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Constructing the optimal power algorithm for AS/RS systems using multi-mobile robots

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Abstract. For any mobile system there is especially advantageous from a business perspective to develop energy-saving techniques that also extend to existing production processes. Therefore, looking for ways to enhance the energy efficiency of robot operations to maximize energy consumption efficiency is of considerable significance, a route-planning issue that refers to finding the shortest path to meet the predetermined goal location in a certain complex environment. So, one of the energy saving methods for a multi-mobile robot environment is to find the optimal path for a mobile robot that can improve power consumption. In this paper, an optimal power algorithm for "automatic storage and retrieval system" using multi-mobile robots is introduced based on efficient motion planning among a group of multi-mobile robots that gives a significant improvement in the level of energy consumption. Energy mechanism can be achieved using electrical power quantities on real robots, models or analytical equations based on robots' physical model. The simulation results indicate that the algorithm enhanced power consumption efficiency.

1. Introduction

Automatic storage and retrieval system (AS/RSs) had been represented as controlled through a computer system for automatic storage and retrieval from specialist storage locations by using an automatic system to handle operations and eliminate human intervention. To do this, a program system is used to work with automated retrieval and recovery mechanisms [1]. The robot is driven by electric motors powered by a battery and the average speed throughout the mission remains constant. Minimum power formulation may be an interesting approach for mobile robots, particularly in applications where battery weight is a critical issue. Minimum power problems can be difficult to solve with classical methods because they involve both the nonlinear dynamics of the robot and a combination of

Restrictions. One way to reduce energy for robots focuses on motion planning to reduce the force of motion. Therefore, it is imperative to consider a specific solution when the battery is running out of power. One such solution is to replace a robot that has run out of battery with another robot with a full battery. In robot competition, energy and time are the main factors that determine the performance Hence the importance of multi-mobile robots within the same environment, noting that there is another benefit from using multiple mobile robots, and among those benefits such as increasing speed,

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increasing stability to resist system failure and many features that increase the performance efficiency of a multi mobile robots versus single robotAS [2].

In general, a multi-Robot System may typically be defined as a group of robots running in the same environment. Usually robotic devices, though, can range from basic sensing, data collection and analysis to sophisticated human-like robots capable of communicating in very complex ways with the environment. [3]. From a classical point of view, mobile robots operate on a fixed energy supply, provided by some batteries. The constraint of the energy supply demanded human interface to recharge the batteries where mobile robots are devices distinguished by their ability to traverse diverse environments. There is a need for planning the motion of robots in order to get the optimal path that leads to optimal power consumption. Thus, mobile robots route preparation is a central feature of mobile robots science. The key aim of route planning is to find a path free from collisions, through an obstacle environment, from a specified starting place to a target destination while following certain criteria [4]. Using either static or dynamic environments, the object storage structures may be configured. In the static environment, only the robot can move while all other objects in this environment have no movement; while in the dynamic environment, several different entities (such as moving vehicles and moving paths) have the potential to move. Overall, the dynamic environment has more concerns than static route planning as the robot uses sensory input to sense the actual location and trajectory of moving objects in the environment [5]. In today's times, computational optimizations and simulations are the two most used methods to modelling and learning AS/RS. Researchers such as Lerher, Šraml, Borovišek, Potrč [6], Yang, Miao, Xue, and Qin [7] studied optimization of AS / RS operation using 'modern optimization methods' to improve warehouse system performance. De Koster, Le-Duc and Roodbergen [8], Gu, Goetschalckx, McGinnis [9], Baker, Canessa (2009) [10] present a general study of warehouse engineering and control methods suggested by De Koster, Le-Duc and Yugang [11] Kuo, Krishnamurthy, and Malmborg are Mathematical Concept Models for Efficient Autonomous Vehicle Action (AVS / RS) centered around the AS / RS Loader [12], and Manzini, Gamberi and Regattieri provide a multi-parameter hierarchical model for the product storage device to the picker with product customization On the basis of category [13]. Fukunari, Malmborg, Hur, Nam, Yin, Rau, Dooly, Lee et al. Presented comprehensive studies. Fukunari and Malmborg coined the term "interleaving" related to coupling storage and retrieval parameters to generate DC loop loops in the same cycle [14]. Hor and Nam proposed stochastic methods for estimating the AS / RS performance of a unit load [15], Yin and Rau analyzed the dynamic range of the AS / RS-based sequencing rules of the unit load [16].Twin-shuttle AS/RS [17], Dooly and Lee raised a shift-based sequencing problem. In an overall state-of-the-art analysis, authors Roodbergen and Vis [18] found that AS/RS research could best leverage the power of simulation by comparing various designs. While taking more aspects of architecture into account, especially in conjunction with numerous control policies. A small amount of energy is taken in by mobile robots. To increase the running time of the robot before the batteries are discharged, it is necessary to improve the energy efficiency of the robot. Modelling the energy consumption of a robot has many benefits. One of the major drawbacks of preparing a challenge is sufficient energy. If the estimated energy demand for executing the task exceeds the energy available, an energy-conscious robot will assign the task of recharging the batteries the highest priority.

In addition, it will be necessary for the robot to identify if the mission can be performed with the minimal energy available to the robot [19]. Robotic cell energy optimization also focuses on optimizing the individual robot paths (local optimization) with regard to the physical shortcomings of robots and the obstacles to be avoided [20]. Currently, there is a growing interest in new innovative methods and tools for optimizing robotic energy consumption. From a business viewpoint, it is Particularly beneficial to develop energy-saving strategies that also apply to current manufacturing processes and are responsible for minimal change possibilities. The remainder of the paper is organized as follows:

- The system description will be given in a way of how the mobile robot can choose the optimal path for power optimization,

- Finding the optimal path that leads to a power optimization of the mobile robot will be mentioned with the mathematical model via a formulated equation that calculates the shortest path finding problem, then the algorithm can be used to seek the features of the optimal path and then choose the shortest path of the mobile robot that provides the optimal power consumption,
- Analysis results with the *drawings* are mentioned,
- Some conclusions are mentioned.

2. System description

This study deals with the design of a system to store and retrieve a group of materials organized in rows and columns within an area. Its intersections reflect locations of storage. As shown in Figure 1, the title of any content is defined by the row and column number inside it, also a single delivery and receiving port. A method of storing and retrieving a batch of orders (materials) by using a number of robots are suggested here.
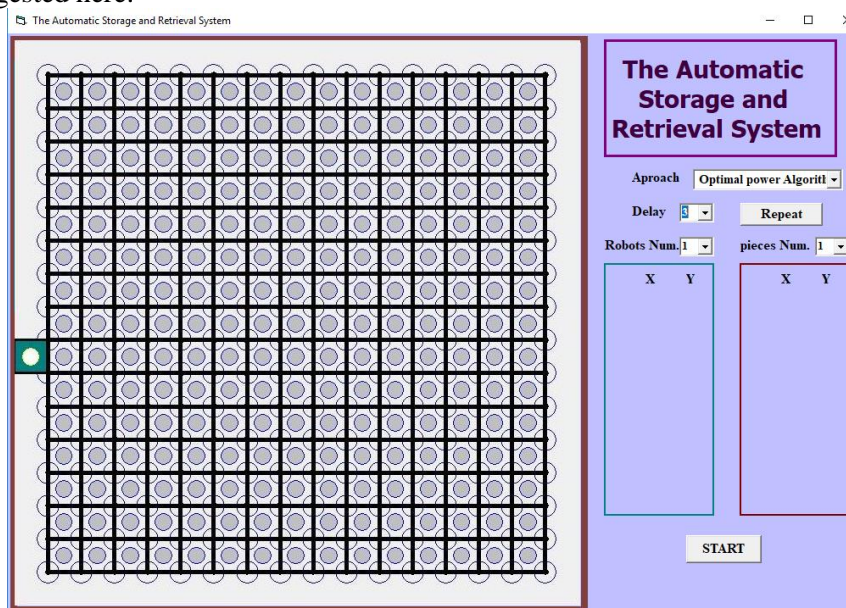

Figure 1. Environment for mobile robot.

3. Optimal power algorithm

First, the notion of this algorithm is to determine the distance of order individually from the point of delivery and, second, to determine the distance of each robot from the delivery point, and then calculate all delivery possibilities for each robot for all orders at coming and at going to the delivery point. All probabilities are calculated using a combination algorithm by calculating the sum of the paths for the delivery of all orders. In each probability distribution of orders to robots, the shortest path is taken as the best case for all probabilities, which represents the shortest distance traveled for all robots, this represents the least power consumed to implement the task (Optimal power) and complete it in the least time.

The steps for implementing the combination algorithm by following the following:

Point 1: Distance guess between the orders and the point received: the following equation is used
 Disrcv(i)=Abs(Xor(i)-Xrec) + Abs(Yor(i)-Yrec)
Point 2: The distance between the orders and all the robots is estimated by:
Disrbt(I,j)=Abs(Xor(i)-Xrob(j) + Abs(Yor(i)-Yrob(j))
Point 3: The computation of the length of total paths, use one of the permutation algorithms.
The distance between each robot is combined with the duration of the routes back and forth between the order point and the receiving point.
Select the total distance for each chance.

For this work from the first robot to the last one in each probability

$$Total(I) = Total(I) + 2 * disrcv(i) + disrb(j)$$
$$Next\ i$$

Point 4: choose the minimum distance. Form all the last probabilities choose the minimum distance to be the optimal power spent

Point 5: move the robot as to the arranged sequence.

Point 6: Collision avoidance among robots when they move:

1. Arrange the robots in a decreasing manner according to their distances from the received place.
2. Through the movement of the robots, each robot checks 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 its movement.
4. The last step is repeated until the distance with the other robot is greater than the size of one cell.

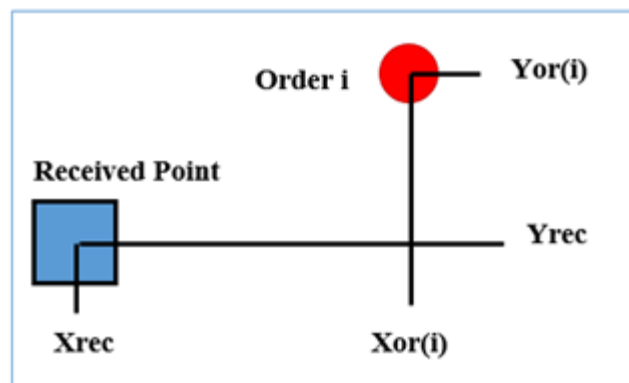The last two steps are repeated until all robots complete their tasks.

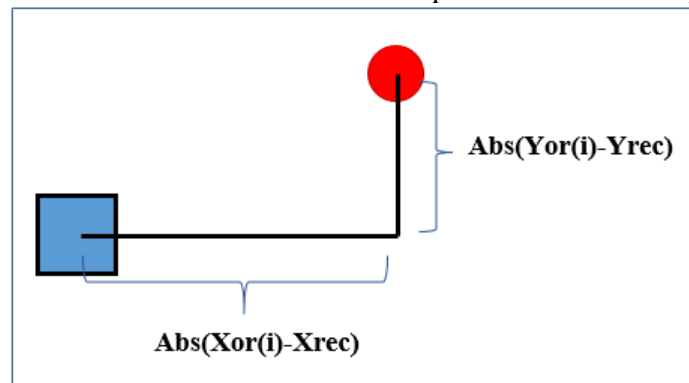**Figure 2.** "The assortment axis of the request and the receiver point".

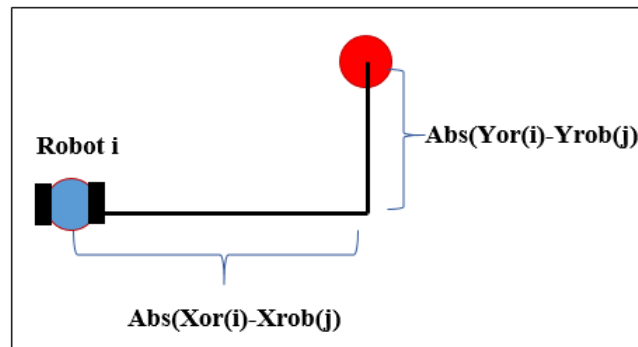**Figure 3.** "The length between any request i and the receiver".

Figure 4. "The long between request I and the robot j".

4. Simulation results

The proposed algorithm (optimal power algorithm) is simulated to analyse the process of storage and recovery using Visual Basic Program Language and to evaluate using laptop contain an Intel Core i5 in the Windows environment. To simulate the performance of the proposed algorithm and compare it with a previously developed algorithm, two methods were implemented. The first is to apply the optimal power algorithm, assuming that robots will not collide when performing tasks. The second is to apply the optimal route of the previous algorithm to a collision between robots. In order to determine the length of the path to complete the mission, the second simulations are performed as well as for different order goals and for both algorithms. The first simulation is to determine the optimum time to complete the task, while the second simulation is to evaluate the average distance of the path during the job execution. In this section, two simulation experiments are added. The first is to use the optimal Path algorithm to measure the arrival time average to complete the task, while the second simulation is performed by measuring the arrival time average during the execution of the tasks using the optimal Power algorithm. The following success metrics have been used for a measurable study of these approaches:

1-Storage and retrieval completion path (L): The usage of this metric is for calculating the total path to the order number for the storage and retrieval process.

2- Storage and recovery completion time (t): The usage of this metric is for calculate the number of orders by the percentage of completion time.

The simulation screenshots at different time stages using the optimal path algorithm are represented in Figure 5 (a)-(e) (No collision among the robots). Figure 6 (a)-(e) shows the simulation screenshots using the optimum power algorithm at different time levels (With collision among the robots). The primary objective of this simulation is to demonstrate the relationship between the orders number and the store and retrieval period of achievement for both circumstances.

A comparison of the arrival time average for both the optimal power algorithm and the optimal path algorithm is shown in Figure 7. The average of the total paths for an optimal power algorithm is shown in figure 8 (a to d). a) 2 robots b) 3 robots c) 4 robots d) 5 robots. The average total path for the optimal path algorithm is shown in figure 9. A) 2 robots b) 3 robots c) 4 robots   d) 5 robots. A comparison of the average total path for both the Optimal Path Algorithm and the Optimal Power Algorithm is shown in figure 10.
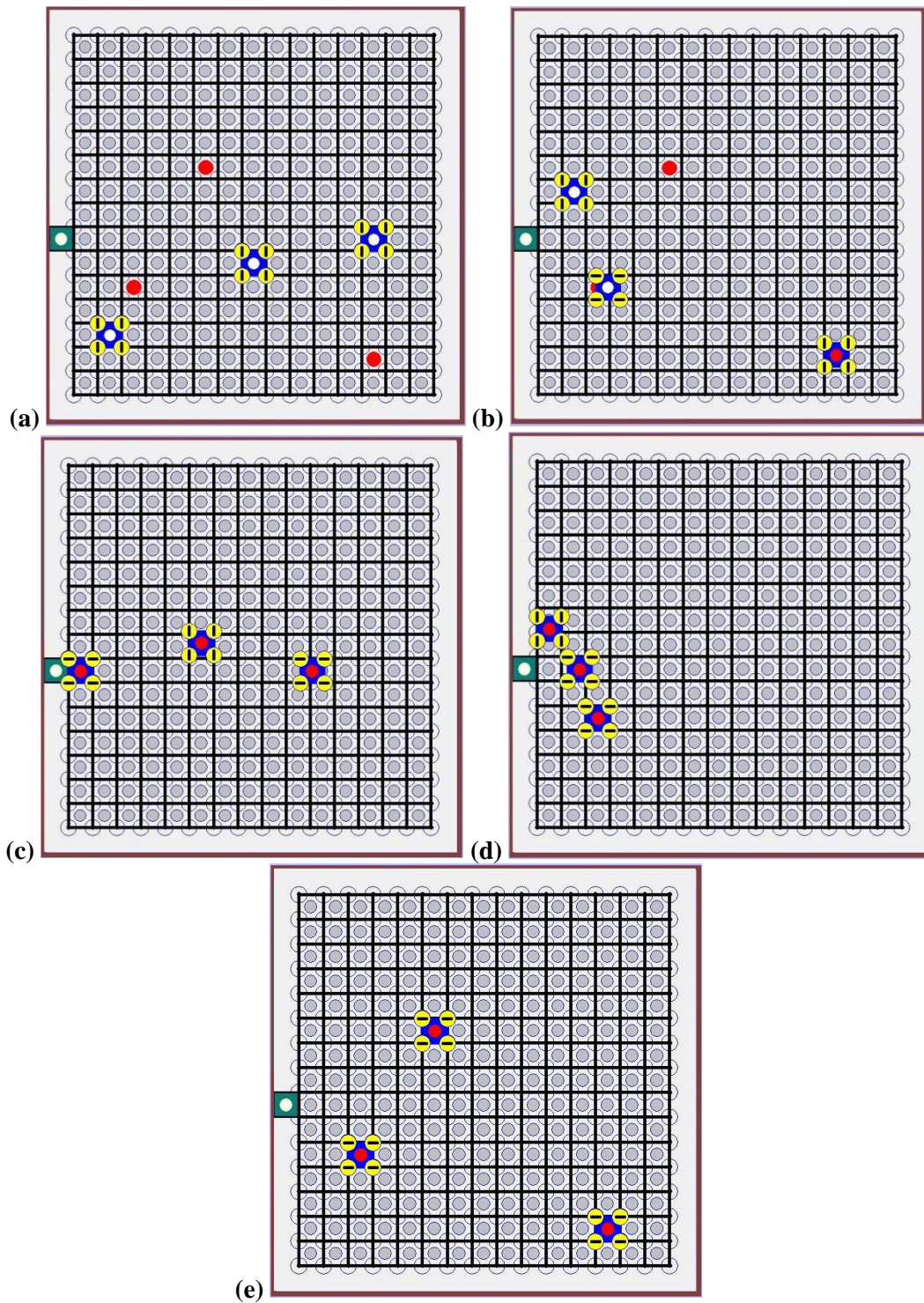
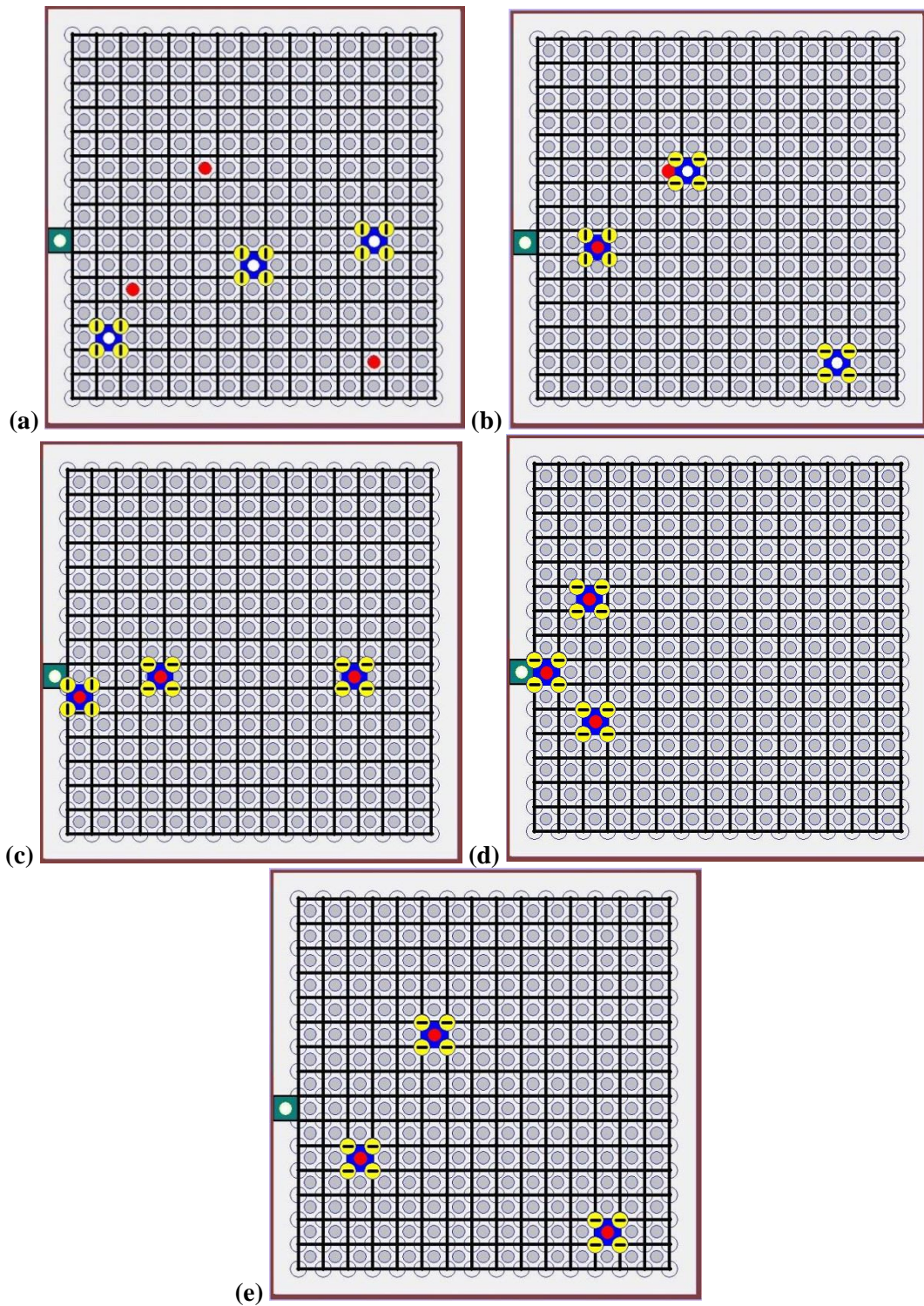**Figure 5.** "The average of the arrival time using the optimal Path algorithm".

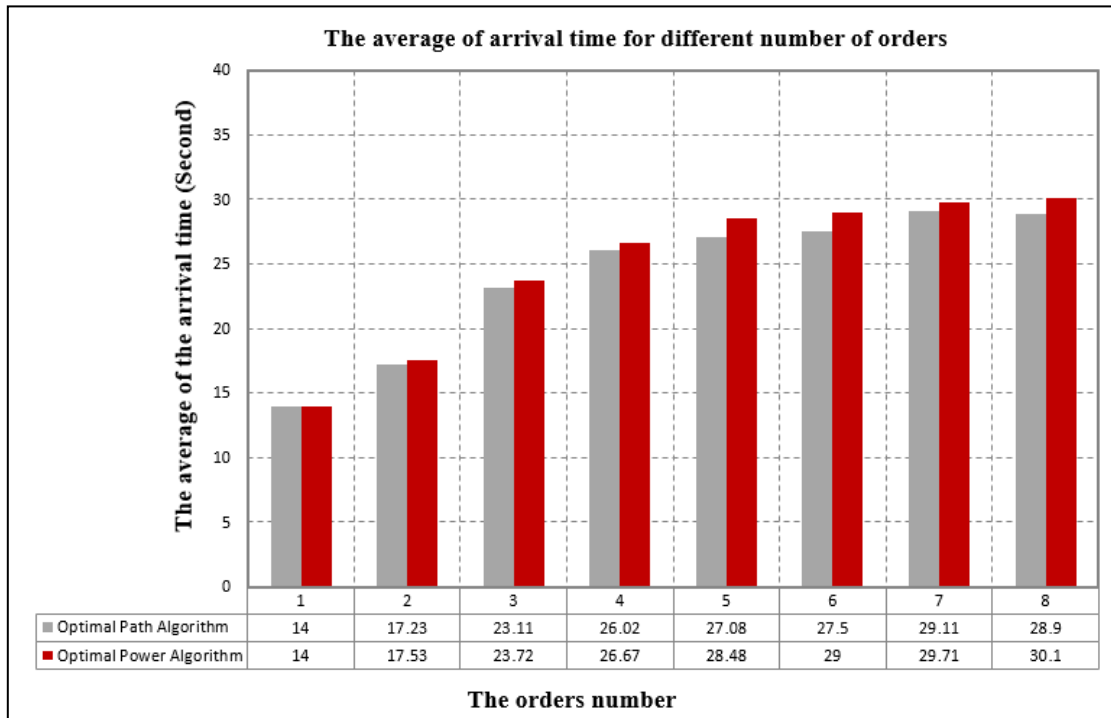**Figure 6.** "The average of the arrival time using the optimal Power algorithm".

Figure 7. Comparison of the estimated time of arrival for both the optimal power algorithm and optimal path algorithm.
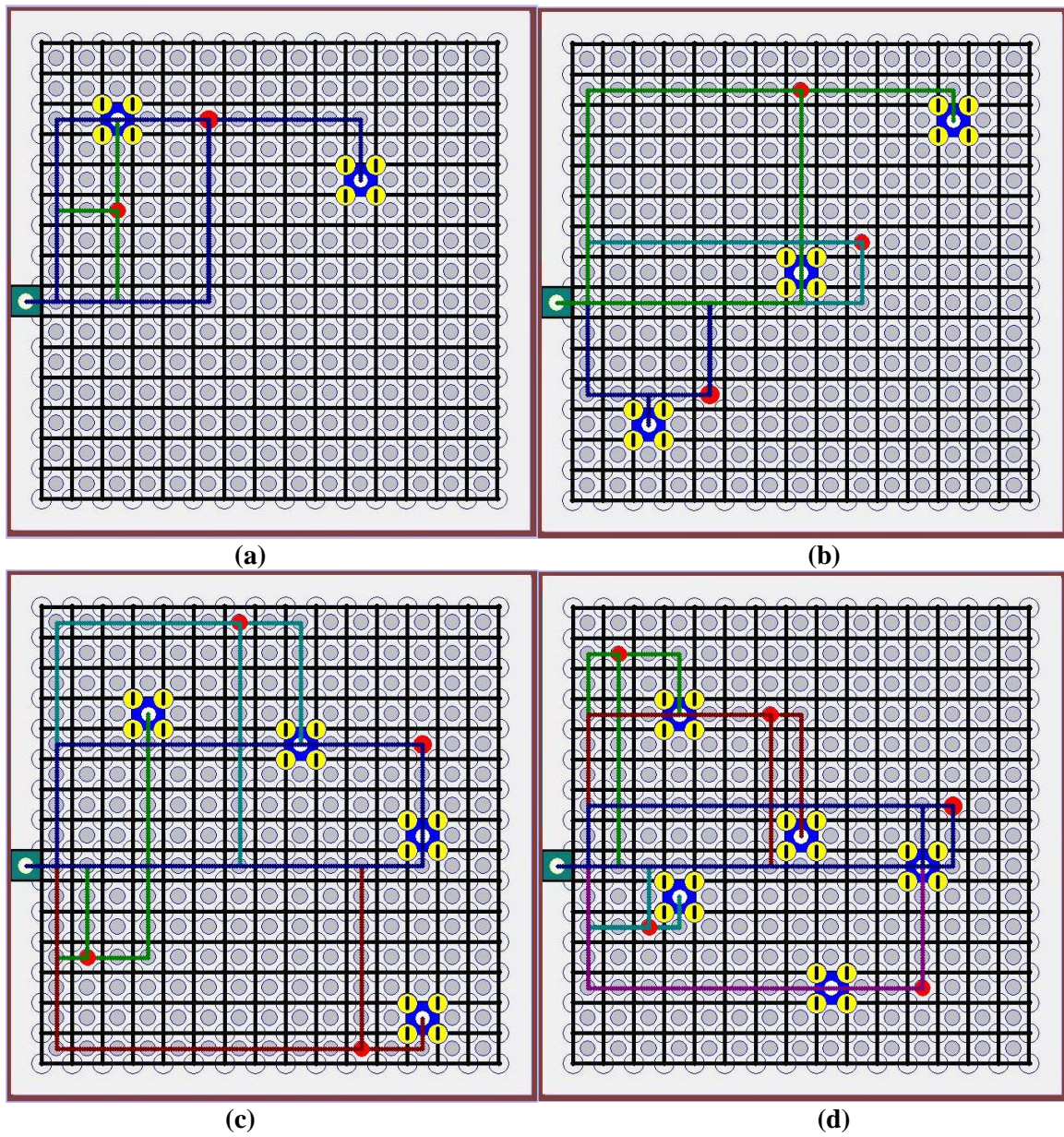
Figure 8. The mean of the total path for the optimal power algorithm. a) Two robots b) Three robots c) Four robots d)Five robots.
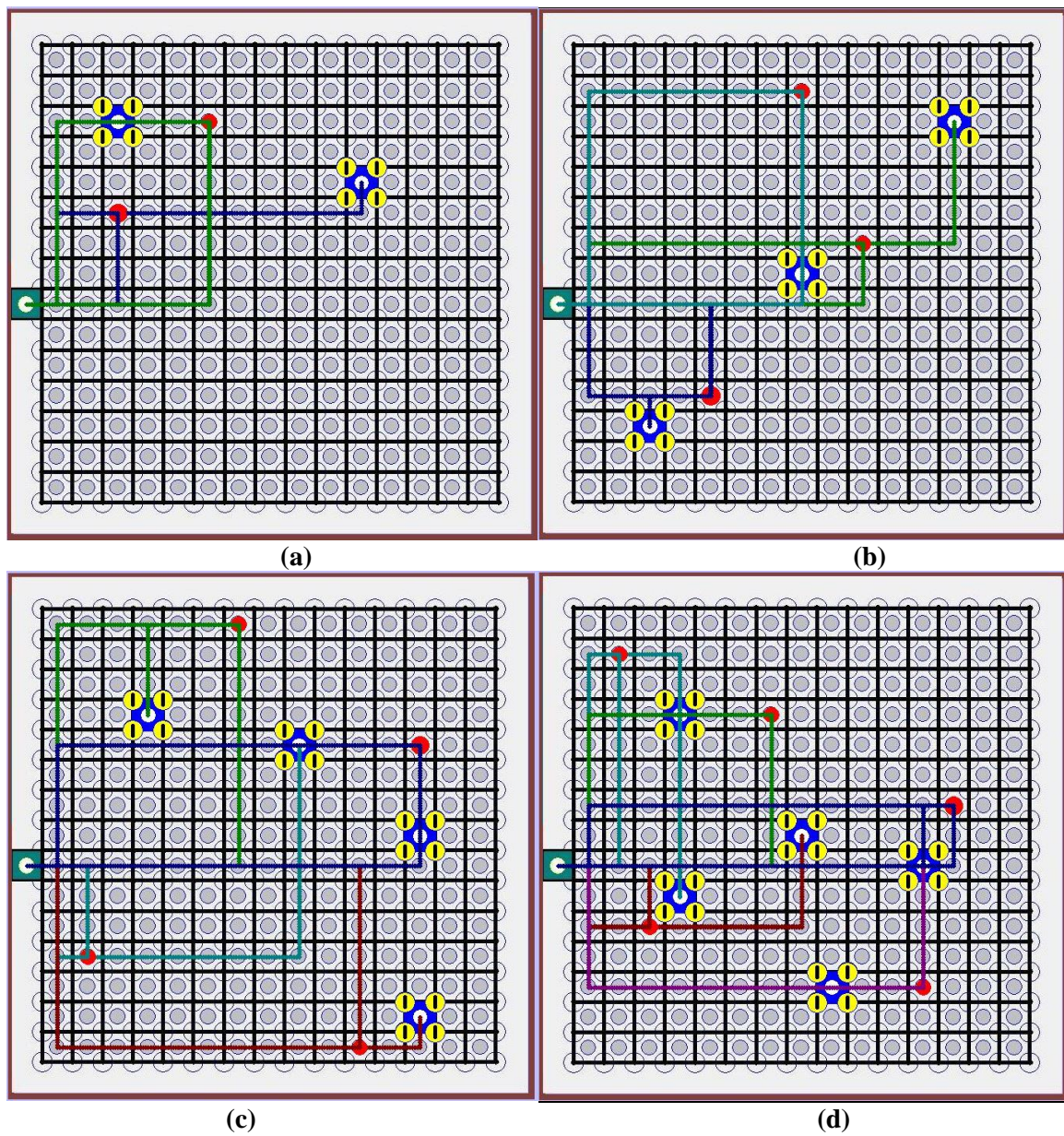
Figure 9. Total average route for the optimal Path algorithm's total path. a) Two robots b) Three robots c) Four robots d) Five robots.
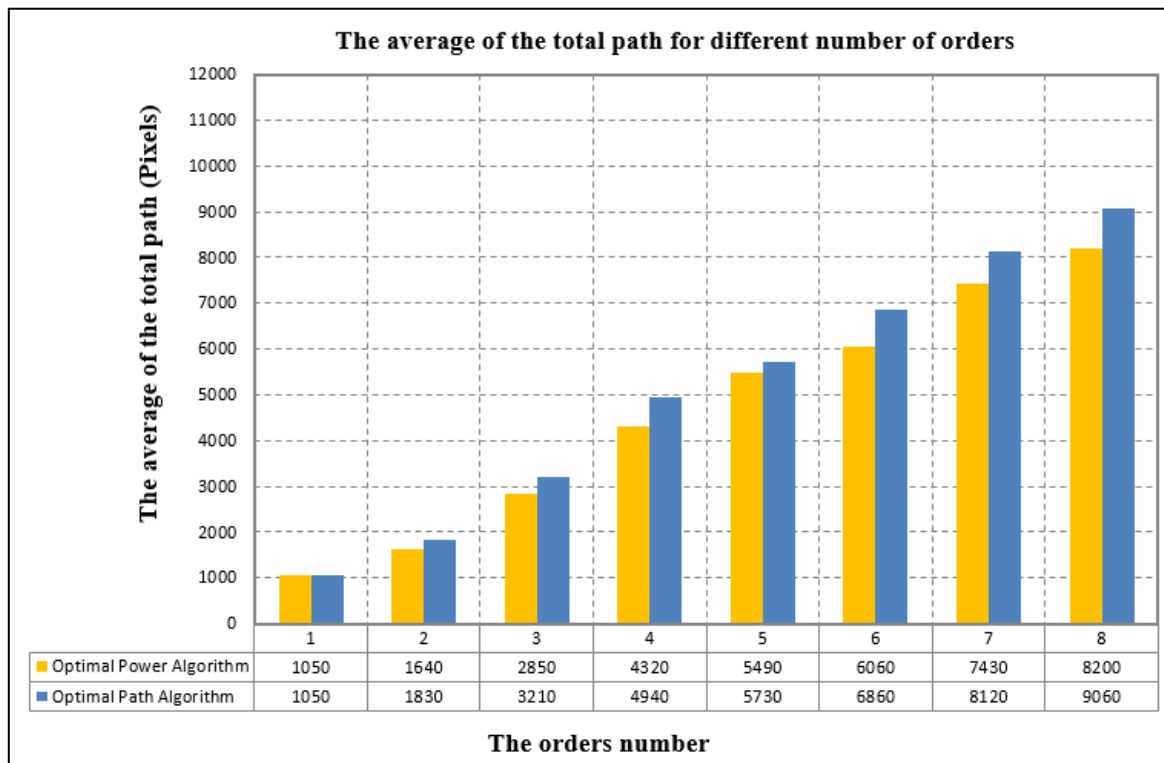
Figure 10. Comparison of the overall route average for both the Optimal Path Algorithm and the Optimal Power algorithm.

5. Conclusions

In this paper, using several numbers of orders with many numbers of mobile robots, a storage and recovery method (optimal power algorithm) in the static setting is suggested. In an area with various numbers (1 to 8) of requests and robots, simulation findings are applied. The findings shows that as increasing the orders number, the time proficient among the robots for the two the optimal path and optimal control increases too. The optimal power algorithm offers the best output in an achieved time than the optimal line   one. From the results, it is found that as the number of request raise the achievement path increases, also. In other words, the optimal power algorithm leads to a reduction in time arrival, which means faster, and a decrease in the overall direction, which means faster with low power consumption.

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