25.43	34.27
		ACO		4410.68	5905.76	88.85	11.15	49.30
		JVM		3961.27	4867.03	98.93	1.07	75.81
5	fl417	GA	11861	15945.57	23287.99	74.38	25.62	3.66
		PSO		16857.57	19975.99	70.36	29.64	31.58
		ACO		13564.25	18228.38	87.44	12.56	46.32
		JVM		12064.19	14865.06	98.32	1.68	74.67
6	u724	GA	41910	58608.09	83013.84	71.51	28.49	1.92
		PSO		60518.09	72853.87	69.25	30.75	26.17
		ACO		48155.24	69071.94	87.03	12.97	35.19
		JVM		43423.92	56971.93	96.51	3.49	64.06

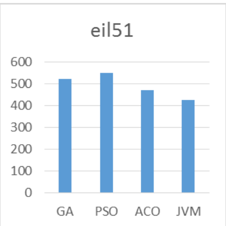

Fig. 16(a): eil51

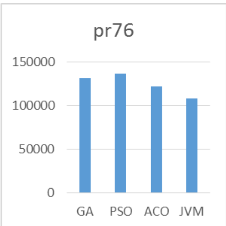

Fig. 16(b): pr76

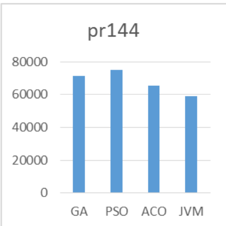

Fig. 16(c): pr144

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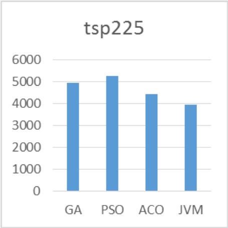


Fig. 16(d): tsp225

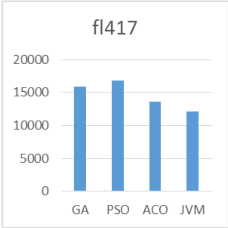


Fig. 16(e): fl41

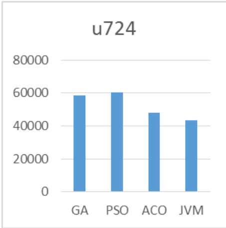
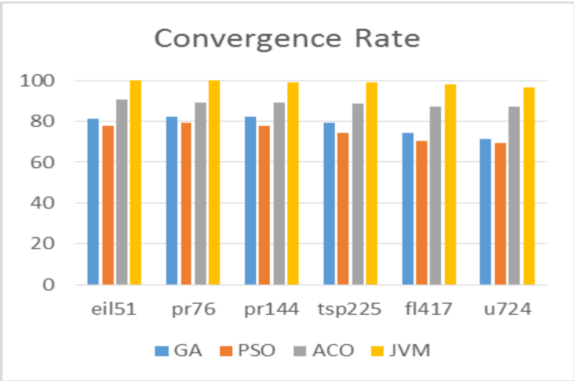


Fig. 16(f): u724

Fig. 16: Analyses the performance based on fitness value.



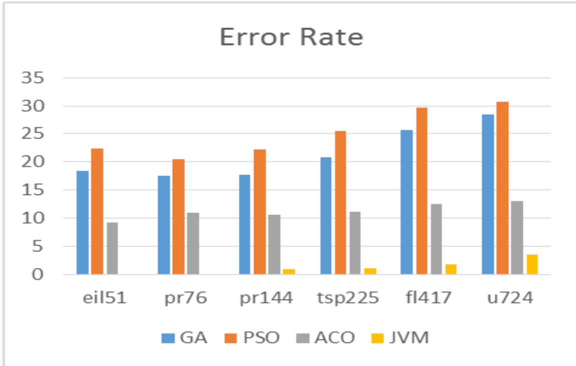


Fig. 17: Analyses the performance based convergence rate. **Fig. 18**: Analyses the performance based error rate.

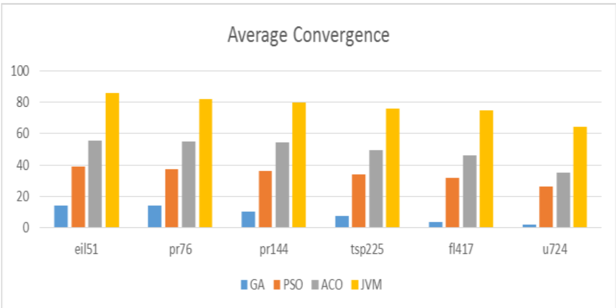


Fig. 19: Analyses the performance based average convergence rate.

same. Then the average convergence rate for JMA, GA, PSO and ACO are 85.95%, 14.40%, 38.86% and 55.30% respectively. Further, in terms of error rate also, this form of supremacy is continued for all instances. On the other hand, the convergence rate of the proposed algorithm is more than 96.51% for large instance u724, whereas the existing GA, PSO and ACO are achieved the rate of 71.51%, 69.25% and 87.03% for the same. It is exposed from the [Table 1] that the average convergence rate existing algorithm is lower than prosed JMA in all the instances. The examination of the proposed algorithm dominated the existing ACO, PSO and GA in all the performance assessment parameters.

Analyses based on fitness value

The fitness value is one of the important assessment criteria which give the tangible result of the optimal solution. From [Fig. 16], it is understood that the performance of java macaque algorithm outperforms the other existing algorithm in terms of fitness value. From the existing algorithm, the ACO suite well for solving the large-scale instance but the proposed JMA out-performed ACO in all the instances. Let us consider the sample instance name u724 in which the ACO has the best fitness value of 48155.24 whereas the JMA has the fitness value for the instance as 43423.92.

Analyses based on convergence rate

The convergence rate indicates the quality of the optimal solution generated from the population. [Fig. 17] illustrates the assessment of proposed algorithm against the existing algorithm w.r.t to the convergence rate. The convergence rate of the JMA is above 95% for all the instances. Hence the instance fl417 has the lowest value of 70.36% convergence rate in the PSO and the highest of 98.32% for the JMA, while the ACO stand next to the proposed JMA with the value of 87.44%. The proposed java macaque algorithm dominates the existing algorithm in terms of convergence rate.

Analyses based on error rate

The performance of the algorithm w.r.t error rate is presented in [Fig. 18]. The evaluation of the proposed algorithm in terms of error rate is important for the analysis. The best error rate indicates how far the best individual convergence rate deviates from the optimal fitness value while the worst error rate demonstrates the difference between the convergence rate of the worst individual from the population and the optimal solution. Thus, the maximum value of error rate for the java macaque algorithm is 3.19%, Ant colony optimization is 12.97%, particle swarm optimization is 30.75% and the genetic algorithm is 28.49% correspondingly. Similarly, the minimum value of error rate of JMA is 0%, for instance eil51 and pr76 whereas the genetic algorithm has 18.46%, the particle swarm optimization has 22.42% and ACO has 9.18% for instance eil51 respectively. JMA obtained the better performance compared with existing algorithm.

Analyses based on average convergence rate

[Fig. 19] depicts the result analysis of average convergence rate in comparison of the proposed algorithm with existing algorithms. Thus, the investigation in terms of average convergence for JMA has shown the dominance over the other algorithm. On average, the average convergence rate of JMA has attained value above 60% but the GA, PSO and ACO, obtained value above 1%, 26% and 35%. The JMA achieves the maximum value of 85.95% while the ACO 55.30% respectively. By contrasting the performance of JMA and ACO for the average convergence rate is quite better for both algorithms.

CONCLUSION

In this paper, we proposed the new java macaque algorithm based on the social behavior of java macaque monkey. The features of the proposed JMA have been explained in this paper which suits well for solving the optimization problems. Hence, the authors have analyzed the performance of JMA on the NP-hard TSP problem and compared its results with the existing algorithm like GA, PSO and ACO. The robustness of the JMA has been clearly illustrated with respect to fitness value, convergence rate, error rate and average convergence rate. Therefore, it may be concluded that JMA is one of the efficient algorithms in the field natural-inspired optimization algorithms and achieves better result for the optimization problem.

CONFLICT OF INTEREST
There is no conflict of interest.

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FINANCIAL DISCLOSURE
None

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