Automatic Storage and Retrieval System using the Optimal Path Algorithm

Conference Paper *in* Iraqi Journal for Electrical And Electronic Engineering · June 2020

DOI: 10.37917/ijeee.sceeer.3rd.18

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Iraqi Journal for Electrical and Electronic Engineering
Conference Article

Automatic Storage and Retrieval System using the Optimal Path Algorithm

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Abstract
The demand for application of mobile robots in performing boring and extensive tasks are increasing rapidly due to unavailability of human workforce. Navigation by humans within the warehouse is one among such repetitive and exhaustive task. Autonomous navigation of mobile robots for picking and dropping the shelves within the warehouse will save time and money for the warehousing business. Proposing an optimization model for automated storage and retrieval systems by the goals of its planning is investigated to minimize travel time in multi-robot systems. This paper deals with designing a system for storing and retrieving a group of materials within an environment arranged in rows and columns. Its intersections represent storage locations. The title of any subject is indicated by the row number and the column in it. A method was proposed to store and retrieve a set of requests (materials) using a number of robots as well as one receiving and delivery port. Several simulation results are tested to show this improvement in length of path and time of arrival.
KEYWORDS: Multi-mobile robot, AS/RS system, static environment.

I. INTRODUCTION

Warehousing is the function involving storage and retrieval of raw materials, components, and finished goods as well as shipments of goods. However, auto-store is a new way of thinking when it comes to warehousing where main purpose for the product is to improve the quality of the internal logistics. In auto-store, the heart of the systems is an automatic storage system operated by robots. This is the key product under the Logistics branch. It can reduce the need of labor, maximize the use of storage and run 24 hours per day, as well as being a green energy product when it comes to distribution[1]. Consumers demand faster delivery, access to labor increasingly difficult, and increased competition. So, Goods to Person (G2P) robotics is one solution where (G2P) robotics can be classified into three types such as Pick Assistant with Autonomous Mobile Robot (PA-AMR's), Autonomous Mobile Robot (AMR) and Automated Storage and Retrieval System (ASRS). A comparison between them showing in the following table 1 [2, 3]. Robotics & automation is rapidly becoming a key success factor in ecommerce and is about to make a very large impact on the world of logistics. From AMRs and AS/RS to track & trace technologies and advanced supply chain software, it is a game changer enabling increasingly speedy, safe and error-free distribution, shorter time to market and ultimately lower costs to businesses and consumers. Robots can work in “harsher” conditions than humans, requiring less light and heating, and they also require less energy than traditional trucks [4, 5]. Multi Robot System MRS can be characterized as a field of research that investigates the use of multiple robots operating in the same environment.

TABLE 1
COMPARISON BETWEEN PA-AMR'S, AMR AND ASRS SYSTEMS.

PA-AMR	AMR	ASRS
• Pick Assistant with AMR base, often including Lidar. ▪Human collaborative robots	• Autonomous Mobile Robot, (incl. AGV's using fiducials) • 'Dark warehouse.	• Automated Storage and Retrieval System. • Dark warehouse.
• Deployed in existing warehouse infrastructure • Augmented picking. • Highest H&S specifications, such as lifting heavy goods, working among humans. • Low pick speed.	•Mainly deployed in existing warehouse infrastructure. • Move pods (shelves) to a pick & pack station. •Flexible & fast changing warehouse/sorting space. • Space efficiencies. • Low-medium pick speed.	• Mainly deployed in new warehouses. • Includes high speed shuttle systems. • Medium to high goods density • Auto Store type warehouse pick speed is low-medium.
Fetch, MIR, VECNA	Swiss log, VECNA, GREY, …	EXOTIC, DEMATIC, OPEX,….

Robotic systems are mobile platforms, equipped with sensors and actuators, able to interact with other similar devices and with the environment in order to perform (simple or complex) tasks [6]. A multi-robot exploration task consists of the locations of n robots and m targets as well as a cost function that specifies the cost of moving between locations. The objective of the multi-robot exploration task is to find an allocation of targets to robots and a path for each robot that visits all targets allocated to it so that the team objective is achieved. In this paper, In this paper, one team objectives is investigated which minimize the sum of the path costs over all robots that leads to minimum time required for each cycle There are a lot of path planning algorithms which give minimization for path and time where going from one point to another is one of the challenges that mobile robots have to face today. The problem of robot navigation deals with finding a path with the shortest distance and hence the shortest time of travel, through a terrain that may be partially or totally defined by a lane, track or just specified by one or more way points between a starting point and ending point even in the presence of stationary or moving obstacles [9, 10]. The multi-robot exploration task is to find an allocation of targets to robots and a path for each robot that visits all targets allocated to it so that the team objective is achieved. In this paper, one team objectives is investigated which minimize the sum of the path costs over all robots that leads to minimum time required for each cycle [7, 8].

Line follower robots can be used in path planning to design the object storage system [11-15]. The performance of the robot can be increased by assuming that the line follower robot moves on a predetermined path [16]. The line follower system has the property to drive the robot properly [17]. Many fields nowadays use follower robot, such as transport building materials and transport luggage which increase the use of this type of system [18].

Efficient navigation of mobile robots defined as a generation of collision-free path and design of control law, which gives the desired path following. A great effort has been made to solve Robot Motion Planning (RMP) problems. Path planning for a mobile robot, which is an important content in the field of intelligent robot research, is typically stated as finding a sequence of state transitions for the robot from its initial state to some desired goal state. The path is optimal if the sum of the transition costs is minimal across all possible sequences through the map [19-22]. There are a lot of path planning algorithms that give minimization for path and time where the going from one point to another is one of challenges that mobile robots have to face today. The problem of robot navigation deals with finding a path with the shortest distance and hence the shortest time of travel, through a terrain that may be partially or totally defined by a lane or track or just specified by one or more way points between a starting point and ending point even in the presence of stationary or moving obstacles [9, 10]. In engineering, there are two different approaches to problem solving: mathematical or heuristic approach. In the mathematical approach, it is more concerned with the solution than with the calculations are feasible for algorithms. In the heuristic approach, the algorithm has to use special knowledge of the problem area. The heuristic approach can use multiple different ways of solving problem from looking from start to finish [23, 24]. Planning the layout of our AS/RS is based on a table of inquiry and the frequencies when manufacturing individual products. Distribution of products during an AS/RS operation depends on factor of inquiry (FOI), product height (PH), storage space usage (SSU) and path to dispatch (PD). Another boundary condition included within any optimization algorithm is that the factor of inquiry may change dynamically during AS/RS operation regarding actual market

requirements. Considering all the parameters resulted in a multi-objective optimization problem.
In this paper, the study investigate one team objectives which minimize the sum of the path costs over all robots that leads to minimum time required for each cycle [25].

The goal of this paper is to provide a simple of low-cost high accuracy AS/RS system, suitable for store and retrieval more than one order using multi-mobile robot. The proposed algorithm is described in section II. Simulations results are explained in Section III. The conclusions discussed finally.

II. AUTOMATIC STORAGE AND RETRIEVAL SYSTEM

This section deals with designing an optimization model for automated storage and retrieval systems by the goals of its planning to minimize travel time in multi-robot systems. This research deals with designing a system for storing and retrieving a group of materials within an environment arranged in rows and columns. Its intersections represent storage locations. The title of any subject is indicated by the row number and the column in it, as shown in Fig. 2. A method was proposed to store and retrieve a set of requests (materials) using a number of robots as well as one receiving and delivery port.

Optimal Path Algorithm

The idea of this algorithm is based on determining the delivery point after each order, firstly, and how far it is from all robots. Second, calculate all possibilities for delivery from each robot and all orders back and forth to the delivery point. All probabilities are calculated using the compatibility algorithm where the total paths to deliver all orders are calculated to deliver all orders and at every possibility for the distribution of orders on robots, the longest path is taken as the worst case for this possibility, then look for the possibility that the worst case is the least possible to represent the best possibility Optimal paths to complete the task in the shortest time. The steps for implementing this algorithm are as follows:

Step1: Estimation the distance between the orders and the received point: The coordinate axis of the order and the received point are shown in Fig. 2. The distance between the order i and the received point (Fig. 3 is computed by using the following equation:

$$Disrcv(i) = Abs(Xor(i) - Xrec) + Abs(Yor(i) - Yrec) \quad (1)$$

Step2: Estimation the distance between the orders and all the robots: The distance between the order i and the robot j (Fig. 4 is computed by using the following equation:

$$Disrbt(I,j) = Abs(Xor(i) - Xrob(j) + Abs(Yor(i) - Yrob(j)) \quad (2)$$

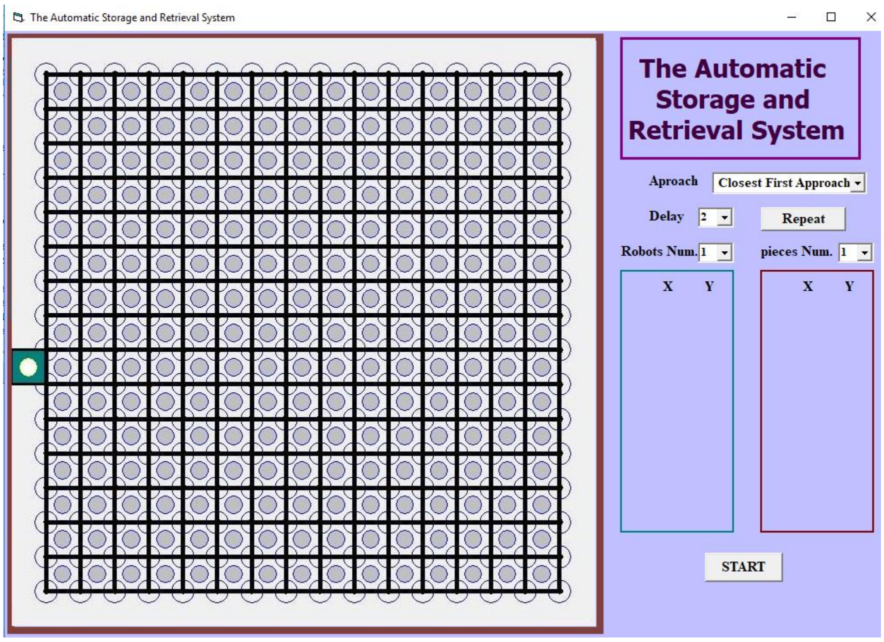

Fig.1 The automatic storage and retrieval environment.

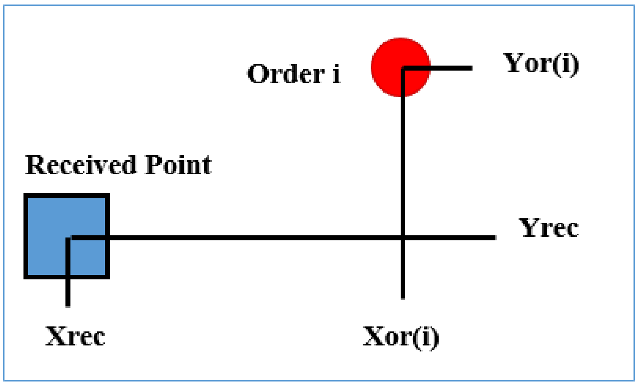

Fig.2 The coordinate axis of the order and the receiver point.

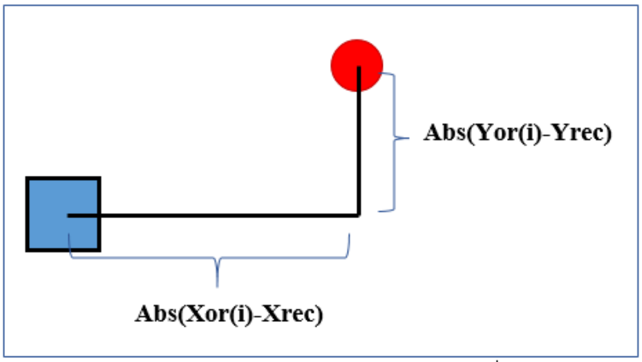

Fig.3 The distance between any order i and the receiver point.

Step3: Use one of the permutation algorithms to compute the length of total paths. The summing of the lengths of the paths for back and forth between the orders and receipt with the addition of the distance between each robot.

$$Total(I,j) = 2 * disrcv(i) + disrb(j) \quad (3)$$

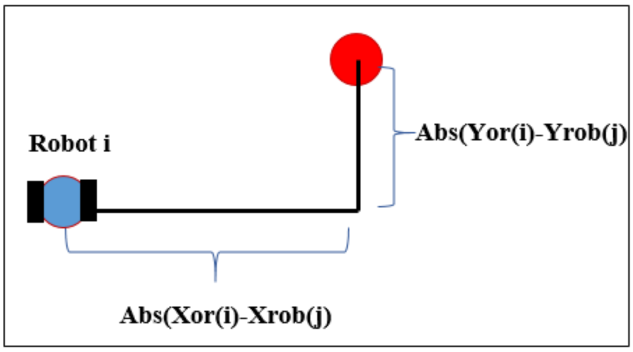

Fig.4 The distance between the order I and the robot j.

Step 4: choose the maximum distance: For each probability choose the maximum distance: Max of total (j,j)

Step 5: search for the minimum distance among all the maximum ones. This path represents the probability of the optimal path.

Step 6: move the robot according to the arranged sequence

Step 7: Collision avoidance among the robots when they move.

1. Arranged the robot in decreasing manner according to their distances from the received place.
2. Through the moving of the robots, each robot check the distances with the other robots.
3. If the distance is less than the length of one cell in the environment then the robot with the higher order must stop his movement.
4. The last step is repeated until the distance with the other robot is greater than the size of one cell.
5. The last two steps are repeated until all robots complete their tasks.

III. Simulation Results

The proposed algorithm (optimal path algorithm) is simulated to investigate the store and retrieval operation using Visual basic programming language and tested in the Windows environment using an Intel core i5. Two methods were implemented to simulate the performance of the algorithm and its estimator. The first is to implement the algorithm with the assumption of avoiding collision between robots while performing tasks. The second represents the application of the same algorithm with cause’s collision between robots.

Two simulation experiments are implemented in this section: The first is to calculate the optimum time to complete the task while the second simulation is done by calculating the average path length during the execution of the tasks. For a measurable analysis of these approaches, the following performance metrics are used:

1. The storage and retrieval completing path (L): this metric is used to measure the total path for the storage and retrieval process to the number of the orders.

2. The storage and retrieval completing time (t): this metric is used to measure the percentage of the completing time to the number of the orders.

Fig. 5 (a)–(f) represent the Screenshots of the simulation at different time steps using the optimal path algorithm (No collision among the robots).

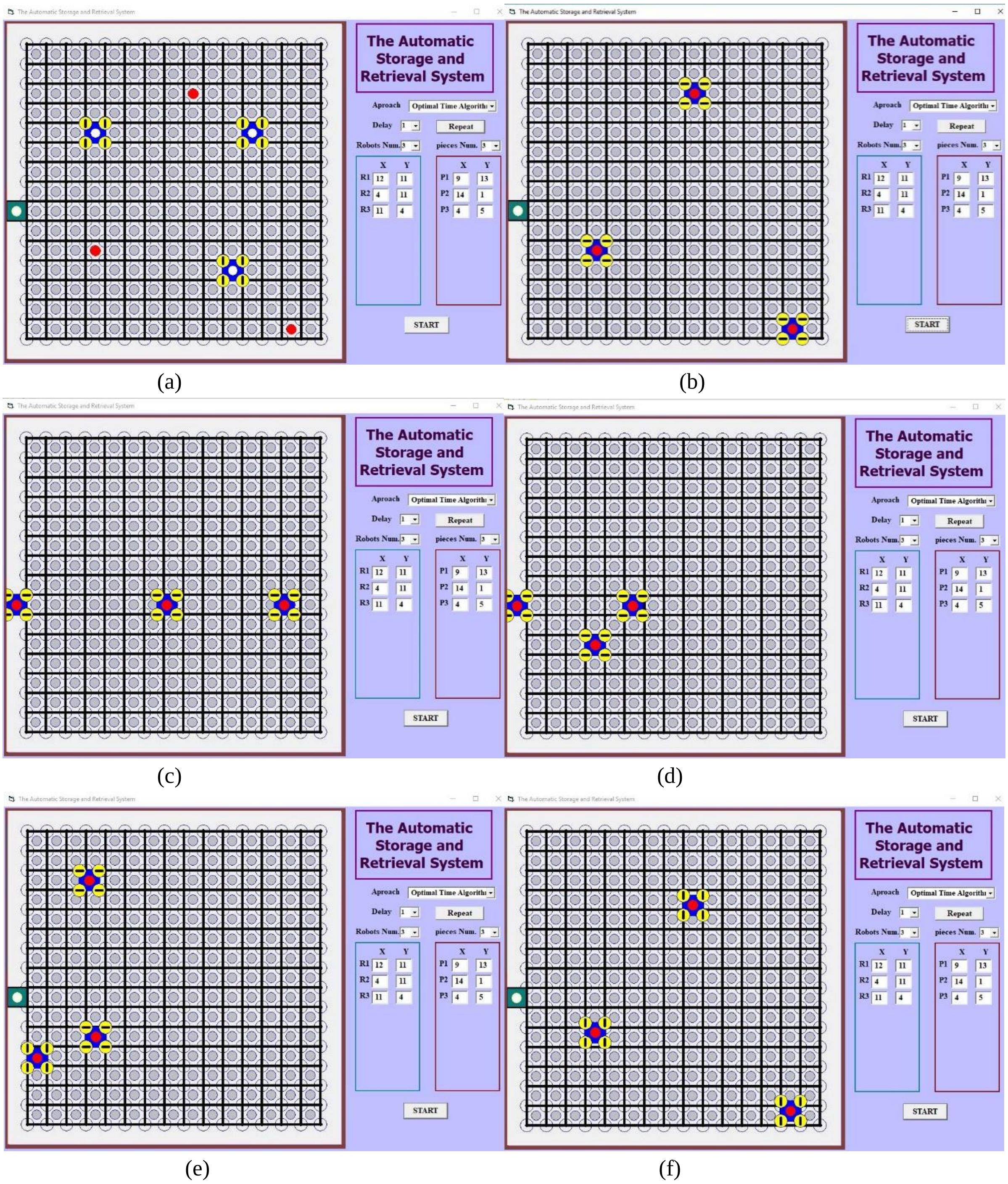

Fig. 5 The average of the arrival time using the optimal time algorithm (No collision among the robots).

Fig. 6 (a)–(f) represent the Screenshots of the simulation at different time steps using the optimal path algorithm (With collision among the robots). The main goal of this simulation is to show the relation between the number of orders and the store and retrieval accomplishment time for both cases.

Fig. 7 (a)–(6) represents the simulation of the minimum path for a different number of orders and robots (1, 2, 4 and 6) using the optimal path algorithm

Fig. 8 shows a comparison between the number of orders and the accomplishment percentage. As the number of the orders increases in the collision and non-collision environment, the accomplishment percentage increases, too.

Fig. 9 shows a comparison between the number of orders and the minimum accomplishment path for both the collision and non-collision environment. As the number of orders increases in the environment, the accomplishment increases, too.

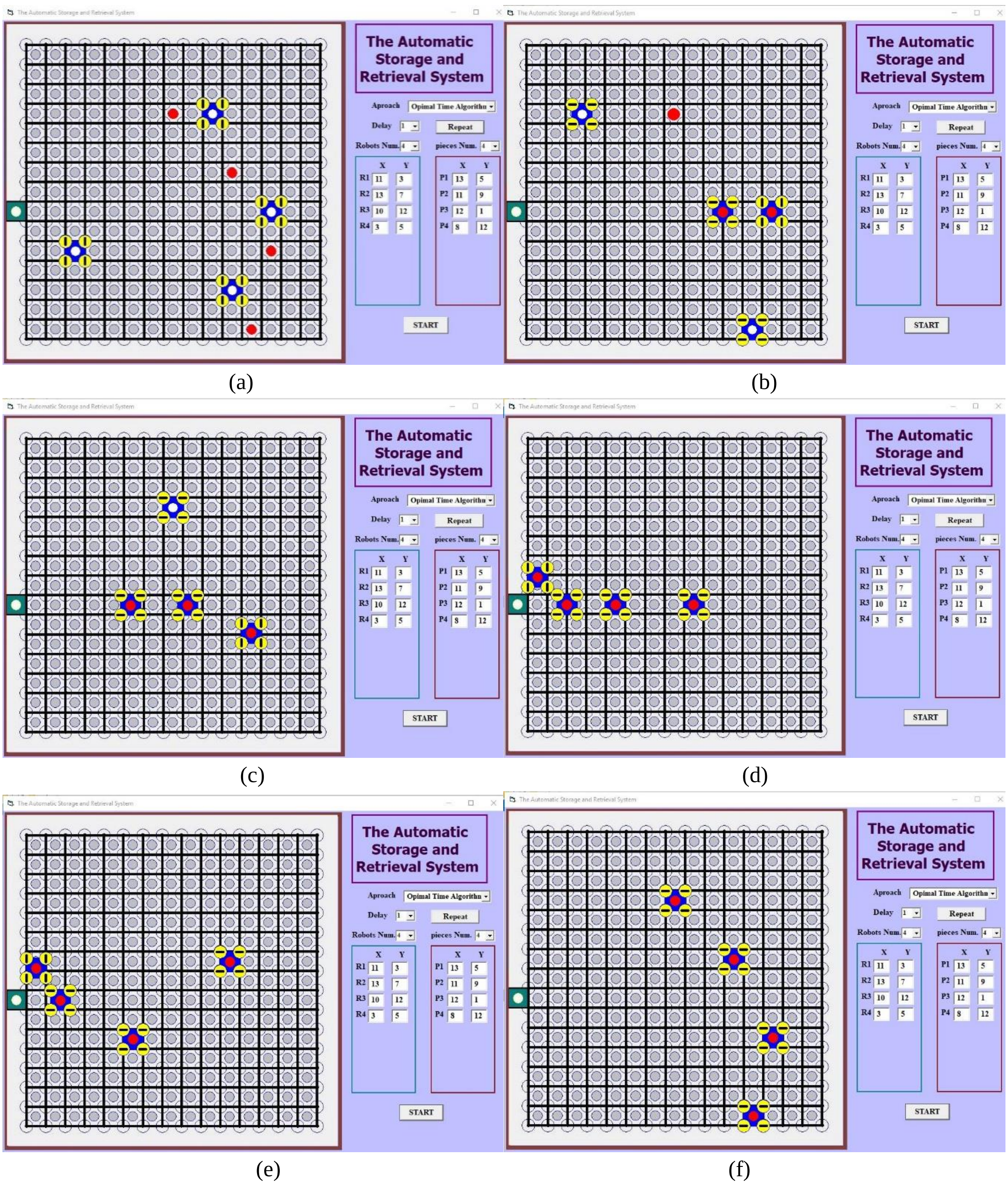

Fig. 6 The average of the arrival time for the optimal time algorithm (Collision avoidance algorithm).

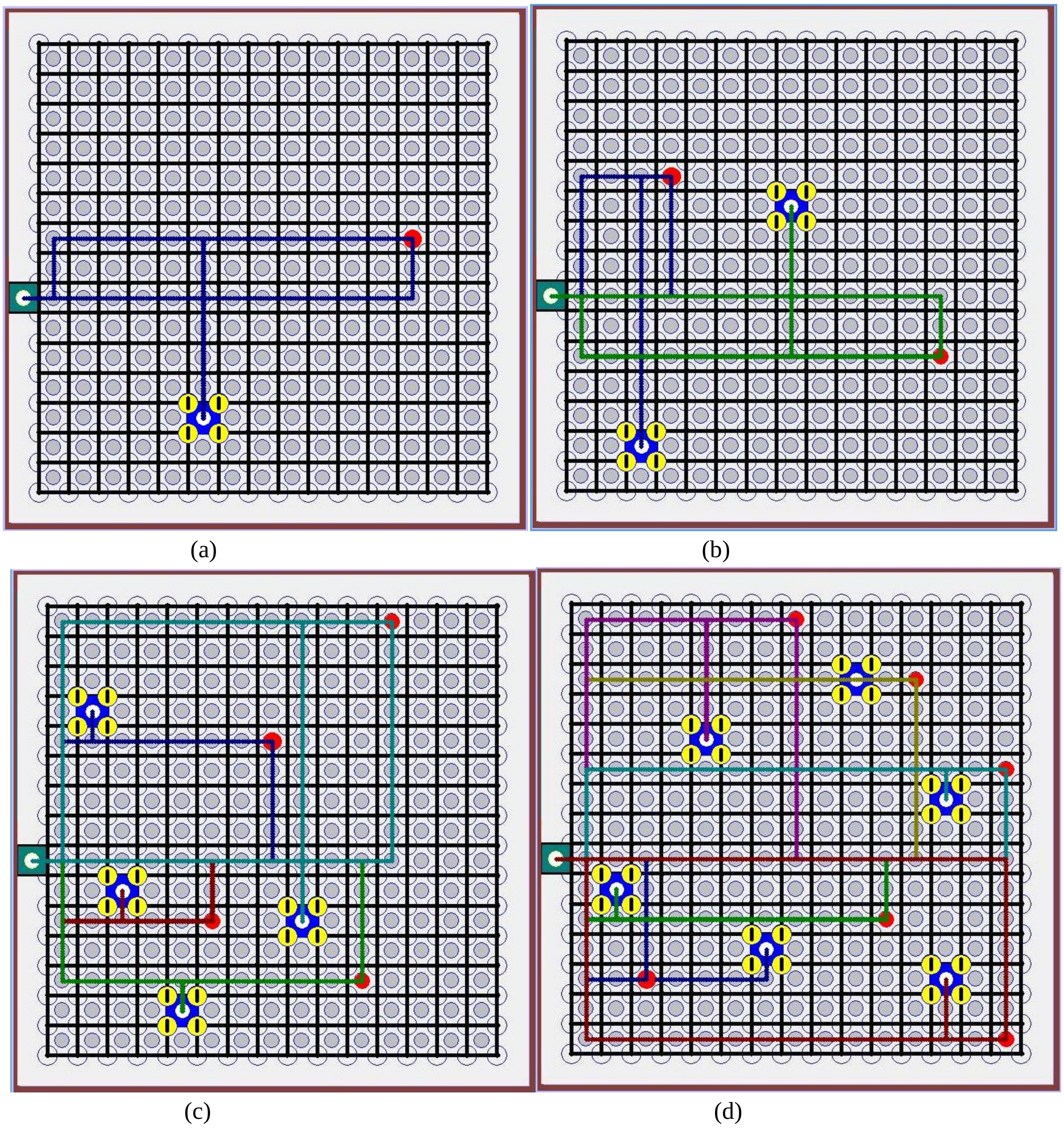

Fig. 7 The average of the total path for the optimal paths algorithm. a) one robot b) Two robots c) Four robots d)Six robots.

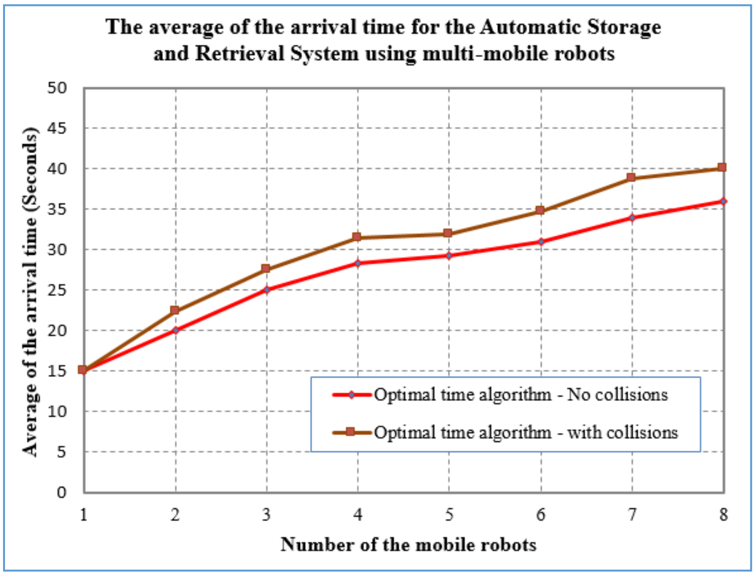

Fig. 8 Comparison the average of the arrival time for both the collision and not collision avoidance mobile robots.

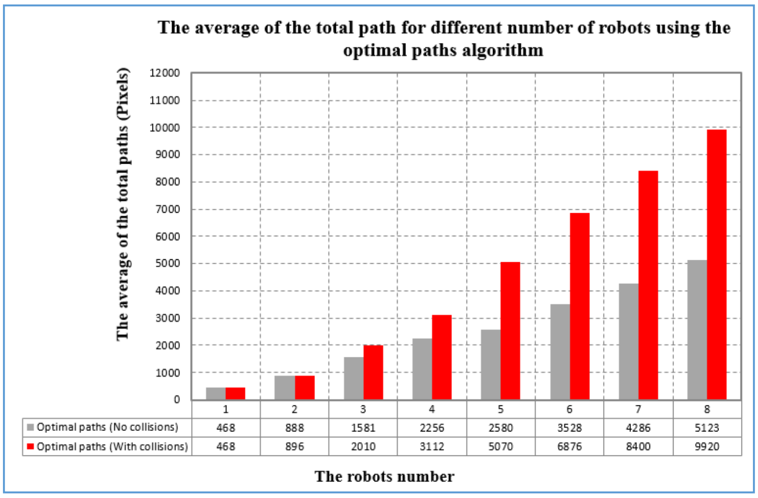

Fig. 9 Comparison the average of the total path for the optimal paths algorithm (collide and not collide robots).

IV. Conclusions

In this paper, a storage and retrieval approach (optimal path algorithm) in the static environment is proposed by using several numbers of orders with several number of mobile robots. Simulation results are implemented in an environment with a different number (1 to 8) of orders and robots. The results show that as the number of orders increases, the accomplishment time also increases for both collision and non-collision among robots The Non-collision environment has the best performance than the other one in an accomplishment time. From results, it is found that The accomplishment path increases when the number of orders increases for both environment. Also, the non-collision environment has the shortest accomplishment path comparing to the other approach.

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