

OPTIMISATION OF KNAPSACK PROBLEM WITH MATLAB, BASED ON HARMONY SEARCH ALGORITHM

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Abstract: The design and operation of logistic systems is a complex problem of engineering. The optimization of logistic systems and processes is the key factor of the economical operation. There are different methods and tools to support this optimization field. The networking of the logistic systems and processes led to the development of new heuristic methods and tools to support the optimization of systems with high complexity. A huge number of logistic problems can be related with the knapsack problem. Within the frame of this paper the authors describe the application of harmony search based algorithm with MATLAB fourth-generation programming language to solve the knapsack problem. The authors developed a new bandwidth correction method to this harmony search algorithm, by the aid of which it is possible to control or modify the convergence of the algorithm.

Keywords: harmony search, logistics, MATLAB, optimization

1. Introduction

In today's economy, the pressure is on to make the operations of supply chain from purchasing to distribution more efficient. The supply chain includes the logistic operations of purchasing, production, services, distribution and recycling. These functions are complex. The purchasing process includes the following operations: scheduling of transportation; selection of transportation method and resources; transportation; unloading of products; receiving, control and registration of products; storage in the warehouse; building of loading units; transportation to the production process [1, 2]. These operations depend on the structure of the purchasing system, which can be centralized or decentralized. The development of purchasing processes led to the appearance of special purchasing methods: just in time; just in sequence, just in case, etc. The production logistics includes a huge number of technology and logistics related operations: transportation into the input storage of production plant; transportation to the production lines; selection of production resources for the operations; scheduling of internal transportation through production lines or resources; selection of internal transportation resource; identification of products and other resources; handling of production resources; internal storage (buffering); receiving and control of products; packaging; building of loading units; transportation to the output storage [3, 4]. The development of the production processes led to the appearance of different aims to be fulfilled: increasing utilization of production and logistic resources; decreasing lead time; decreasing of stocks; decreasing of technology and logistic related costs; increasing flexibility; increasing transparency; increasing quality of products and processes; decreasing environmental pollution; integration of the production processes into the controlling and information system of the enterprise. The quality of services is

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defined by the availability, flexibility, accuracy, probability of the fulfillment of an order. The service logistics is related with a huge number of logistic operations: transportation, shipping, packaging, warehousing, loading, building of loading units. The distribution process includes the following operations: transportation of final products into the final product storage; scheduling of receiving; selection of loading resources; receiving and control of final product from the point of view quality and quantity; commissioning; packaging; building of loading units; loading of transportation vehicles; distribution [5]. The recycling logistic includes the following logistic operation: definition of sources of wastes; selection of storage places of wastes; scheduling of transportation; selection of transportation resources; registration; scheduling of distribution; collection of wastes and used materials; transportation; sorting of wastes; warehousing of wastes [6, 7].

As the above mentioned assignments show, supply chains are so complex, that there are different methods to support the aim of their optimization. One of these methods and tools is the optimization by the aid of mathematical modeling.

2. Literature overview

The characterization of different material flow systems can be useful to find the best solution methods for the design problem of the logistic systems. There are several characteristic solutions defining typical groups among the possible varieties of systems to support the selection of design methods and tools [8].

There are a huge number of variations of knapsack problems from the single constraint version to large scale multiple resource constraints problems. Knapsack problems belong to the problems of combinatorial optimization.

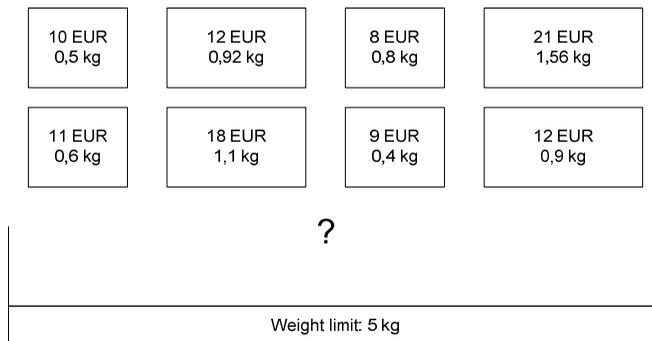


Figure 1. One dimensional knapsack problem

The one constraint knapsack problem focuses on the question: which products should be chosen to maximize the profit while still keeping the overall weight (or other natural parameter of the product) under or equal to the defined limit? In the case of multiple resource constraints more parameters should be taken into consideration.

Some special and generalized algorithms were created and published in different research works: the first exact solution methods focused on either bounded or unbounded problems [9, 10]; the new solution methods are based on heuristic: assessing solution quality of biobjective 0-1 knapsack problem using evolutionary and heuristic algorithms [11], bounded set-up knapsack problem [12], image knapsack problems [13]. The heuristic

optimization methods can be used either in the case of internal logistic related problems [14] or external logistic networks [15]. The complexity of supply chains required up to date methods to find near-optimal network design solutions for investment, operation and maintenance. The optimization of global supply chain is also possible using heuristic methods [16]. The importance of design methods is especially strong in the case of large scale systems and networks, and in the case of these it is expedient to use metaheuristic based algorithms [17]. Much literature has been published in the field of optimization of large scale networks and complex engineering systems by the aid of harmony search algorithm. There are several applications for harmony search algorithms from the sizing optimization of truss structures [18] to the transport energy modeling [19] or nuclear energy production [20].

One of the main streams of literature in the field of hybrid metaheuristic addressed the development of complex algorithms using harmony search method. The harmony search algorithm can be used to create hybrid algorithms to develop more effective solution methods for large systems [21, 22, 23]. Harmony search algorithms make it possible to realize global harmony search [24, 25] and local-best harmony search [26]. Some authors analyzed the effect of parameters of harmony search algorithms, for example from the point of view effects of initial memory and identical harmony to the convergence [27].

3. Harmony search algorithm

The harmony search algorithm is based on the performance process of jazz musicians. The group members of the jazz band try to find the best pitches to create a good harmony. The designers of engineering systems, machines or processes try to find the best parameters to create an optimized system or process. In the optimization process of the harmony search algorithm, the musicians of the band can be replaced with each decision variables of the physical parameters of the systems. The optimization process consists of the following steps: define the problem and initialize the algorithm parameters; initialize the harmony memory; create a new harmony from the harmony memory; update the memory; repeat the steps until the termination criteria are satisfied [28].

The first step of the optimization process is the initialization of the problem, which is the objective function with the constraints. The parameters of the algorithm must be specified: number of solution vectors in the harmony memory (HM), harmony memory consideration rate (HMCR), pitch adjustment rate (PAR) and the termination criteria. The next step is the initialization of the harmony memory. This step means the definition some possible solutions of the real problem. The third step is the calculation of new harmonies (new solutions of the real problem). This improvisation is based on the following formula:

$$p_i^* = \begin{cases} p_i^* \in (p_i^1, p_i^2, \dots, p_i^{HMS}) & \text{with HMCR} \\ p_i^* \in P_i & \text{with } (1 - HMCR), \end{cases}$$

where HMCR is the probability of choosing one parameter from the memory. If the new harmony vector is better, then the worst one, then the worst one is deleted and the new one is included. This process has to be continued until the termination criteria.

4. HS application with MATLAB

We have developed a MATLAB application for harmony search algorithm. After the development we tested the algorithm with several test functions. Within the frame of this capture we describe the test result with the following function:

$$F(x, y) = (x^2 + y - 11) + (y^2 + x - 7)$$

For the test parameters the pitch adjustment rate, the bandwidth and the harmony memory consideration rate was chosen. In the case of the above mentioned test function the best HMCR was about 80%.

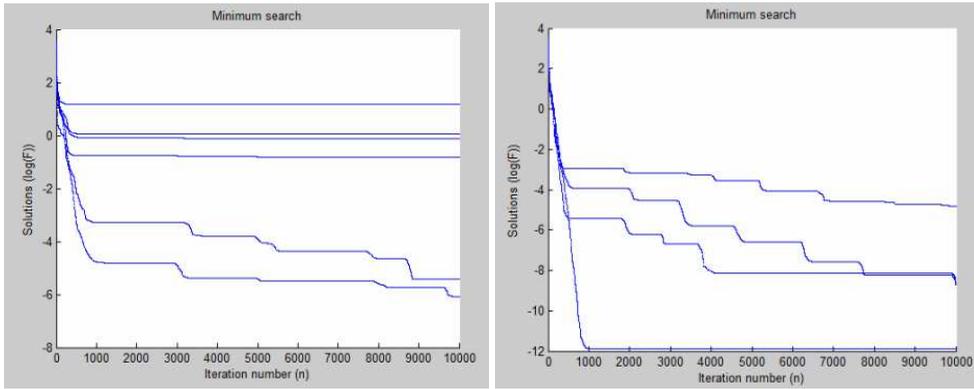


Figure 2. Test result of the harmony search algorithm with different HMCR (50%, 80%)

The second phase of the testing was the analysis of the effect of pitch adjustment rate. Analyzing the pitch adjustment rate with fixed harmony memory consideration rate the best PAR was about 15%.

The third phase of the testing was the analysis of the bandwidth with fixed harmony memory consideration rate and pitch adjustment rate (HMCR = 80%, PAR = 15%). The value of the chosen bandwidth influences the convergence of the algorithm. In the case of the above mentioned test function we see that, a higher bandwidth value is better than a smaller. The optimal solution for the bandwidth is between 0,15 and 0,35.

The above mentioned sort analyses demonstrate the importance of the algorithm parameters. Without analysis of the effect of parameters it is not possible to develop an effective search algorithm. It is important to notice, that the general optimization of the parameters is not possible; they are depending on the problem and the structure of the searching field.

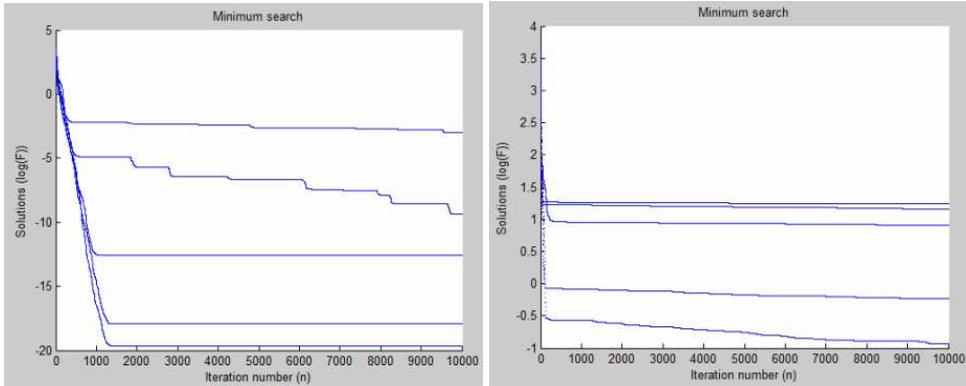


Figure 3. Test result of the PAR (10%, 90 %), with fixed HMCR

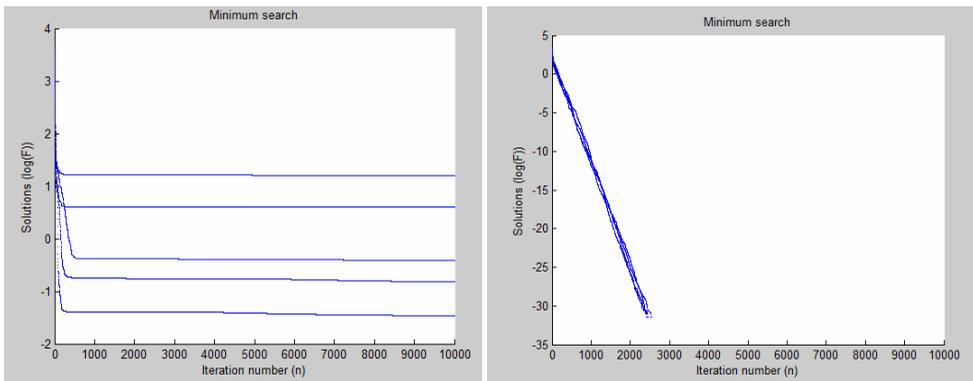


Figure 4. Test result of the bandwidth with fixed HMCR and PAR (0,05; 0,25)

To demonstrate the efficiency of the harmony search algorithm the bounded knapsack problem was chosen. There is a set of items, with each item having a related income and weight (see Figure 1). The objective is to pick some items with maximal income while the total weight of items must not exceed the weight limit. In the case of the knapsack problems the coefficients are scaled to become integers and they must be almost always positive.

$$f(x) = \sum_{j=1}^n c_j \cdot x_j \rightarrow \max$$

$$\sum_{j=1}^n a_j \cdot x_j \leq C \text{ and } \sum_{j=1}^n w_j \cdot x_j \leq W$$

$$0 \leq x_j \leq r_j \text{ and } x_j \in Z \text{ and } j = 1 \dots n$$

The application of the knapsack problem with harmony search was realized with MATLAB. The code of the algorithm was quite simple, as the following short part of the code shows the using of HMCR:

```

if HMCR>rand(1)
    for n=1:xek
        u=round(rand(1)*(yek-1)+1);
        Y(1,n)=Q(u,n);
    end

```

The most harmony search algorithms use static parameters. We developed and implemented a dynamic bandwidth, by the aid of which the convergence of the algorithm can be controlled while running the optimization process.

```

BW(1,k)=A1(1,k)*rand(1)*bw+(max(H(:,k))
    -min(H(:,k)))*rand(1)*2*bwu;

```

where “bwu” can be chosen from three ways:

```

bwu=bw;
bwu=bw*((i-n+1)/i);
bwu=bw*((i^2-n^2)/i^2);

```

The first version is simple and robust; the last two is refine the bandwidth with the current iteration number. All three ways have their own random variables in the program, to make the final result better together. The results of two knapsack problem are demonstrated by the aid of Figure 5.

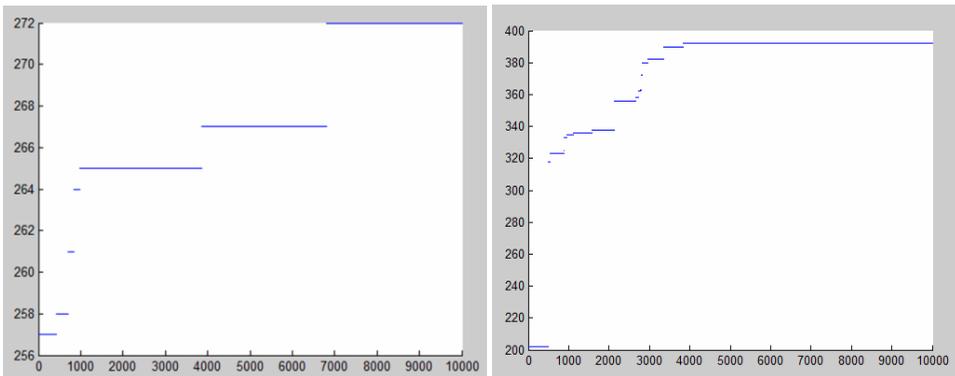


Figure 5. Result of a knapsack problem with harmony search based MATLAB application

5. Summary

The engineering systems are more and more complex. Engineers are looking for up to date tools and methods to solve the problems of these systems. Heuristic optimization is one of the most powerful methods to design and control huge complex systems and processes.

Within the frame of this paper the authors described a possible optimization method of knapsack problems with harmony search algorithm. They developed a new bandwidth operator, by the aid of which the convergence of the basic algorithm can be supported. Future research areas can be the followings: optimization of different knapsack problems with harmony search algorithm (bounded knapsack problem, unbounded knapsack problem, multiple choice knapsack problem, subset sum problem, quadratic knapsack problem, set-union problem, multiple constraint knapsack problems or knapsack like problems, such as bin packing, cutting stock or assignment problems). As a result of the demonstrated research it can be expected that in the future years more and more optimization application will be developed by the aid of harmony search algorithm.

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