International Journal of
Intelligent Systems and Applications in Engineering
ISSN:2147-6799 www.atscience.org/IJISAE
Advanced Technology and Science
Original Research Paper

A Hybrid Algorithm for Automated Guided Vehicle Routing Problem

Cansu Soyleyici*[1], Sinem Bozkurt Keser[2]

Accepted 3rd September 2016

Abstract: Nowadays, automatic systems become crucial in many factories to achieve some tasks such as minimizing cost, maximizing efficiency, quality, and reliability. The planning is important for manufacturing systems to adopt changing conditions. Also, manufacturers want to obtain fast, reliable, qualified and economic products. Flexible Manufacturing Systems (FMSs) are used to meet this need. FMSs make production fast, qualified, reliable and economic by using computer-controlled structure that includes robots and transportation systems. Automated Guided Vehicles (AGVs) and FMS are thought to be integrated because FMSs use AGVs as a part of transportation in the factory. AGVs are used to carry loads, in other words products, in production areas, warehouses, factories that use magnets, landmarks, laser sensors, lines to know where they are. AGV scheduling and routing is NP-hard and open-ended problems. In the literature, there are many algorithms and methods are proposed to solve these problems. In this study, we present a hybrid algorithm that is composed of simulated annealing (SA) and Dijkstra's algorithm to solve the routing problem. The hybrid algorithm is compared with SA algorithm in terms of distance cost using benchmark problems in the literature.

Keywords: *Automated Guided Vehicle, Flexible Manufacturing Systems, Simulated Annealing Algorithm, Dijkstra, Routing, Vehicle Route Planning, Automatic Systems.*

1. Introduction

Many factories use automated systems to improve quality while minimizing cost to meet demands of customers in competitive market. There can be uncertainties and changes due to this competition. The result of these uncertainties and changes is decreasing performance and flexibility. Therefore, routing and scheduling is important to prevent such an undesired condition. Flexible Manufacturing Systems are used to meet this need. FMSs make production fast, reliable, qualified and economic by using computer-controlled structure that includes robots and transportation systems. Coordination in FMSs is important for production and transportation because it is required to schedule limited resources in industry. If FMSs are well-planned, coming jobs are done on time. Therefore, production and transportation is carried out smoothly. AGVs are indispensable parts of FMSs. Here, AGVs are responsible for transportation in FMSs.

AGV control includes duty assignment, routing and scheduling [1]. AGV routing and scheduling can be done either online or offline. While offline planning requires prior knowledge related to tasks (it can be nodes, duties and so on), online planning enable to give new tasks [2].

Actually, AGV scheduling and routing problems are very complex in reality. However, this problem will be solved in this paper by simplifying and ignoring some conditions. Details related conditions, assumptions and constraints will be given insection 2.

[1] Eskisehir Osmangazi University, Electrical and Electronics Engineering, Eskisehir – 26480,TURKEY
[2]Eskisehir Osmangazi University, Computer Engineering, Eskisehir – 26480,TURKEY
** Cansu Soyleyici:Email: cansusoyleyici@gmail.com*
Note: This paper has been presented at the 3rd International Conference on Advanced Technology & Sciences (ICAT'16) held in Konya (Turkey), September 01-03, 2016.

As mentioned before, scheduling and routing of AGVs is NP-hard problem. Therefore, there are so many researches in literature and also researchers have been still trying to deal with it. There are various methods to solve AGV or vehicle routing problem such as simulated annealing algorithm, genetic algorithm, tabu search and so on. Also, some hybrid algorithms are available in the literature.

(Pei-Sen Liu and Li-Chen Fu; 1989) dynamically solve the vehicle routing, scheduling and planning problem by using A* algorithm, minimax criterion and some heuristic rules. They model the problem as optimal routing assignment of p AGVs among m workstations in order to accomplish n tasks by using AGV in FMS. (Zbigniew J. Czech and Piotr Czarnas; 2002) investigate the vehicle routing problem with time windows. Parallel-simulated annealing algorithm is proposed to solve routing problem assuming that there is a central depot of cargo and n customers a particular distance far away from the depot. The effectiveness of the method is tested on some well-known instances of the problem. (Sheng-Wei Lin et al; 2006) apply an algorithm combining simulated annealing with local search approach to handle capacitated vehicle routing problem (CVRP) and test the algorithm on fourteen benchmark problems having different settings. (Takashi Onoyama et al; 2006) propose an algorithm to solve vehicle routing problem for a cooperative logistics network by using genetic algorithm. They use multistage GA and a method of multistage point evaluation to satisfy the optimization of a cooperative logistics network. Here, they claim that the method of multistage GA gives a chance to obtain accurate solution under various conditions. The paper of (Yusuke Morihiro et al; 2006) is about an online 'Tasks Assignment and Routing Problem'called asTARP. Their method is for an initial task assignment of autonomous distributed vehicle systems that uses finite buffer capacity. Also, the purpose of the method is to decrease the computation time of route planning by using initial task assignment. In other words, the importance of selecting initial task in a right way is emphasized. (NaiQi Wu and MengChu Zhou; 2007) propose an algorithm to find shortest time routes by controlling deadlock and blocking in AGV systems because they are undesired. (Lyamine Bouhafs et al; 2007) propose a hybrid algorithm that uses tabu search and ant colony algorithm to solve ‘Capacitated Location-Routing Problem’ that is composed of ‘Facility Location Problem’ and ‘Vehicle Routing Problem’. The purpose of using tabu search is to find distribution centers with reasonable configuration. Also, the purpose of using ant colony algorithm is finding a route for configuration found in tabu search step. Another tabu search method is proposed by (Cui-hua Guan et al; 2010) for vehicle routing problem. They suggest that their approach is more intuitive and easy to understand client-direct-arrangement solution method coded with C language. (Haihua Li et al; 2012) improve the tabu search for the vehicle routing with fuzzy demands. The purpose is to minimize total distance. Traditional tabu search is compared with the proposed improved tabu search to see the effectiveness of the algorithm.

In this work, SA algorithm is combined with Dijkstra’s algorithm to improve the performance of SA algorithm. Then, SA and hybrid SA are compared in a table to show effectiveness of new algorithm. Details of the algorithm are given in the following parts.

This paper is organized into four sections. Section.2 gives the information about used algorithms in proposed method. Also, this part includes problem statement, in other words, assumptions and constraints. Test results for proposed algorithm are given in section.3. Finally, section.4 is a conclusion part that summarizes all of them in the paper with a short paragraph.

2. Proposed Methodology

Implemented hybrid algorithm consists of both SA and Dijkstra. SA gives a route for each AGV and Dijkstra enhance the routes by shortening them. So, performance of the SA algorithm is increased by Dijkstra.

Before the implementation of algorithm, assumptions and constraints should be determined because of ease of coding. Assumptions and constraints are given as the following:

- All nodes are connected with each other.
- There is one depot and more than one distribution center.
- All AGVs are capacitated and total demand must be smaller than or equal to the total capacity of AGVs.

2.1. Simulated Annealing Algorithm

Simulated annealing algorithm is a metaheuristic method that is used to find maximum or minimum of a function without trapping local maximums or minimums. Algorithm starts with an initial solution and tries to find better solution by randomly changing some neighbors. However, some high-cost solutions are selected if the probability of it is greater than a probabilistic value [12].

Actually, this method can be associated with cooling process of metal. In thermodynamics, metals should be cooled carefully and slowly. When the metals are abruptly cooled, theyfragile structure that is undesired. At the same way, if there are abrupt changes in simulated annealing algorithm, it may trap local values. Therefore, small changes are preferred for both.

Simulated annealing method is used in electronic circuit design, image processing, path finding problem, travelling salesman problems, scheduling problems [13]. In this paper, SA is used for routing of AGVs.

2.2. Dijkstra’s Algorithm

Dijkstra’s algorithm is used to find shortest path between nodes in a graph by using open list and closed list logic proposed by Edsger W. Dijkstra in 1956 [14]. In this paper, Dijkstra’s algorithm is used to make the distance found by SA shorter.

Pseudo codes of SA and hybrid SA are given in algorithm 1 and algorithm 2, respectively to show the difference between them.

Algorithm. 1:Simulated Annealing Algorithm

```
Start
Input: AGV data set
Output: Routes of AGVs
Generate an initial solution, S
Select a value for initial temperature, T
Select a value for minimum temperature, Tmin
while (T <Tmin)
   Generate a neighborhood solution S’ of S
   Δ=DistanceCost(S’) - DistanceCost(S)
   If Δ<0, S=S’
   Generate a number r between 0 and 1.
   End if
   If Δ≥0, S=S’ with exp (-Δ/T) > r
   T=α*T
   End if
end while
Stop.
```

Initial solution in (1) of Algorithm 1 is found using nearest neighbour strategy. Each service node is firstly ordered minimum to maximum according to distance to depot. Then, each service node is assigned to each AGV respectively. This step continues until no service node is left.

Algorithm. 2:Hybrid Simulated Annealing Algorithm

```
Start
Input: AGV data set
Output: Optimal Routes of AGVs
Generate an Initial solution, S
Select a value for initial temperature, T
Select a value for minimum temperature, Tmin
while (T <Tmin)
   Generate a neighborhood solution S’ of S
   DijkstraOrder(S’)
   Δ=DistanceCost(S’) -- DistanceCost(S)
   If Δ<0, S=S’
Generate a number r between 0 and 1.
   End if
   If Δ≥0, S=S’ with exp (-Δ/T) > r
   T=α*T
   End if
end while
Stop.
```

The *DijkstraOrder* function is applied each route of AGV in neighbourhood solution S’. This function is ordered the route of each vehicle considering the shortest path cost.

3. Results and Discussion

The algorithms are coded with C#. The tests for hybrid algorithm are done on a laptop with Windows 7, Intel Core i7 CPU and 8 GB Ram.

Simulated Annealing and hybrid SA algorithms are compared in terms of best distance costs using problem set by Augerat et al [15]. The instances range from 32 to 80 service nodes. Number of AGVs is changed from 5 to 10 according to problem set. In addition, capacities of each vehicle for all problem set is 100. The problem set description and best distance cost results obtained using SA and hybrid SA are given in Table I.

Table 1. Problem Data Set

Problem Set Name	***Number of Service Nodes***	***Number of AGV***	***Capacity***	***Best Cost with SA***	***Best Cost with Hybrid SA***
A1	32	5	100	808,55	**803,66**
A2	33	5	100	**662,00**	675,70
A3	33	6	100	746,80	**743,44**
A4	34	5	100	**788,72**	791,86
A5	36	5	100	**831,32**	835,09
A6	37	5	100	694,91	**694,26**
A7	37	6	100	990,06	**979,92**
A8	38	6	100	765,41	**764,68**
A9	39	5	100	854,89	**853,15**
A10	39	6	100	848,94	**838,32**
A11	44	6	100	965,61	**952,21**
A12	45	7	100	992,47	**982,79**
A13	45	7	100	1182,3	**1173,58**
A14	46	7	100	985,58	**928,00**
A15	48	7	100	1150,04	**1128,41**
A16	53	7	100	1082,72	**1075,01**
A17	54	8	100	1259,40	**1223,16**
A18	55	9	100	1144,63	**1133,11**
A19	60	9	100	1439,17	**1412,75**
A20	61	10	100	1124,03	**1113,16**
A21	62	8	100	1387,27	**1357,39**
A22	63	10	100	1736,10	**1717,60**

Some parameter settings are required to run simulated annealing algorithm and values of them are crucial. Parameters, expressions and corresponding values are given in Table 2.

As seen in Table 1, hybrid SA gives better results except for three of 27 results in terms of distance. Visualization of first data set A1 is made with simulated annealing in Figure.1 and with hybrid simulated annealing in Figure.2 for better understanding.

Table 2. . Parameters used in hybrid SA

Parameters	***Expression***	***Value***
T	Temperature	100
Tmin	Minimum temperature	1
r	Annealing ratio	0.2
α	Cooling parameter	0.9999

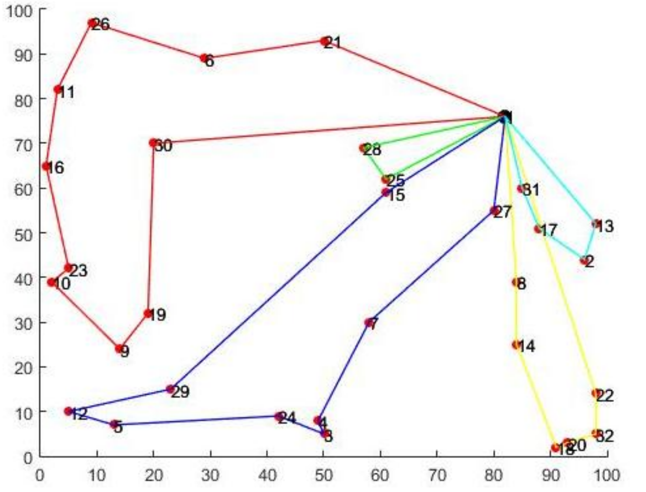

Figure 1. Vehicle route planning solution for SA using problem set A1

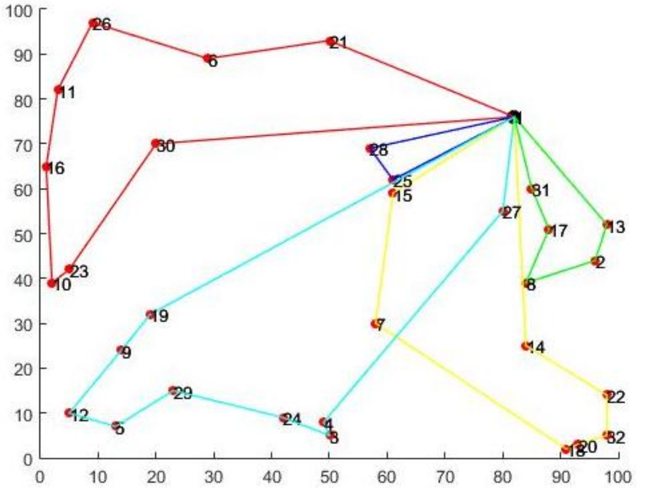

Figure 2. Vehicle route planningsolution for hybrid SA using problem set A1

Figure.1 gives the route of the AGVs as the following:

Route for AGV 1: 1-21-6-26-11-16-23-10-9-19-30-1
Route for AGV 2: 1-28-25-1
Route for AGV 3: 1-15-29-12-5-24-3-4-7-27-1
Route for AGV 4: 1-8-14-18-20-32-22-1
Route for AGV 5: 1-31-17-2-13-1

Figure.2 gives the route of the AGVs as the following:

Route for AGV 1: 1-21-6-26-11-16-10-23-30-1
Route for AGV 2: 1-28-25-1

Route for AGV 3: 1-19-9-12-5-29-24-3-4-27-1
Route for AGV 4: 1-15-7-18-20-32-22-14-1
Route for AGV 5: 1-31-17-8-2-13-1

As seen above, routes for AGVs are generally different in Figure.1 and Figure.2 but it is not important because algorithm is probabilistic and can give different results at each run. It is required to control whether total distance is getting smaller or not. Distance can be controlled with Table I and it can be said that SA is improved by using Dijkstra's algorithm.

4. Conclusion

So many factories use automatic systems due to developing technology to minimize cost and maximize efficiency, quality, and reliability. FMSs are used to meet this need. AGVs play big role in this for the duty of transportation. It is required to make route planning of AGVs to use them effectively due to costs. SA algorithm is the one of the common methods in literature to solve the routing problem of AGVs. In this study, it is combined with Dijkstra's algorithm that is another common method in literature. Hybrid algorithm is tried on problem set by Augerat et al as mentioned before. Obtained results show that the hybrid approach gives better distance results. In the future work, the algorithms are planned to handle the problem for the autonomous AGVs.

References

[1] Luka Kalinovcic, Tamara Petrovic, Stjepan Bogdan, Vedran Bobanac (2011). Modified Banker's Algorithm for Scheduling in Multi-AGV Systems. Automation Science and Engineering (CASE), 2011 IEEE Conference on, Trieste, Italy.Pages.351-356

[2] Vedran Bobanac and Stjepan Bogdan (2008). Routing and Scheduling in Multi-AGV Systems Based on Dynamic Banker Algorithm, Control and Automation, 2008 16th Mediterranean Conference on, Ajaccio, France.Pages. 1168-1173

[3] Pei-Sen Liu and Li-Chen Fu (1989). Planning and Scheduling in a Flexible Manufacturing System Using a Dynamic Routing Method for Automated Guided Vehicles, *Robotics and Automation, 1989. Proceedings., 1989 IEEE International Conference on, Scottsdale, AZ, 1989*. Pages. 1584-1589

[4]Zbigniew J. Czech and Piotr Czarnas (2002). Parallel Simulated Annealing for Vehicle Routing Problem with Time Windows, Parallel, Distributed and Network-based Processing, 2002. Proceedings. 10th Euromicro Workshop on, Canay Island. Pages. 376-383

[5] Shih-Wei Lin, Kuo-Ching Ying, Zne-Jung Lee and F.-H. Hsi (2006), Applying Simulated Annealing Approach for Capacitated Vehicle Routing Problems", 2006 IEEE International Conference on Systems, Man and Cybernetics, Taipei, Taiwan. Pages. 639-644

[6] Takashi Onoyama,,Takuya Maekawa,Sen Kubota, Norihisa Komoda (2006). GA Applied VRP Solving Method for a Cooperative Logistics Network, 2006 IEEE Conference on Emerging Technologies and Factory Automation, Prague. Pages. 1101-1106

[7]Yusuke Morihiro, Toshiyuki Miyamoto, Sadatoshi Kumagai (2006). An Initial Task Assignment Method for Autonomous Distributed Vehicle Systems with Finite Buffer Capacity, 2006 IEEE Conference on Emerging Technologies and Factory Automation, Prague. Pages. 805-812

[8] NaiQi Wu and MengChu Zhou (2007), Shortest Routing of Bidirectional Automated Guided Vehicles Avoiding Deadlock and Blocking, IEEE/ASME Transactions on Mechatronics, Vol. 12, No. 1. Pages. 63-72

[9] Lyamine Bouhafs, Amir Hajjam and Abderrafiaa Koukam (2008), A Tabu Search and Ant Colony System Approach for the Capacitated Location-Routing Problem, Software Engineering, Artificial Intelligence, Networking, and Parallel/Distributed Computing, 2008. SNPD '08. Ninth ACIS International Conference on, Phuket,. Pages. 46-50

[10] Cui-hua Guan,Yan Cao, Jing Shi (2010). Tabu Search Algorithm for Solving the Vehicle Routing Problem, Information Processing (ISIP), 2010 Third International Symposium on, Qingdao. Pages. 74-77

[11] Haihua Li, Zongyan Xu, Feifei Zhou (2012). A Study on Vehicle Routing Problem with Fuzzy Demands Based on Improved Tabu Search,Computational and Information Sciences (ICCIS), 2012 Fourth International Conference on, Chongqing. Pages. 73-76

[12] Cheng Zhu, Luohao Tang, Weiming Zhang (2014). Multi-vehicle Coordination and Flexible Scheduling based on Simulated Annealing Algorithm, The 26th Chinese Control and Decision Conference (2014 CCDC), Changsha. Pages. 2686-2691

[13] Pelin Alcan and Hüseyin Başligil (2010).A literature Review for the Simulated Annealing Method on the Parallel Machines Since 2003, 14th International Research/Expert Conference, Pages. 289-292

[14] Dijkstra, E. W. (1959). "A note on two problems in connexion with graphs" (PDF). Numerische Mathematik 1: 269–271. doi:10.1007/BF01386390.

[15] (2016) Vehicle Routing Dataset. [Online].http://www.coin-or.org/SYMPHONY/branchandcut/VRP/data/index.htm.old#A