Maze Solving Using Image Processing Techniques

***Abstract*—** Maze solving using image processing can be performed using morphological operations where the maze is represented as a binary image, with the walls of the maze represented as black pixels and the paths through the maze represented as white pixels. The technique uses morphological operations, such as erosion and dilation, to extract the structure of the maze. The proposed method solves all the mazes with a single way in and out with less computational cost than previously proposed solutions such as backtracking.

***Keywords*- Image Processing, morphological operations, erosion, and dilation**

I INTRODUCTION

A maze is a complex network of paths or passages designed to challenge individuals attempting to navigate through it. Mazes have a wide range of applications, including entertainment, education, and robotics. Identifying a maze involves recognizing its various pathways, obstacles, and objectives. While traditional methods of solving mazes involve trial and error or systematic approaches, advanced techniques like reinforcement learning and some algorithms like wall follow etc., are used to solve mazes.

Morphological operations are a set of image processing operations that process an image based on its shape. These operations are defined on the pixels of an image, where each pixel is either 0 or 1 (black or white). The basic morphological operations are dilation and erosion.

The authors in the paper [1] discusses the use of morphological operations for feature extraction in fingerprint recognition systems. It describes the steps involved in feature extraction using morphological operations, which also include binarization. The proposed method is effective in extracting accurate features from fingerprint images, which can be used for identification and verification purposes.

Morphological processing is used in this paper [2] to analyse images of coconut tree trunks for the identification of cracks and holes. Morphological operations, such as erosion and dilation, are applied to preprocess the input images and enhance the edges of the cracks and holes. Morphological reconstruction is used to fill the gaps within the cracks and holes. The processed images are then segmented using a thresholding method, and features, such as area, perimeter, and circularity, are extracted from the segmented regions to classify the cracks and holes.

Morphological operations, including erosion, dilation, opening, and closing are used to extract features from colon biopsy images for cancer screening [3]. Combined with texture analysis, features such as size, shape, and texture of cells are extracted and used to classify images as cancerous or non-cancerous, improving detection accuracy.

In this work, a method is proposed to solve maze using morphological operations. The goal of the technique is to find the path from the start point of the maze to the end point. As the already existing techniques mentioned in introduction requires a large computing power and costly in terms of processing the proposed method overcomes the problem as morphological processes are very simple compared to complex algorithms and are very cost efficient in terms of computation.

The remaining sections of the paper are outlined as follows: Section 2 discusses the proposed methodology, Section 3 narrates the implementation and result, and Section 4 summarizes conclusion and future work.

II PREPOSED METHODOLOGY

The proposed method involves the following steps as shown in Figure 1 and is outlined as follows:

1. Load the image of the maze.
2. The loaded image is thresholded to convert it to a binary image.
3. The maze is now converted to binary image, with the walls of the maze represented as black pixels and the paths through the maze represented as white pixels.
4. Next, dilation is applied to the binary image. Dilation is an operation that increases the size of the white regions in the image by adding pixels to the boundaries of the white regions. The structuring element used here is an array with '1's of dimension 1x 7.
5. After dilation, a second morphological operation called erosion is applied to the image. Erosion is an operation that decreases the size of the white regions in the image by removing pixels from the boundaries of the white regions. The purpose of this step is to remove any isolated white pixels that were created during dilation and to ensure that the white regions are connected.
6. Now the image has only one connected region which is the solution path of the maze.
7. Path can be traced from the start to end point.
8. Finally, the solution path found is superimposed on the original binary image of the maze to show the solution.

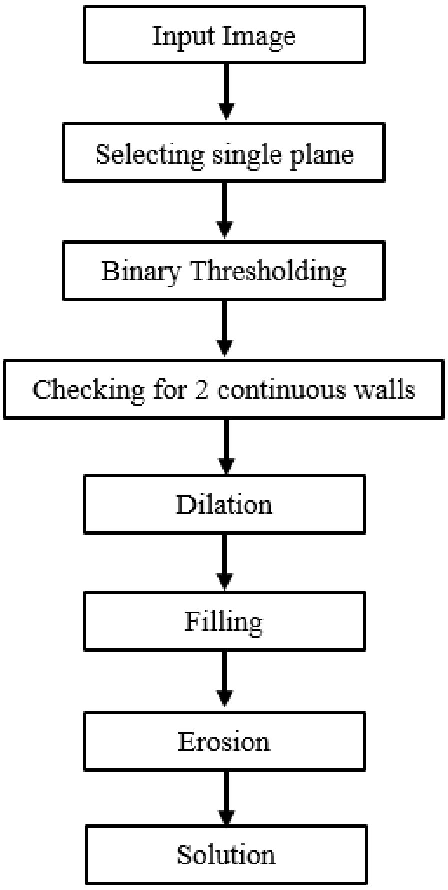

Figure 1: Block diagram of proposed method

III IMPLEMENTATION AND RESULT

First, Original Image of the Maze has been read. Figure 2 shows the sample image of the maze.

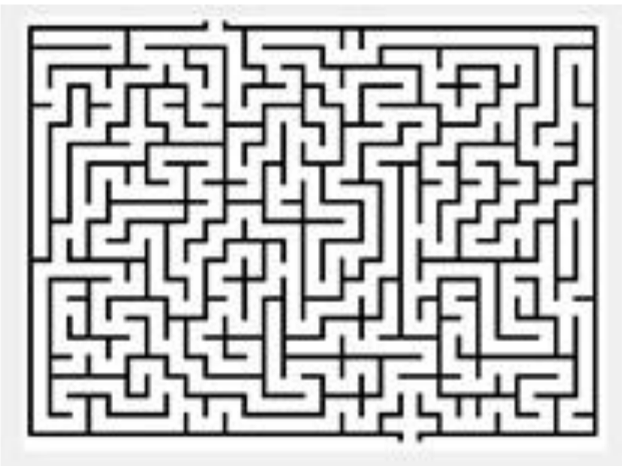

Fig.2: Sample maze

The second step is selecting a single colour plane from the input image. This is done by checking if the image is a combination of RGB and then choosing the most prominent color plane. The selected color plane is then used for further processing and analysis to identify the maze path.

The maze is now converted to binary image, with the walls of the maze represented as white pixels and the paths through the maze represented as black pixels. This is to ensure that all the irregularities in the colours are normalised into only black and white. It is done by setting an optimized intensity limit, where pixels with intensity values less than the limit are set to black, and pixels with intensity values greater than or equal to the limit are set to white.Figure 3 shows the binary thresholded image of the sample maze taken.

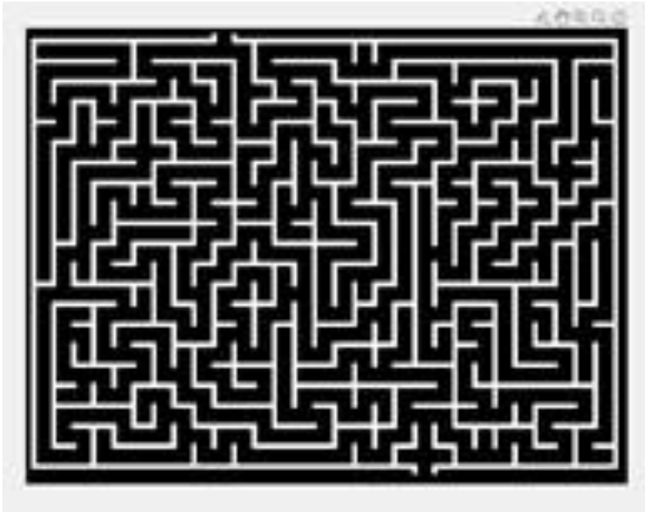

Fig 3: Binary Thresholded Image

Checking whether the maze in Figure 3 is formed with any 2 continuous walls. Checking for two continuous walls is to determine whether the maze contains only one solution, and that is possible only when there are two continuous walls, and all other protrusions are related to one of the walls by some means. Figure 4 shows that the sample maze is formed with continuous two walls i.e., red-wall and cyan-wall, which means the maze has only one solution.

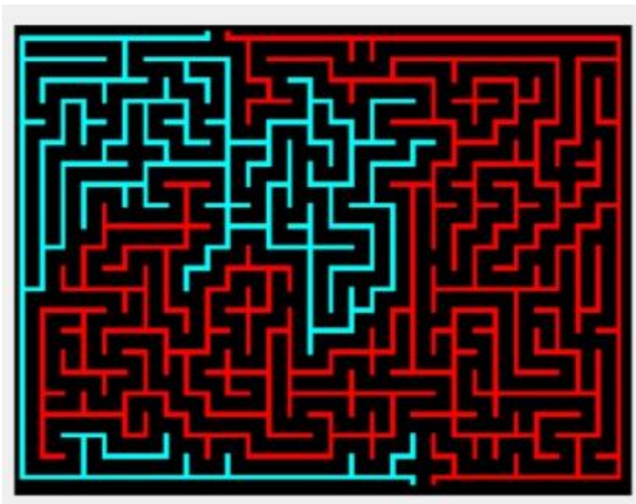

Fig.4: checking for the two walls.

Performing dilation on the maze formed in Figure 4.
Figure 5 shows the resultant wall which is formed after removing one wall from the dilated maze.

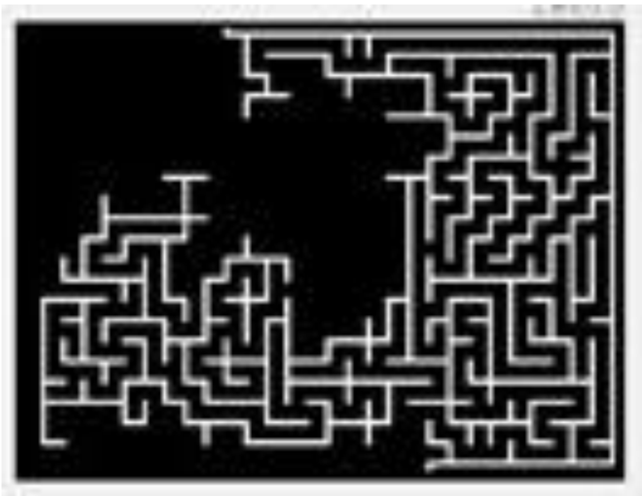

Fig.5: Removing one wall.

The small holes of the resultant maze shown in Figure 5 have been filled, which then generates the maze as shown in Figure 6.

Fig.6: Filling

Erosion has been done on the resultant image Figure 6. Erosion was used to shrink the black pixels and remove small protrusions in the resultant image. Figure 7 shows the eroded maze image.

Fig.7: Erosion

Finally, Subtraction of images was performed. That is, we subtract eroded image Figure 7 from the Dilated Image Figure 6 to Obtain the Solution for the maze.

$$\text{Solution} = \text{Dilated Image} - \text{Eroded Image} \qquad (1)$$

To understand the path clearly one of the layers has been extracted. Blue layer was extracted as shown in Figure 8.

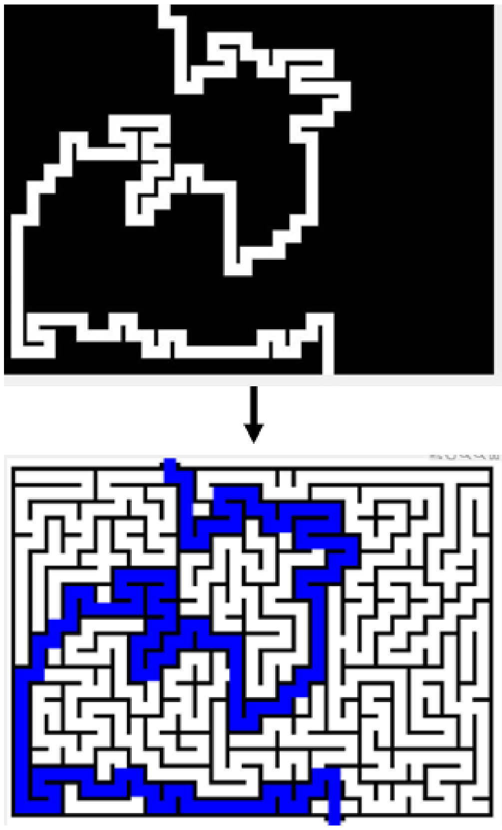

Fig.8: Resulting path of image.

IV. CONCLUSION

In this work, a path for the maze is identified using morphological operations. The proposed method overcomes the complexity in finding path for mazes by applying suitable image processing techniques. This approach is only limited to finding the path of mazes that has only one path. So, work can be extended to overcome the mentioned problem.

Morphological operations can be used in robotics for maze solving, with promising future scope in areas such as autonomous robots, swarm robotics, soft robotics, and educational robotics. By using morphological operations, robots can navigate through mazes more effectively and efficiently. This technology has numerous applications, including search and rescue missions, exploration of hazardous environments, and educational purposes. Combining soft robotics with morphological operations can lead to greater flexibility and dexterity in navigating through mazes. Overall, the future looks promising for the use of morphological operations in maze-solving in robotics.

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