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Optimizing Industry Trade-Off Problems in Big Data Management Using Evolutionary Algorithms: A Comparative Study

PhD **Ahmed K. Abbas**
Diyala University, Baquba, Iraq

Abstract. **This paper proposes a novel approach to solve complex industrial big data management problems using genetic algorithms (GA), particle swarm optimization (PSO), ant algorithms (ACO) and cultural algorithms (CA). The research aims at efficient resource allocation, balancing conflicting objectives such as cost minimization, resource utilization and quality improvement. The proposed approach offers a comprehensive framework that combines the advantages of different optimization techniques, providing decision makers with important insights into optimal big data strategies in their industries. The results of the study show the effectiveness of the hybrid approach in achieving optimal decisions, which improves operational efficiency and strategic decision making in the era of big data.**

Keywords: **bigdata, ant colony optimization, cultural algorithms, genetic algorithm, particle swarm optimization.**

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Introduction

In recent years, the exponential growth of data created in various industries has presented significant challenges in effective management and utilization. The emergence of big data requires new approaches to process huge amounts of data while considering competing objectives such as cost optimization, resource allocation, and quality improvement [1]. To address these challenges, the integration of advanced optimization techniques is attracting attention. This paper focuses on the use of genetic algorithms (GA), particle swarm optimization (PSO), ant algorithms (ACO), and cultural algorithms (CA) to solve complex big data management problems in industrial environments [2]. The aim of the study is to investigate the effectiveness of hybrid optimization techniques in solving industrial big data problems. Through comparative analysis, the performance of each algorithm in solving multidimensional challenges presented by big data in different industrial sectors is evaluated.

The objective of this inquire about is to examine the viability of hybrid optimization approaches in settling industry-specific trade-offs inalienable in enormous information administration. Through a comparative investigation, the study assesses the execution of each algorithm concerning its capacity to address the multifaceted challenges postured by enormous information inside assorted mechanical settings [3]. By synthesizing the qualities of GA, PSO, ACO, and CA, the proposed approach offers a comprehensive arrangement custom fitted to the complexities of each industry, encouraging educated decision-making and key arranging within the period of big data.

After the developmental calculations appeared up inside the explore various papers proposed in this field to unwind different real-world issues. The investigators as well-made various strategies of developmental calculations, the first basic procedures are: Ant colony optimization, Cultural algorithms, Genetic algorithm, Particle swarm optimization etc.

Evolutionary computation

Evolutionary computation is one of the foremost imperative areas in computer science and artificial intelligence. The title of this sort of calculations is based on embracing Darwinian standards. Developmental computation can be classified moreover as trial-and-error issue solvers. Utilizing developmental computation to illuminate the issues of worldwide optimization strategies can be considered moreover as meta-heuristic algorithms. One of the foremost vital viewpoints of these calculations is the use of a populace of candidate solutions instead of fair emphasizing over one solution within the look space. The utilize of population of arrangements in evolutionary methodologies makes them more viable and not influenced by the issue of local optimal within the search space [4].

Genetic Algorithms

The genetic calculation could be a method that fathoms an optimization issue by employing a population of candidate solutions (called individuals) that advanced toward superior arrangements. Each candidate solution encompasses a set of sub-variables that called chromosomes. The chromosomes will can be changed and changed amid the evolutionary forms. The issue arrangements can be spoken to in numerous shapes such as binary of 0s and 1s or genuine coded such as numbers or real array of numbers [5]. Figure 1 appears primary steps of genetic algorithms.

Particle swarm optimization

Particle swarm optimization (PSO) may be a unused population based optimization strategy created in 1995 by Dr. Eberhart and

Dr. Kennedy [6]. The Creators propelled by common social behavior of bird running and fish tutoring to create these calculations. PSO is exceptionally comparative with Genetic Calculations (GA) in:

1. The framework is initialized with a population of irregular arrangements.

2. The calculation looks for optima by overhauling arrangements.

Be that as it may, PSO contrasts than Genetic algorithms in these focuses:

1. In PSO, there's no crossover and change.

2. In PSO, the potential arrangements (particles), fly through the issue space by taking after the other optimum particles (local and global).

In past a few a long time, PSO has been effectively connected in numerous investigate and application ranges. It is illustrated that PSO gets way better comes about in a speedier, cheaper way compared with other strategies [7].

Ant colony optimization

This calculation may be a strategy of the swarm intelligence strategies, and it employments a few metaheuristic optimizations. It is proposed in 1992 by Marco Dorigo and after those numerous analysts upgraded the algorithm. The calculation primarily was pointing to explore for an optimal way in a chart, based on the behavior of ants looking for a way between their colony and a source of nourishment. The first thought has since broadened to unravel a more extensive class of numerical issues, and as a result, a few issues have emerged, drawing on different viewpoints of the behavior of ants [8].

Cultural algorithms

Cultural evolution calculations are strategies that empower societies to advance or adjust to their focal points and situations at higher rates than organic evolution. Cultural algorithms (CAs) created by Reynolds [9] are determined from the cultural advancement phenomenon. There are two levels of advancement in cultural calculation. These two levels are micro-evolution and macro-evolution. Smaller scale developmental or population level regularly is shaped of a population based randomized look calculation like hereditary calculation, genetic programming. The advancement handle within the population level is primarily based on the small-scale level intuitive between individuals. In macro-evolutionary or cultural level, encounters of the individuals extricated from population level can be saved and utilized to affect the course of the look handle in a broader way [10].

Problem definition

Linear Programming (LP) could be a sort of problems utilized in businesses for getting an improved utilize of vitality, diminishing costs of fabricating and planning [11].

The issue can be communicated as take after:

minimize/maximize $F(X_i) = C_1{\cdot}X_1 + C_2{\cdot}X_2 + C_3{\cdot}X_3 + \ldots + C_n{\cdot}X_n$

subject to $A_1{\cdot}X_1 + A_2{\cdot}X_2 + \ldots + A_n{\cdot}X_n < DB_1{\cdot}X_1 + B_2{\cdot}X_2 + \ldots + B_3{\cdot}X_3 < E$

where X_i:vector of variables to be fathomed for and C_i: vector of costs for each variable and A_i, B_i: the vectors of imperatives coefficients, D and E are: imperatives itself.

In this study, we'll illuminate one sort of this issue (for one real-world application) utilizing genetic calculation, PSO, Ant Colony and cultural algorithms.

Factories Production Problem

Two components create a best-seller toy bomb-doll. But each toy requires a sum of 100Kg of black powder for a high explosive arrangement utilized on its creation [11]. There are 3 providers that create it, each one with a diverse cost:

- B1: $10.00 / ton
- B2: $5.00 / ton
- B3: $7.00 / ton

To transport the items from a provider to a production line too incorporates a cost:

To	A	B
From B1	5	6
From B2	9	8
From B3	6	7

Let's call P(X) as the benefit function of the doll offers, after doing a few calculations, the benefit equation gets to be as a work of six factors as take after:

$$P(X) = 300{\cdot}(T/10) — (8{\cdot}(T_1A + T_1B) + 3{\cdot}(T_2A + T_2B) + 5{\cdot}(T_3A + T_3B))$$
$$— (5{\cdot}T_1A + 9{\cdot}T_2A + 6{\cdot}T_3A + 6{\cdot}T_1B + 8{\cdot}T_2B + 7{\cdot}T_3B)$$
$$— (9{\cdot}(T_1A + T_2A + T_3A) + 7{\cdot}(T_1B + T_2B + T_3B))$$

Where $T = TA + TB = T_1A + T_2A + T_3A + T_1B + T_2B + T_3B$

And there are some constrains:-

TA <= 550 (factory A can as it were hold 550 T)

TB <= 700 (factory B as it were hold 700 T)

T_1 <= 390 (supplier 1 can as it were supply 390 T)

T_2 <= 460 (supplier 1 can as it were supply 460 T)

T_3 <= 370 (supplier 1 can as it were supply 370 T)

T_1A, T_2A, T_3A, T_1B, T_2B, T_3B are integers >= 0

Note that T_{ij} is the sum of black powder obtained from provider *i* and taken to manufacturing plant *j*. So, we have a maximization problem that has 6 variables and 5 constraints. To solve this problem, we will use algorithms as will be described in next section.

Algorithms Steps for solving the problem

To solve the problem of Factories Production we will use four algorithms which are genetic algorithm, Ant colony, Cultural algorithms and particle swarm optimization. The steps and design of these methods will be described in this section.

Genetic Algorithm Method

In this method we first need to represent the variables. In this study we use the integer code representation. So, each solution will be represented using array of six variables as shown below

$$T_1A \rightarrow T_2A \rightarrow T_3A \rightarrow T_1B \rightarrow T_2B \rightarrow T_3B$$

After that a number of solutions randomly initialized to represent the first population. From constraint we know that all the values must be integer and greater than zero. In the parent selection step, the best two parents will be selected to generate from them new two children.

In the crossover step, we used the one point cross over. One point will be selected randomly and then the chromosomes of the two selected parents will be exchanged to create the chromosomes of the two new solutions or children. Next figure shows this process.

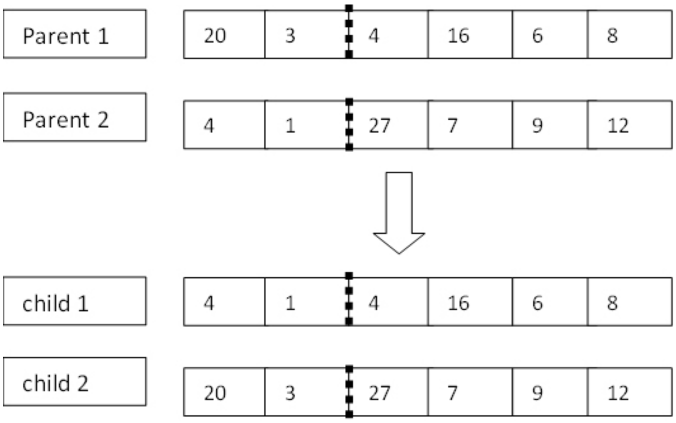

Fig. 1: Crossover step

For the mutation process, a gene will be selected randomly and it will either be added or subtracted by value of 1. In mutation, the solution may change entirely from the previous solution. Hence GA can come to a better solution by using mutation. When the crossover and mutation executed the new two children will be replaced with the worst two solutions in the population. After that the evolution process will be continue until the required criteria reached.

Particle swarm optimization method

To solve the problem using PSO we need a good representation method sense, we need to store the variables and its velocities for each generation. Next figure shows the representation of the variables. We see that each particle contains six variables to represent its position and another six variables to represent the velocity of these positions and there is also a cost which will be computed from the cost function (fitness function). For each particle there is also a small history to store the best previous position for this particle (the cost and the position).

To store particle position → To store particle velocity → cost → Best personal

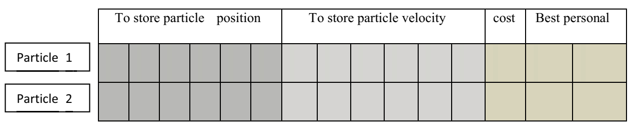

Fig. 2: position and velocity

To compute the velocity of the particles, we will use the simplest form of PSO algorithms, where the velocity is computed from three values which are Previous particle Velocity, Best particle personal position and best overall particle position. The following equation will be used to compute the new velocity for each particle

$$V_i = w \cdot V_{i\_prv} + c1 \cdot (Ppbest — P_i) + c2 \cdot (PGbest — P_i)$$

After that the new particle position can be computed from this equation

$$P_i = P_{i\_prv} + V_i$$

These two equations will guide the all-other particles in the swarm to the direction of the global optima gradually. Next figure shows the mathematical representation of the PSO vectors that used to direct the particles to the best solution.

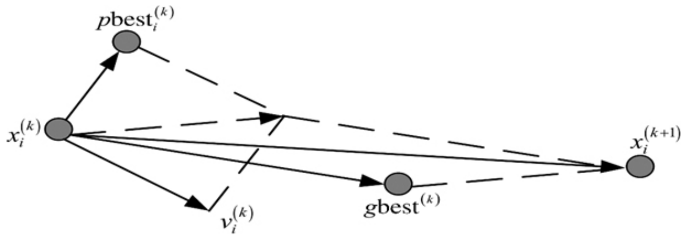

Fig. 3: Mathematical representation of the PSO vectors

For the culture algorithms and ant colony algorithms we used the same representation of genetic algorithms but only the names will be changed. For example, in the ant colony algorithm the solutions will be called ants.

Results and discussion

To compare the performance of the optimization algorithms we execute three experiments.

Experiment 1

In the first experiment we used the following parameters for each algorithm as described in the following tables:

Table 1

Parameters of the Genetic Algorithm

Parameters of the Genetic Algorithm	
Population Size	50
Number of Variables	6
Mutation Operator	0.2
Crossover Operator	0.7
Representation	Integer Coded
Parent Selection	Best Two
Replacement Method	Worst Two

Table 2

Parameters of PSO Algorithm

Parameters of the PSO Algorithm	
Swarm Size	50
Number of Variables in each Particles	6
w	1
Damping factor	0.99
C_1	2
C_2	2

Table 3

Parameters of Ant Colony Algorithm

Parameters of The Ant Colony Algorithm	
Ant Numbers	50
Number of Variables in each Ant	6
Initialization	randomly

Table 4

Parameters of Culture Algorithm

Parameters of The Culture Algorithm	
Population size	50
Number of Variables	6
Acceptance Ratio	0.35
Alpha	0.3
beta	0.5

After executing the first experiment with different number of generations we got the following results presented in the following table 5. For each algorithm we execute it three times and take the average of the best solution.

The results show that the Ant Colony algorithm works very well and outperforms all other algorithms especially when the number of generations is small. The particle swarm optimization method is also better than the genetic algorithm method in many cases of number of generations. From the other side, The PSO algorithm can quickly go to the direction of the optima. We can see also the that difference between the best value obtained in the two algorithms are big in the case of running 100 generations, and then starts to become smaller and smaller until the case of 500 generations where the genetic algorithm gets a value better than the PSO algorithm. This means that the PSO algorithm is better when the number of generations is small and the genetic algorithm is preferable when number of generations is big. The results also show that the Cultural algorithm performance is the worst one.

Table 5

Show the best obtained value of the four algorithms using different number of generations

Number of Generations	Genetic Algorithm	Particle Swarm Optimization	Ant Colony Optimization	Culture Optimization
100	10775	11422	**11531**	6847
200	10936	11834	**11956**	7152
300	11482	11793	**11921**	6866
400	11576	**12091**	12044	6854
500	11883	**12057**	12034	6906

Experiment 2

To measure the convergence of the two algorithms, we run another experiment using the same parameters of the algorithms in the first experiment as described in Table 1,2,3 and Table 4. In this experiment we will not measure the best obtained value of each algorithm which may not represent the convergence of algorithm, instead of that we will measure the average of all best obtained value from all generations. This value will be a good indication for the behavior of the algorithms. Table 6 shows the results of this experiment. As in the first experiment, the Cultural algorithm performance is the worst one.

Table 6

The average of the Best obtained value in each generation of the four algorithms using different number of generations

Number of Generations	Genetic Algorithm	Particle Swarm Optimization	Ant Colony Optimization	Culture Optimization
100	11322.3	**11757.0**	11484	6805
200	11744.3	**11887.3**	11795	7004
300	11996.6	**12095.6**	11497	6748
400	12375.0	**12380.6**	11833	6823
500	**12356.3**	12104.3	11935	6881

The results of table 6 also show that the PSO algorithm works better than the other algorithms in most of the cases. And we can see in the table that there is a big difference between the values of PSO and GA algorithms which indicates that the PSO algorithm when it goes in the direction of the optimal value it may not change its direction and so all the time the results become better and better.

Experiment 3

In this experiment we will show the figures that show the behavior of the used algorithms by showing all obtained best values. Next two figures show this information.

We can see from the results that the PSO and Ant Colony algorithms are more stable and once it reaches a good value it may not go to worst value again. Also, the PSO algorithm sometimes jumps leaps in the direction of optima. On the other side the GA goes to the optima step by step and during the evolution process it may become bad and then return to better value.

Conclusion

In conclusion, the integration of Genetic Algorithms (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), and Cultural Algorithms (CA) presents a promising approach to handle the challenges related with enormous information administration inside different mechanical settings. Through our examination, we have illustrated the adequacy of these hybrid optimization strategies in tending to industry-specific trade-offs, such as fetched minimization, asset allotment, and quality improvement.

Our investigate underscores the significance of leveraging progressed optimization calculations to explore the complexities of huge information, empowering decision-makers to create educated choices that optimize operational productivity and vital results. By synthesizing the qualities of GA, PSO, ACO, and CA, our approach offers a flexible system able of adjusting to the special necessities of diverse businesses, from fabricating to healthcare to back.

Besides, the comparative examination conducted in this think about gives important bits of knowledge into the execution of each calculation in tending to huge information challenges, facilitating the choice of the foremost fitting optimization procedure based on particular industry needs and targets. By tackling the control of these progressed methods, organizations can pick up a competitive edge in managing and leveraging their information resources viably.

Able to see from the results that PSO and ant colony calculations are more steady, and when exceptions happen, self-evident awful values may now not show up. The PSO calculates these

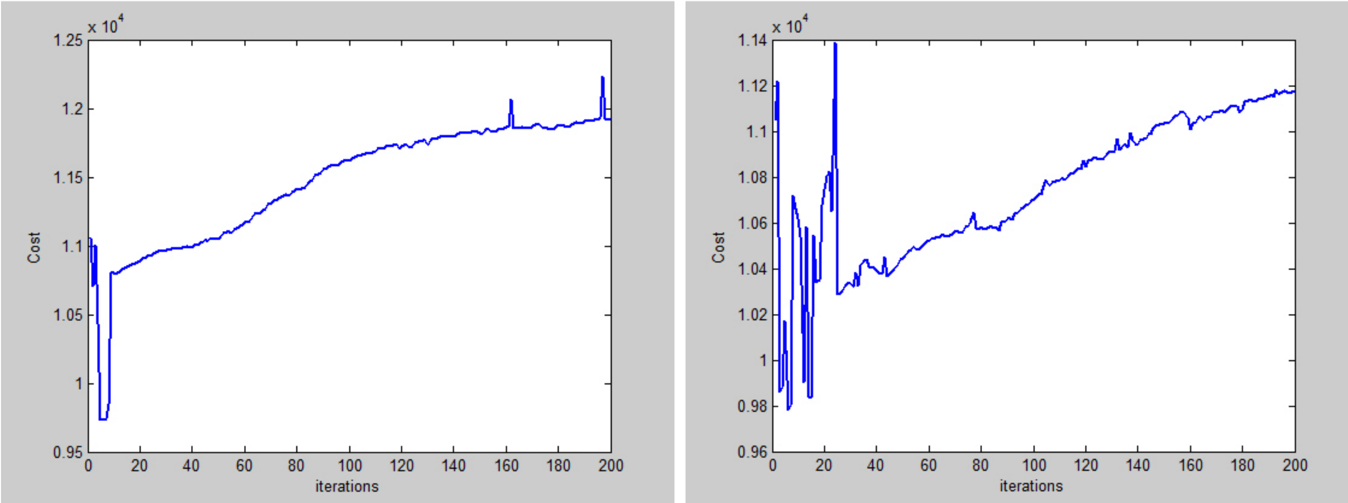

Fig. 4: The results of Genetic algorithm best values during evolution

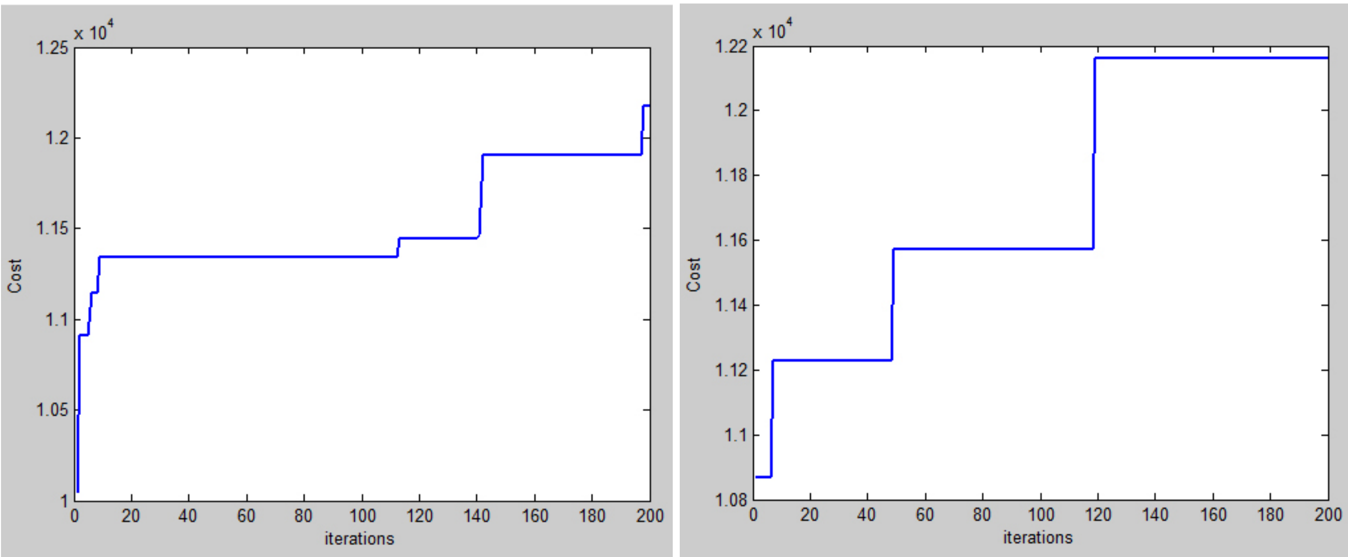

Fig. 5: The results of PSO algorithm best values during iterations

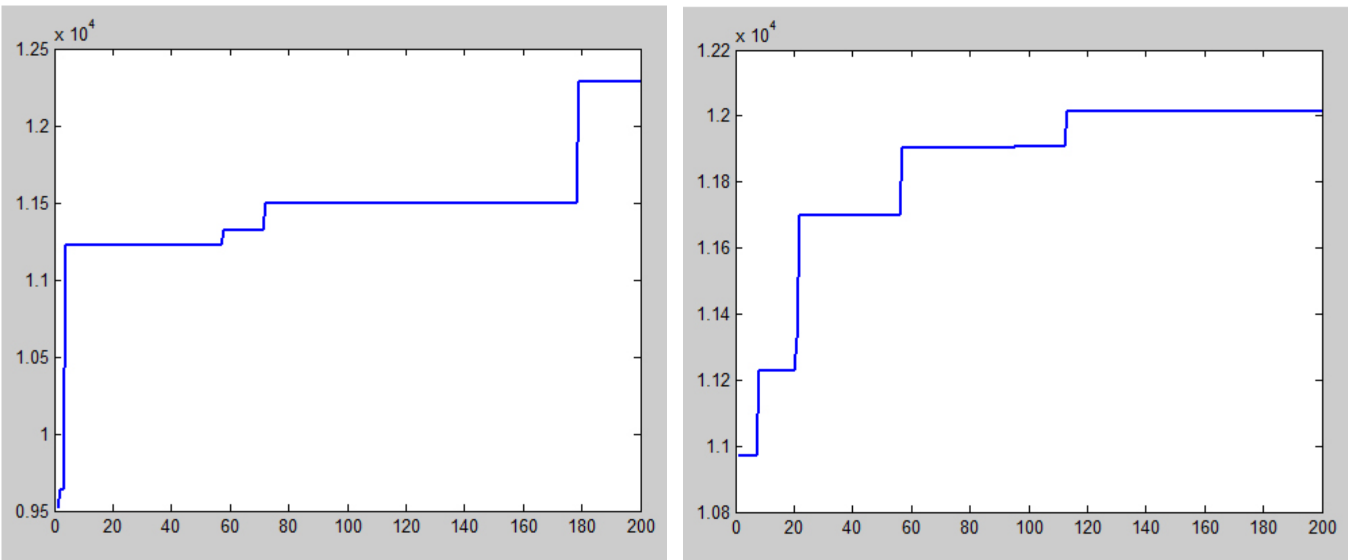

Fig. 6: The results of Ant Colony algorithm best values during iterations

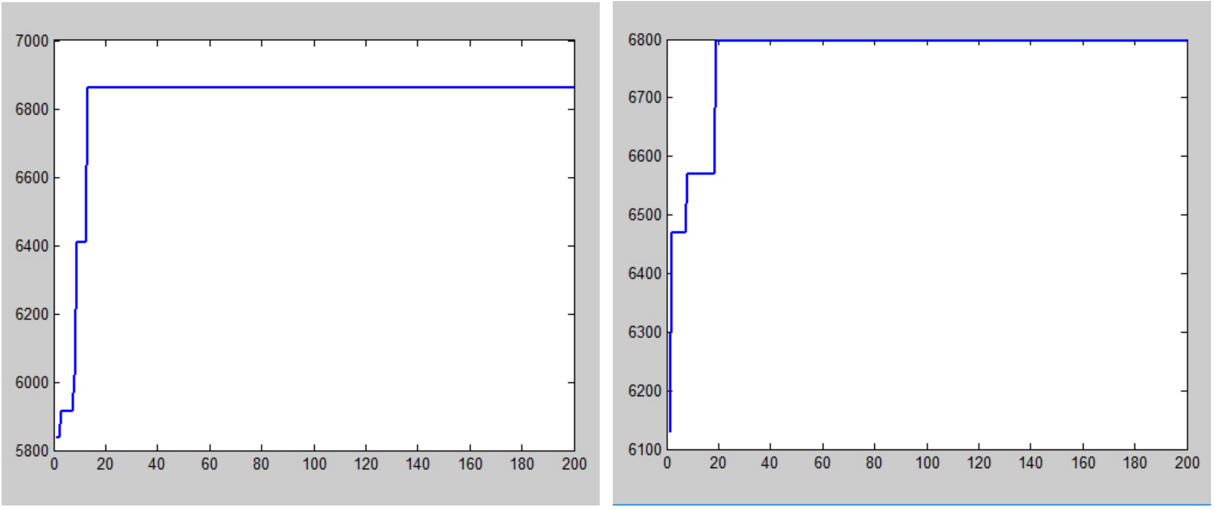

Fig. 7: The results of Cultural algorithm best values during iterations

changes presently and afterward also within the ideal rate. On the other hand, the genetic algorithm moves towards the ideal step by step, may get more regrettable within the prepare of encourage advancement, and after that gotten to be way better once more.

Future work

Looking ahead, future inquire about might investigate extra hybridization techniques, as well as the integration of machine learning and artificial intelligence procedures, to advance upgrade the capabilities of enormous information optimization systems. Also, practical execution and real-world case considers may give more profound bits of knowledge into the appropriateness and adequacy of these approaches in tending to industry trade-offs and driving unmistakable commerce results.

In pith, our ponder underscores the urgent part of progressed optimization strategies in forming long run of huge information administration, advertising imaginative arrangements to the complex challenges confronted by industries in tackling the potential of their information assets. Through persistent advancement and experimentation, ready to open modern roads for maximizing the esteem of huge information and driving maintainable development and competitiveness over assorted mechanical divisions.

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Information about Authors:

Ahmed Khuthair Abbas — PhD in Engineering. Computer Science Department, Diyala University, Baquba, Iraq. E-mail: dr.ahmed.k.abbas@uodiyala.edu.iq

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Оптимизация отраслевых задач в управлении большими данными с использованием эволюционных алгоритмов: сравнительное исследование

канд. техн. наук **Ахмед Х. Аббас**
Университет Диялы, Баакуба, Ирак

Аннотация. **В статье предлагается новый подход к решению проблем управления большими промышленными данными с использованием генетических алгоритмов, оптимизации роя частиц, муравьиных алгоритмов и культурных алгоритмов. Исследование направлено на эффективное распределение ресурсов, балансирование противоречивых целей, таких как минимизация затрат, использование ресурсов и улучшение качества. Данный подход предлагает комплексную структуру, которая сочетает в себе преимущества различных методов оптимизации, предоставляя лицам, принимающим решения, важные сведения об оптимальных стратегиях работы с большими данными в своих отраслях. Результаты исследования показывают эффективность гибридного подхода в достижении оптимальных решений, что повышает операционную эффективность и принятие стратегических решений в эпоху больших данных.**

Ключевые слова: **большие данные, муравьиный алгоритм, культурные алгоритмы, генетический алгоритм, оптимизация роя частиц.**

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Информация об авторе:

Ахмед Худайр Аббас — канд. техн. наук. Факультет компьютерных наук, Университет Диялы, Баакуба, Ирак. E-mail: dr.ahmed.k.abbas@uodiyala.edu.iq

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