Performance evaluation of optimization algorithms for capacity allocation in a production network

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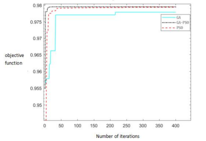
Abstract

How to share resources flexibly and effectively in the production network to bring greater economic benefits has become an important issue. This paper studies the capacity allocation of a production network under the consideration of demand satisfaction. We formulate the capacity allocation problem of the production network as an optimization model, and apply three heuristic algorithms to solve it with Matlab software. We also conduct the data analysis in the numerical experiments for comparing the optimal solutions and convergence speeds of the presented three algorithms at several examples.

Discussion

Convergence comparison of the algorithm



From the results and convergence degree of the three algorithms, the optimal solution and corresponding value deviation of the three algorithms are not very large, the average demand satisfaction of the optimization is about 0.977, but the capacity allocated by the three algorithms is very different. In the convergence speed, the genetic algorithm is slower than the other two algorithms, and has a certain jump. In the 25th convergence, although the convergence speed of PSO is slightly smaller than that of PSO based on genetic screening rules, the two algorithms have little difference in solving accuracy. For example 1, the particle swarm optimization algorithm based on genetic screening rules has the fastest convergence speed, and it has reached convergence at the 20th iteration.

Sensitivity analysis

GA-PSO

$C_1=1.8$

Learning factors C_2	Average demand satisfaction	Average operation time（s）
1.7	0.951244487659856	89.3723095
1.8	0.951324545867619	88.3713095
1.6	0.951324083001722	101.6106936

PM=0.4

Learning factors C_1	Average demand satisfaction	Average operation time（s）
1.5	0.951324746099309	102.8591088
1.8	0.951244487659856	89.3723095
1.3	0.950689992244836	95.1305445

$C_2=1.7$

Crossover probability PC	Average demand satisfaction	Average operation time（s）
0.5	0.951324746098132	89.8899532
0.4	0.951244487659856	89.3723095
0.6	0.951324746099309	91.7448739

PC=0.4

Mutation probability PM	Average demand satisfaction	Average operation time（s）
0.5	0.951689992244836	89.8899532
0.4	0.951244487659856	89.3723095
0.6	0.951324746098132	90.3723095

Problem description

In a production network, it is an important issue to allocate the capacity optimally in a balanced way while achieving a maximum demand satisfaction. The optimization problem to be solved is the capacity allocation of a production network based on the random demand of products and the capacity of the factory.

Formulation of Optimization Problem:

Suppose that there are N factories and M products in this production network. The index number for the factory is j, and its production capacity is Sj. The index number for the product is i, and its random demand is Xi. The production capacity Dj if factory j produces product i.

An Optimization Model:

$$\mathrm{MAX\,Dem}=\frac{E\left[\sum_{j=1}^{N} D_{j,i}\right]}{E[X_i]} \quad (1)$$

$$\sum_{j=1}^{N} D_{j,i}\le X_i, \forall j,i\in N^+ \quad (2)$$

$$\sum_{i=1}^{M} D_{j,i}\le S_j, \forall j,i\in N^+ \quad (3)$$

$$D_{j,i}\ge 0,\ \ \forall j,i\in N^+ \quad (4)$$

$$\mathrm{MAX\ Dem}\ge 90\% \quad (5)$$

The objective function (1) represents the average demand satisfaction of the production network. Constraint (2) indicates that the capacity allocated to product i should be less than or equal to the demand Xi for product i. Constraint (3) indicates the total allocated capacity of plant j shall not exceed the capacity Sj. Constraint (4) indicates the capacity allocated by factory j to product i is greater than or equal to 0. Constraints(5) ensures the average demand satisfaction should be greater than 90%.

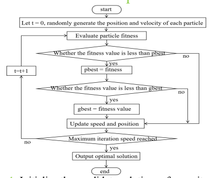
Description of mathematical symbols of models

Symbol	Definition
Sj	Factory j production capacity
Xi	Demand for product i
$D_{j,i}$	Capacity allocated to product i by plant j
MAX Dem	Average demand satisfaction of production network
$\sum_{j=1}^{N} D_{j,i}$	Sum of capacity allocated by plant j
$\sum_{i=1}^{M} D_{j,i}$	Sum of capacity to which product i is allocated

Results

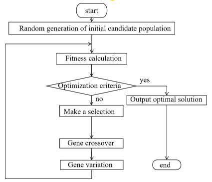
Three Solving Algorithms :

1. Particle swarm optimization algorithm:



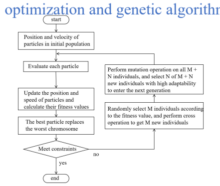
Step1: Initialize the candidate solutions of capacity allocation, set the parameters of particle swarm optimization algorithm, the number of iterations T, the number of candidate solutions n, the location and speed of candidate solutions, and the learning factors $C1$ and $C2$.
Step2: Substitute the position of each candidate solution into the objective function to obtain the corresponding objective function value. Record the individual extremum of each candidate solution and the overall extremum of all candidate solutions.
Step3: Compare the objective function value of each candidate solution with individual extremum and global extremum, and update if the value is excellent.
Step4: Update the position and speed of each candidate solution.
Step5: Determine whether the iteration conditions are satisfied, if Yes, exit the procedure; otherwise, return to Step 3.
Output : The optimal value of objective function (1) and corresponding candidate solution, i.e. demand satisfaction and allocated capacity.

2. Genetic algorithm:



Step1: Initialize the population that randomly generates capacity allocation.
Step2: Evaluate and calculate the fitness of individuals in the candidate solution population.
Step3: Judge whether the fitness meets the optimization termination criteria, such as meeting the output optimal solution, exit the algorithm; if not, enter step 4.
Step4: Individuals are selected according to the adaptability obtained in the previous step. Individuals with high adaptability are more adaptable to the environment, are selected to stay, and those with low adaptability are eliminated.
Step5: Randomly select two individuals from the individuals left in the previous step, and generate new individuals by cross operation according to the set cross probability.
Step6:In the selected individuals, randomly selected individuals generate new individuals by mutation operation according to the set mutation probability.
Step7:After crossover and mutation, a new generation of population will be generated. Return to step 2.

3. A hybrid algorithm combined by particle swarm optimization and genetic algorithm:



Step1: Initialize the candidate solution of capacity allocation and set the parameters of particle swarm optimization algorithm.
Step2: Evaluate each particle's candidate solution, and substitute the position of the candidate solution into the objective function to get the corresponding objective function value. The individual extremum of each candidate solution and the global extremum of all candidate solutions are recorded.
Step3: Compare the objective function value of each candidate solution with individual extremum and global extremum, and update if the value is excellent.
Step4: Update the position and speed of each candidate solution.
Step5: Replace the worst chromosome of genetic algorithm with the best particle in particle swarm optimization algorithm, and record the objective function value.
Step6: Judge whether the end condition is reached. If it is reached, it will end and enter (7). Otherwise, enter the crossover and mutation operation, enter (2).
Step7: Output the optimal objective function value and corresponding candidate solution, that is, demand satisfaction and allocated capacity.

Analysis of algorithm examples

Algorithm parameter setting

	PSO	GA	GAPSO
popsize	300	300	300
maxgen	500	500	500
C1	1.8	-	1.8
C2	1.7	-	1.7
PM	-	0.4	0.4
PC	-	0.4	0.4

Factory and product information data sheet

Plant node j	Factory capacity Sj	Market nodes i	market demand X_i
1	17951	1	5265
2	1399	2	3806
		3	2223

Algorithm results

PSO

Capacity allocation	Factory 1	Factory 2
Product 1	4473.48292185921	2240.51240249666
Product 2	1608.51707814079	482.801680990617
Product 3	0	2139.68591651272
Average demand satisfaction		0.97942844219103

GA

Capacity allocation	Factory 1	Factory 2
Product 1	3920.32532164273	2809.25971545838
Product 2	2080.4830855021	0
Product 3	81.191592855161	2053.74028454162
Average demand satisfaction		0.977688002114006

GA-PSO

Capacity allocation	Factory 1	Factory 2
Product 1	4305.36217064395	2407.63782835605
Product 2	0	2092.00000099999
Product 3	1776.63782935605	363.362170643961
Average demand satisfaction	0.979539522856951	

Conclusions

We solved an optimization problem for the production capacity under several scale of production networks with different production capacity and demand. Numerical examples are solved with a particle swarm algorithm, a genetic algorithm, and a hybrid optimization algorithm via MATLAB platform. In the numerical experiments, the optimal solutions and convergence speeds of these three algorithms are compared at different examples. This study can be applied to meet multiple capacity allocation scenarios in production networks, and provide a relatively balanced solution for capacity allocation in production networks.

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