Machinery Optimal Layout Design of a Production System with the Aim of Reducing Transportation Costs Using an Imperialist Competitive Algorithm

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Abstract

In this study, solutions for machinery layout with the aim of reducing transportation costs will be discussed. To do this, an imperialist competitive algorithm (ICA), which is a very complicated and effective meta-heuristic algorithm is introduced. In the offered algorithm, different kinds of machinery layout are considered in single-row as a country and then the best possible layout is developed based on ICA phases such as revolution and absorption policy, population displacement and production and applying its steps on the machinery, possible layouts are investigated by considering the distance of machinery pairs and components' manufacturing routes.. The results show that using this algorithm, layout of machines would have the most favorable form based on used machinery to produce components.

Keywords: an imperialist competitive algorithm, machinery layout, transportation cost.

1. Introduction

After the Industrial Revolution and increased competition between manufacturers and rising of customer expectations, a need to massive changes in production systems was felt. Beside this, other issues such as reducing startup time, increasing production volumes, increasing the variety of components, reducing the cost of investment in tools and equipment, reducing required space, better overall control, and many other issues, created new dimensions to the competition market of manufacturers, and group technology strategy is one of the designed strategies to respond to these needs. Group technology is a production technique through which components with the same features is put in the same group, and a set of machinery used to produce them are appropriately categorized and established in the same unit. Today, along with the increasing development of technology, modern industries such as manufacturing goods have shorter lifetime against market changes, and they also have high product variety, low volume and reduced number of orders and so they have routing problems of conveyors for transportation of material [4]. Much research has been carried out in this field including the followings: in 2006 the economic costs of transportation was investigated using locating land use. In this work locating land use, which is a powerful device for lowering the costs of transportation, was used. With the help of this device, the optimum possibility of establishment of different kinds of urban land use and the demand to travel to these uses is minimized which ultimately led to decrease in transportation costs induced by demand decrease [5]. Also in 2012, small and medium enterprise logistics' costs and the effect of targeted subsidies were analyzed. This study was allocated to develop a conceptual model in order to investigate and analyze the effective costs on support process in small and medium enterprises in automobile and nutrition industries. Here the effect of targeted subsidies on logistics costs and cost reduction strategies were studied relying on subject literature in logistics' domain and case studies done in aforementioned enterprises [6]. In this paper, we have dealt with examining a solution to layout machinery based on components' production line. To do this, by introducing ICA, the costs of displacement would be calculated based on layout and the distance of machinery from each other.

2. Experimental section

ICA is a method in evolutionary calculations which seeks to find the optimum response of different optimization problems. This algorithm provides an algorithm to solve mathematic problems by mathematical modeling of social-political development process. The basis of this algorithm consists of matching policy, ICA, and revolution. This algorithm emulates the evolution of the procedure of social, economic and political evolution or mathematical modeling of some components of this process, and so

provides operators in the form of regular as algorithms that can help to solve complex problems of optimization. Actually, the algorithm considers the solutions of optimization problems in the form of countries and through a repetitive process that gradually tries to enhance solutions and ultimately get us to the optimum solution of the problem. In this algorithm, the initial solutions are addressed as country options. The ICA phases are as follows.

2.1. Forming the early empires

In optimization, the aim is to find an optimal solution in terms of problem variables. We create an array of the problem variables that must be optimized, and we introduce the array as a country. In an optimization problem next Nvar, a country, is an array of length of Nvar * 1. This array is defined as Country = $[p_1, p_2, \ldots, p_{Nvar}]$. To start the algorithm, as much as $N_{Country}$, initial countries are created. We choose as much as N_{imp} of the best members of this population as imperialists. The remaining N_{Col} of the countries form colonies, each of which belongs to an empire. For initial division of colonies among imperialists, we ascribe each imperialist a number of colonies, which is in proportion to its power. At this study, countries reflect the order of machines together, and an example of a country is displayed below. In this case, five machines are used.

Country:	Machine1	Machine3	Machine5	Machine2	Machine4

2.2. The absorption policy (the movement of colonies towards imperialist)

At this phase, the colonizer or emperor starts to absorb based on power. In this regard, based on two parameters of α and β and using the following equation, the probability of choosing any empire is calculated. This probability reflects the number of colonies assigned to an empire.

$$p = e^{-\alpha \left(\frac{\cos t_i}{\cos t_{\min}}\right)} \quad (1)$$

Where, the value of $cost_i$ represents the fitness of empire and value of $cost_{min}$, the fitness of the weakest empire.

2.3. Revolution

Revolution or random displacement of a colonized country to a new random position is modeled. In algorithmic perspective a revolution enables the overall evolutionary movement to be rescued from being stuck in local valleys of optimality that in some cases causes the improvement of the position of a country and takes it to a better optimality range. Accordingly to create a revolution, an empire is selected at random and then randomly a country is selected at random and its' values are randomly changed.

2.4. Shift of the position of the colony and empire

During the colonies' movement towards the colonizer country, some of these colonies may reach a position better than imperialists (to reach some points in the cost function that produces less cost than the value of cost function in imperialist positions). In this case, the colonizer and the colony countries alter each other, and the algorithm continues with the colonizer country in the new position. This time it is the new imperialist country that starts assimilation policy on its colonies.

2.5. Colonial competition

The power of an empire is defined as the power of the colonizer country plus a percentage of the total power of its colonies. Each empire that fails to increase its power and loses its competitiveness would be eliminated in the imperialist competition. This elimination is done gradually, i.e. over time. The weak empires, lose their colonies and stronger empires, conquer these colonies and add their power. Accordingly, power of an empire is calculated with the following equation and each of empires that have less power, devotes a colony of their empire to more powerful emperors.

$$\text{imp cost}_i = \sum_{k=1}^{n} \text{cost}_k \quad (2)$$

Where, n represents the number of colonies in the empire i.

$$\text{avrage}_i = \text{imp cost}_i / n \quad (3)$$

$$\cos t\ of imp = avrage_i \times zeta + \cos t_{imp\,i} \quad (4)$$

2.6. Empire elimination

During the inevitable imperialist competitions, weak empires gradually collapse, and their colonies are passed into the hands of stronger colonizer empires. Accordingly, after different phases if the number of colonies of an empire is equal to one, this emperor has reached collapse phase, and it should be transferred to another empire as colony.

3. Results and Discussion

Our goal in this paper was to design a layout of machinery to produce components with the lowest cost of transportation. We assume that we need five M_1, M_2, M_3, M_4, and M_5 machines to produce four C_1, C_2, C_3, and C_4 components. Tables 1 and 2 show two different routes for manufacturing. In both tables, the number of possible routes for the production of each component is same but the layout of machines are different for each route. Figures 2 and 3 show the layout of machines to produce component 1in routes 1 (a), 2 (b), and 3 (c) respectively, from tables 1 and 2. For example, to produce component 1, the layout of machines on route 1 from table 1 is M5, M4, M2 and M3 and on table 2 is M5, M2, M4 and M3.

Table.1. Manufacturing route

Machine	Component 1		2				3			4
	Route 1	2	3	4	5	6	7	8	9	10
M1				1	2				3	2
M2	3	4	4			3	4	3	1	1
M3	4	2	1			1	2	1	2	3
M4	2	3	2			4	3	2		
M5	1	1	3	2	1	2	1	4		

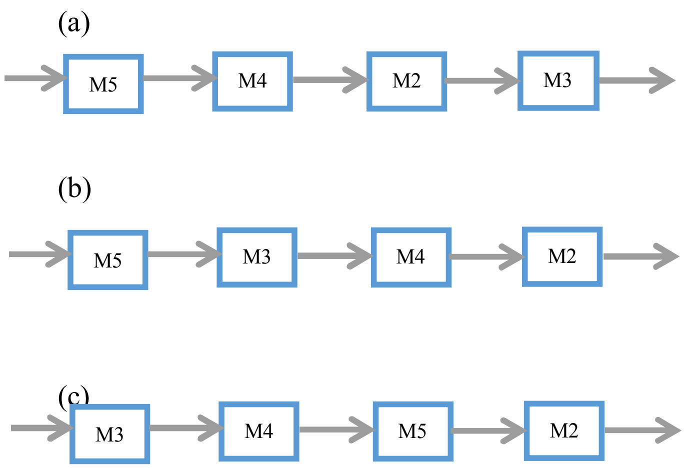

Fig.2. Possible layouts to produce component C_1 from table 1

Table.2. Manufacturing route

Machine	Component 1		2				3			4
	Route 1	2	3	4	5	6	7	8	9	10
M1				1	2				4	4
M2	2	4	4			3	4	3	2	1
M3	4	3	1			1	2	1	3	3
M4	3	2	2			4	3	2		
M5	1	1	3	2	1	2	1	4	1	2

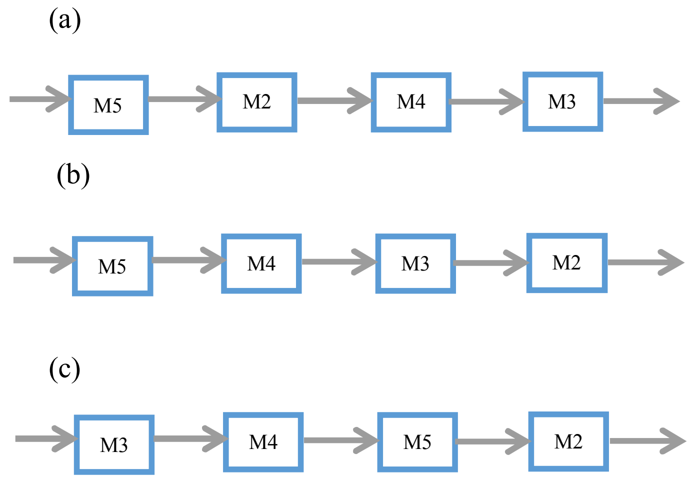

Fig.3. Possible layouts to produce component C_1 from table 2

In addition to possible layouts, the distance between the pair of machines must be specified. In figure 4, distance values are shown with matrix b_{ij}.

$$
\begin{array}{cc}
 & \begin{array}{ccccc} 1 & 2 & 3 & 4 & 5 \end{array} \\
[b_{ij}] = \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array} & \begin{bmatrix} 0 & 10.0 & 10.0 & 11.5 & 8.5 \\ 10.0 & 0 & 9.0 & 9.0 & 8.5 \\ 10.0 & 9.0 & 0 & 9.5 & 9.5 \\ 11.5 & 9.5 & 9.5 & 0 & 10.0 \\ 8.5 & 8.5 & 9.5 & 10.0 & 0 \end{bmatrix}
\end{array}
$$

Fig.4. The distance between adjacent machinery

Next, the ICA will be proposed to produce components and machinery design, and parameters used in this algorithm are defined as follows:

Number of initial countries: Pop_size = 16

Number of empires: Count imp = 4

Rate of revolution: revolution_rate = 20%

The number of repetitions: Generation = 100

$\alpha = 0.6$
$\beta = 0.4$
$Z = 0.1$

The values of these three parameters of α, β, and Z should be considered to be between zeros to one, so if data are changed a little, then the possibility of balancing data, using the coefficients should be provided. In other words, if the values of these three parameters are chosen big, then they would lose their sensitivity to small changes.

To implement the ICA, MATLAB is used. The results show that the best layout of machinery will be as follows 5 (a) and 5(b) respectively, from table 1 and 2.

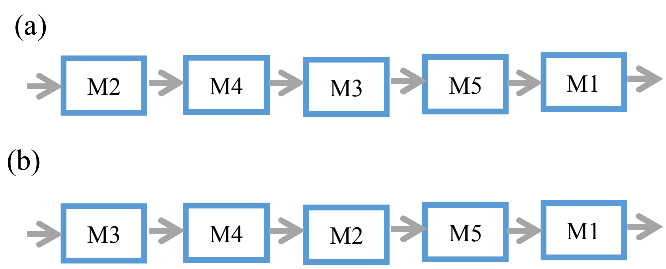

Fig.5. The obtained layouts of the algorithm

Figure 6 shows the cost of moving components per 100 repeats. According to the figure, the estimated cost for the layout of figures 5(a) and 5(b) is respectively 2475 and 2902 dollars.

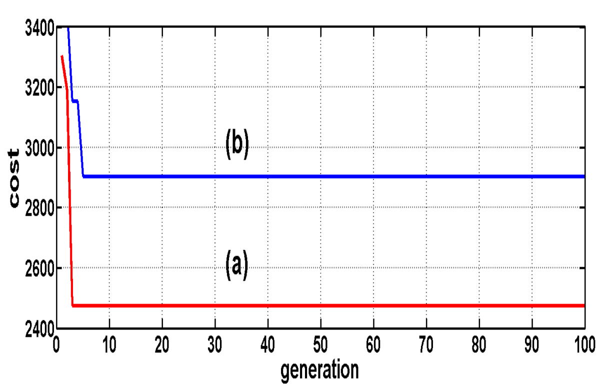

Fig.6. The cost calculated per 100 repeat algorithm

4. Conclusion

In this paper ICA was proposed to design components and machinery layout for material transportation. Using mathematical model of the algorithms and applying its steps on the machinery, possible layouts were investigated by considering the distance of machinery pairs and components' manufacturing routes. Due to larger search space and versatility in creating new solutions, this algorithm has a high speed in finding the optimal solution, which can play a significant role in solving mathematical problems and cost functions. With this algorithm, the optimal machinery layout was designed to produce components with the lowest transportation cost.

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