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Image Reconstruction Algorithm Using R-Tree Approach and Delaunay Triangulation

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Abstract: To perform image reconstruction, the significant pixels need to be found. For this image segmentation is performed. Image segmentation can be considered as a cluster procedure in feature space. Each cluster can be encapsulated in a bounding box which contains the connected parts of the edges found using edge-detection techniques like canny, sobel or a combination of both. The boxes can further be stored in R-trees using suitable child – parent relationship. In this paper, we will explore to use a combination of canny and sobel edge detection techniques and then store the edges in R-tree to perform image segmentation. Then Delaunay triangulation is performed to produce the reconstructed image.

Keywords: Image Reconstruction, Edge Detection, R-Tree, Delaunay Triangulation

I. INTRODUCTION

Image segmentation is a process of grouping an image into homogenous regions with respect to one or more characteristics. It is the first step in image analysis and pattern recognition which has been extensively studied for a few decades due to its applications in computer vision such as: Medical imaging (locate tumor), Object detection in satellite image, Face/fingerprint recognition, Traffic monitoring. Online image search engine etc. Image segmentation responsible for extracting semantic foreground objects correctly from a given image, the performance of the subsequent image analysis procedures like retrieval will strongly dependent on the quality of the segmentation.

In our paper we propose to segment an image on basis of its connected edges and store the edges in an R-tree using bounding boxes. The edges found using canny and sobel shall be encased in a rectangle of the least possible size. If a particular rectangle lies fully inside another triangle, then it is said to be the child of the latter. Using this child – parent relationship, an R-tree is formed. Now random sampling of pixels is performed to give the set of pixels for Delaunay triangulations, which produce the reconstructed image

II. DIGAITAL IMAGE PROCESSING

Image may be defined as a 2D function, f(x,y), where x and y are spatial (plane) co-ordinates, and the amplitude f at any pair of co-ordinates (x,y) is called INTENSITY of the image at that point. The term GRAY LEVEL is used often to refer to the intensity of monochrome images. In the Case of gray scale image, the intensity value of each pixel is 0 ~ 255. The field of digital image processing refers to processing digital images by means of a digital computer. Digital image processing is the use of computer algorithms to perform image processing on digital images. Some of the application involves Television Signal Processing,, Satellite Image Processing, Medical Image Processing , Robot Control, Visual Communications , Law Enforcement etc

III. EDGE DETECTION

An edge detection like canny or sobel takes a grayscale image as its input and returns a binary image of the same size, with 1’s where the function finds edges in the original images and 0’s elsewhere. The purpose of edge detection in general is to significantly reduce the amount of data in an image, while preserving the structural properties to be used for further image processing. Several algorithms exists, like John F. Canny (JFC) in 1986 [4]. Even though it is quite old, still it has become one of the standard edge detection methods and it is still used in research [5] [6].

A. Canny:

The canny method finds edges by looking for local maxima of the gradient of image. The gradient is calculated using the derivative of a Gaussian filter. The method uses two thresholds, to detect strong and weak edges, and includes the weak edge in the two thresholds, to detect strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges. This method is therefore more likely to detect true weak edges. Steps involved in canny edge detection are Smoothing, Finding gradients, Non-maximum suppression, Double thresholding, Edge tracking by hysteresis

Figure 1. Edge detection using Canny method

B. Sobel:

The Sobel method finds edges using sobel approximation to the derivative. It returns edges at those points where the gradients of 1 is maximum. In this method all the edges that are not stronger than a default threshold value are ignored, we can also specify our own threshold value. Most edge detection methods work on the assumption that the edge occurs where there is a discontinuity in the intensity function or a very steep intensity gradient in the image. Using this assumption, if one take the derivative of the intensity value across the image and find points where the derivative is maximum, then the edge could be located. The gradient is a vector, whose components measure how rapid pixel value are changing with distance in the x and y direction.

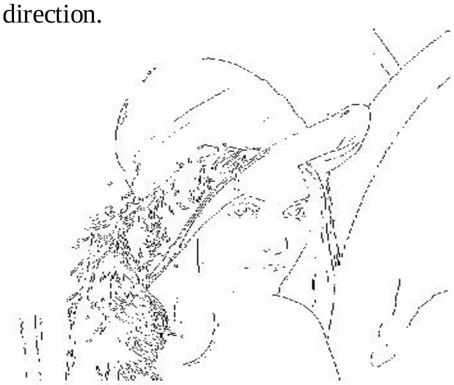

Figure 2. Edge detection using Sobel method

Figure 3. Edge detection using Canny and Sobel mix method

IV. R-TREE APPROACH

The R-tree[8] is one of the more popular approaches for spatial access methods and a number of R-tree variants. The R-tree is simply a hierarchical tree where the higher level node is an MBR (minimum bounding rectangle) that encloses a set of child MBRs or data objects in the lower level.

R-trees are tree data structures that are similar to B-trees, but are used for spatial access methods, i.e., for indexing multi-dimensional information; for example, the (X, Y) coordinates of geographical data. The data structure splits space with hierarchically nested, and possibly overlapping, minimum bounding rectangles (MBRs, otherwise known as bounding boxes, i.e. “rectangle", what the "R" in R-tree stands for). Each node of an R-tree has a variable number of entries (up to some pre-defined maximum). Each entry within a non-leaf node stores two pieces of data: a way of identifying a child node, and the bounding box of all entries within this child node[7].

The R-tree indexing structure is basically constructed of a number of multi-dimensional rectangles, and is balanced dynamically with all the data objects stored in the same level. At the bottom level (Leaf-level), each MBR is generated by enclosing data objects. Each node in the Leaf-level or non-Leaf level is allowed to have a number of children between upper-bound and lower-bond values. There is no minimum number of children required in the root level. The root node can store any number of children up to the maximum child allowance.[9]

Using Canny and Sobel edge detection technique we have found the edges of the image. The edges so found are not fully connected owing to the various kinds of masks applied. The connectivity of the edges changes according to the mask applied. Thus each connected edge is encapsulated in a bounding box of the least possible size. Hence the 2D image is spatially segmented into a set of bounding boxes each with varying dimensions up to the size of the image.

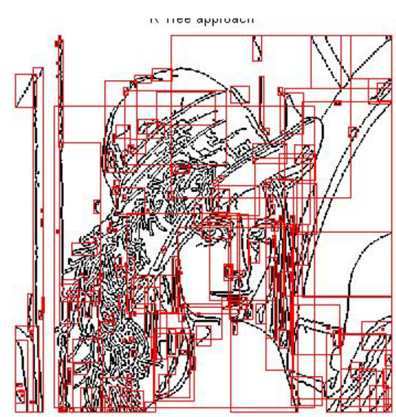

Figure 4. R-Tree Approach

V. DELAUNAUY TRIANGULATION

A Delaunay triangulation for a set P of points in the plane is a triangulation DT (P) such that no point in P is inside the circumcircle of any triangle in DT (P). Delaunay triangulations maximize the minimum angle of all the angles of the triangles in the triangulation; they tend to avoid skinny triangles.

Delaunay triangulation [1] has been extensively used for generation of image from irregular data points. In the Delaunay triangulation method [2][3], the location of the global nodes defining the triangle vertices and then produce the elements by mapping global nodes to element nodes. Element definition from a given global set can be done by the method of Delaunay Triangulation.

For a set of points on the same line there is no Delaunay triangulation. (The notion of triangulation is degenerate for this case.) For four points on the same circle (e.g., the vertices of a rectangle) the Delaunay triangulation is not unique: the two possible triangulations that split the quadrangle into two triangles satisfy the "Delaunay condition", i.e., the requirement that the circumcircles of all triangles have empty interiors.[7]

Delaunay triangulation (DT) can be used to effectively partition the image [10] and simultaneously the tessellation grid of the DT can be adapted to the structure of the image by combining region and edge information. The Delaunay triangulation of a set of points generates regularly shaped triangles and is preferred over alternative triangulations for image segmentation. The DT can be constructed by several methods. Most common is the Incremental Method [11].

To construct the image partition, the triangulation starts with a set of candidate points/vertices distributed over the entire image. These candidates can be found by various edge and corner detection algorithms [12]. Afterwards, the edge pixels are ordered by their significance. Triangulation is a tool that divide a surface into regions with certain common characteristics. The type of these characteristics depends on the type of triangulation. Delaunay triangulation can divide a surface into regions that are particularly well-suited for image processing applications. Because of the inherent geometric qualities of image subjects, it is desirable that any algorithm for dividing an image into a set of regions should be able to model a wide variety of geometries. Triangles are the simplest building block for such models. As such, it is appropriate to use a triangulation to break down or build up an image.[13]

Triangulation divides a surface into a set of triangles, with each triangle edge entirely shared by two triangles. The advantage of using Delaunay triangulation over other types is that it maximizes the minimum angles of the triangles. In this way, the triangles tend toward equiangularity, which avoids having triangles that are very long and thin. Therefore, the resulting triangulation looks geometrically balanced. Aside from equiangularity, Delaunay triangulation is particularly non-restrictive. Thus, it is ideal for interpolation algorithms, which attempt to avoid introducing distortions[13].

The geometric versatility of triangulation as a tool for breaking down and building up images, combined with the particular geometric advantages of the Delaunay version in the interpolation realm, make Delaunay triangulation an ideal component of pixel interpolation algorithms.[13]

Delaunay Triangulation is also popular due to its following properties:[14]

a. It gives a unique set of Triangles T, provided that no four points in S are co-circular,
b. It guarantees optimal triangulation according to the min-max angle criterion, i.e. the smallest angle is maximal.
c. It gives the smoothest piecewise linear approximation for a given data set.

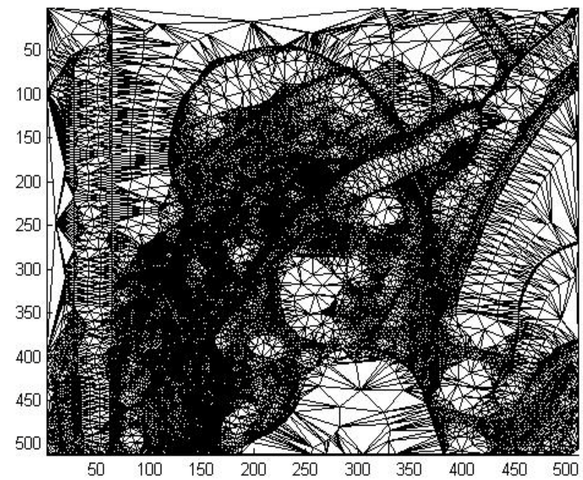

Figure 5. Delaunay Triangulation

VI. MATLAB

MatLab is a high performance language for technical computing. It integrates computation, visualization and programming in an easy to use environment. MatLab is an interactive system hose basic data element is an array that does not require dimensioning. MatLab is complemented by family of applications specific solution called toolboxes. The basic command used here to read the image is imread ('lena.tif'), this command used to read the image from the same directory where the program resides; otherwise we need to initialize the directory path. Once we read the image, using the different commands available for the manipulation of images, we need to implement one by one in the proper order. MatLab provides a very intuitive mode to analyze the image and process them.

VII. ALGORITHM

The algorithm involves following steps:

a) Obtain edged image (canny+sobel)
b) Wherever connectivity breaks a encapsulating bounding box is drawn for the corresponding edge.
c) Compute area of bounding boxes; if area more than threshold(a set minimum value)
d) Then mark the enclosed edge as highly significant.
e) Store the highly significant edge pixels for triangulation and remove them from the image.
f) Reconstruction of Image

VIII. RESULTS

Figure 6. Image Reconstruction after R-Tree Approach

Figure 7. Final image reconstructed

This function displays the PSNR (peak signal-to noise ratio) between two imaged. PSNR is very common in image processing. A sample use is in the comparison on between an original image and a coded/decoded image. A higher PSNR would normally indicate that the reconstruction is of higher quality. It is most easily defined via the mean squared error (MSE) which for two m×n monochrome images I and K where one of the images is considered a noisy approximation of the other is defined as:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2$$

$$PSNR = 10Log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

Table 1 shows the results of PSNR after using the algorithm.

Table 1: PSNR of Different Images

Image	PSNR
Lena	29.3746
Peppers	29.0349
Birdi	30.4326
Mandrill	29.8459
Fruits	31.3847
Goldhill	28.6902
Monalisa	27.7061

IX. CONCLUSION

In this paper we have combined Canny and Sobel Edge Detection techniques by checking the image pixel by pixel. Thus the two images are superimposed onto each other to create an image which contains the edges detected by both Canny and Sobel edge detection techniques. Thus the created image contains the fine details detected by Canny and the strong edges detected by Sobel edge detection technique. For Image reconstruction an approach of R-tee and Delaunay triangulation is applied. The main drawback of this approach is the time consumption. On executing this program in Matlab 7 software, 2 GB Ram, Intel core 2 duo processor. 52 Second were taken. For the future work the time for reconstruction will be huddled either by progressive image transmission or using parallel computing

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