

Modeling and Solution for Multiple Chinese Postman Problems

Jing Zhang

Basic Courses Department
Beijing Union University
Beijing, China
zhangljing4@sina.com

Abstract. The current study for the Chinese postman problem has reached a mature stage, but multiple Chinese postman problems for the study also relatively small. Multiple Chinese postman problem is starting from the post office messenger, requires area at least through every street once a return to the post office. Multiple Chinese postman problems in the study the characteristics of solutions based on the mathematical model, multiple Chinese postman problem into a single Chinese postman problem, simulated annealing method described in detail the design process, but also gives the ant colony algorithm and hybrid genetic algorithm for multiple Chinese postman problem solving ideas. The results show that these algorithms on multiple Chinese postman problem solving are effective, can be a larger probability of obtaining global optimal solution.

Keywords: Multiple Chinese Postman Problems, Simulated Annealing, Algorithm, Ant colony Algorithm.

1 Introduction

Chinese postman problem is a typical combinatorial optimization problem, which in many areas have a wide range of applications. Chinese postman problem is the multi-m postman from the same street (or a different street) starting to take a walking route, respectively, so that each street has one and only one after the postman (except for starting the street), and the shortest total distance. Chinese postman problems are: an n -street, and asked the postman to reach each street once, and only once, and return to the starting point, requiring the shortest walking route. In order to effectively address the minimum completion time, distance, symmetric or asymmetric multiple Chinese postman problems, this paper, genetic algorithm optimization and matrix decoding method is proposed in order to determine by which each street and each postman postman's walk through the line, that is, the postman to find an optimal allocation and walking routes, walking in after the postman, the postman who spent most of time is minimized. Simulation results show that the proposed algorithm is effective.

In practical problems, because the speed of walking each postman may be different, the time limit to complete the postman is a certain practical sense, therefore,

it is necessary to complete all of the time the postman to minimize the maximum value of multiple Chinese postman problems studied. Chinese postman problems related to the research problems in the real world there are great practical value, such as transportation, pipeline, route selection, and design of computer network topology, the postman messengers and so on, can be abstracted into Chinese postman problems or multiple Chinese postman problems.

2 Simulated Annealing

2.1 The Basic Principle of Simulated Annealing

Simulated annealing algorithm is based on the Monte Carlo method for solving a heuristic iterative random search algorithm, which simulates the thermal annealing process of solid material balance problems with random search optimization to find the similarity to the global optimum optimal or near global optimal objective. Simulated annealing algorithm is a problem for the minimum can be applied to the previous update or basic learning process (random or directed). Then, the principle is similar with the metal annealing, in the beginning to minimize or to learn more quickly, the temperature was risen high, then (slowly) to stabilize the temperature.

In this process, the length of each step of the update process with the corresponding parameters is proportional to the temperature of these parameters play a role. Optimal solution in the search process, in addition to receiving optimal solution, there is a random acceptance criteria (metropolis criterion) to accept worse solutions limited, and the probability to accept worse solutions gradually tends to 0, which makes the algorithm may out from the local minimum area, that is possible to find the optimum solution and to ensure the convergence of the algorithm.

2.2 The Basic Steps of Simulated Annealing

Let (T, g) is an instance of combinatorial optimization problems, find $I \in T$, so $g(I) = \min g(i)$, $i \in T$ of the simulated annealing calculation steps can be described as follows: (from textbooks)

1° Set the given initial temperature $t_0 > 0$ and the final temperature t_g , temperature coefficient of α ($0 < \alpha < 1$);

2° The number of iterations $n = 1$;

3° The temperature t_n , from the neighborhood of solution i randomly generate a new feasible solution j ; Calculate the evaluation function $g(i)$ and $g(j)$ The difference $\Delta g = g(j) - g(i)$;

4° If $\min \{(1, \exp(-\Delta g / t_n))\} > p$, which p is $[0, 1]$ random number between, then accept new solution;

5° In accordance with the temperature coefficient of $t_{n+1} = \alpha t_n$ annealing;

6° Increasing the number of iterations n , if n reaches the maximum number of iterations, or to terminate the temperature, stop the iteration, otherwise return 3°.

2.3 Solving Multiple Chinese Postman Problems of the Simulated Annealing Algorithm Model

The objective function is access to all of the objective function of the total path length of the street Minimum and m a postman as a balanced task. Not necessarily the shortest total distance is the task of balancing the various postmen; it is required to "balance" to make certain demands, so we define

$$\frac{\min_{i,j}(g_i - g_j)^2}{\max_{i,j} g_i^2}$$

To characterize the equilibrium level, it is clear that the smaller the value the better.

Simulated annealing, when the temperature is high enough, the system can freely change the configuration, you can move or in the surface free energy as the rules do not walk, that is, the freedom to choose a feasible solution. When the neighborhood solutions of the objective function value than the current solution when the objective function value better to replace the current solution to neighborhood solutions. When the temperature decreases, the system configuration in the energy surface movement will be restricted, and gradually concentrated to the low energy region, in every iteration process, are based on current solution as the center of the neighborhood and then randomly generate a new solution. It also makes simulated annealing method has the ability to escape local optimal solution, through the cooling action to control the speed of convergence. If the resulting solution than the current, the simulated annealing method will make use of probability functions and control the temperature parameters to determine whether to accept the new solution. As the temperature dropped, accept a lower probability of getting smaller and smaller solutions.

3 Genetic Algorithm

Genetic algorithm is developed in recent years a new global optimization algorithm. This reflects the nature of "natural selection, survival of the fittest" evolutionary process. It borrows the biological point of view of genetics, through natural selection, genetic variation and other mechanisms to achieve the improvement of the adaptability of each individual. When the genetic algorithm to solve the problem, we must first deal with problem-solving model structure and parameters of encoding, usually with a string that will issue symbolic of this process. Professor Holland in 1962, the GA algorithm was first proposed the idea to attract a large number of researchers, quickly extended to the optimization, search, machine learning, etc., and laid a solid theoretical foundation.

Chinese postman problems because the local structure of the problem is extremely complex algorithm to slow convergence near local optimal solution, if the increase in mutation rate, they do not get excellent offspring. Genetic algorithms applied to the Chinese postman problems to be overcome on the issue of convergence speed and the main difficulty is the contradiction between the maturities.

3.1 Encoding

For these reasons, this paper uses a dynamic mapping approach to coding, to ensure that the various genetic manipulation of genes obtained are valid. There is two ways postman route, record or records in order to access the street line of the order. If access to the order of 123, the number is 111, easy to show that this encoding and access route is one mapping. Access sequence set r_1, r_2, \dots, r_n , then the requirement that a street map directly to the street number, street maps for a later visit to the street without the serial number list. We adopt the latter in the specific code, if the list directly to the street map with the street number of the method will create difficulties for crossover and mutation operation such as access to the order of the street 1, street 2, street 3, if its code is 123, then the access road intersection with the 321 genes that are ineffective, and mutation of its genes are not valid any gene.

3.2 Evaluation Function

Evaluation function can be directly by a transform path length, the longer the path; the evaluation function is given a lower score, the more likely that the genotype be eliminated. Meanwhile, the evaluation function should be some discrimination; this paper is given to develop appropriate indicators of the strength of the comparison matrix of all individuals, and normalization methods.

3.3 Initial Population

Considering the representation of the initial population, the specific emulated bit up in the first $n+m$ to $n-m+1$ is a random number, the complexity of computing experience and genetic algorithms to select the number of initial population of 10 individuals.

3.4 Genetic Operators

1° Mutation operator

The evaluation function design based on the mutation probability

$$\frac{\max f - f}{\max f - \min f}$$

after appropriate scaling and the constant increase in the minimum point has a certain mutation probability.

2° The selection operator

In order to solve the problem of single source, the use of demo program, the following is a demonstration of several different situations screenshots, for simplicity, we directly demonstrate a single source point of the Chinese postman problem, respectively, in 10 streets, 100 streets, 500 streets were calculus. In order to retain under the optimum of the parent gene, after the parent and offspring to join scores roulette, make a selection.

3° Crossover operators

The right side of the street the shortest distance corresponds to the distance a small street to the offspring in the right and began to consider the parent in the street right in the street, and so on. Direct access point crossover, you can choose the greedy-based

crossover operator, that is randomly selected in the parent of a street as the offspring of the original street from two parent to find the right side of the street streets, and street to calculate.

4 Ant Colony Algorithm

Ant colony algorithm by the Italian scholar, who first proposed a novel simulated evolutionary algorithm. More specifically, the ants in the course of the campaign can leave it on the path through the pheromone, but also in the process of movement that pheromone perception of the existence and strength, and to guide the direction of their movement.

After much careful observation of bionics home and study discovered that ant process, through a substance called pheromone mutual transmission of information. It is the study of ant colony behavior generated. In order to avoid the ants took the same path twice, for each ant to set up a taboo table to record the path it traveled. Toward the pheromones of ants tend to move towards high intensity, so the composition of the large number of ant colony behavior will show a positive feedback effect of information: a path through the more ants, then later chose the greater the probability of the path.

Ant group is through exchange of information between individuals that collaborate with each other mechanism to achieve the purpose of the search of food. Ant colony algorithm has the advantage: it is an adaptive, self-organization, in essence, parallel methods, and positive feedback is a way to promote optimal solution to the evolution of the system has strong robustness, slightly modified model of the ant colony algorithm to be applied to other problems, and it can be combined with a variety of heuristic algorithms to improve the performance of the algorithm.

Chinese postman problems in the field of combinatorial optimization problem is a typical problem to solve this problem have a greater practical significance, and this problem can be testing new algorithms as a criterion, so this issue has been a research focus. But the algorithm also has a slow convergence and easy to fall into local optimum and other shortcomings. There is no theoretical basis, adjusted and determined by experiment.

5 Conclusion

The gene encoding algorithm is simple and can clearly reflect the relationship between the postman and the streets and visit the order, and of the decoding method, optimizing distance for symmetric and asymmetric multi-Chinese postman problem. Minimizing this distance all the postman conducted a study and proposed hierarchical genetic algorithm to optimize the number of Chinese postman problem.

This is because large-scale multiple Chinese postman problems is difficult to find the optimal solution, but also requires a lot of time, so research in this area should also continue to deal with multiple Chinese postman problems algorithm further improved, try using a new algorithm for find a better solution as soon as possible. Using this algorithm, the simulation test, effectively solve the problem of multiple

Chinese postman problems, and achieved a quite satisfactory solution, verify the feasibility and effectiveness. However, the results on the schedule for further analysis results are still found scattered. Hybrid genetic algorithm of this paper is better than the genetic algorithm alone has improved a lot.

Acknowledgment. The work is supported by Funding Project for Academic Human Resources Development in Institutions of Higher Learning under the Jurisdiction of Beijing Municipality (PHR (IHLB))(THR201108407). Thanks for the help.

References

1. Eiselt, H.A., Gendreau, M., Laporte, G.: Arc Routing Problems, Part I: The Chinese Postman Problem. *Operations Research* 43(2), 231–242 (1995)
2. Thimbleby, H.: The directed Chinese Postman Problem. *Software: Practice and Experience* 33(11), 1081–1096 (2003)
3. Assad, A.A., Pearn, W.-L., Golden, B.L.: The Capacitated Chinese Postman Problem: Lower bounds and solvable cases. *American Journal of Mathematical and Management Sciences* 7(1-2), 63–88 (1987)
4. Minieka, E.: The Chinese Postman Problem for Mixed Networks. *Management Science* 25(7), 643–648 (1979)
5. Nobert, Y., Picard, J.-C.: An optimal algorithm for the mixed Chinese postman problem. *Networks* 27(2), 95–108 (1996)
6. Corberán, A., Martí, R., Sanchis, J.M.: A GRASP heuristic for the mixed Chinese postman problem. *European Journal of Operational Research* 142(1), 70–80 (2002)
7. Pearn, W.L., Liu, C.M.: Algorithms for the Chinese postman problem on mixed networks. *Computers & Operations Research* 22(5), 479–489 (1995)
8. Ghiani, G., Improta, G.: An algorithm for the hierarchical Chinese postman problem. *Operations Research Letters* 26(1), 27–32 (2000)
9. Pearn, W.L., Chou, J.B.: Improved solutions for the Chinese postman problem on mixed networks. *Computers & Operations Research* 26(8), 819–827 (1999)
10. Pearn, W.L.: Solvable cases of the k-person Chinese postman problem. *Operations Research Letters* 16(4), 241–244 (1994)
11. Ralphps, T.K.: On the mixed Chinese postman problem. *Operations Research Letters* 14(3), 123–127 (1993)