Optimization of Order-Picking Routes Based on Hybrid Particle Swarm Algorithm

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Abstract. Order-picking is a common operation in AS/RS (Automatic Storage and Retrieval System), and it is an effective method to optimize the order-picking for improving the efficiency of the automated warehouse. In this paper, we use a hybrid particle swarm optimization (Hybrid PSO) algorithm to optimize the route. The result has proved that this algorithm is feasible.

Introduction

At present, the study of order-picking routes is abstracted into traveling salesman problem (TSP). This paper concerns more on the picking route of single roadway with fixed shelf system. To solve the order-picking optimization problem more effectively, this paper introduces a hybrid particle swarm optimization (Hybrid PSO) algorithm, which combined particle swarm optimization (PSO) algorithm with genetic algorithm.

Model

The objective of order-picking route optimization scheduling is to minimize the operation distance by arranging appropriate sequence for the order-picking route under the condition of a given task. As the route is shown in Figure 1, one square represents a SKU (Stock Keeping Unit). The operators with turnover box start from the origin and reach each locator in proper order, then pick the goods and travel back to the origin.

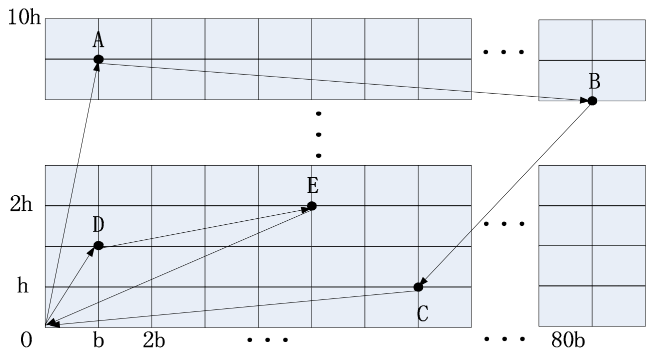

Figure 1 order-picking route

According to the actual situation and operational process, the fixed shelves and stacker operating parameters are set as follows:

(1) The interval between two locators is constant, h for height of cargo box, b for width goods.

(2) The speed of the stacker in horizontal and vertical direction is constant and independent, neglect of start/brake process.

(3) The turnover box was not full or just filled up.

The point (x,y) is presented for waiting goods allocation, where x is for column, y is for layer. When the stacker starts from the origin of coordinates, the distance between i and j is (Eq.1):

$$d_{ij} = \left|x_j - x_i\right| + \left|y_j - y_i\right|$$
(1)

The point (x_j, y_j) stands for goods allocation j, while (x_i, y_i) stands for i.

According to the assumptions, the mathematical model can be established as follows (Eq.2):

$$\min S = \sum_{i,j-1}^{n} d_{ij} \tag{2}$$

Algorithm

Particle Swarm Optimization, PSO, was put forward by psychologist Dr Kennedy and Eberhart in 1995. PSO is a new intelligent optimization algorithm which imitates the behavior of birds.

In particle swarm optimization algorithm, each bird is abstracted as a particle and used to represent a candidate solution of the problem. The state of particle includes two vectors: the position vector and the velocity vector. The position vector can be expressed in type (1) and the velocity vector can be expressed in type (2).

Type(1): $Xi = [xi_1, xi_2, ..., xi_p]$

Type(2): $Vi = [vi_1, vi_2, ..., vi_p]$

The dimensions of the solution space are D and the number of particles is i. The activities of particle simulate the motion of birds and they are integrated into the individual cognition and social influence.

When the moment is t+1, the state of particle is expressed as follow:

$$Vi_{t+1} = \omega Vi + c_1 * r_1 * (pBest_t - Xi_t) + c_2 * r_2 * (gBest_t - Xi_t)$$
(3)

$$Xi_{t+1} = Xi_t + Vi_{t+1}$$
(4)

In these formulas, the letter w, inertia weight, represents the influence of the particles from the current position to the next position. The letters c1 and c2, called acceleration coefficient, represent the degree of particles affected by individual cognition and social patterns. The letters r1 and r2 are random number from 0 to 1. What's more, pBest and gBest are the best position of particles individuals and groups at present.

The particle doesn't have mechanisms such as selection, crossover and mutation. When a particle cluster comes around a local extreme value, the particles cannot search other area of the problem space.

In Hybrid PSO, ωVi in Eq.3 is the mutation operation of genetic algorithm while the $c_1 * r_1 * (pBest_t - Xi_t) + c_2 * r_2 * (gBest_t - Xi_t)$ in Eq.4 is the crossover operation of genetic algorithm. These changes make the current solution and the individual and global extreme value for crossover operation respectively, and create the solution for the new position.

In this paper, we use genetic algorithm to solve the assembly line balancing problem. Here are the main factors which could influence the results:

Factor 1: Particle coding

Particle coding uses integer coding, which means the position of each particle is goods allocation. For example, the code (5, 1, 2, 3, 4) is referred to start from 5 through 1,2,3,4 and go back to 5.

Factor 2: Fitness

The fitness value of particle is the distance of the route.

Factor 3: Crossover

The individuals update themselves by crossing with individual and group extreme values. That is to say, we need randomly choice two positions to cross. Then we cross individuals with extreme values of individual or group. Finally, keep the excellent individuals.

Factor 4: Mutation

Mutation, which is actually a variation happening with small probability, can avoid producing a local optimal solution. First of all, we need randomly choice an individual string among the population, and then in probability exchange the value of two genes which are randomly selected from individual gene string. We get the new individual by keeping individuals, which means updating particles when fitness of the new particles is better than the old one.

Here is the design of Hybrid PSO process (Figure 2):

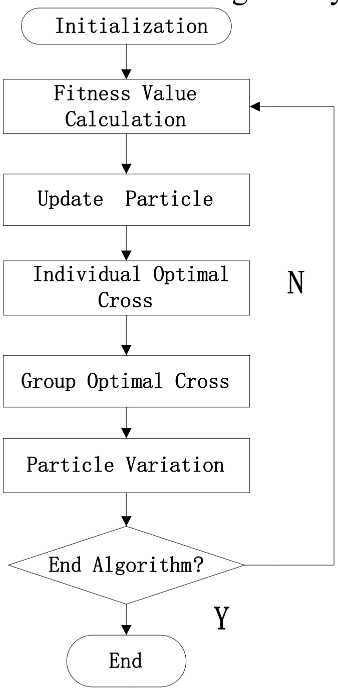

Figure 2

Goods Allocation	1	2	3	4	5	6
Coordinate	(0, 0)	(26, 9)	(12, 8)	(36, 6)	(60, 1)	(4, 3)
Goods Allocation	7	8	9	10	11	12
Coordinate	(4, 2)	(55, 4)	(40, 5)	(17, 1)	(45, 10)	(25, 1)
Goods Allocation	13	14	15	16	17	18
Coordinate	(54, 6)	(18, 4)	(44, 8)	(77, 2)	(10, 2)	(33, 0)
Goods Allocation	19	20	21	22	23	24
Coordinate	(19, 7)	(39, 2)	(50, 3)	(29, 2)	(4, 9)	(70, 8)
Goods Allocation	25	26	27	28	29	30
Coordinate	(45, 4)	(17, 5)	(34, 7)	(6, 5)	(18, 8)	(0, 7)

Table 1

The example of HPSO

A stereoscopic warehouse has 10 layers and 80 columns. Randomly generate 30 invoices, the x-coordinate and y-coordinate of each goods allocation are shown in Table 1.

In this study, we set 1000 for the maximum number of evolution. The probability of crossover is 0.85, at the same time, the probability of mutation is 0.1. We use Matlab R2012b to program the process and get the simulation result. It can be proved that when the number of evolution is 371, the group has no more evolution and reach the minimum, which means the optimal solution is 263. And the shortest route based on hybrid particle swarm optimization algorithm is shown in Figure 3: 1-7-6-28-17-26-10-12-22-18-20-25-21-8-5-16-24-13-11-15-9-4-27-2-29-19-14-3-23-30-1. The shortest route might not be the only, because the genetic algorithm in the process is one of random search algorithms.

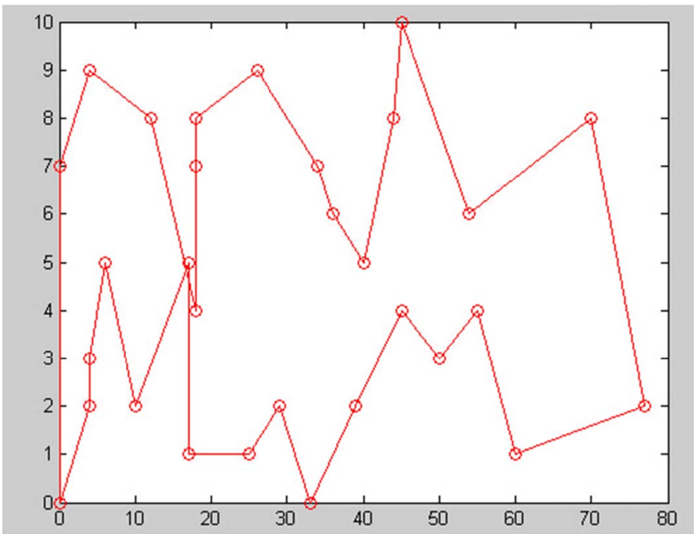

Figure 3

Conclusion

The hybrid particle swarm optimization algorithm has abandoned the method of updating the particle's location by tracking the extreme value. By bringing the crossover and mutation into the traditional particle swarm optimization algorithm, the particles can easily jump out of local optimal solution. This algorithm searches the optimal solution through crossing with individual and group extreme values and the mutation.

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