

An Effective Optimization Algorithm for Ant Colony Vehicular Congestion Management

Tebepah Tariuge¹, Timadi Matthew²

¹Department of Computer Science, Ignatius Ajuru University, Port Harcourt, Nigeria

²Department of Computer Science, Federal University, Yenagoa, Nigeria

Email: tariuge.tt@gmail.com, timadimatiel@gmail.com

How to cite this paper: Tariuge, T. and Matthew, T. (2024) An Effective Optimization Algorithm for Ant Colony Vehicular Congestion Management. *Journal of Computer and Communications*, 12, 119-130. <https://doi.org/10.4236/jcc.2024.129007>

Received: May 7, 2024

Accepted: September 22, 2024

Published: September 25, 2024

Copyright © 2024 by author(s) and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Adaptability and dynamicity are special properties of social insects derived from the decentralized behavior of the insects. Authors have come up with designs for software solution that can regulate traffic congestion in a network transportation environment. The effectiveness of various researches on traffic management has been verified through appropriate metrics. Most of the traffic management systems are centered on using sensors, visual monitoring and neural networks to check for available parking space with the aim of informing drivers beforehand to prevent traffic congestion. There has been limited research on solving ongoing traffic congestion in congestion prone areas like car park with any of the common methods mentioned. This study focus however is on a motor park, as a highly congested area when it comes to traffic. The car park has two entrance gate and three exit gates which is divided into three Isle of parking lot where cars can park. An ant colony optimization algorithm (ACO) was developed as an effective management system for controlling navigation and vehicular traffic congestion problems when cars exit a motor park. The ACO based on the nature and movement of the natural ants, simulates the movement of cars out of the car park through their nearest choice exit. A car park simulation was also used for the mathematical computation of the pheromone. The system was implemented using SIMD because of its dual parallelization ability. The result showed about 95% increase on the number of vehicles that left the motor park in one second. A clear indication that pheromones are large determinants of the shortest route to take as cars followed the closest exit to them. Future researchers may consider monitoring a centralized tally system for cars coming into the park through a censored gate being.

Keywords

Ant Colony Optimization, Adaptability, Congestion, Pheromones

1. Introduction

In addition to air pollution and the inconveniences that comes with traffic congestion, its effect on cost for fuel consumption has increased substantially each year. Vehicle drivers expend excessive time looking for parking space which leads to excessive fuel consumption. This also affects the environment adversely. Current researches have been done on traffic congestion control (TCC). Traffic congestion control can be done indirectly or directly. The indirect control would usually consist of prior notification to vehicle on available parking slot through efficient communication. This style of control involves the use of sensors, visual monitoring and convolution neural network [1]. In the direct way of controlling traffic congestion, there is already existing traffic congestion and a system is required to control the traffic congestion. Drivers' prior awareness of vacant parking space in a park can reduce congestion to an extent thereby reducing their frustration [2]. However, already parked cars are exiting almost at the same time; a different approach for managing congestion should be applied. Finding the most adequate solution to traffic congestion has been challenging due to the unpredictability of the environment [3]. The paper attempts to enhance the CNN based parking system by introducing a system that manages congestions when cars are exiting a motor park at the same time. In choosing a solution to traffic congestion it is important the algorithm chosen should be efficient and adaptive [3]. The car park has two entrance gate and three exit gates. It is divided into three Isle of parking lot where cars can park. The challenge is that several cars can choose to leave the motor park at the same time. If the cars are not properly controlled, it could lead to traffic congestion within the car park. The solution presented in this article solves this problem by making the cars follow the nearest exit to them. The Ant Colony Optimization algorithm was used to simulate the movement of cars out of the car park through their choice exit. The Ant Colony Optimization algorithm is based on the nature and movement of the natural ants. Ants use pheromones to show other ants which route is the shortest route to the source of food [4]. Mathematical computation was used to calculate pheromones in this article.

2. Literature Review

In managing traffic congestion, indirectly various method has be adopted. One of such method was a convolution Neural Network Based Smart Parking System. This system consists of a visual node, server and a web service [1]. The overall system was designed to inform drivers on available parking slots to prevent traffic congestion. This system was limited in controlling an already existing congestion or a traffic congestion that suddenly occurs. This research would attempt to address this gap. Few more indirect examples of traffic congestion control are seen.

Indirect traffic congestion control is reflected in time scheduling in traffic junction. The overall aim as presented by Adebisi *et al.* [5] in their paper "Management of vehicular traffic system using artificial bee colony algorithm" was to use their algorithm based on Artificial Bee Colony to schedule the timing for the green

lights on a traffic Junction to reduce average waiting time. They were able to get an improved performance of 76.67 percent for the average waiting time in contrast to the 53.33 percent without their schedule being in use. However, whilst they were able to get a solution to a possible cause of congestion in traffic junction, their solution was unable to tackle other unforeseen traffic that could arise suddenly. This makes this research relevant because, it attempts to proffer solution to an already existing congestion or a traffic congestion that could arise suddenly.

More researches were carried out on managing traffic congestion. Alsheikhy *et al.* [2] developed a Nobel approach for a smart car parking system which involved using a camera that provided real time information about parking slot through pictures and video streaming. The system was gear to reduce human input to the minimal and reduce cost effective solution to the congestion problem. In addition, Bassam and Samann [6] system used optical character recognition (OCR) system to monitor the availability of vacant parking space. The drivers were pre-informed using IoT mechanism and Simple Mail Transfer Protocol for smart parking. Both papers were channeled to solve existing car parking system by detecting empty and free empty parking slots. Their approach was restrictive because, it could not address already existing congestion and traffic congestion that suddenly occurs.

Routing vehicles through a more convenient route to reduce delivery time of certain goods can also be said to reduce traffic congestion indirectly. Presently, the aim is to find the optimal path can be found putting various criteria in view, using dynamic and meta-heuristic algorithms Boryczka & Bura [7]. In recent years, the internet of things has had to deal with an increase in vehicles. Internet of vehicle is a constituent of the internet of things and also a vehicle for communication. Vehicular communication has a direct effect on network scalability and finding the shortest route. A novel internet system-based algorithm (CACIOV) was used to stabilize a given topology by using an enhanced version of the ant colony optimization (ACO) called the metaheuristic clustering algorithm Ebaadinezhad *et al.* [8].

The paper “Ant-based vehicle congestion avoidance system using vehicular networks” by Jabbarpour *et al.* [3] did a research on a multi-objective ant-based vehicle congestion avoidance system (AVCAS) for proactive congestion avoidance based on real-time traffic information. The proposed goal is: proposing the shortest path with the least congestion and travel time, as well as higher vehicle speed. Non recurring congestion like accident, working zone and weather conditions were implicitly dealt with in AVCAS. The dynamicity properties have been used by researchers to propose solution to traffic congestion. One of such solution is the road map segmentation. Previous researchers had proposed an ant-based algorithm to solve the shortest route problem without considering traffic congestion. Previously algorithm used was static algorithm and A* to find the shortest path in Car navigation system (CNS). Jabbarpour *et al.* [3] claimed to have addressed traffic congestions in their simulations. Some of the more recent researchers used hierarchical routing system (HRS) which is derived from the ant-based

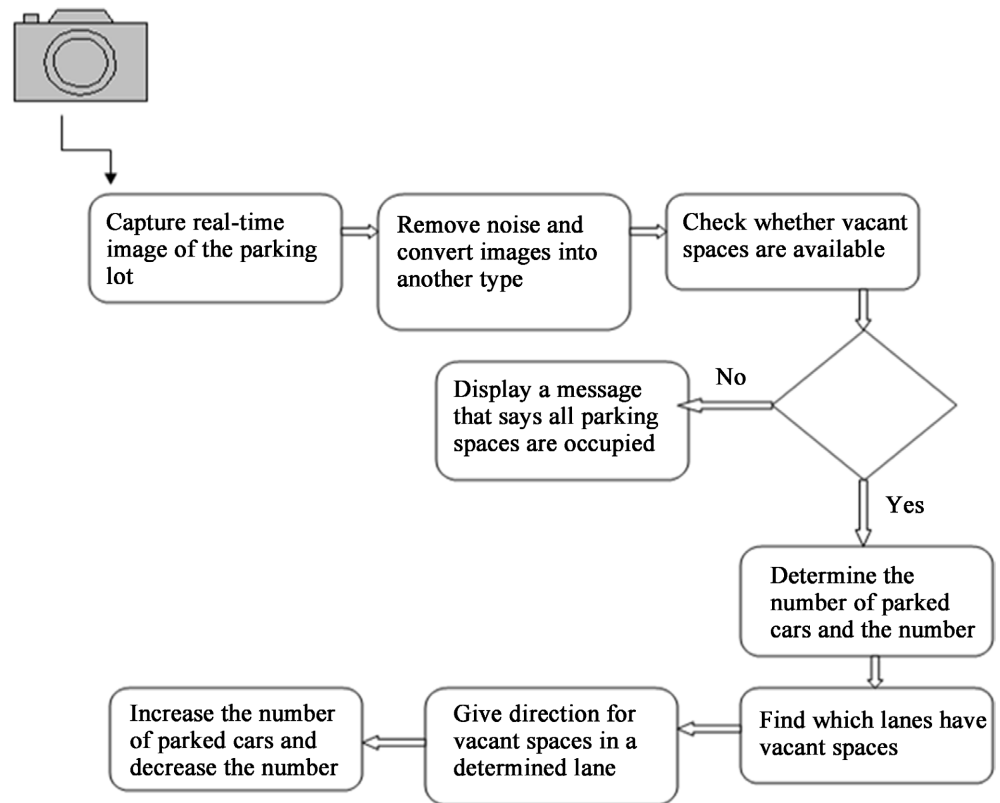
algorithm breaks a road map into many simpler maps. HRS limitation was it not being able to tackle future traffic conditions only the past and the present condition it could tackle. On the other hand, this research attempts to address immediate ongoing traffic congestion and also prevent traffic congestion using the ant colony optimization algorithm.

Romet *et al.* [4] research “Ant Colony Optimization for an Adaptive Transportation System: A New Termination Condition Definition Using an Environment Based Approach” talked about how to deliver goods ordered online to customers and to meet the high demand base of the customers. To meet the demand of the increased demand of delivery of online goods, they proposed an algorithm to solve the vehicle routing algorithm Problem (VRP). They needed the algorithm to be efficient and have adaptive features. Romet *et al.* [4] identified that their proposed algorithm to be used on the VRP was limited in the sense that, it did not deal with situation adaptation at the point of delivery. The goal of this paper was to create a solid foundation that can be built on to form an adaptive transportation system. The approach they chose to build their adaptive transportation system was to use the VRP algorithm which has an intrinsic ability of adapting to the dynamic update of a graph to implement the ant colony. The objectives were to reduce the time for delivery, reduce the distance to travel for delivery and to give customers maximum satisfaction. They proposed to create a base structure where all their electric cars will originate from. Their proposal was based on the combination of the ant colony and the VRP algorithm that implemented it. The VRP algorithm has the inherent ability to adapt to the updates of a graph that is very dynamic. The self-adaptive convergent nature of the ant colony could not fit into their freight transportation system. In addition, they required that the ant colony had a self-adaptive convergent feature that could fit into the environment at the least. They then implemented the VRP solution to their freight transportation system.

Sarith & Chandra [9] applied the bee colony algorithm in a different way as seen in a model that exhibited the behavior of swarm in bee colony in solving optimization problem in terms of cost and time. The model was projected to a dynamic model of commodity transportation issues that are multidimensional. They were able to deal with the uncertainties of real life scenario with their model with impressive performances. Conversely, their model was unable to put the environmental topography into consideration during implementation.

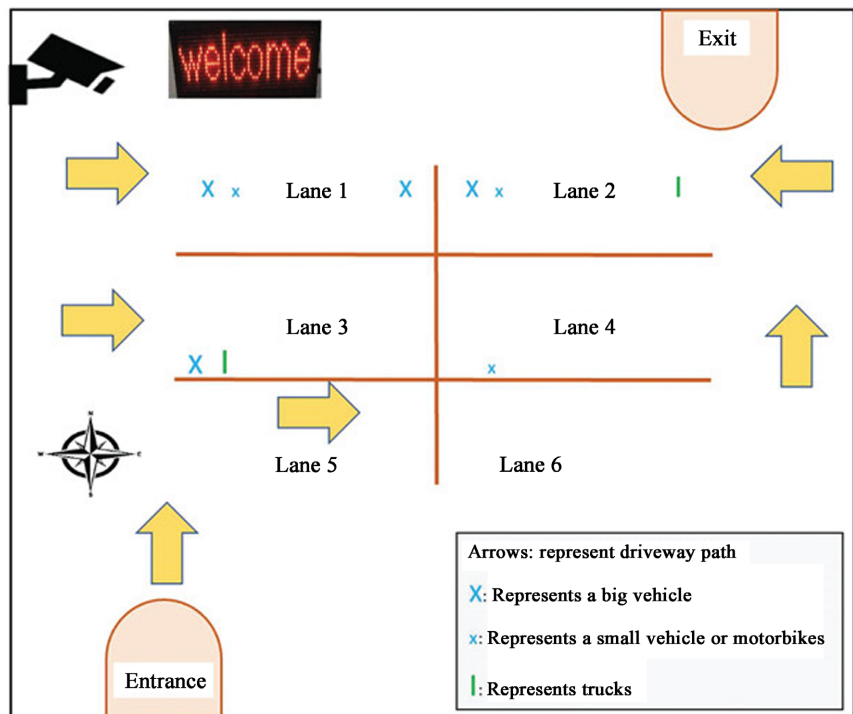
3. Current Approach

The current car park system consists of a camera that gives real time data to vehicle drivers about available parking spaces. The data also include the total number of vehicle parked in the car park and the available spaces for parking. The vehicle drivers are given instruction on how to go about parking in the available spaces in the car park. The overall system used the convolutional neural network tool like the AlexNet tool. The flow chart of the current approach is presented in **Figure 1**:



Source: Alsheikhy *et al.*, (2023).

Figure 1. Flowchart of Current approach.



Source: Alsheikhy *et al.*, (2023).

Figure 2. Parking lot of Current approach.

4. ACO Based Car Park Control Model

The propose simulation is about a car park that has 2 entry points and 3 exit point (see **Figure 2**). The cars are to choose the shortest exit point closest to them using the ant colony optimization algorithm. Monitoring which car park is empty, the closest exit gates will be controlled by a centralized system. There will be a sensor at the entry and exit to keep track of which car has left the car park. On entrance into the car park, each car will be given a tally that reflects the parking slot for the said car. The tally is controlled by a software in the control room. In addition, the software will control all exit gates with radio frequency. More so, the software implements the ant algorithm which indicates to the car through the tally the shortest and closest exit gates to it. The letter “car” in our **Figure 3** will represent a normal car. The exit points are the routes to be taken to get food.

4.1. The Propose System Implementation

The ant colony algorithm will be implemented in the Software. The software controls the gate and the tally using some form of communication signal. These

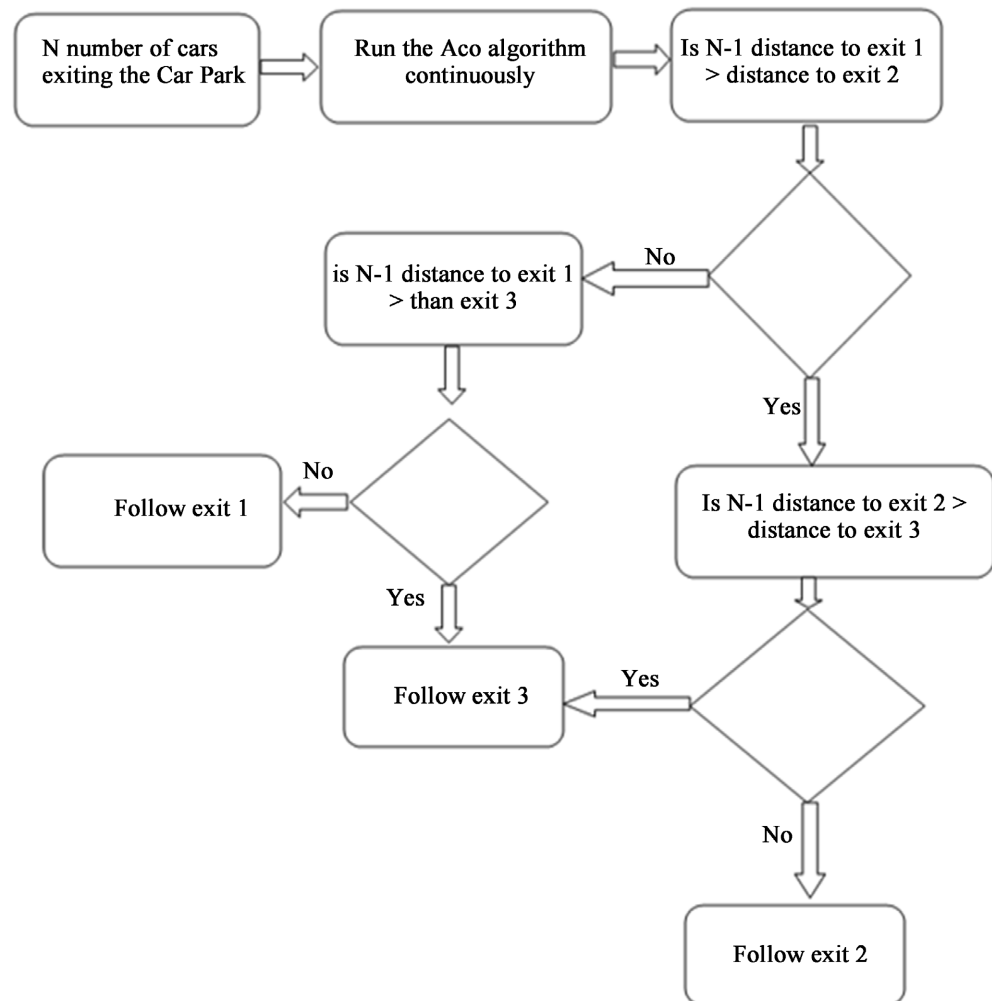


Figure 3. Flowchart for proposed system.

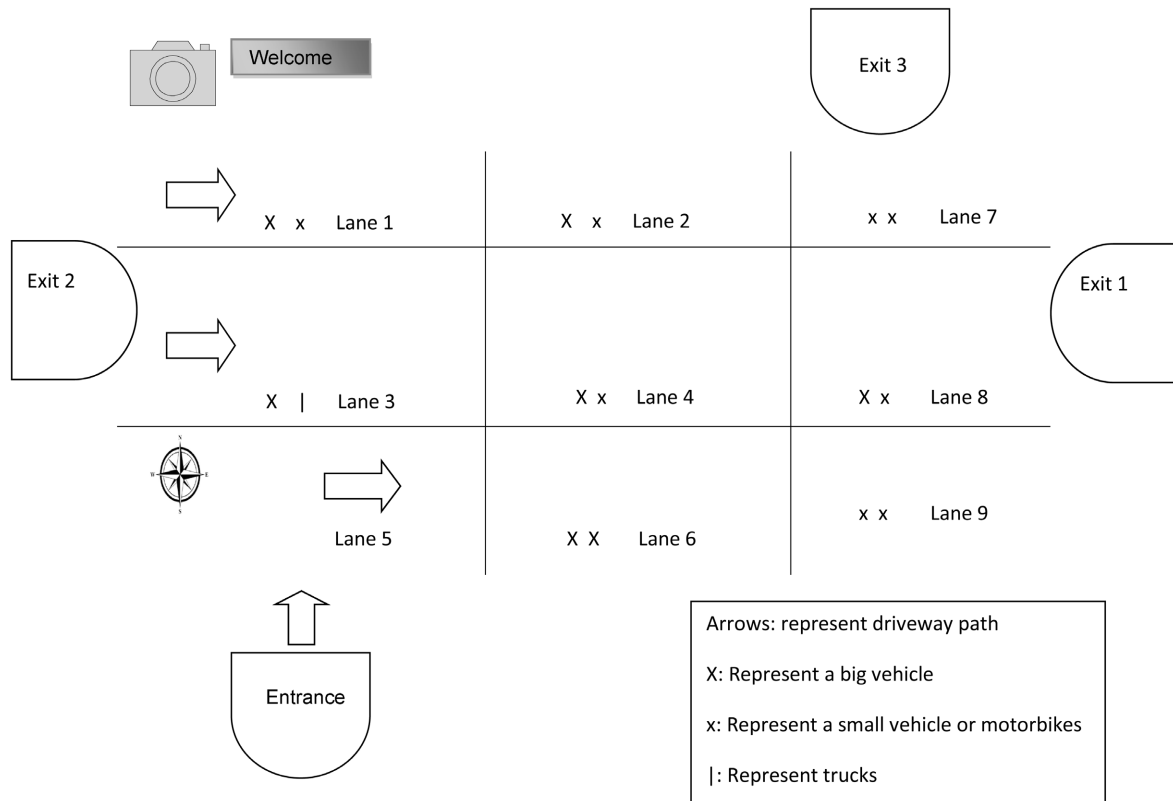


Figure 4. Carpark for proposed System.

communication signals are made up of packets that will be programmed to act like artificial ants. The signal will be stronger at shorter distances from a car to its closest exit. The stronger signal represents high pheromone deposited by the digital ants whilst lesser pheromone represents weaker signal. Therefore, when a car wants to leave the car park, it gets a signal from the software through its beeping tally which exit to take.

4.2. The Ant Colony Algorithm

The artificial ants will be expected to deposit pheromones on their way to either of the exit points (see Figure 4). Subsequent artificial ants will be able to choose the path with the most pheromones which will represent the shortest way out of the motor park.

$$\text{The equation } L_1 \Delta \tau_{ij}^k = 1/L_{K0} \tag{1}$$

where L_1 = the length of the route from car park to exit 1;

i and j = shows the edge connecting two nodes;

$\Delta \tau_{ij}^k$ represents the amount of pheromone deposited on the edge connecting “ i ” to “ j ”;

K = the artificial ant.

Using the equation above: Car 1 to Exit 2 = $1/4 = 0.25$;

Car 2 to Exit 3 = $1/8 = 0.12$;

Car 3 to Exit 1 = $1/15 = 0.06$.

Car 1 to Exit 1 has the largest value. This means it has the largest pheromone deposits on that path. Chances are that, all the cars parked at the first isles will exit through exit 1 based on the ACO algorithm. This principle applies to cars that are closer to exit 2 and exit 3.

The first equation did not put into account the vaporization factor of the pheromones. With that in mind, the equation now becomes:

$$\tau_{i,j} = (1 - p)\tau_{ij} + \sum_{K=1}^m \Delta\tau_{ij} \tag{2}$$

p is a constant that defines evaporation rate. When p equates to 0, it means there is no evaporation. When P equates to 1, it means the evaporation level is at its maximum.

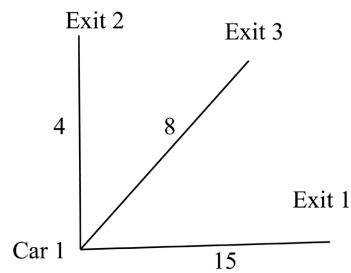


Figure 5. Pheromone Graph 1.

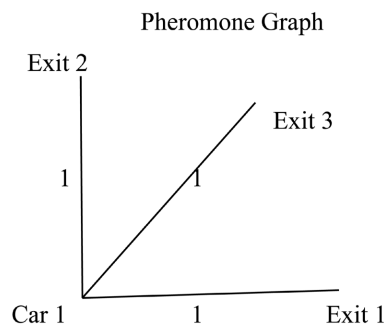


Figure 6. Pheromone Graph 2.

Assumptions made in this simulation are: All routes have a pheromone value of 1 and the p value = 0.5. The routes having a pheromone value fixed at “1” mean that all 3 routes have been traversed by a Car ant.

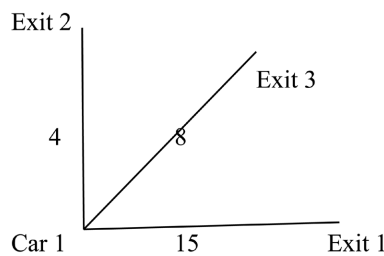


Figure 7. Calculating the probability.

With the values given in the above figures, probability equation is used to

calculate the best path the car ant can follow. Another equation is considered below:

$$P_{i,j} = \frac{(\tau_{i,j})\alpha(\eta_{i,j})\beta}{\Sigma((\tau_{i,j})\alpha(\eta_{i,j})\beta)} \tag{3}$$

where $(\eta_{i,j})$ is the quality of the edge i, j on the graph and $(\tau_{i,j})$ is the pheromone level on the edge i, j . the denominator of the equation takes into account all the quality of the edges and the pheromone values of the edges that can be considered from the node i . For the purpose of this simulation, the author does ignore the α and the β values by evaluating both values to 1.

Using the graphs in **Figures 5-7**:

From Car to Exit 1

$$P = \frac{1 * \frac{1}{4}}{1 * \frac{1}{4} + 1 * \frac{1}{8} + 1 * \frac{1}{15}} = 0.626 \tag{4}$$

From Car to Exit 2

$$P = \frac{1 * \frac{1}{8}}{1 * \frac{1}{4} + 1 * \frac{1}{8} + 1 * \frac{1}{15}} = 0.31 \tag{5}$$

From Car to Exit 3

$$P = \frac{1 * \frac{1}{15}}{1 * \frac{1}{4} + 1 * \frac{1}{8} + 1 * \frac{1}{15}} = 0.16$$

5. Result and Discussion

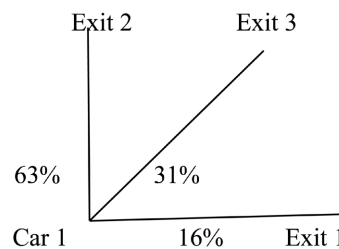


Figure 8. Graph values in Percentage.

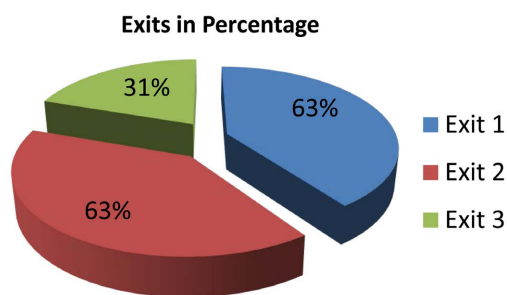


Figure 9. Exits in percentage.

Exit 1 has the highest percentage with a value of 63% (see **Figure 8 & Figure 9**). The interpretation of the chart is that Cars parked at the left isle of the car park have a greater tendency to exit from Exit 1, followed by Exit 2 which has a value of 32% and lastly Exit 3 which value is 16%. The same principle applies to other cars parked on other isles in relationship to the three Exit gates around the isles. This experiment also shows that an increase in pheromones number can increase the percentage of a particular route. If the pheromones deposited from Car 1 to Exit 2 is increased from 1 to 5, its percentage increases from 63% to 86% (see **Figures 10-14**).

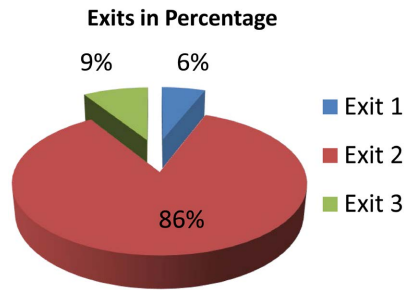


Figure 10. Exits in percentage.



Figure 11. Tally showing Exit gate for the middle car.

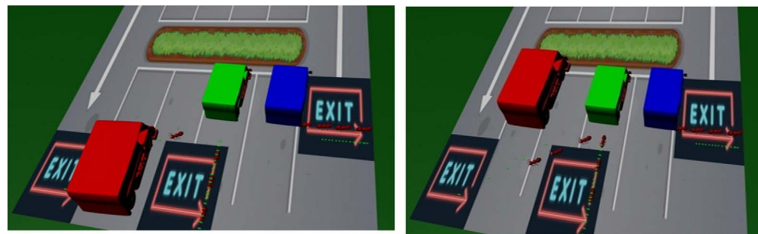


Figure 12. Ants depositing pheromones through the middle exit.

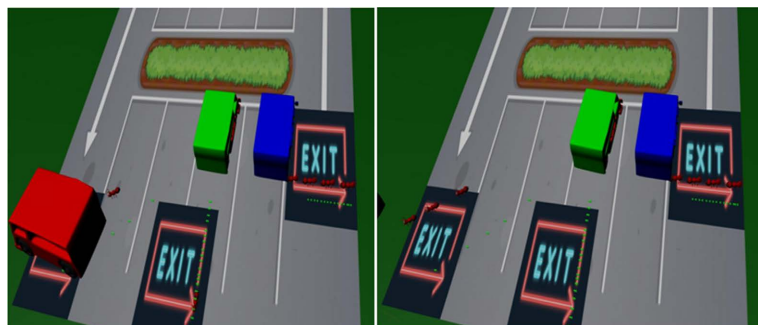


Figure 13. Red Car follows the left exit gate.

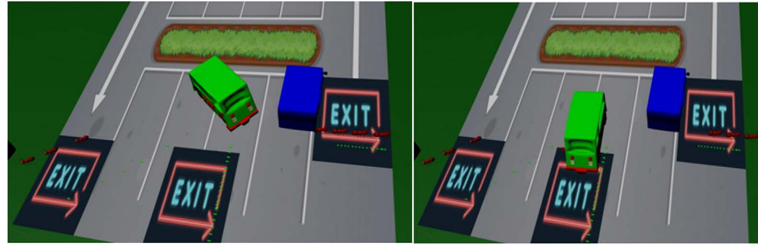


Figure 14. Middle car passes through the gate with the most pheromones deposited on its path.

6. Conclusion

The adaptability nature of the ants has been used to solve problems like the vehicle routing algorithm problem. It also forms the basis of the Ant Colony optimization algorithm. The ACO was used to solve navigation problems in a car park. The findings of the experiment showed that pheromones are largely a determinant of the shortest route to take. The other aspect of cars coming into the park through a censored gate being monitored by a centralized tally system was not adequately covered in this article. Future researcher may want to look into these areas.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Abu-Asaad, H.A. (2023) Cnn-Based Smart Parking System. *International Journal of Interactive Mobile Technologies (ijim)*, **17**, 155-170. <https://doi.org/10.3991/ijim.v17i11.37033>
- [2] Alsheikhy, A.A., Shawly, T., Said, Y.F. and Lahza, H. (2022) An Intelligent Smart Parking System Using Convolutional Neural Network. *Journal of Sensors*, **2022**, 1-11. <https://doi.org/10.1155/2022/7571716>
- [3] Jabbarpour, M.R., Jalooli, A., Shaghghi, E., Noor, R.M., Rothkrantz, L., Khokhar, R.H. and Anuar, N.B. (2014) Ant-based Vehicle Congestion Avoidance System Using Vehicular Networks. *Engineering Applications of Artificial Intelligence*, **36**, 303-319. <https://doi.org/10.1016/j.engappai.2014.08.001>
- [4] Romet, P., Gechter, F., Aglzim, E. and Grunder, O. (2020) Ant Colony Optimization for an Adaptive Transportation System: A New Termination Condition Definition Using an Environment Based Approach. *Hal Open Science*, **1**, Article 270122. <https://u-bourgogne.hal.science/hal-03545439>
- [5] Adebisi, R.F., Abubilal, K.A., Tekanyi, A.M.S. and Adebisi, B.H. (2017) Management of Vehicular Traffic System Using Artificial Bee Colony Algorithm. *International Journal of Image, Graphics and Signal Processing*, **9**, 18-28. <https://doi.org/10.5815/ijigsp.2017.11.03>
- [6] Bassam, R. and Samann, F. (2020) Smart Parking System Based on Improved OCR Model. *IOP Conference Series: Materials Science and Engineering*, **978**, Article 012007. <https://doi.org/10.1088/1757-899x/978/1/012007>
- [7] Boryczka, M. and Bura, W. (2013) Ant Colony Optimization for the Multi-Criteria Vehicle Navigation Problem. In: Czarnowski, I., Jędrzejowicz, P. and Kacprzyk, J.,

Eds., *Agent-Based Optimization. Studies in Computational Intelligence*, Vol. 456, Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-34097-0_2

- [8] Ebadinezhad, S., Dereboylu, Z. and Ever, E. (2019) Clustering-Based Modified Ant Colony Optimizer for Internet of Vehicles (CACOIOV). *Sustainability*, **11**, 2624. <https://doi.org/10.3390/su11092624>
- [9] Saritha, R. and Vinod Chandra, S.S. (2019) Multimodal Foraging by Honey Bees toward Optimizing Profits at Multiple Colonies. *IEEE Intelligent Systems*, **34**, 14-22. <https://doi.org/10.1109/mis.2018.111144149>