Service Robot Path Planning using A Star Algorithm in a Moving Obstacle Scenario for Cleaning and Sanitization

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Abstract

Mobile robots have been widely used in challenging real-world situations in recent years. Reduced human-to-human contact as well as autonomous routine cleaning, sanitization, and support in crowded settings are the main uses of service robots. Service robots are required on congested platforms such as train platforms, hospital patient areas, industry, college, school, and employee and public engagement locations. A different industry began experimenting with service robots during the COVID-19 pandemic. Both stationary and movable barriers can be found on railway platforms. The only source of obstacle position coordinates is the installed cameras.A service robot uses the A star algorithm to avoid or alert itself to impediments to carry out regular cleaning and sanitization. The programme covers all spots as quickly as possible, saving time and effort. The trials were conducted on a grid area featuring moving barriers. MATLAB is used for simulations and analysis. The major advantage of utilising A star is the substantial decrease in memory and computation needs. Numerous additional locations, including offices, hospitals, colleges, and schools, can use the same set of systems. Autonomously cleaned and sanitised public roads, highways, and toll areas can be achieved.

Keywords: Path planning, A star algorithm, Service robot, Obstacle avoidance.
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1. Introduction

Theproblem of path planning is a very common one in which the shortest path between two vertices, or start and finish points, in a given area, is determined. The route shows the least expensive way to move from the starting point to the desired state. However, finding the shortest path between two sites is frequently insufficient. People might need to find the fastest route between several specified points. The travelling salesman problem [1], in which the path must pass through every vertex in the graph, vehicle routing problems [2], in which the vehicle delivers goods to multiple designated locations, and path planning for tourist attractions [3], in which we must find a path through each viewpoint that interests us, are examples of this kind of problem. These kinds of issues fall within the category of the multi-point path planning problem, which is an NP-hard problem (Non-deterministic Polynomial) [4]. A service robot will proceed to each destination in turn, finishing the predetermined routine tasks.

The global crisis has been brought about by the COVID-19 pandemic that has been going on recently. The lack of personnel to handle such circumstances is extensively investigated. Safe social distance rules, regular cleaning, and environmental sanitation have all become essential safety precautions to reduce the transmission of the virus. There are already several examples of how service robots are being deployed in pandemic situations to aid in and prevent viral spread [5]. The global service robots' market is forecast to develop at a faster growth rate

[6] than the previous years. In hospitals, railway platforms, schools, coaching, and other crowded zones where patients come, engage, and leave; healthcare professionals and other colleagues are more vulnerable to virus infections. Therefore, maintaining a clean and sanitary atmosphere is essential for preventing the spread of illnesses. The goal of developing an automatic service robot isto clean and sanitize congested areas where different groups of people are constantly arriving and exiting.

In the investigation of service robots, drones and automated guided vehicles have recently made significant advancements in the fight against the pandemic [7]. These AI-assisted robots that are integrated with technology distribute supplies to COVID-19 patients, effectively implement body temperature measurement during safe entry check-ins and social distancing, routinely sanitize infected areas, and frequently clean high touch points like hospital floors, walls, and door handles [8]. Another key component of cleaning robots is their ability to comprehend their environment and create synergy with them. Therefore, the perception method is a crucial factor in determining the robot's robustness and overall effectiveness.

The construction of a multi-point path planner service robot for cleaning and sanitization is the major goal of this study. In this paper, we suggest a surveillance camera-assisted adaptive cleaning and sanitizing approach for the planner surface. The surveillance system's job is to keep an eye on and spot both stationary and moving obstructions.As a result, the multi-point path planner systems suggested in this technique do not need a lot of processing power or expensive intuitive sensors. The recommended adaptive cleaning approach algorithm is simulated in MATLAB using test data from the surveillance system.In this study, we assess the effectiveness of the suggested cleaning method in terms of calculations, memory utility, and area coverage. The structure of this paper is as follows: The work that has already been done in the fields of service robots and algorithms is covered in section 2. An algorithm for multi-point path planning is presented in section 3. The adaptive cleaning technique in surveillance systems avoiding obstructions is covered in section 4. Section 5 discusses the trials and findings under various map settings. And the last section 6, conclude and examines possible future research avenues.

2. Related Work

Numerous traditional methods, including dynamic programming, branch-bounding, and branch-cutting, have been offered [9] as solutions to such path-planning issues. All of these methods, which are incredibly accurate, can only be used in networks with a few nodes. Additionally, certain heuristic algorithms can approximate solutions to a graph with more nodes, including Tabu Search Algorithm [10], Fuzzy Logic, Ant Colony, Genetic, Bee Colony [11], and some hybrid algorithms [12].The bat algorithm [13] is a swarm intelligence-based heuristic search algorithm that is capable of finding the overall best answer. To improve convergence and accuracy, Pan et al. [14] developed the hybrid bat method by combining the bat algorithm and the particle swarm algorithm. Howevermost hybrid approaches are rather time-consuming. Second, the targeted location update approach of the bat algorithm has been enhanced. In the travelling salesman problem, the improved bat algorithm improves the bat algorithm's local and global search performance, and the approach it utilised serves as an inspiration.

Many studies have been conducted in the past few decades to produce service robots. Area coverage is one of the rising issues in cleaning applications, and investigationfor coverage route planning has been thoroughly researched under numerous aspects, including design, control, autonomy, perception approaches, and connection strategies between different service robots. For instance, Wu et al. [15] discussed the usage of propeller-thrust and vacuum suction approaches as adhesion mechanisms for cleaning vertical surfaces when discussing the design elements of cleaning robots.

Different sorts of locomotion solutions have been proposed to address speed limitations and control complexity. Gao et al. [16]

offered, as an illustration of a robot with Swedish wheels for omnidirectional mobility with purpose of floor-cleaning. Robotic mobility in eight directions has been demonstrated through testing of the robot's kinematics and motion control. A staircase-cleaning robot was demonstrated by Megalingam et al. [17] and featureda tracked belt for movement and a cleaning brush mounted to the front side of the robot to aid in stair climbing. An A-staralgorithm-based zig-zag path planning method for a Tetris-inspired self-reconfigurable cleaning robot was demonstrated by Le et al. [18]. By utilizing the robot's ability to change shape, they further confirmed the suggested strategy for navigating confined environments. The shortest path planning process uses this robot platform as well [19]. By altering the obstacle density in the test bed environment, they further verified the suggested approach and expanded the platform morphologies to include diamond, hexagon, and rhombus-based shapes.

Adapting to synchronization between therobots is another crucial component in cleaning and sanitizing service robots to boost productivity with a rapid cleaning approach. A real-time synchronically sweeping technique with comprehensive coverage path planning for numerous cleaning robots was put forth by Luo et al. in [20]. Using neural networks with biological inspiration, this method creates an effective path that enables robots to avoid colliding with objects and other robots and to cooperate. The strategy aims to increase the effectiveness of cleaning with several cleaning robots. Megalingam et al. [21], proposed a method of using swarm robots as another way to use several slave robots under the control of a master robot to cover a wide area quickly. Kurazume et al. [22] created a cleaning robot system in a different study that has a cooperative positioning system. By utilizing landmark data from numerous robots in a cooperative positioning system, the proposed method focuses on lowering localization errors.Our technique improves the location updating strategy for dynamic neighbourhood operations.

3. A Star Algorithm

One of the many search strategies that take input and then calculatea number of potential tracks and then provide a result is the A star algorithm. This approach is used extensively in path planning. It employs the best search to find the least expensive route from a particular start sector to the target one. The pointer moves through the map in an orderly priority queue of adjacent track sectors while adhering to the track with the lowest known heuristic cost. Because it considers the portion that has already been calculated, this algorithm has a high level of accuracy. This algorithm is the best search algorithm since it determines the sector's least expensive track. The fundamental idea behind this approach is based on the following equation:

$$f(x) = g(x) + h(x) \quad \text{… (i)}$$

where x is a sector on the given map, g(x) represents the total distance from the start sector to the current one, andthe heuristic function h(x) represents that is used to determine the distance from the current position x to the desired location [23]. This technique results in a way for the robot to explore a different path after hitting a dead end and to avoid paths that lead there. For this, two lists one closed and the other open are made. The A star algorithm's basic building blocks are a closed list and an open list. A closed list is used to write and save tested and evaluated sectors whereas an open list is used to record adjacent sectors to those already calculated, calculate the distances moved from the initial sector with distances to the target sector, and also save the parent sector of each sector. These parents are used at the algorithm's final step to planning the track from the target.

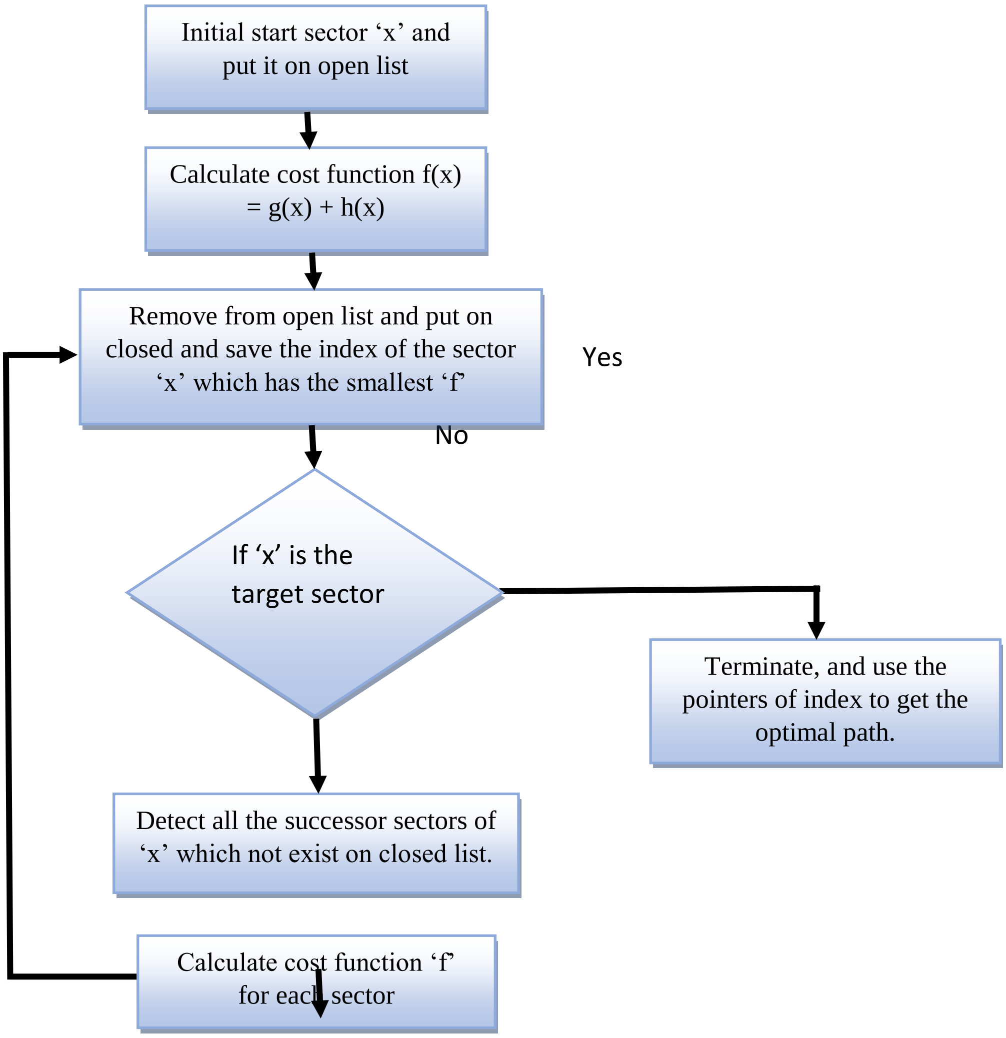


Figure 1: Flow chart of A Star Algorithm

4. Obstacle Avoidance

Numerous details in the environment's image serve as the inputs for the problem. Numbers or traits pertaining to the primary image of the surroundings may be the output form of image processing. These days, robotic applications that use vision sensors as cameras are rapidly growing since they give us a lot of information about the environment as opposed to conventional sensors, which just give us information about distance or level of colour. Additionally, webcam prices are falling faster than those of any other sensor [24]. A camera captures an image of the environment, and MATLAB software then receives this image. The algorithm using image processing for obstacle identification is used to apply basic morphological commands to this image and determine the robot's current location, obstacles' forms and spaces, and the goal.

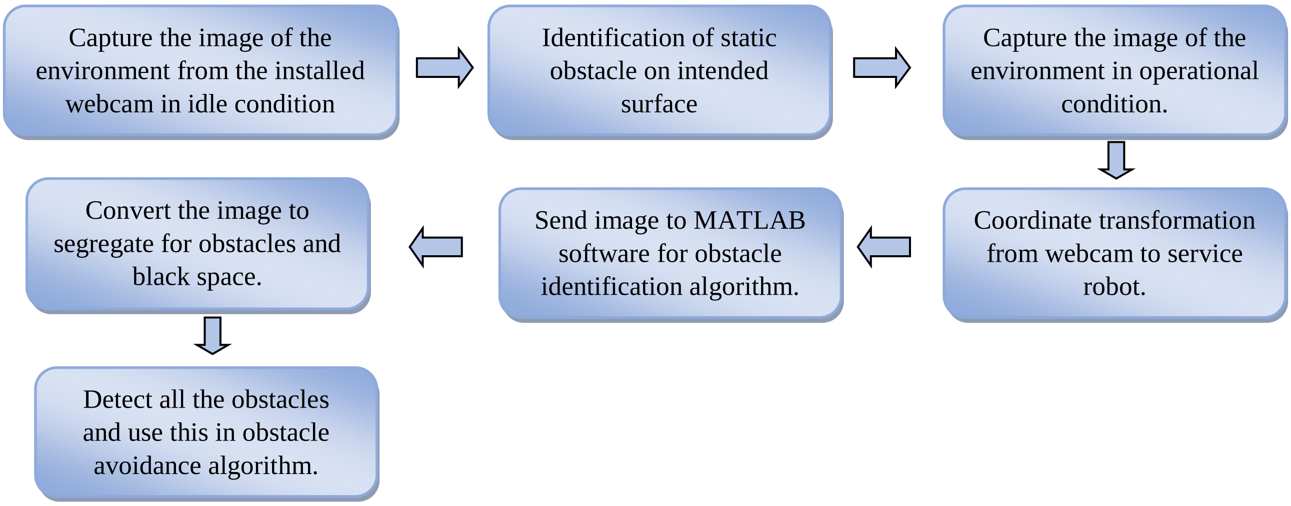


Figure 2: Flow chart of obstacle avoidance mechanism

5. Experimental Result

In the experiments, initially, the static obstacle problem was solved on 15*15 grids. Multiple paths were investigated and the ones with the fewest turnings were chosen to get the shortest distance travelled from the start position to the goal position. The optimal path from the start (15, 1) to the goal (1, 15) points is shown in Figure 3(b).

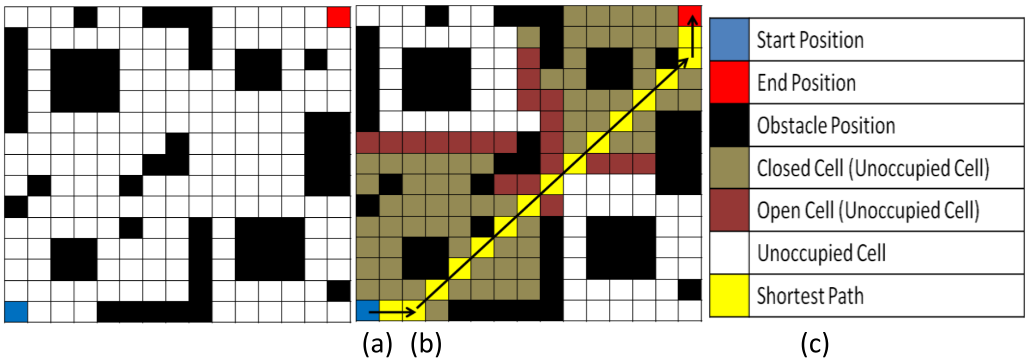
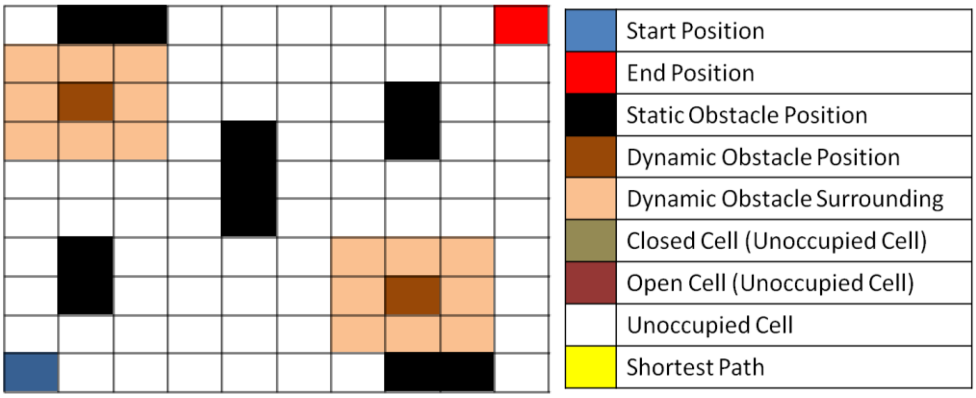


Figure 3: (a) Static obstacle grid with start point (15, 1) and goal point (1, 15); (b) Best optimum path with arrow direction; and (c) colours representing their software applications.

The proposed method for determining the best optimal path is then applied in dynamic environments. In a dynamic environment, some of the obstacles are static and others are in motion. In this dynamic problem, static obstacles are shown in black, and a moving obstacle is shown in maroon. We consider two men as moving obstacles who can move randomly in any direction. The moving obstacle can take one step with a two-step movement of the service robot. The immediate surrounding grids of moving obstacles are also treated as obstacles for avoiding collision with the service robot. Figure 4 shows the initial problem of path planning and the path traced by the robot shown in figure 5.



(a) (b)

Figure 4: (a) The initial path planning problem with start point (10, 1) and goal point (10, 1), and (b) the colours corresponding to their software applications.

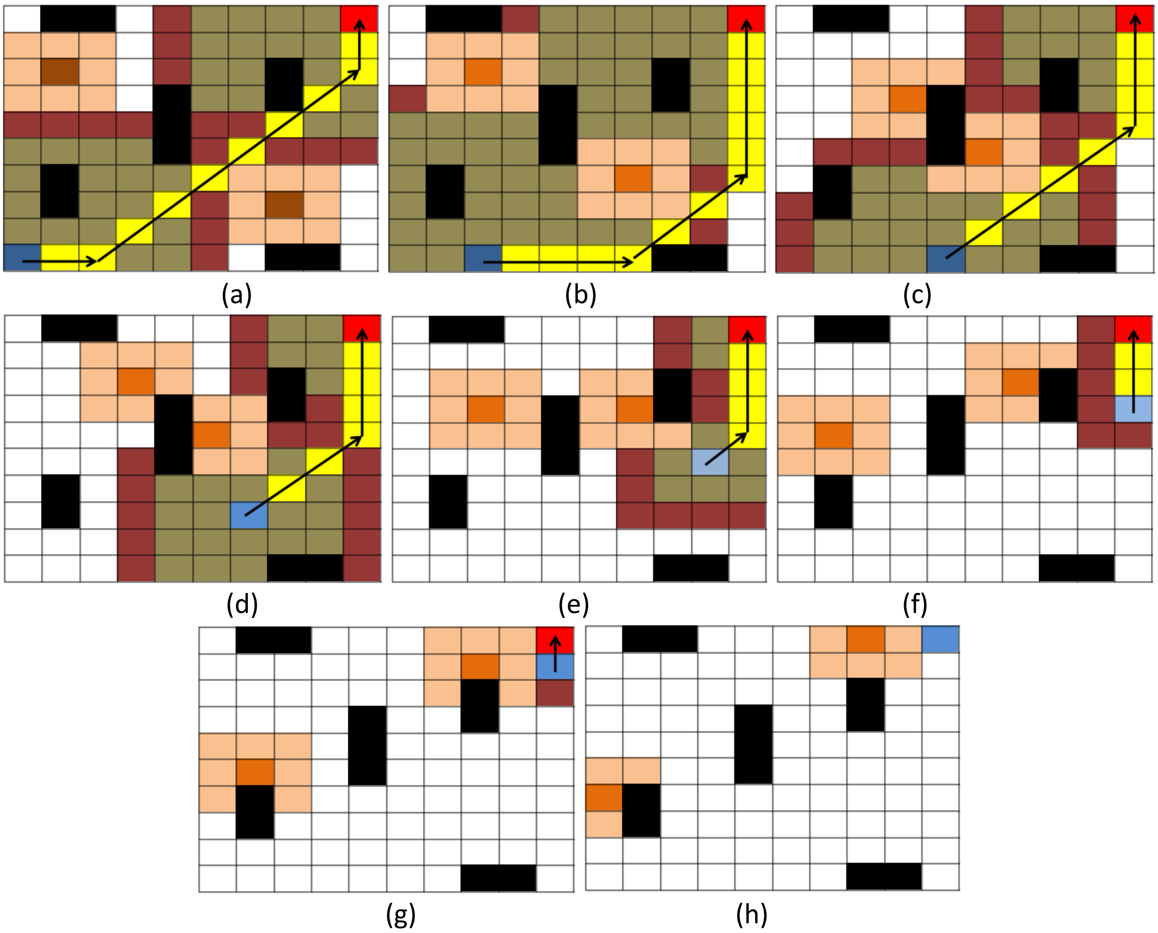


Figure 5: Steps involved in a dynamic path planning problem

The table below depicts the positional transformation of obstacles and the optimal path. The number of calculations for the software decreases as the distance between the start and goal points decreases, which aids it in determining the fastest and best optimum path.

Table 1: Position coordinates of the start point, moving obstacles, and final point

Step	Start Position	Obstacle 1	Obstacle 2	Final Position
(a)	(10,1)	(3,2)	(8,8)	(1,10)
(b)	(10,3)	(3,3)	(7,7)	(1,10)
(c)	(10,5)	(4,4)	(6,6)	(1,10)
(d)	(8,7)	(3,4)	(5,6)	(1,10)

(e)	(6,9)	(4,3)	(4,7)	(1,10)
(f)	(4,10)	(5,2)	(3,7)	(1,10)
(g)	(2,10)	(6,2)	(2,8)	(1,10)
(h)	(1,10)	(7,1)	(1,8)	(1,10)

The multi-point path planning problem depicted in figure 6 can be modelled as a railway platform with pre-installed webcams for surveillance and obstacles in static and moving modes.

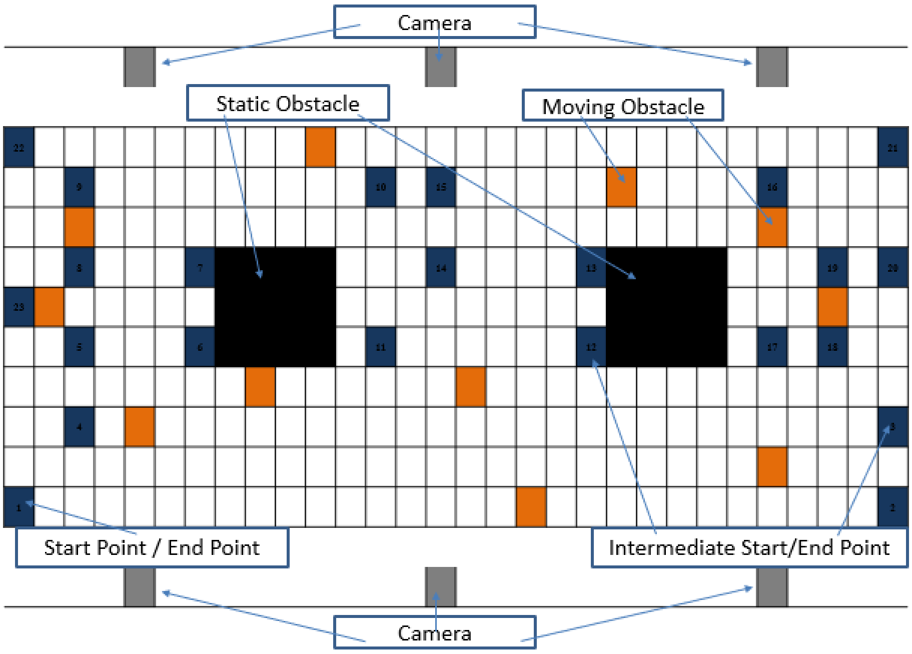


Figure 6: Multi point path planning problem for covering all nodes in turns.

The static obstacles may be treated as the beam support area and shops, and the moving obstacles as passengers. The service robot will move from its starting point to its destination, equipped with a cleaning and sanitization manipulator.Here in the multi-point path planning the size of the robot is assumed to be the size of the cell. The spraying area include the adjacent cell of current cell. The camera coordinates are transformed to service robot coordinates and perform the desired work.

In this case, the initial and final points are the same, and the service robot begins at point "1" sequentially covering all "16" nodes before returning to its initial position. The service robot is programmed in such a way that it will signal the moving man to move aside and wait for a while. If the obstacle does not move then the robot avoid the obstacle and complete the duty. Figure 7 illustrate the path traced by the service robot covering all nodes.

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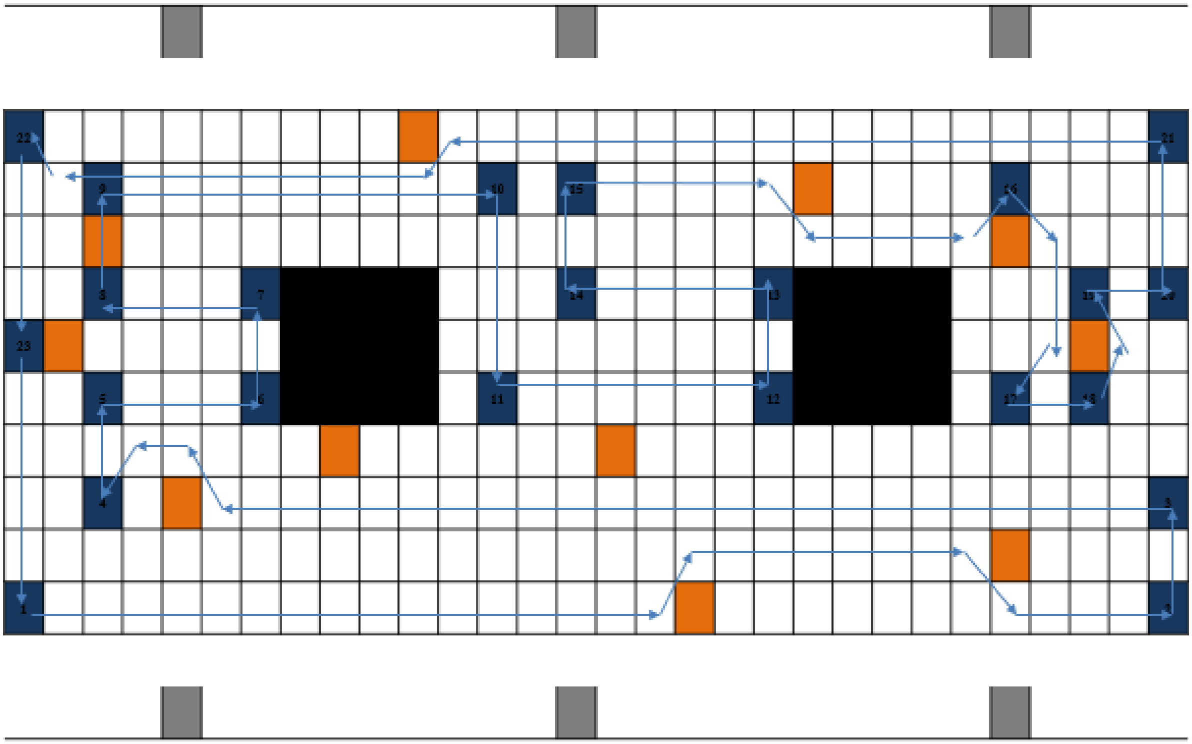

Figure 7: Traced path by service robot.

6. Conclusion and Future Scope

This work created a simulation for a robot navigation system that relies on segmenting the image to speed up processing and has obstacles to avoid. In order to discover the best path based on the map of the environment, MATLAB software was used to construct the A star method and divide the bigger space into smaller portions. The field of mobile robot path planning has two branches: online and offline. As a result, many algorithms and methods are still being developed to offer the best answers for all the problems they encounter. The range of work can be further expanded by adding more service robots in the future. Additionally, by processing videos, the similar method can be developed for navigation.

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