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Automatic Obstacle Detection for a Star Algorithm using Digital Image Processing

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Abstract

In this paper we propose a system which will automatically detect the obstacle on the proposed route of a moving body using image processing techniques applied on the visual scene. This scene (image) is divided into number of equal parts and each part are checked to find the part of obstacle present in it, then all those segmented parts which is having some portion of the obstacle are taken together and remaining segmented parts are considered as free path, i.e., without obstacle. The output of algorithm is in the form of block identification numbers which represents block containing obstacle. This output can be feed to A* algorithm [1, 2, 3] and automatic mobile robot path planning can be implemented using A* algorithm.

Key words: Visual Scene, Intelligent mobile robot system, Obstacle detection

1. Introduction

An intelligent mobile robot system is a type of autonomous mobile vehicle that is capable to independently plan its own route and navigate through obstacles to reach a specified destination. There is no human input or intervention except apart from specifying the destination point [1].

Obstacle detection is the problem of identifying an obstacle from a visual scene or more generally addressing obstacle queries like, location of obstacles, number of obstacles present, etc. Performing reliable obstacle detection is an important task as it is one of the key requirements for intelligent mobile robot system. To realize a fully autonomous general purpose detection system is still a challenge. Parts of difficulties arise from the visual processing involved as the obstacle can appear in different scale, lighting condition, rotation etc.

Due to invention of sophisticated modern digital camera, digital image processing is now used in path planning of mobile robot [2]. It reduces complexity and cost of mobile robot. Image capture form digital camera can be decomposed and processed for extracting the features on the image. Using a digital image in obstacle detection is less complex and less time consuming as processing of data need not to be performed every time [3]. Application of digital image processing in path planning of mobile robot overcomes the limitations of usage of sensors [4].

A* algorithm is the most popular algorithm for finding shortest path from source to target. A* is an algorithm that is widely used in path finding and graph traversal, the process of plotting an efficiently traversable path between points, called nodes. Starting with it maintain a priority queue [3] of the node. The lower value of F(x) for the given value of node x higher will be its priority. In each step of algorithm it maintains priority queue, lower value for given f(x) higher will be its priority. In each stem of algorithm the node with least value of f(x) will be removed from queue. The algorithm continues till a goal node has lower value of f(x) than any node in the queue or the queue is empty.

Limitation of Sensors

Sonar and IR Sensor used for getting the information of surrounding of mobile robot and creating work space of mobile robot. Sonar sensors have several physical limitations [5] that prevent them from always reliably capturing geometric features from the environment. This limitation arises because the sonar beam does not return to the transmitter. The signal emitting from a range sensor [5] is actually like a cone in space which prevents in getting clear picture of mobile robot workspace.

Other limitations of sensor are, range limit and Sensing Time. Range limits [5] are the limits on the minimum and maximum distances to the obstacle that can be measured by the sensor. Sensing time [5] is time taken by sensor to sense the information i.e. time taken in reaching the mobile robot after reflection. In general, the accuracy of measurement is decreased when the distance to the obstacle is increased. Also, some sensors have an option to adjust the maximum range, such that the sensor resolution varies inversely with the maximum range.

2 Vision Based Mobile Robot Path Planning

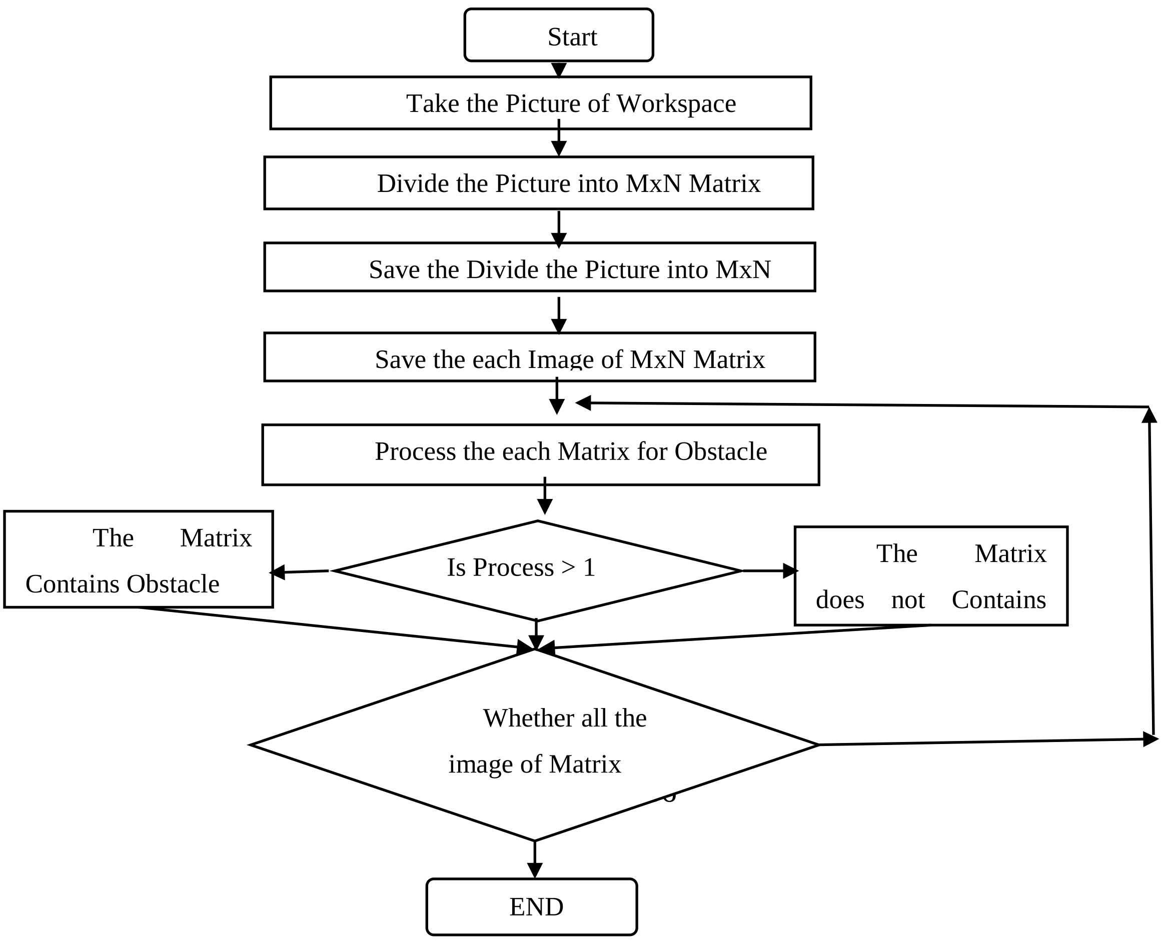
In recent year’s compact, high resolution, cost effective digital cameras are in use. It has opened new area in the field of path planning of mobile robot for obstacle detection. This digital camera known as vision sensors are so compact that it can be very easily mounted on mobile robot. It provides accurate information of workspace of mobile robot. In recent research using digital image processing and computing power of processing devices, effective and relevant information of work space is collected. Using digital image processing techniques, captured image is segmented and each segment is processed for detecting the obstacle.

One such application comes in the field of digital image processing and obstacle detection is grid weight approach [4] which consumes very short image processing time and provides an advantageous solution for images processing in autonomous mobile robots guidance [6-8,14]. The choice of grid weight approach is based on the possibility of their hardware implementation on a single VLSI chip [9, 10, 15].

3 Proposed Method for Obstacle Detection

This proposed algorithm uses vision, which is the processing of images dependent on the still images obtained from the environment to attempt to build a reliable obstacle detection system. “Snap shots” of work space is taken using digital camera of the real work space and the data is processed which ultimately performs obstacle detection. A bottom-up approach was taken to develop the system intended. A bottom-up approach implies that the main problem, i.e., obstacle detection was broken down into smaller and smaller sub-problems so that solutions of such sub-problems can be integrated to obtain the solution of the main problem.

Design Flow Chart for Automatic Obstacle Detection



After reading the image and converting it in gray scale image is divided into an mxn matrix. For dividing the image in specific matrix 'looping' is used. New image is saved for each given output of loop by creating Matlab® function. This will create an image graphics object by interpreting each element in a matrix as an index into the figure's color map or directly as RGB values, depending on the data specified.

```
            for v = 1:n ;
            for s = 1:m ;
startr = (v-1)*rf;
startc = (s-1)*cf;
            for i = 1 : rf
            for j = 1 : cf
Img1 (i,j) = Image (startr+i, startc+j);
            end
            end
```

3 Processing of each Image in matrix for the obstacle detection

After saving all the images in specified matrix, now each segment is processed for detection of the obstacle. For this the standard deviation of the images is taken by creating a function in Matlab® which computes the standard deviation of the array. The function gives the square root of an unbiased estimator of the variance of the population from which array is drawn, as long as array consists of independent, identically distributed samples. If array is a matrix, function returns a row vector containing the standard deviation of the elements of each column of array.

The algorithms used for this process is

$$S= \left(\left(\frac{1}{n-1}\right) \sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{1/2}$$

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$$S' = \left(\left(\frac{1}{n-1}\right)\sum_{i=1}^{n}(s_i - \bar{s})^2\right)^{1/2}$$

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Where $\bar{x}= \frac{1}{n}\sum_{i=1}^{n} x_i$ and $\bar{s}= \frac{1}{n}\sum_{i=1}^{n} S_i$ and 'n' is the number of elements in the sample. The two forms of the equation differ only in (n-1) versus 'n' in the divisor.

The process is done for each image with some condition:

1. If processed image is greater than some value, then it is assumed that it has some part of obstacle or full obstacle.
2. If processed image is less than that value, then it is assumed that it does not contain any obstacle.

In whole process the standard deviation of each image is taken and that value is compared with the standard value of the image.

4 Results

Complete flow of Matlab® program and Results obtained:

i. **Automatic Obstacle detection Page.**

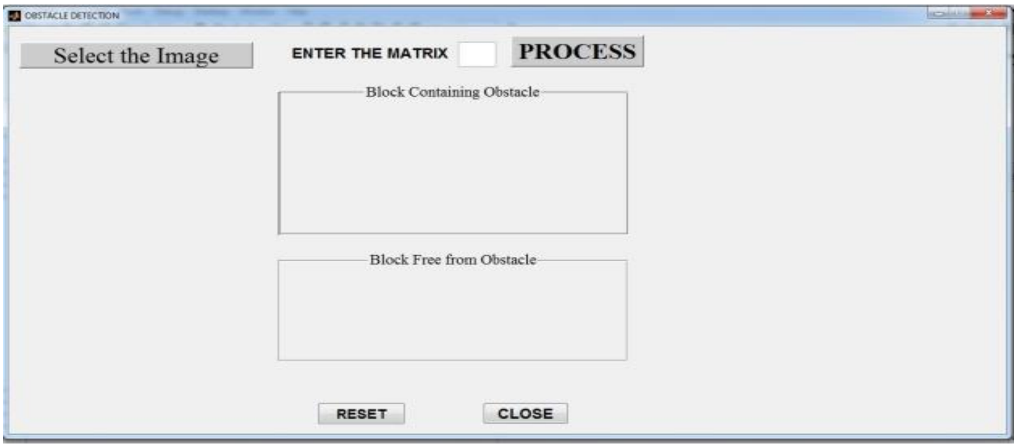

Figure 1 Initial Page for automatic detection of obstacle

ii. **Selection of Image having Obstacle.**

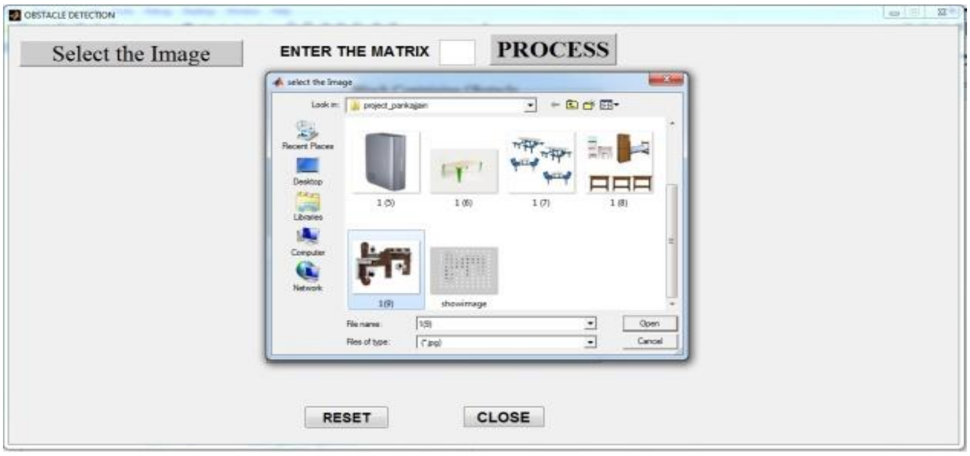

Figure 2 The image is selected which is having obstacle of chairs and table.

iii. Selected Image is shown in axes.

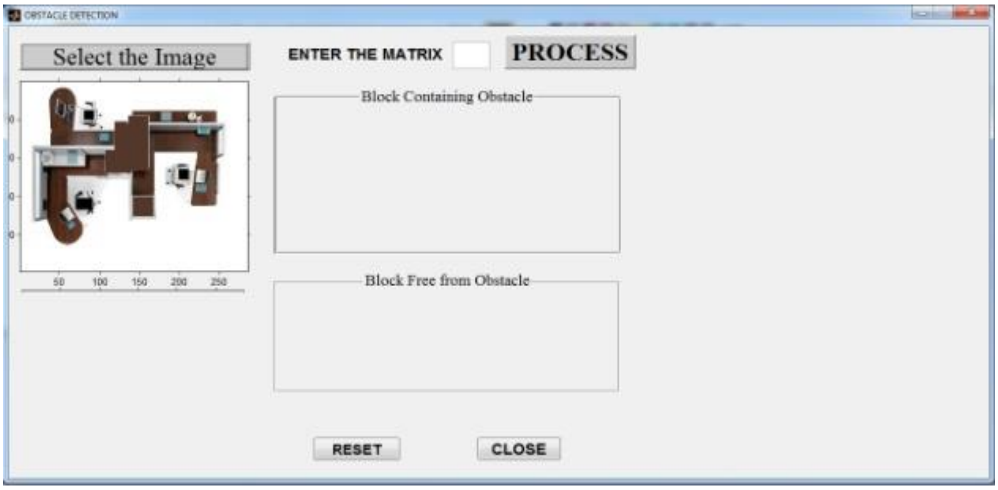

Figure 3 The selected image having obstacle is shown in axes.

iv. Gray converted Image is shown in axes.

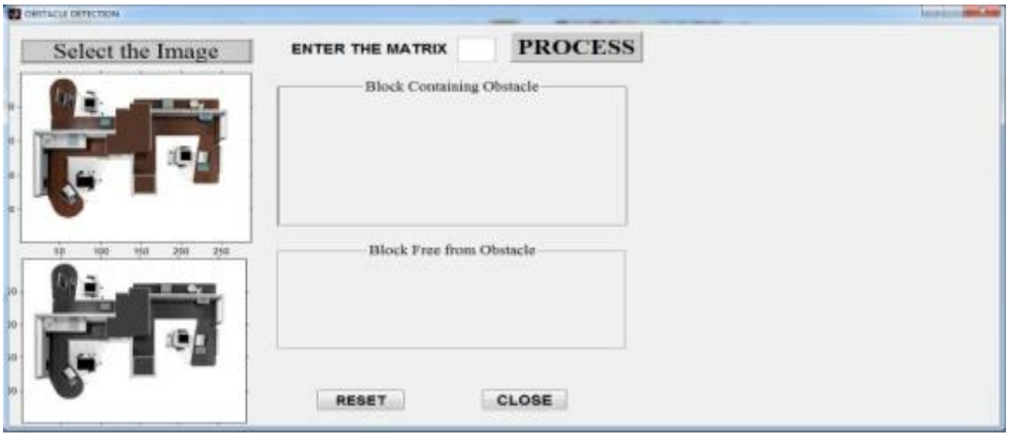

Figure4 Selected image having obstacle is converted into Gray image and shown in axes.

v. Matrix is taken to divide Image into N x M matrix from textbox.

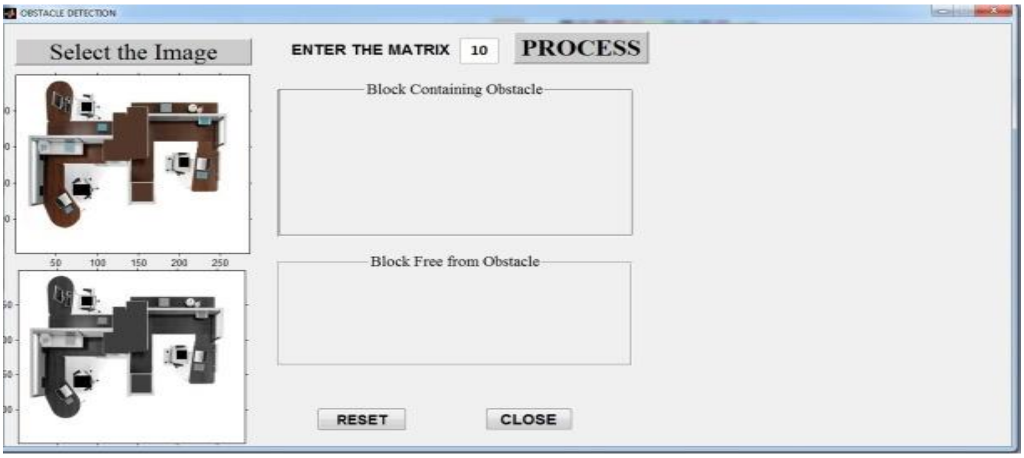

Figure 5 To segment the image matrix is needed ,so 10 x 10 is taken.

vi. **Segmented Image is shown in one of the axes.**

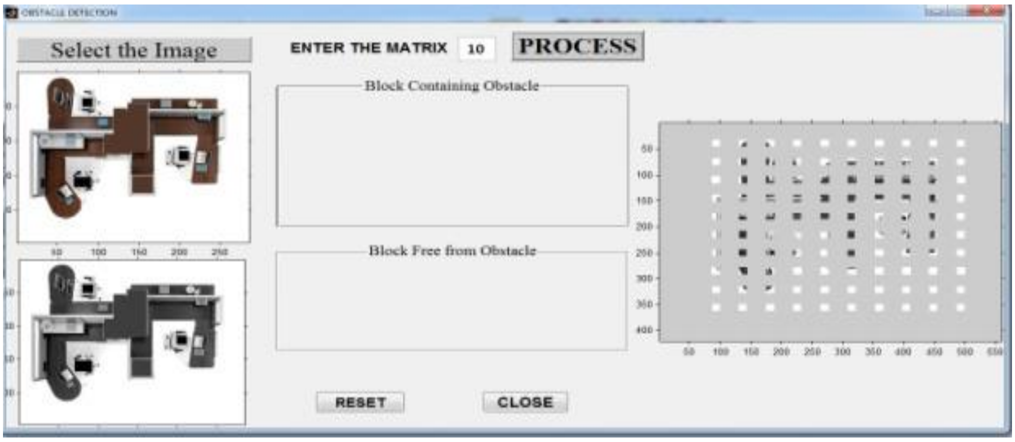

Figure6 Segment 10 x 10 image is shown in axes.

vii. **Each segmented image is processed to find obstacle**

If segmented image is having obstacle shown in one output box.

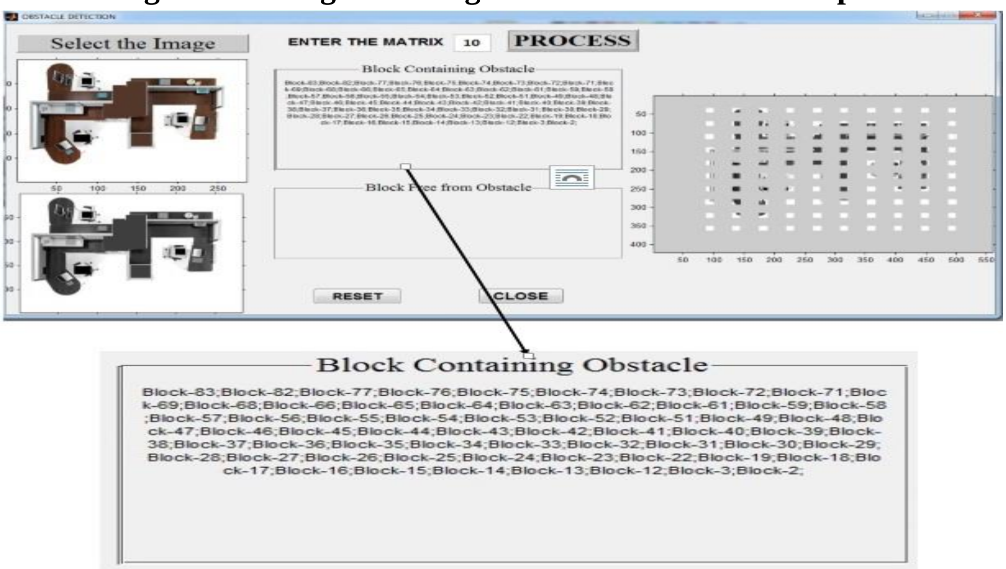

Figure 7 The "Block Containing Obstacle" shown in figure contains the name of the entire segmented block which is having obstacle.

5 Discussion

The main purpose of this work is to identify all the segmented blocks in which obstacles are present and also to locate those segmented blocks which are free from any obstacle.

The Segmentation of image is in block segmentation made (or mode?) in Matlab®, for getting better performance within time. The same result can be obtained using Java coding but the execution time in Java is much higher than that obtained through Matlab coding. It has been observed that there is an improved of 100 seconds as far as the execution time is concerned.

The detection time of obstacle is ~~around~~ also found to be faster than the previous methods like ~~a~~ wavefront based algorithms and Voronoi Diagrams VD(s) [10,11,12] method, as well as detection using individual image pixel.

The output is taken using different threshold levels of processed value and with different matrix value with best output as shown below.

Table 1 Comparison of the results for different processed threshold value

S. no	Threshold Value	Blocks Free from Obstacle	No. of free Blocks	Blocks containing Obstacle
1.	0	0	0	All Blocks
2.	100	All Blocks	64	0
3.	1	1,5,6,7,8,14,15,16,37,38,40, 49,50,51,52,57,58,59,60,61, 62,63,64	23	2,3,4,9,10,11,12,13,17,18,19,20,21,22,23,24 ,25,26,27,28, 29,30,31,32,33,34,35,36,39, 41,42,43,44,45,46,47,48
4.	10	1,5,6,7,8,14,15,16,37,38, 40,42,43,49,50,51,52,57, 58,59,60,61,62,63,64	25	2,3,4,9,10,11,12,13,17,18,19,20,21,22,23,24 25,26,27,28,29,30,31,32,33,34,35,36,39,41, 44,45,46,47,48
5.	50	1,2,3,4,5,6,7,8,14,15,16,18, 20,26,27,32,37,38,39,40,41, 42,43,49,50,51,52,57,58,59, 60,61,62,63,64	39	9,10,11,12,13,19,21,22,23,24,25,28,29,30 31,33,34,35,36,44,45,46,47,48

From the comparison of all the processed threshold values, the best processed value is found to be 10, for getting exact result. So for finding the obstacle in picture it should be segmented into some matrix blocks, but for different matrix we are getting different outputs.

Table 2 Comparison of the results for different matrix block

S. no	Matrix Block	Total No. of Blocks	Blocks Free from Obstacle	No. of free Blocks	Blocks containing Obstacle
1.	4 X 4	16	15,16	2	1,2,3,4,5,6,7,8,9,10,11,12,13,14
2.	6 X 6	36	29,30,31,33,34,35,36	7	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17, 18, 19,20,21,22,23,24,25,26,27,28,32
3.	8 X 8	64	1,4,5,6,7,8,9,40, 46,48,49, 52,53,54,55,56,57,58,59,60,61,62,63,64	24	2,3,10,11,12,13,14,15,16,17,18,19,20,21, 22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,41,42,43,44,45,47,50,51
4.	10 X 10	100	100,99,98,97,96, 95,94,93,92,91,90,89,88,87,86,85,84,81,80,79,78, 77,74,70,67,60,50,40,30,21,20,11,10,9,8,7,6,5,4,1	40	83,82,76,75,73,72,71,69,68,66,65,64,63,62,61,59,58,57,56,55,54,53,52,51,49,48,47,46,45,44,43,42,41,39,38,37,36,35,34,33, 32,31,29,28,27,26,25,24,23,22,19,18,17,16,15,14,13,12,3,2

Conclusion

The objective the present research work was to detect the presence of an obstacle in the path of a mobile robot for a collision free movement of the robot. Using the stated technique, it has been established that the presence of the obstacle in the workspace of the robot can be identified easily and quickly. The proposed algorithm overcome the limitations and problems faced by the well established A* algorithm used for this purpose where the obstacles are identified manually and then the path of the robot is being planned. It is also reiterated that the optimum results can be obtained when segmentation of image is done using 8X8 or 10X10 matrices with a threshold value of 10. However, the limitation of the algorithm is that it will work satisfactorily only when the ambient is flooded with sufficient bright light and the obstacle is static only.

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