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# A Hybrid Method for Assigning Containers to AGVs in Containers Terminal

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Abstract: The problem of loading and unloading ship containers can be decomposed in some sub problems such as storage problem, transportation problem, routing problem, assigning problem, etc... In this paper, we are interested to the assignment of containers to Auto guided vehicles (AGVs) problem. This problem includes three sub problems: routing problem and assignment problem and scheduling problem. We propose a hybrid approach to solve it; Dijkstra algorithm, Genetic algorithm (GA) and a heuristic method to choose the AGV for each container. A comparative study was made between three approaches; the first approach consists of applying the GA, the second one present hybridization between Dijkstra algorithm and GA and the third approach add to the second one the using of heuristic (hybrid method using Dijkstra algorithm, GA and heuristic). Some numerical examples and tests are presented to prove the efficiency of our proposed approach.

*Keywords:* Scheduling, Vehicle Routing Problem, AGV, Containers, Optimization, Genetic Algorithm

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## 1. INTRODUCTION

Due to the complexity of container terminal operation, it's difficult to optimize the whole operations of system with a single analytical model. Therefore, generally the operations of system in the container terminal operation can be divided into two parts: loading outbound containers and unloading inbound ones. The process of loading outbound containers involves three stages: the yard cranes pick up the desired containers from yard blocks and load them out the yard trailers. Then, yard trailer transports the containers to quay cranes, finally the quay cranes loaded the containers onto the vessels. The objective of scheduling containers to AGVs at container terminal is twofold: the first is to assign each container to an AGV, and the second is to sequence the assigned containers on each AGV. Thus, to minimize the makespan of the loading or unloading operation, we have to optimize the dispatching operation and the scheduling operation of

containers to AGVs. The problem of dispatching containers to AGVs consists of choosing the best way of designating a particular AGV to transport a container. This choice should consider into account the specific criteria of performance for the production system. The problem of assigning containers to AGVs in a container terminal can be decomposed into routing problem, dispatching problem and scheduling problem. The first problem is assimilated as a shortest path problem, which is a linear problem, but the combination of this problem with the dispatching problem and the scheduling problem makes the global problem as NP-Complete one. In this paper, we make a comparative study between three approaches: the first approach is the Genetic Algorithm with a random method to assign containers to AGVs and a random method to choose the path traveled by each AGV, the second one is a hybrid approach between the Genetic algorithm with a random method to assign containers to AGVs and an

exact algorithm Dijkstra to compute the shortest path traveled by each AGV, and the third approach is an hybridization between Genetic Algorithm with an heuristic to assign the container to the nearest AGV and an Dijkstra algorithm to compute the shortest path traveled by each AGV.

## 2. LITERATURE REVIEW

In the container terminal, the AGVs are used to transport containers from the loading area to the unloading area or backwards. The primary AGV management functions are defined in work of (Bish and al, 05) as:

- 1) Dispatching function is the selecting and assigning of tasks to vehicles.
- 2) Routing function is the selection of the specific paths taken by vehicles to reach their destinations.
- 3) Scheduling function is the determination of the arrival and departure times of vehicles at each segment along their prescribed paths to ensure collision-free journeys.

The method of assigning tasks to AGVs was studied in the research of (Brikson and al, 07)

### **Longest travel distance rule**

This rule consists in assigning a container whose travel distance to the AGV is the longest, when they are ready for another mission. The system can be modeled as a network with intermediate nodes, which can be used to determinate the path of AGV.

### **Shortest travel distance rule**

The container whose travel distance is computed to be the shortest is assigned to the AGVs when they are ready for another mission.

### **Random rule**

This rule consists in choosing an AGV randomly in order to be assigned to each available container.

(Cao and al, 11) present a model for defining a rule for dispatching AGVs based on fuzzy systems. They considered three input variables: distance between the AGV and the workstation, the number of nodes between the AGV and the workstation and the remaining space in the output buffer of the workstation requester. It creates a rule based manually with all possible combinations. The approach proposed by (Daganzo, 89)] is an intelligent approach of dispatching AGVs based on multiple criteria of fuzzy logic controller, which simultaneously takes into account various aspects in every dispatching decision. The controller operates in two phases; in the first phase they determine which

AGV will be selected considering the use of the AGV, the distance from the AGV to the work center at the output buffer. Many researchers stated that optimization of integrated scheduling of equipment, highly influences the performance of the container terminal (CTs). (Egbelu and al, 84) considered integrated scheduling of quay cranes (QC) and yard tracks (YTs), the problem was formulated as a mixed integer linear programming (MILP) model. The objective is to minimize the makespan of all the jobs. They developed a GA to solve the problem. A dispatching method for automated lifting vehicles ALVs in CTs is presented by (Houmayounou and al, 09). They developed a heuristic algorithm to solve the problem. (Grunow and al, 04) proposed a scheduling method for AGVs, automated yard cranes (AYCs) and QCs in container terminals was proposed. They developed a MILP model and solved it using a GA. A simulated annealing (SA) algorithm was proposed to select the parents in the GA. This hybrid algorithm needs much less computer time than canonical GA. The authors make a recent literature survey of main scheduling and control problems in CTS. They affirmed that a new stream on integrated scheduling had been started a few years before with increased costs. The SA algorithm was used by the researchers to solve the scheduling problems in CTS. The berth allocation problem was solved by (Kim and al, 04) with SA algorithm.

## 3. PROBLEM DESCRIPTION

Note a set of containers stored in different positions named depots at the port. These containers must be transported to a discharging location in order to be transferred by trucks, trains...etc. to clients or to a charging location to be transferred to the ship. The problem consists of transporting these containers from an initial position to a final position by a set of AGVs. But the number of AGVs is limited and it's very small in comparison with containers number. So each AGV must transport a set of containers not once but at multiple travels. It's a repetitive task for each AGV, this task consist on moving to the initial container position and transport it to its final position. This work has to be repeated for all the AGVs. In a previous work (Zaghdoud and al, 12) we proposed a mathematic model of optimizing assignment tasks to AGVs independently of the quay crane which is generally used, then a genetic algorithm approach was proposed to optimize the problem solution by its operators. But this genetic algorithm approach can optimize only the assignment of tasks to AGVs, by the operators of crossing and mutation it can change the set of tasks of any AGV and also the rank of any task of AGV. GA doesn't intervene in the choice of the path travelled by the AGV, because in this

approach each path is randomly chosen. To ameliorate this approach, we propose, for each AGV to take the shortest path in order to move from a position to another. So the routing problem must be solved independently of the assignment problem. The surface of the terminal is not very big and the number of nodes is small, so it's a good idea to use an exact algorithm to compute the shortest path and give it to the AGV. The choice of AGV for each container is also random, so we propose a heuristic (nearest AGV) for the assignment of AGV to the container. To prove the performance of this proposed amelioration, we propose a comparison study between three approaches; the first approach consists to choose randomly the tasks to AGVs and also choose randomly the path travelled by each AGV, the second approach consist to choose randomly the tasks to AGVs but the path travelled by the AGV is the shortest path and the third approach is to choose the nearest AGV to transport each current container by travelling the shortest path.

#### 4. PROPOSED APPROACH

In this paper, we propose a hybridization approach between an Exact Algorithm Dijkstra, heuristic and Genetic Algorithm. The first algorithm is used to compute the shortest path travelled by each AGV, the heuristic (nearest AGV) is used to choose the AGV and the Genetic Algorithm is used to optimize the dispatching of containers to AGVs, by its operators of cross-over and mutation. This approach is applied to calculate the global multi-objective function value which is the aggregation of three functions corresponding respectively to total working time, equilibrium of charge between AGVs and respect of task time window. The criterion of total working time is the time made by all AGVs to move all containers from their initial positions to their final positions. The equilibrium of AGVs charges criterion consists in minimizing the difference in working time between the AGVs, the vehicle is autonomous and it is very important to save the energy consumption. The respect of time windows criterion minimizes the delays of time on the operation of moving a container from its initial position to its final position.

#### GA Approach

This approach focuses on assignment a randomly available AGV to a container, and then we choose a randomly available path for the AGV routing.

1. Choose a task respecting precedence constraint
2. Choose a random available AGV

3. Compute a random path to go from current position of the AGV to the initial position of container
4. Compute a random path to transport the container from its initial position to its final position
5. Repeat steps 1 to 4 for the N tasks
6. Compute the objective function:
 
$$F_{cost} = \lambda * d_{empty} + \mu * d_{full}$$
7. Generate initial population randomly
8. Apply the AG with its operator's selection, crossover and mutation
9. Correct whenever individuals after crossover and mutation by computing the shortest path for  $d_{empty}$
10. Stop algorithm, when the solution does not evaluate significantly after a certain number of generations

#### GA & DIJK Approach

In this approach, the assignment of available AGV to tasks is randomly, but the choice of an AGV path is made by applying the Dijkstra algorithm.

1. Step1 and Step2 is the same of the GA approach
2. Compute the shortest path to go from current position of the AGV to the initial position of container
3. Compute the shortest path to transport the container from its initial position to its final position
4. Step5 to Step10 is the same of the GA approach.

#### GA & DIJK & HEUR Approach

The assignment of tasks to AGVs is performed by choosing the nearest available AGV through applying a heuristic and each AGV have to take the shortest path computed by Dijkstra algorithm.

1. Step1 of GA approach
2. Choose the nearest available AGV
3. Step2 to Step4 of GA&DIJK approach

The three approaches use the genetic algorithm in order to find the best solution of scheduling containers to AGVs, but they differ on the rule of

choice an AGV and on the choice of the path taken by AGV.

## 5. EXPERIMENTAL STUDIES

### 5.1 Scenario

The application of these approaches is made with a computer having 2GO of RAM memory and 1.5GHz processor speed. The language application is C++. We tested the approaches with different number of tasks and AGVs. The genetic algorithm parameters are: the probability of individuals selected from every population for crossing is 0.7 and the probability of individuals selected for mutation is 0.1. For each number of tasks (20, 40 and 60), we make the average of ten running tests and then we computed the objective function value variation with generation number variation. For each approach, we make the tests for 20 tasks and 4 AGVs, 40 tasks and 6 AGVs and for 60 tasks and 8 AGVs. After this step, we make a comparison study between the results obtained from the three approaches. The graphs above show the estimated costs based on the evolution of generations. The port is modeled as a graph having 10x10 km<sup>2</sup> of surface and 10 nodes.

### 5.2 Numerical results

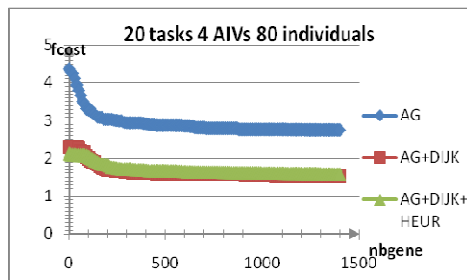


Figure1: Variation of objective function with generations evolution for 20 tasks

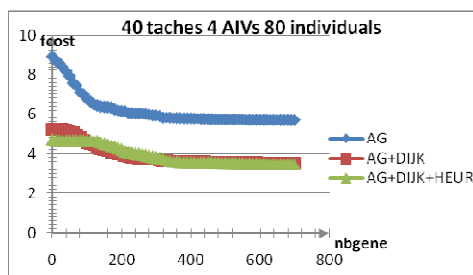


Figure2: Variation of objective function with generations evolution for 40 tasks

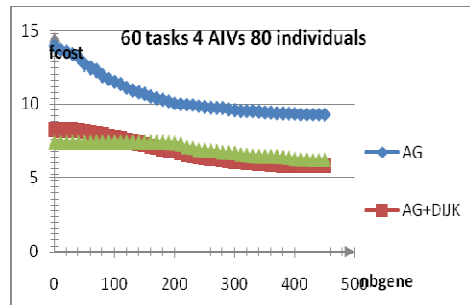


Figure3: Variation of objective function with generations evolution for 60 tasks

	20 tasks 4AGVs	40 tasks 4AGVs	60 tasks 4 AGVs
AG	46.3	41.7	41.9
AG & DIJK	49.3	45.4	45.7
AG & DIJK & HEUR	50.7	46.1	47.5

Table1: running time of approaches

### 5.3 Results discussion

The numerical tests show an important difference equal to 14% between objective function values found by GA approach and the two other approaches. For 20 tasks, the objective function value of GA approach is almost equal to 2.7, but the other approaches objective function values are almost equal to 1.5. But the difference is negligible between the two last approaches. For 40 tasks, the difference is also big 32% between the GA approach with objective function value 6.7 and the two other approaches with objective function value equal to 3.5 and for 60 tasks the difference is also big 18.75% between the GA approach objective function value 9 and the two other approaches with objective function value equal to 6. These results show the performance of adding Dijkstra algorithm in order to optimize the total distance courses by all AGVs. The difference between the GA& DIJK approach and GA & DIJK & HEUR approach is very small, for 20 tasks the objective function values is almost equal to 1.5 (12%). This value is lightly greater than the objective function value for 40 tasks 3.5(14%) for GA & DIJK & HEUR and 3.6(32%) for GA & DIJK. The running time results show that the adding of Dijkstra algorithm does not augmented greatly the execution time of the approach. But it ameliorates significantly the objective function value. As an example, for 20 tasks with GA approach the running time is 46.3s, but with GA& DIJK are 49.3s and with GA & DIJK &

HEUR are 50.7s. The adding of heuristic augments also the value of objective function value, but this remains low.

## 6. CONCLUSION & PERSPECTIVES

This work is the extension of a previous work for (Zaghdoud and al, 12), it was proposed to ameliorate the GA approach by adding DIJKSTRA algorithm to optimize the vehicle routing problem and a heuristic in order to guide the genetic algorithm approach to optimize the assigning problem. A comparison study between three approaches is made; a genetic algorithm approach, a hybrid genetic algorithm approach; DIJKSTRA algorithm and genetic algorithm where the exact algorithm was used to compute shortest path and a hybrid approach; genetic algorithm, heuristic and DIJKSTRA algorithm. The results show the performance of the hybrid approach to solve this problem. It show also the great performance of genetic algorithm to find the best solution independently of the method chosen to the assignment in the initial population. In order to have the best solution we request to choose the third approach GA & DIJK & HEUR, because with this approach we can have a gain of time.

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	D1	D2	D3	N4	N5	N6	N7	N8	N9	N10
D1	0	7.3	9.5	4.6	5.3	2.2	5	1.4	3.6	3.2
D2	7.3	0	2.2	13	8.2	5	2.2	7.8	5.6	4.4
D3	9.5	2.2	0	10.7	5.1	2	6.5	12.7	7.1	1
N4	4.6	13	10.7	0	5.6	8.7	11.5	2	3.6	8.6
N5	5.3	8.2	5.1	5.6	0	3.1	1.4	4.2	2	3
N6	2.2	5	2	8.7	3.1	0	2.8	7.3	5.1	6.1
N7	5	2.2	6.5	11.5	8.7	2.8	0	5.6	3.4	4.4
N8	1.4	7.8	12.7	2	7	7.3	5.6	0	2.2	7.2
N9	3.6	5.6	7.1	3.6	2	5.1	3.4	5.6	0	5
N10	3.2	4.4	1	8.6	3	6.1	4.4	7.2	5	0

**Appendix**

The matrix of random distances

The matrix of distances computed with Dijkstra

	D1	D2	D3	N4	N5	N6	N7	N8	N9	N10
D1	0	6.4	4.2	3.4	5.3	2.2	5.0	1.4	3.6	3.2
D2	6.4	0	2.2	9.4	3.6	4.2	2.2	7.8	5.8	3.2
D3	4.2	2.2	0	7.6	4	2	3.2	5.6	6.2	1
N4	3.4	9.4	7.6	0	5.8	5.6	7.2	2	3.6	6.6
N5	5.3	3.6	4	5.8	0	3.1	1.4	4.4	2.2	3
N6	2.2	4.2	2	5.6	3.1	0	2.8	3.6	5.3	1
N7	5.0	2.2	3.2	7.2	1.4	2.8	0	5.8	3.6	2.2
N8	1.4	7.8	5.6	2	4.4	3.6	5.8	0	2.2	4.6
N9	3.6	5.8	6.2	3.6	2.2	5.3	3.6	2.2	0	5.2
N10	3.2	3.2	1	6.6	3	1	2.2	4.6	5.2	0