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Capacitated Inventory Control Through Lot Sizing Using Harmony Search Algorithm

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ABSTRACT

Inventory management (IM) software is a software system used for various purposes like for tracing inventory level, orders, sales and deliveries. It can also be used in the manufacturing industry to generate a work order, bill of materials and other production-related documents. IM software is used to avoid product overstock and outages. It is implemented for organizing inventory data that were generally stored in hardcopy form or in spreadsheets previously. Lot-sizing problem (LSP) in material requirement planning (MRP) systems belongs to those problems that industrial manufacturers face daily in organizing their overall production plans. Lot sizing plays an important role in minimization of total cost (i.e. sum of setup and holding cost). Many heuristic methods have been developed to solve LSPs, but most of them are applicable for small instances. Harmony Search Algorithm (HSA) is one of those which are considered to be novel when compared to other metaheuristic algorithms. It is an emerging metaheuristic optimization algorithm, which has been employed to cope with numerous challenging tasks during the past decade as it is fast, time efficient, accurate and effective. Based on the requirements of manufactured goods, MRP refers to the net demand of parts or materials. But these demands without any change may be inappropriate for placing an order or manufacturing. Lot sizing is to coalesce the computed net demand by a certain unit in consideration with the cost reduction and work efficiency. The problem aims to find production planning which takes the minimization of total setup costs and inventory holding costs. In this project, HSA has been applied to solve the problems and overcome the issues.

Keywords: Harmony Search Algorithm, inventory management, lot sizing, material requirement planning

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INTRODUCTION

Inventory is the basic unprocessed materials, work-in-process (WIP) goods and finished goods that are under the consideration to bethe segment of a business's credits that are equipped or will be equipped for sale. As the turnover of inventory is one amongst theprincipal sources of profit generation and therefore the subsequent financial gain for the industry's investors, inventory forms one amongst the foremost most major assets of an industry. Currently, billions of dollars are associated with the inventories of manufacturing firms, which cause very large (interest) costs. A small reduction of the inventory and/or production costs without lessening of the service level can boost the profit considerably. Especially, in the case of irregular capacity, efficient manufacture schemes are fundamental for short delivery time and on-time delivery, which are important competitive priorities. To hold up decision-makers by creating their higher producing resource planning scheme with apt practices is one among the foremost most appealing challenges of production planning. [1-3]

INVENTORY MANAGEMENT

Inventory management (IM) could be a key function that affects the potency of the supply chain as well as the financial scenario of the organization. Current-day inventory is coped by advanced system applications that want a continual and careful evaluation of each external and internal problem. Need for inventory occurs at various different stages in a firm. In case of a manufacturing industry, inventory could also be within the style of raw merchandise, WIP of finished products. Along with these, there's also a necessity to keep the spare elements for repairing the product. Inventory procural, storage and its management in any organization for smooth supply chain management come with immense prices. Inventory management activities are based on managing the subsequent costs efficiently:

A. Ordering cost (OC)
B. Carrying cost (CC) or holding cost (HC)
C. Shortage or stock-out cost of replenishment

HARMONY SEARCH ALGORITHM

Methodology

Soft computing techniques emerged to overcome the shortcomings of the traditional techniques which required labor and also they were time consuming. There are many soft computing techniques of which a few are listed below:

1) Fuzzy Logics
2) Genetic Algorithm
3) Harmony Search Algorithm
4) Simulated Annealing Strategy
5) Particle Search Optimization
6) Ant Colony Optimization
7) Baysien Organize
8) Differential Development

The method used for controlling inventory at optimum level used here is the Harmony Search Algorithm (HSA) which is one of the soft computing techniques inspired from music. [4-5]

Harmony Search Algorithm

It draws the motivation from harmony improvisation and obtained considerable results in the field of optimization, although it is a relatively nature-inspired computational algorithm. The HSA was originally inspired by the improvisation process of Jazz musicians. Each musician resembles to each decision variable, musical instrument's pitch range links to decision variable's value range, musical harmony at certain time corresponds to solution vector at certain iteration and audience's aesthetics corresponds to objective function. Just like musical harmony is improved time after time, solution vector is improved iteration by iteration.

Implementation

The platform for the proposed algorithm is a PC with 3.1 GHz CPU and 8-GB RAM with Windows 10 Operating System. The algorithm used here is coded and executed in Matlab R2017a.

A numerical example has been taken to illustrate the algorithm. Initially, the lot-sizing problem (LSP) has been defined and the requirement for the product is shown in Table 1. The CC and the OC have been taken as $1 and $250, respectively.

Table 1. *Requirement of the product.*

Period	1	2	3	4
Requirement	20	50	70	90

The simplest model of inventory LSP is a single item with no shortages allowed.

Mathematical formulation for the model takes the following form:

$$\min\left(\sum_{i=1}^{n} Asi + cIi\right) \quad (1)$$

subject to

$$I_0 = 0 \quad (2)$$
$$I_{i-1} + x_i\, Q_i - I_i = R_i \quad (3)$$
$$I_i \geq 0 \quad (4)$$
$$Q_i \geq 0 \quad (5)$$
$$X_i \text{ € } 0\{0,1\} \quad (6)$$

where n is the number of periods, A is the setup cost per order, C is the carrying cost per unit per order, R_i is the requirement for the period I, I_i is the ending inventory, $X_i =$ 1, if the order is placed I, else 0.

The objective function (1) includes a penalty charge A for each order placed and c for each unit carried in inventory over the next period. Equation (2) specifies that no initial inventory is available. Equation (3) tries to satisfy the net requirements. The order quantity, Q_j, covers all the requirements until the next order. Equation (4) is the non-negativity restriction on the inventory levels (no shortages allowed). Equation (5) is the non-negativity restriction on the order quantities and Equation (6) forces the decision variable z_i to be 0 (do not place an order on period i) or 1 (place an order). Given that the initial inventory is zero, $I_0 = 0$, it is observed that $z_i = 1$ by Equation (3), if $R_1 > 0$. Due to the minimization nature of the problem, the ending inventory at each period is minimized to avoid the penalty charge c, particularly $I = 0$. Primarily, the parameters of HSA, i.e., HMS, NHM, maxit, HMCR and PAR, are defined. Random solutions (0s and1s) are generated for the LSP as shown in Table 2.

Table 2. *Generation of different solutions*

HMS	Solution generated
1	1 0 0 0
2	1 1 1 0
3	1 1 1 1

The cost for each harmony is calculated using the function handle as shown in Table 3.

Table 3*. Cost calculations.*

Period (*P*)	1	2	3	4	Fitness function
Requirement (*R*)	20	50	70	90	
Solution developed	1	0	0	0	
Quantity	230	0	0	0	
Inventory	210	160	90	0	
Carrying cost (CC)	460	0	0	0	
Ordering cost (OC)	200	0	0	0	
Total cost (TC)	660	0	0	0	660

Similarly, the cost is calculated for the remaining harmonies as shown in Table 4.

Table 4. *Corresponding costs of different harmonies.*

Solutions generated	Corresponding cost
1 0 0 0	660
1 1 1 0	690
1 1 1 1	800

A random number is generated and if it is less than HMCR, a New Harmony (NH) from the existing HM is generated randomly:

$$\text{NH} = [1\ 0\ 1\ 0]$$

Now another random number is generated and if it is less than PAR, the above NH is modified by swapping:

$$\text{NH} = [1\ 1\ 0\ 0]$$

If the initially generated random number is greater than HMCR, another solution is generated randomly:

$$\text{NH} = [1\ 1\ 0\ 1]$$

The costs of the above harmonies are shown in Table 5, but only one of them is selected for further processing of the HSA.

Table 5. *Cost calculations.*

NH	Cost
1 0 1 0	530
1 1 0 0	650
1 1 0 1	670

If the new calculated cost is less than the worst cost in the above HM, it is replaced.

For replacing the worst harmony, the following procedure is followed.

1. The existing HM and the new generated solution are combined as shown in Table 6.

***Table 6**. Combined matrix.*

Combined matrix	Corresponding cost
1 0 0 0	660
1 1 1 0	690
1 1 1 1	800
1 1 0 0	650

2. Combined matrix (CM) is then sorted with respect to the cost by which the worst harmony gets the last position in the matrix as shown in Table 7.

***Table 7.** Sorted matrix.*

Sorted matrix	Corresponding cost
1 1 0 0	650
1 0 0 0	660
1 1 1 0	690
1 1 1 1	800

3. The worst harmony is removed from the CM as shown in Table 8.

***Table 8**. Final matrix.*

Final matrix	Corresponding cost
1 1 0 0	650
1 0 0 0	660
1 1 1 0	690

Then the steps of improvisation and updating are repeated until the termination criteria are reached.

The above discussed procedure of improvising is repeated until the termination criteria are reached or until the remaining number of iterations is completed. Finally, the best harmony results are extracted from the harmony memory which contains the best cost and the corresponding solution.

The only difference between uncapacitated and capacitated problems is the capacity constraints. Capacity constraints mean that the retailer can supply '*n*' or '0' number of raw materials at any point of time. So in case the retailer is not in a position to supply any raw material at any particular time, the next period's demand should also be considered and bought in the previous period itself. [6-7]

RESULTS AND DISCUSSION

Problem-1

As per the implementation discussed above, the following problem is taken from P. Sai Krishna with OC and HC as \$780 and \$97.83, respectively, in which the best cost of \$9069 is observed for different parameters. The requirement for different periods is as shown in Table 9. The values of HMCR and PAR are taken as 0.85 and 0.2, respectively. The results are given in Table 10 and Figure 1.

***Table 9**. Requirement of the product in Problem-1.*

Period	1	2	3	4	5	6	7	8	9	10	11	12
Requirement	15	5	15	110	65	165	125	25	90	15	140	115

***Table 10**. Iteration vs. best cost.*

Iteration no.	Best cost
1	10,047.45
25	9069.15
70	9069.15
150	9069.15
250	9069.15
400	9069.15
550	9069.15
650	9069.15
700	9069.15
750	9069.15
800	9069.15
900	9069.15
1000	9069.15

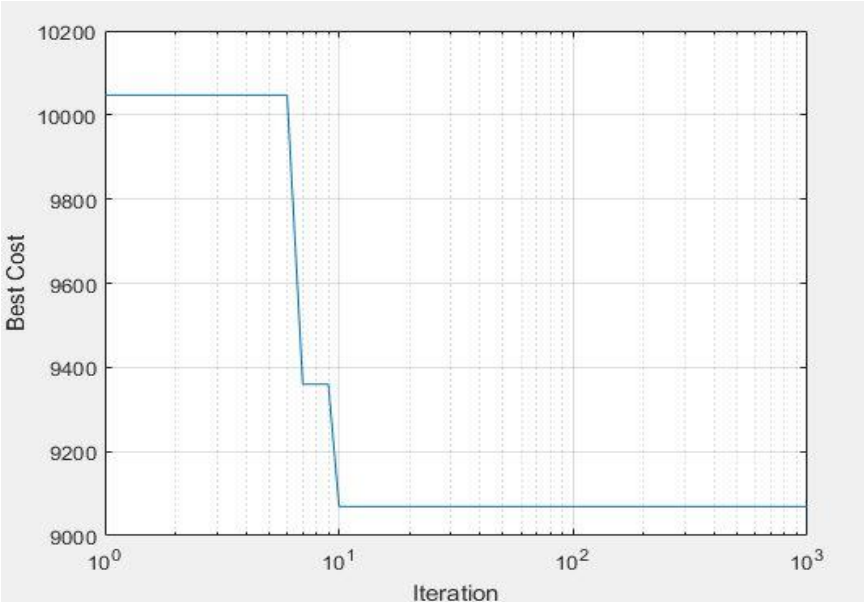

Fig. 1. *Iteration vs. best cost for Problem-1.*

Problem-2

A 12 × 12 multi-level LSP is taken from Huan Neng Chiu and Tsong Ming Lin, whose best cost obtained is $3540 for various parameters. The bill of materials (BOM) structure of the problem is illustrated in Figure 2 and the problem is executed with the OC and HC as per the literature. The requirement for different periods is shown in Table 11. The results are shown in Table 12 and Figure 3.

Table 11. *Requirement of the product in Problem-2.*

Period	1	2	3	4	5	6	7	8	9	10	11	12
Requirement	40	90	30	80	70	60	50	100	120	100	90	40

Table 12. *Iteration vs. best cost.*

Iteration no.	**Best cost**
1	6440
25	4440
70	4140
150	3540
250	3540
400	3540
550	3540
650	3540
700	3540
750	3540
800	3540
900	3540
1000	3540

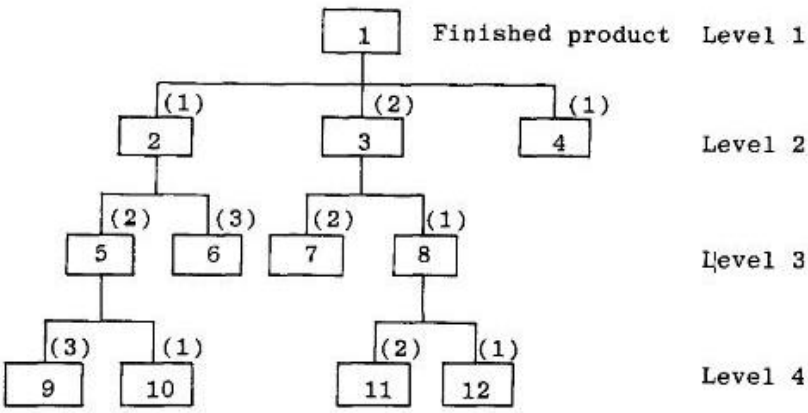

Fig. 2. *BOM structure of the product.*

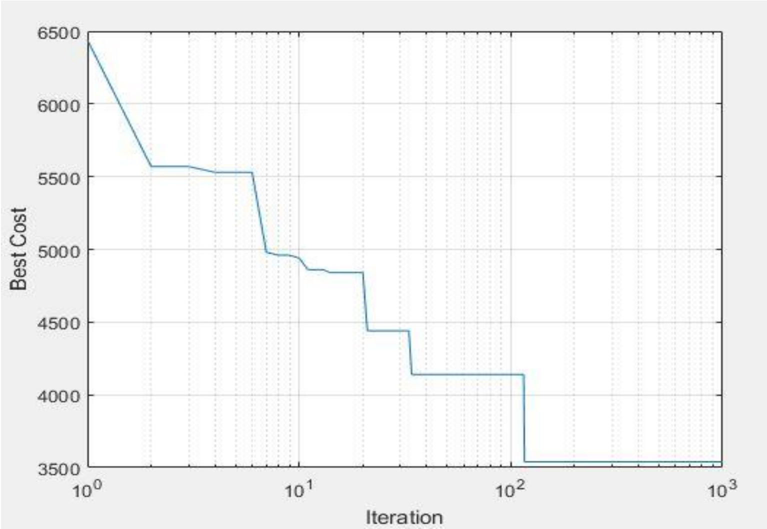

Fig. 3. *Iteration vs. best cost.*

Problem-3

The following 1 × 12 problem with capacity constraints is taken from P. Sai with OC and HC as \$780 and \$97.83, respectively, in which the best cost of \$9069 is observed for different parameters. The requirement for different periods is as shown in Table 9. The values of HMCR and PAR are taken as 0.85 and 0.2, respectively. The results are as given in Tables 13, 14 and Figure 4.

Table 13. *Requirement of the Product in Problem-3.*

Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Requirement	15	5	15	110	65	165	125	25	90	15	140	115
CC	1	0	∞	∞	∞	∞	∞	∞	∞	∞	∞	0

Table 14. *Iteration vs. best cost.*

Iteration No.	Best Cost
1	31675.8
25	30988.25
70	30988.25
150	30988.25
250	30988.25
400	30988.25
550	30988.25
650	30988.25
700	30988.25
750	30988.25
800	30988.25
900	30988.25
1000	30988.25

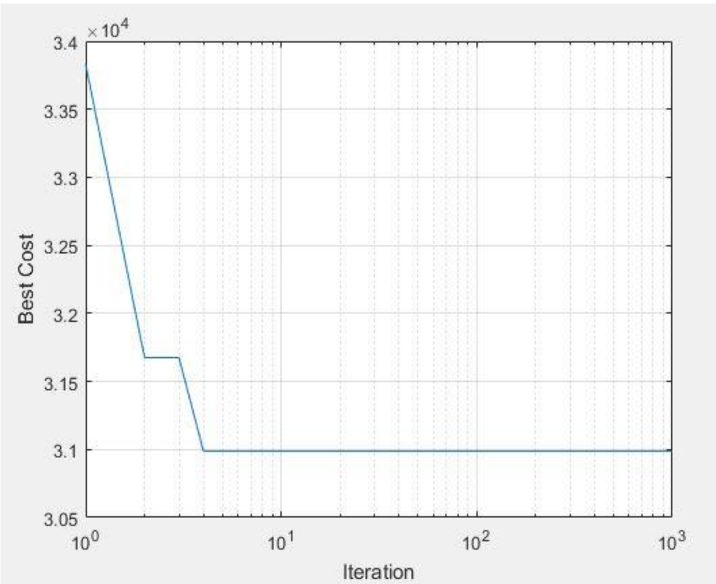

Fig. 4. *Iteration vs. best cost.*

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Problem-4

The following problem has been taken from a manufacturing industry. The requirement of the assembly and BOM structure is shown in Table 15 and Figure 5. The industry follows lot-for-lot technique for inventory management. By using the proposed algorithm, the costs have been reduced to a very large extent as shown in the table. The parameters are taken similar to that of the above problems. The results are discussed in Table 16 and Figure 6.

Table 15. *Requirement of a product for Problem-4.*

Period	1	2	3	4	5	6	7	8	9	10	11	12
Requirement	8	10	9	11	8	12	11	9	10	8	7	13
Capacity constraints	1	∞	∞	∞	∞	∞	∞	0	∞	∞	0	∞

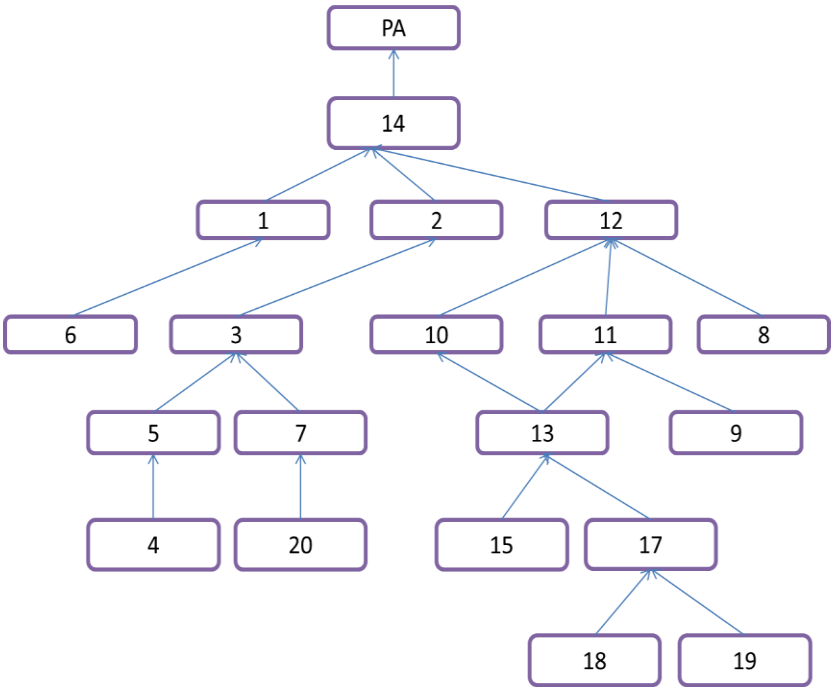

Fig. 5. *BOM structure of the product.*

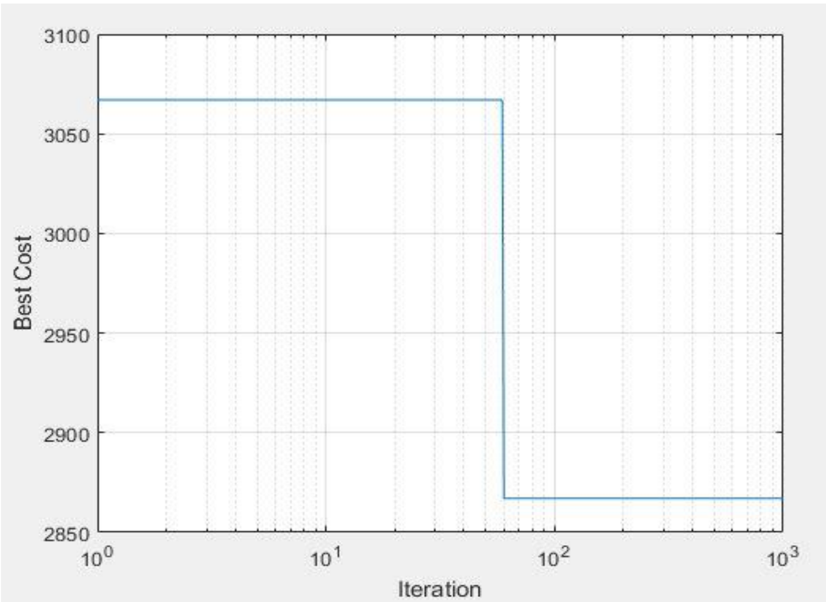

Fig. 6. *Iteration vs. best cost.*

Table 16. *Iteration vs. best cost.*

Iteration no.	Best cost
1	3067
25	3067
70	2867
150	2867
250	2867
400	2867
550	2867
650	2867
700	2867
750	2867
800	2867
900	2867
1000	2867

SUMMARY

Every problem is executed 40 times and the best results have been saved. It is observed that the HSA gave better results than the other algorithms in a certain amount of time. As the coding is done in Matlab software, the execution time has been reduced to a large extent compared to that of C language.

CONCLUSION

An attempt has been successfully made to develop the HSA. A very simple numerical solution has been illustrated to understand the working of the algorithm. Both single and multi-level uncapacitated and capacitated LSPs have been taken from the existing literature to prove the efficiency and accuracy of the developed algorithm.

According to the results, it is clear that HSA took lesser time to reach the optimum results and is proved to be very efficient. The results so achieved were much accurate in terms of computing time compared to other soft computing techniques.

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