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Obtaining Feasible Paths with Obstacle Avoidance using Watershed Algorithm through Simulation

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Abstract

Objective: To get collision free feasible path for mobile robot application in manufacturing environment based on watershed segmentation technique through simulation using Matlab code. **Methodology:** A Matlab code has been written in order to simulate the collision free path to complete a task by the mobile robot. The watershed algorithm is proposed and implemented for a sample image of a working environment representing different machines as rectangular shapes using Matlab code to obtain water rigid line. **Findings:** The concept of natural watershed is simulated for mobile robot application. Finally, the water rigid lines are obtained using Matlab code. The simulation of this work is tested with different sample images and it works satisfactorily. **Applications/Improvements:** Water rigid lines are considered as collision free feasible paths for mobile robot to perform certain task like material distribution in manufacturing system.

Keywords: Marker Controlled Approach, Water Rigid Line and Obstacle Avoidance, Watershed Algorithm

1. Introduction

The image processing is one of the techniques to adopt in robotic field by many researchers in order to determine feasible paths for robotic application. The analog and digital image processing techniques are also used for this purpose. The analog or visual techniques of image processing can be used for the hard copies like printouts and photographs. The Digital Processing techniques help in manipulation of the digital images using computers. The data on the image may contain deficiency. To get over such deficiencies and to get originality of information, it requires the different phases of processing. The image processing consists of many steps such as image acquisition, pre-processing, segmentation, representation, description, recognition and interpretation. All these stages of image processing are generally necessary to use actual image information to implement real time task like material distribution in a manufacturing environment.

Among the different stages of image processing, the segmentation is one of the most important steps[1] in image processing. Image segmentation is the process of isolating objects in an image from the background, so that each region is homogeneous with respect to some property, such as grey value or texture[2]. Image segmentation means assigning a label to each pixel in an image such that pixels with same labels, share common visual characteristics. There are many techniques available for the image segmentation such as threshold based segmentation, edge based segmentation, region based segmentation, clustering based image segmentation, markov random based segmentation and hybrid techniques[3]. These segmentation methods differ from their computation complexity and segmentation quality. Computation complexity is one of the important criteria for image segmentation, it should be considered carefully in the case of real time image segmentation[4].

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Watershed algorithm which is a morphological method for image segmentation is based on region processing. The watershed algorithm has some unique characteristics over other developed segmentation methods such as the resulting boundaries of objects always form closed and connected regions. The boundaries of the resulting regions always correspond to contours of objects and the union of all the regions, forms the entire image region and it has low computation time in comparison with other segmentation methods[5].

The direct implementation of watershed transforms to a gradient image results in over-segmentation due to noise and other local irregularities. A gradient image is a directional change in the intensity or colour in an image. It may be used to extract information from images. Over-segmentation means a large number of segmented regions on the sample image. A practical solution to this issue is to limit the number of allowable regions using preprocessing technique. Several approaches have been proposed to avoid the over-segmentation such as markers method, region merging methods, scale pace approaches, methods based on partial differential equations for image denoising and wavelet techniques combined with a watershed transformation.

Here, the watershed algorithm is implemented to determine the water rigid line which is used as the path for various applications such as planning the routes on circuit boards, obtaining the hierarchical routes for networks in wireless mobile communication and planning feasible paths for robotic applications.

In[6] developed a methodology to obtain the improved segmented image using random walk process as preprocessor in watershed algorithm. The simulation was performed through Matlab coding for 2D images. Using random walk processor, the segmented image could be improved.

In[7] developed an approach to analyze the hand written text using watershed algorithm, which is used for security purposes. The different features of a hand written images are extracted satisfactorily.

In[8] developed a methodology to obtain an improved segmentation of images using random flooding process as pre-processor with watershed algorithm. The simulation is performed through Matlab coding. It provides continuous and thin closed contours of object in an image.

In[9] proposed a methodology for segmenting the regions in an image and their boundaries of the object were identified by watershed algorithm and difference in strength (DIS) technique. The initial segmentation was obtained using K-means clustering algorithm. The watershed algorithm on the segmented image resulted in over-segmentation. This issue was avoided using difference in strength technique. It provided an accurate edge maps of image with no broken lines and the final edge detection result is one closed boundary as per actual region.

In[10] proposed a watershed algorithm with 1-nearest neighbor (1-NN) classification method to remove irrelevant splitting lines and to merge regions. The 1-NN is used to remove redundant watershed lines and thus merging of regions is possible. This concept is implemented using color image. This proposed algorithm was tested on microscopic histological images for cancer cell detection.

In[3] proposed a technique of watershed algorithm with marker controller approach based on curvelet transform. The pre-processing is performed on an image using marker controlled approach based on curvelet transform which is used to avoid deficiencies and over-segmentation and to enhance the contrast of the image. It may be used in different fields like image analysis, scene analysis and pattern recognition.

In[5] proposed watershed algorithm with topological gradient approach for avoid over-segmentation. The gradient approach was used to avoid over-segmentation and the unwanted contours due to the noise on an image. In this approach, the main edges of the image were detected first and then computed using the watershed of the gradient image.

From the above reports it is inferred that the watershed algorithm results in over-segmentation due to noise and other irregularities. Hence, it is very much necessary to perform a suitable pre-processing operation on the input image before applying watershed algorithm to reduce noise and other irregularities. The Pre-processing converts input image into more suitable image for the further image processing analysis. Many researchers have proposed various pre-processing methods such as gradient approach, marker based, fuzzy based approach, 1-NN approach, K-means clustering, curvelet transform and random walk process.

3. Watershed Algorithm

In watershed algorithm, a digital image is used and the value of each pixel of the image represents the elevation at that point. The object boundaries are defined as higher

elevation region within object and each local minimum elevation region is considered as a separate catchment basin. The imaginary hole is pierced at each local minimum of the catchment basin and water is flooded into the entire catchment basin through imaginary hole. When rising of water in distinct catchment basins are about to merge, a barrier or dam is built to prevent the merging. The barrier or dam considered as a watershed lines or water rigid line6.

3.1 Pre-processing using Marker Approach

The pre-processing is performed for many purposes like noise removal, slant removal, grayscale conversion, binarization and normalization[11]. The direct application of the watershed algorithm may lead to over-segmentation due to noise and other irregularities. It means large number of segmented regions produced in the output image. A solution to this problem is to limit the number of allowable regions by incorporating a suitable pre-processing technique[5].

In this research work, the marker based approach is implemented to control the over-segmentation issue in the output image using user written Matlab code. A marker is a connected component belonging to an image. The marker includes the internal markers, associated with objects of interest and the external marker, associated with the back-ground. The marker selection typically consists of two steps such as pre-processing and definition of a set of criteria that markers must satisfy. The smoothing filter is used in pre-processing for reduce a blur and noise. This step can minimize the effect of small spatial detail (or) to reduce the large number of potential minima (irrelevant detail) which is the reason of over-segmentation[12].

In the marker controlled watershed segmentation, foreground object computed using morphological operators such as opening by reconstruction and closing by reconstruction then background markers are computed using distance transform and finally watershed transform applied on the modified image. The flowchart for marker controlled pre-processing approach is shown in Figure 1.

3.2 Flow Chart for Watershed's Algorithm

In this research work, a representative image of a manufacturing working environment is considered as input for watershed algorithm. Initially, the colour image of the working environment is converted into grayscale image.

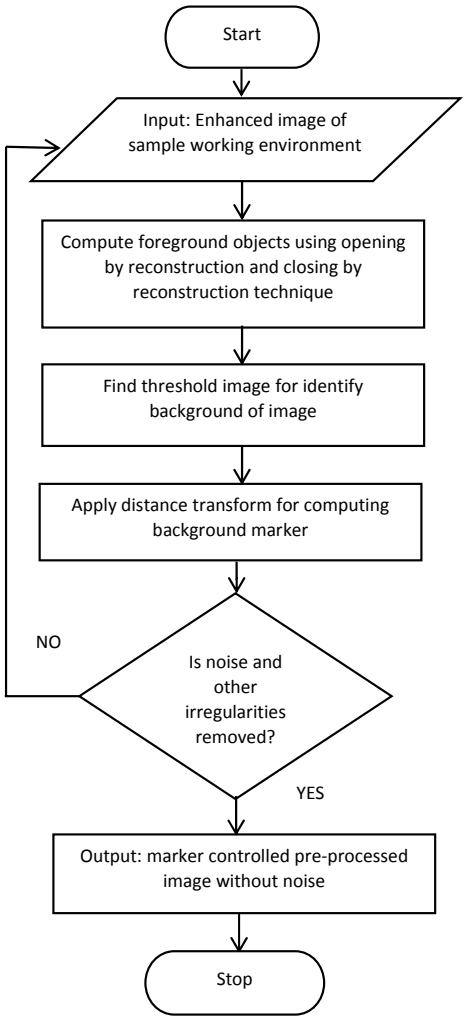

Figure 1. Flowchart for marker controlled pre-processing approach.

Then the edges of objects in the sample image are detected using sobel edge detection method. And, then, the gradient magnitude of image is computed. The gradient magnitude is high at boarders of the edge and low at inside the object. If the watershed transform is directly applied on gradient magnitude image, it results in over segmentation in the output image. So, it needs pre-processing before applying the watershed transform. The foreground marker is computed using opening by reconstruction and closing by reconstruction technique. The background marker is computed using the distance transform technique on the sample image. Then the watershed transform is applied on the sample image and the corresponding water rigid lines are obtained. The flow chart for watershed algorithm is given in the Figure 2.

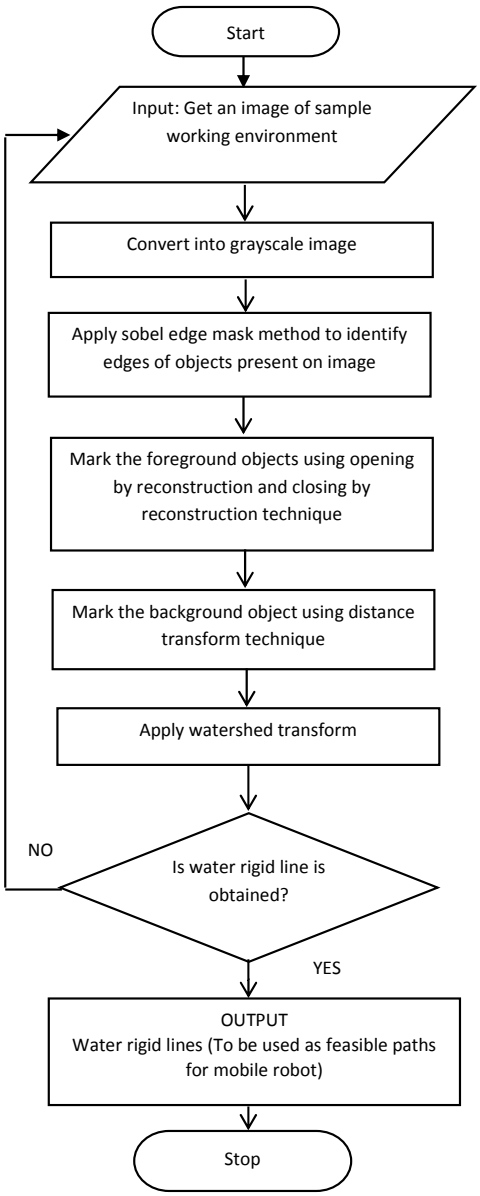

Figure 2. Flowchart for Watershed Algorithm.

4. Simulation of Watershed Algorithm

The simulation of watershed algorithm is implemented for the given working environment consists of different machines through user written Matlab code. In this work, a sample image of a manufacturing environment for material distribution task is considered for simulation purpose. All machines available within the working environment are considered as rectangular in shape for simulation. The simulation of complete work is described in detail.

4.1 Computing Gradient Magnitude

The digital image of a sample manufacturing environment is considered as an input image for the watershed algorithm. In this research work, a sample image is created in colour which represents the real factory environment. In future, the actual or real digital image of factory may be used for this simulation work. The colour image of working environment is converted into grayscale image because it needs only edges not colour information. The edges of object in the input image are detected using sobel edge detection method. The sobel edge method has better noise suppression characteristics compared to other edge detection method[4]. The necessary Matlab code has been written to compute the gradient magnitude.

4.2 Marking Foreground Objects

If the watershed transforms directly applied on gradient magnitude image, it produces over segmented image. Hence, a suitable pre-processing is necessary before applying watershed transform. Here, marker based pre-processing approach is used through Matlab coding. In this approach, the foreground marker is computed using opening by reconstruction and closing by reconstruction technique. Opening by reconstruction is erosion followed by morphological reconstruction. Closing by reconstruction is dilation followed by morphological reconstruction. These are connected blobs of pixels within each of the objects. Reconstruction based opening and closing are more effective than standard opening and closing at removing small blemishes without affecting the overall shapes of the objects.

4.3 Computing Background Markers

The background marker is computed using the distance transform on the input image. The distance transform is used to separate background image from foreground. The threshold of the image is calculated in which the dark pixels are represent background and white pixels represent object in an image. Finally, the background of the image is separate from object using distance transform.

4.4 Applying Watershed Algorithm

The watershed transform is applied on the distance transformed output image and the corresponding water rigid lines are obtained. These water rigid lines are in the form of connected boundaries that separate nearest objects.

The water rigid lines are considered as feasible paths for mobile robot to perform any specified task. Since, many feasible paths are obtained through water rigid line, it will be required some optimization heuristics to obtain optimal path to complete the specified task with relatively less time and distance.

5. Results and Discussions

The watershed algorithm is implemented for the simulated manufacturing working environment shown in Figure 3 which consists of seven different machines with machine identification code from 1, 2, … 7. This sample image of the simulated environment is created only for simulation purpose through Matlab coding. Initially, an image of the working environment is given as input to the simulation coding. The different machines in the manufacturing environment are represented as rectangular in shape for simulation purpose.

The stage output from the Matlab simulation is shown in Figures 4, 5, 6, 7, 8 and 9. The actual image of the working environment is converted in to gray scale image output shown in Figure 4. The edges of the machines are detected using Sobel edge detecting technique of Matlab and the output for the sample image is shown in Figure 5. Then the technique called "image open and close by reconstruction" is applied to the edge detected output image of the working environment and the corresponding output image is shown in the Figure 6. Then the distance transform technique is employed to represent the background and

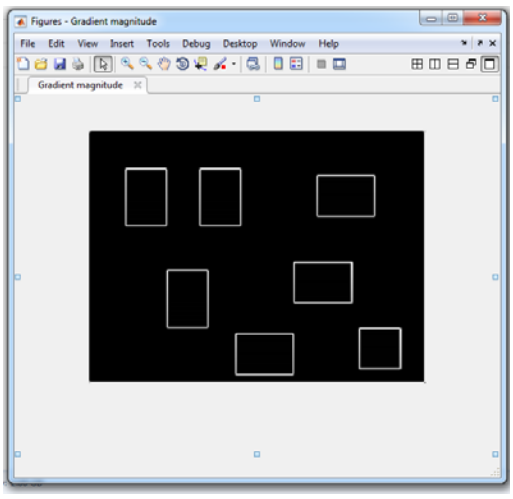

Figure 3. Representation of different machines with in working environment (Sample Image).

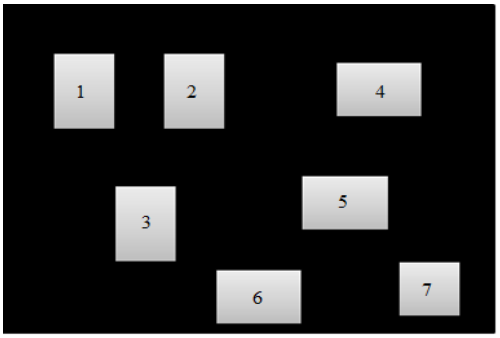

Figure 4. Matlab output - Gray scale image of the environment.

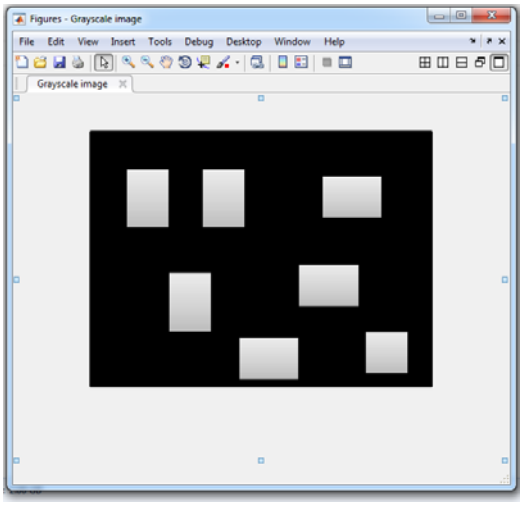

Figure 5. Matlab output image after sobel edge detection technique.

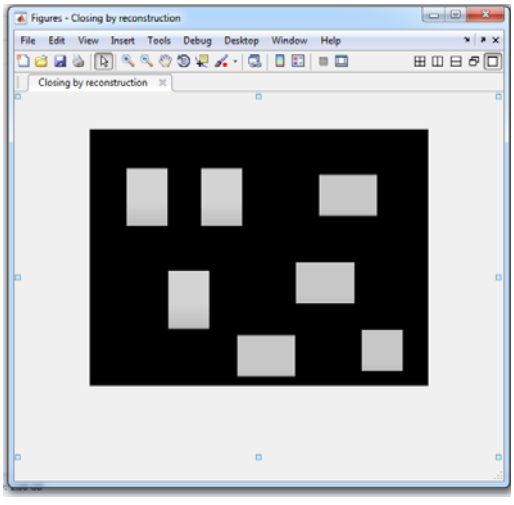

Figure 6. Image after open and close by reconstruction technique.

its corresponding output image is shown in the Figure 7. The watershed transform operation is performed in order to get the watershed line between the machines available within the sample working environment image. The watershed rigid line generated through Matlab code for the sample image is shown in the Figure 8.

The above mentioned water rigid lines are the representative path for the mobile robot in order to complete the specified task within the working environment. Many numbers of different paths may be feasible to get using the water rigid line for the mobile robot application.

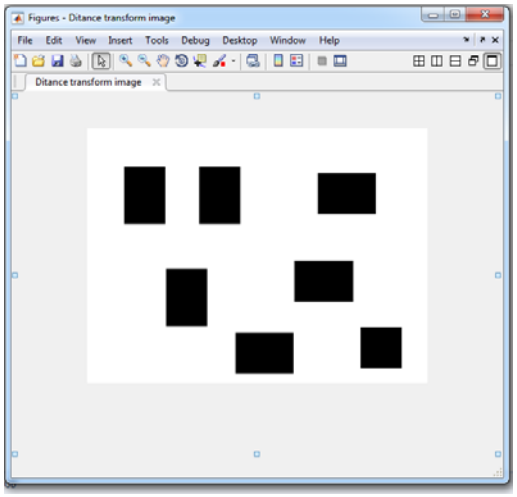

Figure 7. Output image shows the background marker through distance transform technique.

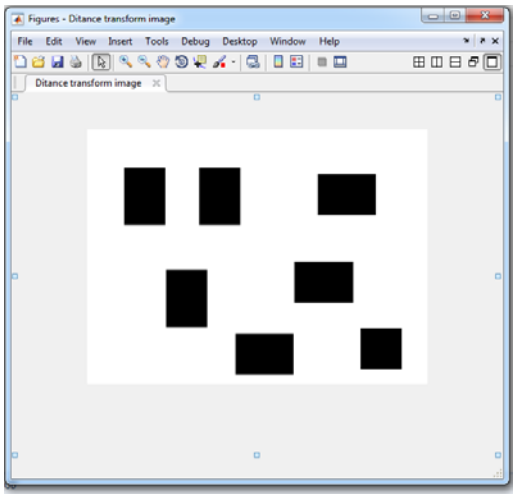

Figure 8. Output image of the environment after watershed transform.

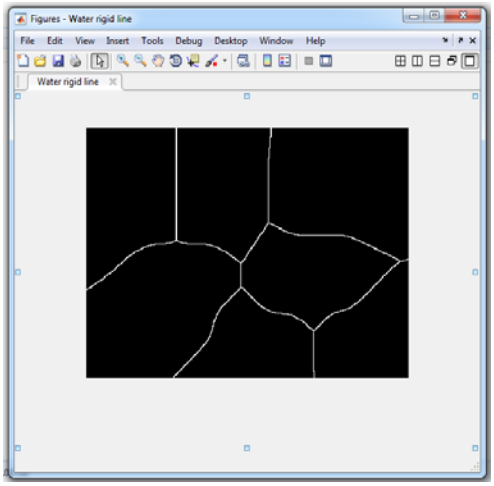

Figure 9. Extraction of water rigid line represents the feasible paths of the sample environment.

Hence, the extraction of only the water rigid line from the output image is required to get all the feasible paths. The extracted water rigid line for the sample image used is shown in Figure 9. When this water rigid line is used as path for mobile robot, the collision with machines and other element present within the working environment is avoided, which is one of the important requirements in case of path planning.

6. Conclusion

The watershed algorithm is proposed along with marker based approach as a pre-processor to obtained feasible paths for mobile robot application. A Matlab code has been written to simulate the watershed algorithm with sample image of a manufacturing environment. The proposed algorithm produces the water rigid line. This water rigid lines are used perform many different applications including mobile robot navigation. This proposed method will generate many feasible solutions for the mobile robot application. Hence, it is planned to implement any one the heuristic algorithm to obtain optimal solution among many feasible solutions.

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