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Research paper

Single-Camera Computer Vision Algorithm for Robot Shortest Path Estimator using morphological structuring element with variable sizes

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Abstract

The robotic challeng of developing and implementing a shortest-path finding algorithm to reach a destination without bumping into obstacles has been tackled in this paper. The proposed algorithm is utilized a single ceiling fixed camera and based on the mask and robot size with different sizes for dilation mask. The implementation has been successfully produced thirty-three computer vision figures and two comparison tables of simulation results by using morphological structuring element with different sizes. This paper's proposal of optimal path finding algorithm is effeciently save robot energy in reaching targets.

Keywords: *Robotic Vision, Shortest Path Estimator and Variable Size Morphological Structure, Energy Saving*

1. Introduction

Image processing and computer vision researches have effectively been accomplished the aims of estimating the path between a source and a distention in a given space. These details are used for the path planning [1]. The goal of path planning is to determine first a path and then the shortest or optimal path of the mobile robot from current location to destination within a static or dynamic obstacle environment [2] [3] [4]. Several sensors as laser sensors, ultrasonic sensors and stereo-camera-based range sensors are commonly utilized to detect obstacles in natural environments. On the other hand, most of these sensors are too costly to use for low-cost service in some application compared to web cameras. With the purpose of doing jobs, robots have to be intelligent and should decide their own depending on their jobs. It is necessary to plan path for reducing a cost such as time, energy and distance [5].

The contributions presented in this paper can shortly be listed:

- A shortest path planning algorithm is designed.
- Shortest path finding process is based on the mask and robot size.
- The proposed algorithm used different sizes for dilation mask.
- The dilation images by double structuring element size with specified size are revealed.
- Using single camera to detect obstacles in natural environments.
- Energy saving by computing the optimal path of the mobile robot

2. Related existing work

The idea is how to avoid obstacles by planning the shortest path using computer vision [6]. There are no dearth in literature to investigate this idea. Consequently, Khaili [7] proposed path planning algorithm in a dynamic environment. This is achieved in three steps. Firstly, a visibility tree is constructed. Secondly, location calculations are performed. Thirdly, seek the shortest path. Deepu and Murali [8] investigated path generation for robot navigation using a single ceiling mounted camera. The paper focus on finding a shortest path.

Shim and Cho [9] presented a robot localization algorithm using surveillance cameras based on 2-D location map. Akshay [10] provided time-efficient A* algorithm for robot path planning. The proposed A* algorithm determines the heuristic function's value just before the collision phase rather than initially and exhibits a good decrement in processing time with higher speed. This paper involves MATLAB simulation of robot movement from source to goal. Several cases are considered with proposed A* algorithm which exhibit maximum 95% reduction in processing time.

Patel et al [11] presented a shortest path 7×7 maze estimation algorithm using single camera. Yao et al [12] proposed a novel 1D graph algorithm. Kitanov et al [13] developed a shortest path algorithm by Estimation of image lines, extracted using Random Window Randomized Hough Transform line detection algorithm. Xiong and Choi [14] presented a location estimator as a landmark identification algorithm to be compared with a references map. Nadav and Katz [15] designed a 2-D/3-D video analysis algorithm to estimate and detect nearby obstacles. Chinnaiah et al [16] developed and FPGA-based implemented an obstacle avoidance algorithm.

3. Proposed algorithm

This work focus is on supporting a novel method to discover a shortest path in an indoor environment to easy movement of robots. The proposed system also senses to avoid obstacles in a path using a ceiling-fixed camera to capture an upper view of the room. The proposed system does not use any of other sensors to detect the obstacles or to plan a path.

The captured image is handled based of image processing techniques to separate between floor and obstacles (number of obstacles are free).After the obstacles are identified, the server identify the source and destination to enable the system to calculate the shortest path using computer vision. This work is done by m-file MATLAB and vision function for reducing the processing time.

The proposed algorithm does not take into account the speed of the robot, rather than focuses on how to find and draw the shortest path between the source (robot) and the target (destination). The proposed algorithm is designed to avoid all obstacles. Using morphology technique (dilation) [1] to increase size of obstacles to avoid obstacles on the robot sides. The size of mask (morphological structuring element) that used in dilation step dependent on robot step size. The proposed algorithm reduces the required time to reach the goal by following the same path between the two centers of the robot and the target (the shortest path is the strength line between two points regardless of the obstacles). The proposed algorithm reduces the time for searching and calculating all other paths to select the shortest path.

The integration' model of the algorithm into a CPS system may be achieved as in Vladareanu et al [17] [18] [19] [20] [21], where a Portable Robotic 3D contact control system has been proposed and applied on a Robot Leg.

3.1.Distance estimation and path planning algorithm

. Input image (see Figure 1) is converted to black and white (see Figure 2) and Noise removed (see Figure 3) using morphology technique White blobs dilation (see Figure 4). The robot selects destination (see Figure 5). Bresham's method [1] is utilized to obtain all x and y points of the shortest path between the source and a destination.

Fig. 1: Original image

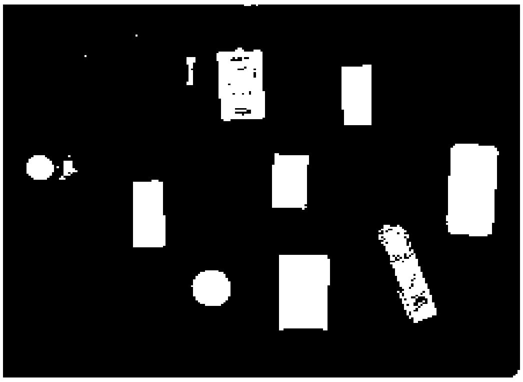

Fig. 2: Binary Image

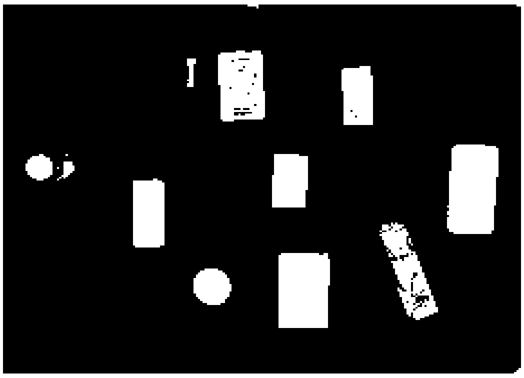

Fig. 3: Image Enhancement

Fig. 4: Image Dilation

Fig. 5: Source and destination selection

The robot stops at encountered obstacles (see Figure 6 and Figure 7). This is the first intersection point. Mark it by a green cross (see

Figure 8). Check where else the shortest line intersected this obstacle, mark that in a yellow cross (see Figure 9). As in Figure 10 and Figure 11, there are two possible ways to move from the green to the yellow cross points, then the shortest path is followed with the minimum distance (see Figure 12). The robot move forward pixel by pixel (until another obstacle is encountered) as shown in Figure 13 and Figure 14.

Fig. 6: Use bresham's method to spot the shortest path.

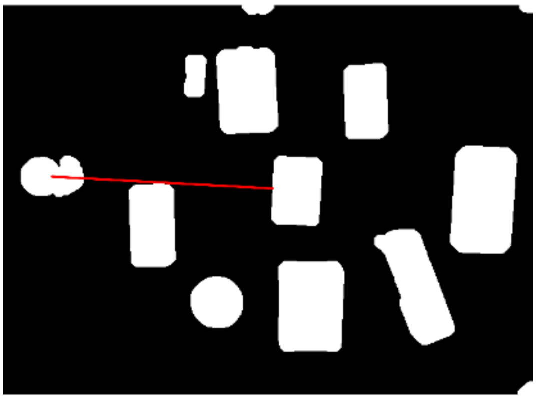

Fig. 7: Calculate the shortest line between source and destination

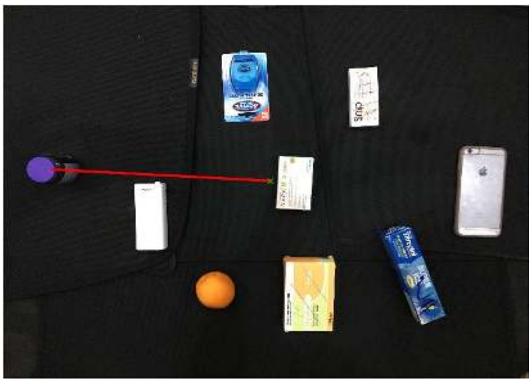

Fig. 8: The shortest path is obtained using the dilated image of objects.

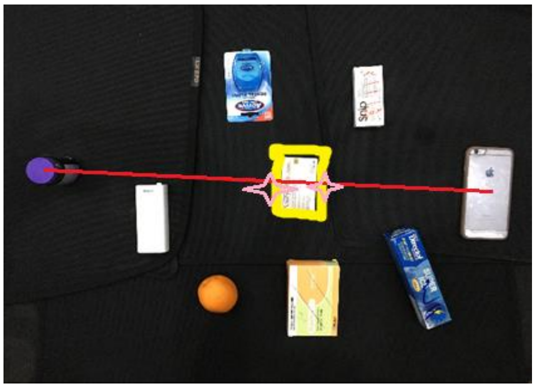

Fig. 9: Checking the shortest line intersected with obstacles

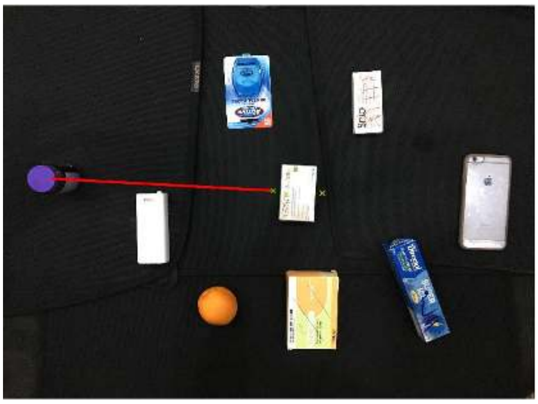

Fig. 10: Two points identified to cross the obstacle

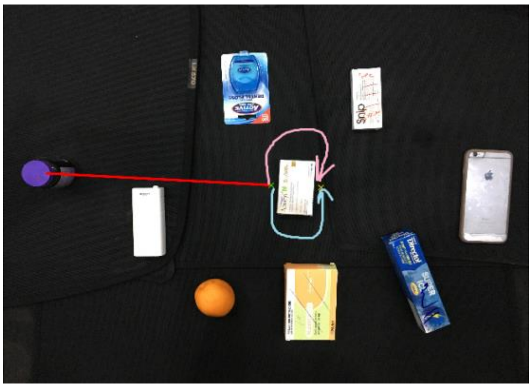

Fig. 11: Possible ways between two points

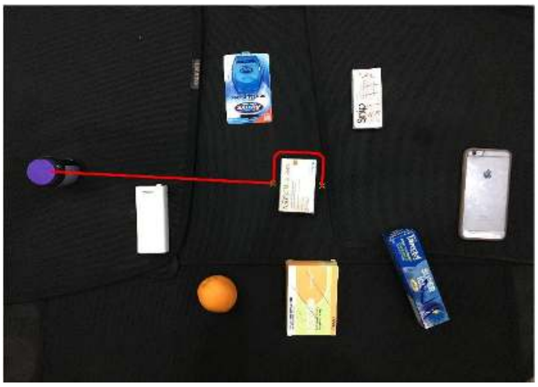

Fig. 12: Choosing the shortest path between two points

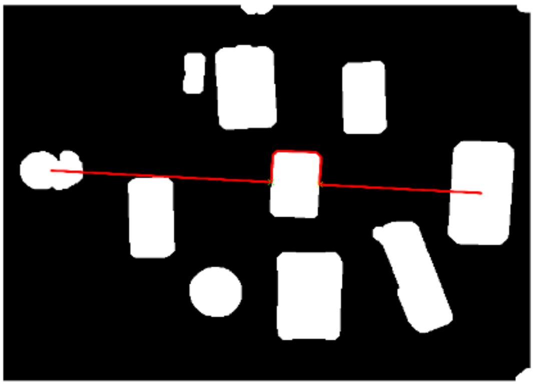

Fig. 13: Path moving forward to its destination (binary)

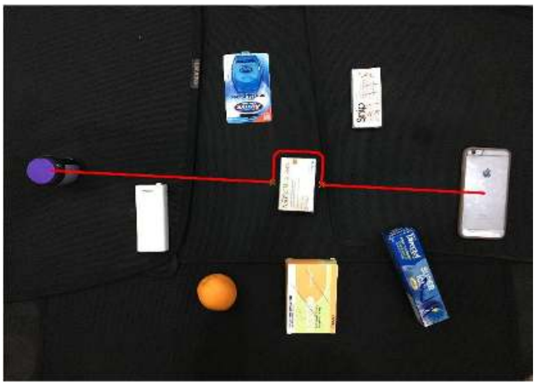

Fig. 14: Path moving forward to its destination (color)

4. Result analysis

The observations from simulations are listed in Table 1. The results of the proposed algorithm are then compared with the conventional algorithm which calculated the distance between two objects without obstacles avoidance according to and the Euclidean distance and the distance with obstacles avoidance according to proposed algorithm. We noted the proposed algorithm reduce time and path length as compared with other techniques. A series of figures staring from Figure 15 up to Figure 22 has been depicted test samples.

Table 1: Simulation results and comparision

Fig	Distance With Obstacle Avoidance (cm)	Distance Without Obstacle Avoidance (cm)	Difference (cm)
15	3.1859e+03	4.7523e+03	1.5665e+03
16	1.3228e+03	2.5053e+03	1.1824e+03
17	1.0262e+03	1.0989e+03	72.7339
18	1.6953e+03	3.3353e+03	1.6400e+03
19	1.5469e+03	1.9327e+03	385.8156
20	880.9230	880.9230	0
21	2.0729e+03	3.1253e+03	1.0524e+03
22	770.8225	770.8225	0

Fig. 15: Tested image 1

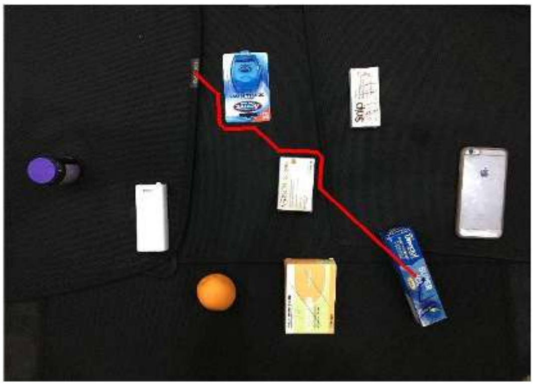

Fig. 16: Tested image 2

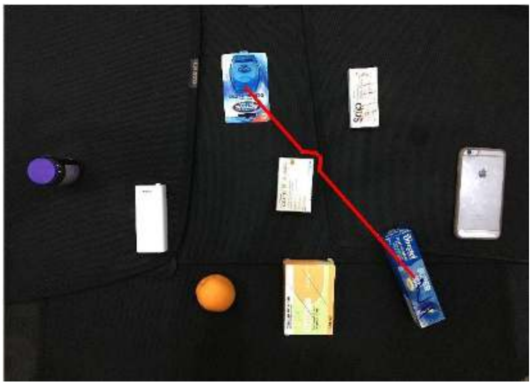

Fig. 17: Tested image 3

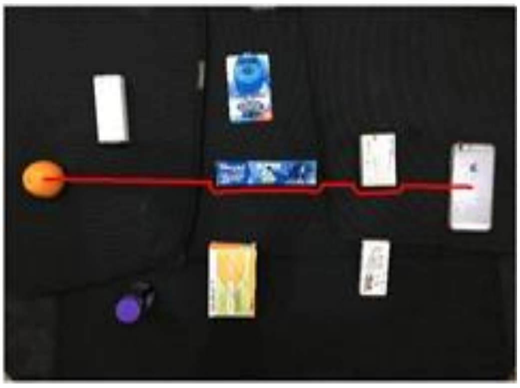

Fig. 18: Tested image 4

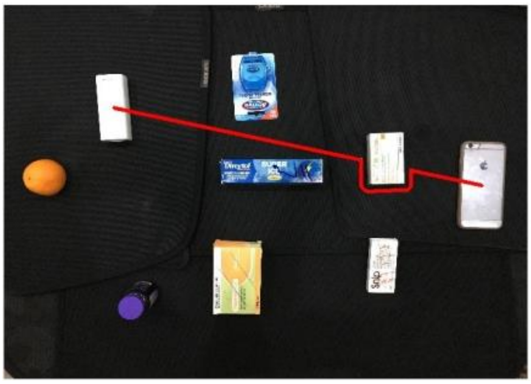

Fig. 19: Tested image 5

Fig. 20: Tested image 6

Fig. 21: Tested image 7

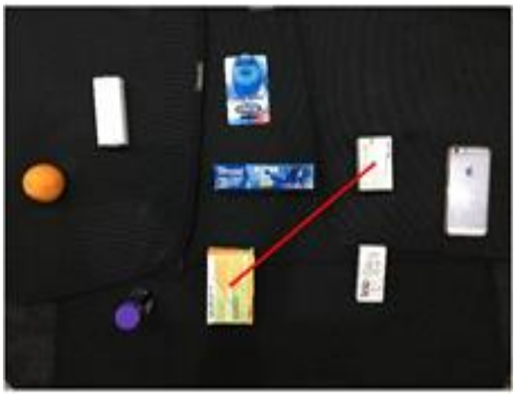

Fig. 22: Tested image 8

The size of robot affects the selection of the mask size (morphological structuring element) used in the shortest path finding process. The proposed algorithm used different sizes for dilation mask. Figure 23, Figure 27 and Figure 31 depicted dilation images using morphological structuring element with specific size. Figure 24, Figure 28 and Figure 32 revealed the shortest path planning for the robot of Figure 23, Figure 27 and Figure 31 respectively. The dilation images by double structuring element size with specified size are revealed in Figure 29, Figure 30 and Figure 33. Accordingly, Figure 30, Figure 32 and Figure 34 have sketched the shortest path planning of Figure 29, Figure 31 and Figure 33 respectively.

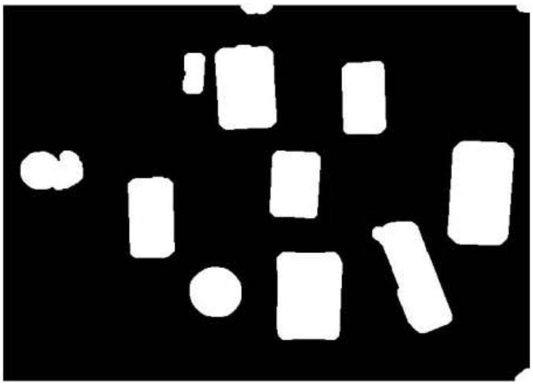

Fig. 23: Dilation image

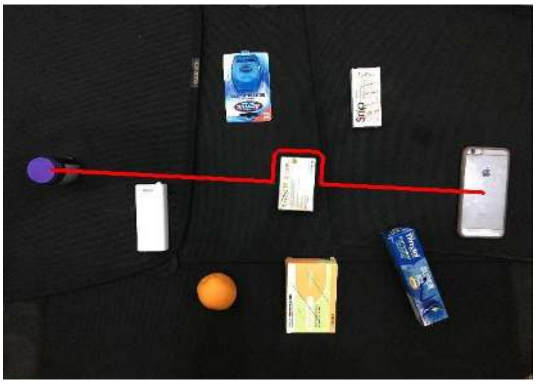

Fig. 24: Shortest path planning

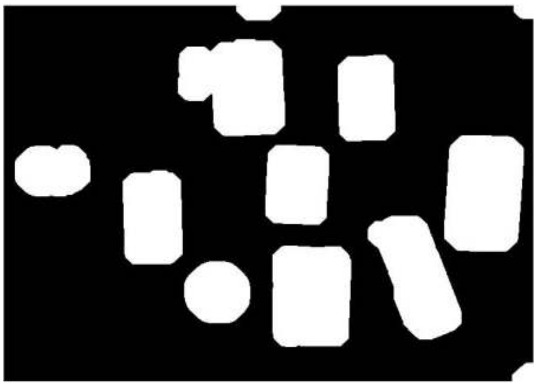

Fig. 25: Dilation image

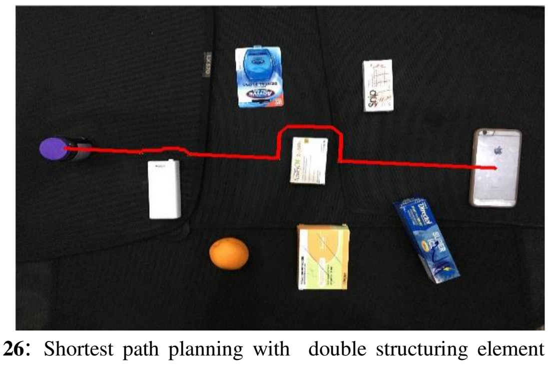

Fig. 26: Shortest path planning with double structuring element with specified size

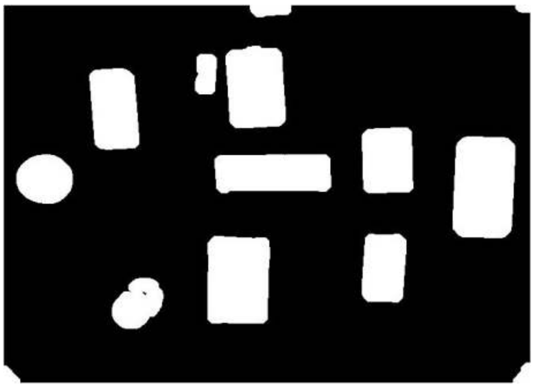

Fig. 27: Dilation image for structuring element

Fig. 28: Shortest path finding

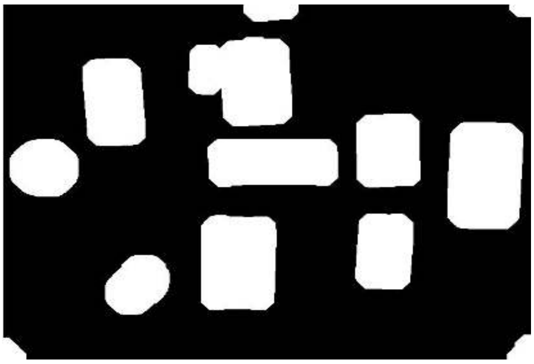

Fig. 29: Dilation image

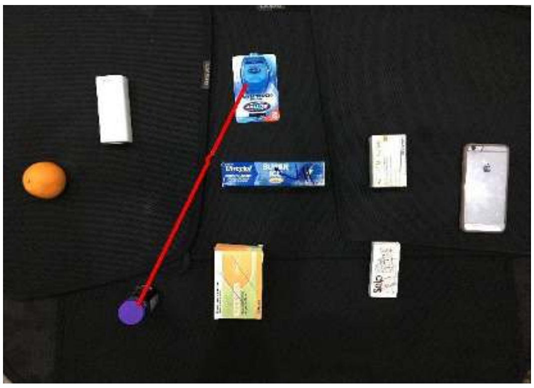

Fig. 30: Shortest path planning with double structuring element with specified size

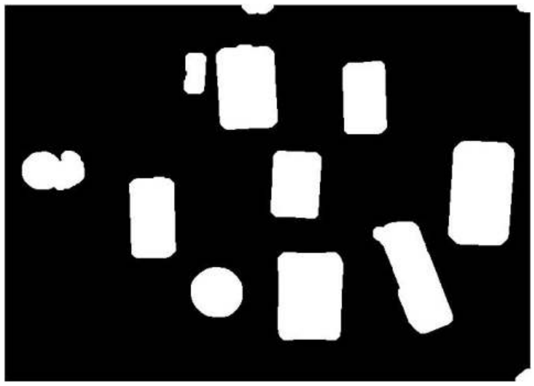

Fig. 31: Dilation image for structuring element with specified size

Fig. 32: shortest path planning for structuring element with specified size

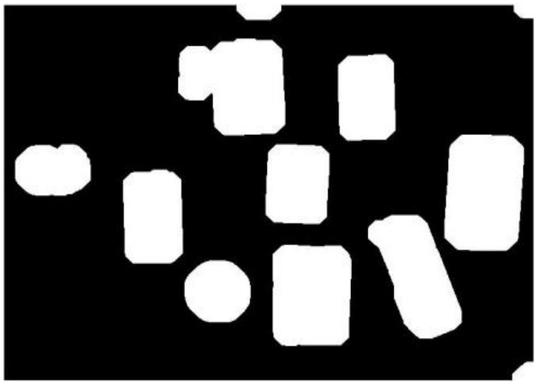

Fig. 33: Dilation image with double structuring element with the specified size

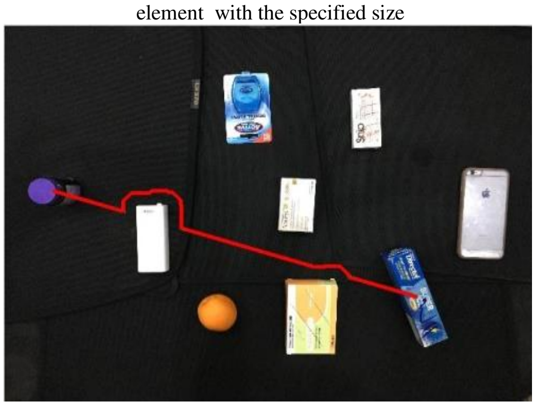

Fig. 34: shortest path planning with double structuring element with the specified size

Table. 2 summarizes the results of the shortest path planning when using morphological structuring element with different size as depicted in a sequence of figures staring from Figure 23 up to Figure 34.

Table 2: Simulation results and Comparison when using morphological structuring element with different size

Figure	Distance with Obstacle Avoidance and specific structuring element size (cm)	Distance with Obstacle Avoidance and double structuring element size (cm)	Difference (cm)
23, 24, 25 and 26	1.6861e+03	3.3687e+03	1.6826
27, 28, 29 and 30	3.1253e+03	5.1110e+03	1.9857
31, 32, 33 and 34	2.5128e+03	4.7523e+03	2.2395

5. Conclusion

A shortest path finding algorithm has been efficiently developed and implemented for mobile robot using single fixed camera. The designed algorithm has been based on morphological structuring element with different sizes The proposed algorithm is implemented using MATLAB software package.

6. Future work

The next of this project would be to adaptive this system to able to identify dynamic obstacles and detect a path to make sure it does not collision happen with the dynamic obstacle. The proposed algorithm may be implemented as a single ASIC or in an FPGA-based system [22] [23] [24] [25]. Addition task would be that the system be able to deal with outdoor environment. A breakthrough approach for shortest path finding may be achieved via fuzzy entropy [26].

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