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Extraction of Road from Satellite Images Using Morphology and Active Contours

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Abstract

Road extraction from a satellite image plays a vital role in traffic management, urban planning and GPS navigation after updating maps. Many methods are available for road extraction, which include mathematical morphology, LEGION networks, road vectors, level set and mean shift, etc. A novel method is presented in this paper which uses mathematical morphology, filtering and active contours for extraction of selected part of road. The proposed algorithm is tested on various satellite images of urban areas.

Keywords: *Morphology, edge detection, active contours*

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INTRODUCTION

Road extraction from satellite images plays an important role for improving the lives of people by providing useful information about traffic and navigation. In the study by Wang *et al*., various road extraction methods from remote sensing images are compared in terms of advantages and disadvantages [1]. Automatic road extraction using LEGION networks is proposed in Yuan *et al*. [2]. But the segmentation process does not include smoothening and is very complex. In the study by Ghaziani *et al*., unstructured road extraction using global thresholding and morphology is proposed [3]. But this method does not work well for urban areas which have multiple objects. In the study by Li *et al*., an automatic road extraction technique using road vectors is proposed [4]. However, it requires manual correction for inaccurate roads. Morphology-based road segmentation in urban areas from satellite images with high resolution is proposed by Gaetano *et al*. [5]. But it includes complex morphological operations. Combination of level set and mean shift methods for road extraction is discussed by Revathi and Sharmila [6]. However, it has inaccuracy in terms of unexpected road lines, unidentified road regions in level set method and kernel bandwidth used for mean shift method.

Adaptive Thresholding

When it comes to segmentation for road extraction, the images must be processed after their conversion into binary form. Thresholding is one of the major techniques used for this conversion in which a pixel can be allocated either white or black value. A number of thresholding techniques exist, like method by Otsu, histogram-based, mean-based, etc. But adaptive thresholding realizes best results in case of variations in illuminations on images which are frequently seen in urban areas captured by satellite [7]. After comparing a pixel with average of surrounding pixels, if its value is under the average, it is assigned black otherwise white in this specific method. This method works efficiently as it preserves lines with high contrast but ignores soft changes in gradient.

Noise Removal Technique

Median filter is found to be most efficient in noise estimation. It is found robust to simple line edge structures. It can be used to estimate noise variance as it does not need global features. In addition, median filter helps in smoothening the image while preserving the edges which is indeed important for road extraction.

Morphological Operations

Road extraction becomes a challenging task for multi resolution images due to variability

in road appearance visually and occlusions from objects like trees, buildings, shadows and cars. Mathematical morphology can be used for analyzing the basic structure of any object as well as removing unwanted components in an image. Therefore, all the objects other than road can be removed using morphology by specifying connected components. To highlight the road borders, pixels interior can be also removed with the help of morphology.

Edge Detection

Edge detection plays a major role in extracting features and image enhancement [8]. It helps in filtering out unwanted information while preserving structural properties of an image. It is based on abrupt changes of intensities. Canny, Prewitt, Roberts, Sobel, etc. are the basic edge detectors. Among them, Sobel edge detector is based on convolving the image with an integer-valued, small and separable filter in the vertical and horizontal directions and is very fast in computation. Therefore, edge detection can be used as a post processing step in road extraction to preserve road edges.

Active Contours

In the algorithm proposed by Chan and Vese, there is no requirement of edge function [9]. It works robustly in noisy images. By initializing one contour, all interior contours can be identified automatically in this method. The initial curve's position may be anywhere in the image and may not surround the objects to be detected.

PROPOSED ALGORITHM

The basic steps in the proposed algorithm are:

1. Input Image.
2. Convert into grayscale image.
3. Adjust the image to the threshold intensities of the road.
4. Convert the image into binary image using adaptive thresholding.
5. Filter the image to remove noise using median filter.
6. Remove unwanted objects using morphological operations.
7. Detect the edges using Sobel filter.
8. Merge the original grayscale image with the edge detected final image.
9. Initialize a selected area for road extraction.
10. Apply active contour algorithm (Chan-Vese)
11. Resultant image with extracted road from initialized area.

EXPERIMENTAL RESULTS AND DISCUSSION

The proposed algorithm was applied to images with developed urban area (Figure 1a), developed sub-urban area (Figure 2a), image with connected roads (Figure 3a) and image with multiple roads (Figure 4a). The adaptive thresholding and intensity adjustments according to road gave better results in road identification. Thereafter, morphological operations removed all small objects like buildings, trees, cars, etc. which appeared as occlusions in exact road appearance. Finally the superimposed image of original on final edge detected image (Figure 1b, 2b, 3b and 4b) gave a clear highlight of all the roads (Figure 1c, 2c, 3c and 4c). Active contour algorithm gave the image with active contours (Figure 1d, 2d, 3d and 4d) and final segmented result of road extraction after initializing a selected area in the image (Figure 1e, 2e, 3e and 4e).

CONCLUSION

The proposed algorithm is less in terms of complexity as compared to other methods like LEGION-based, level set and mean shift, road vectors, etc. The basic problem of removing multiple objects causing ambiguity has been solved to a considerable extent. This has given an important role of mathematical morphology in extracting basic structures from an image. This method has proved to be helpful in extraction of selected part of road or roads under selected area in the image. The time consumption of active contour algorithm can be further reduced by an efficient technique based on automation. It can be modified also by region growing technique which segments the image on basis of selected seeds by the user.

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Fig. 1: *Proposed Algorithm Applied on an Image with Developed Urban Area. (a). Original Image, (b). Final Edge Detected Image, (c). Merged (Original and Edge Detected), (d). Image with Active Contours, (e)Final Extraction of Road.*

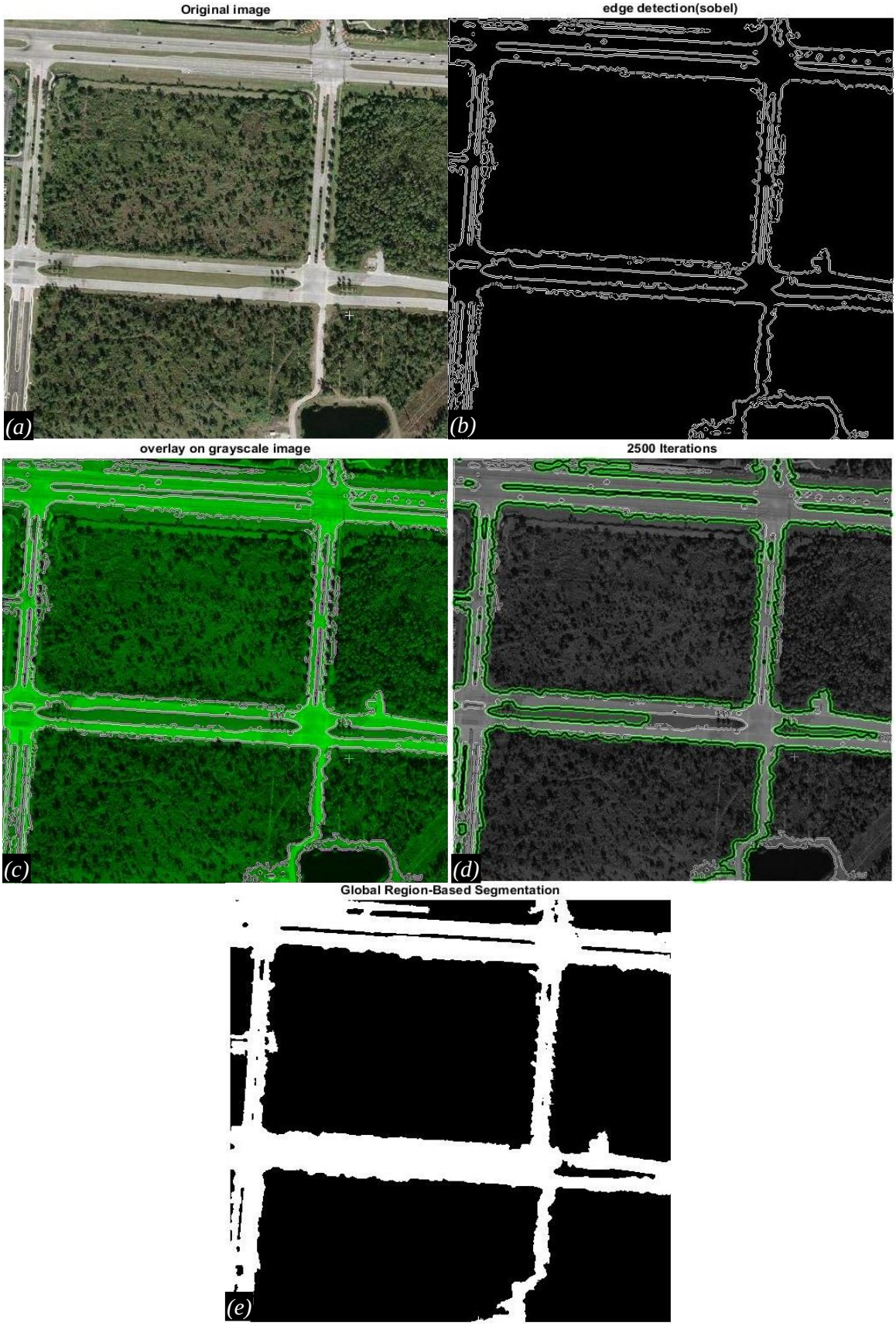

Fig. 2: *Proposed Algorithm Applied on an Image with Developed Sub-Urban Area. (a). Original Image, (b). Final Edge Detected Image, (c). Merged (Original and Edge Detected) Image, (d)Image with Active Contours, (e). Final Extraction of Road.*

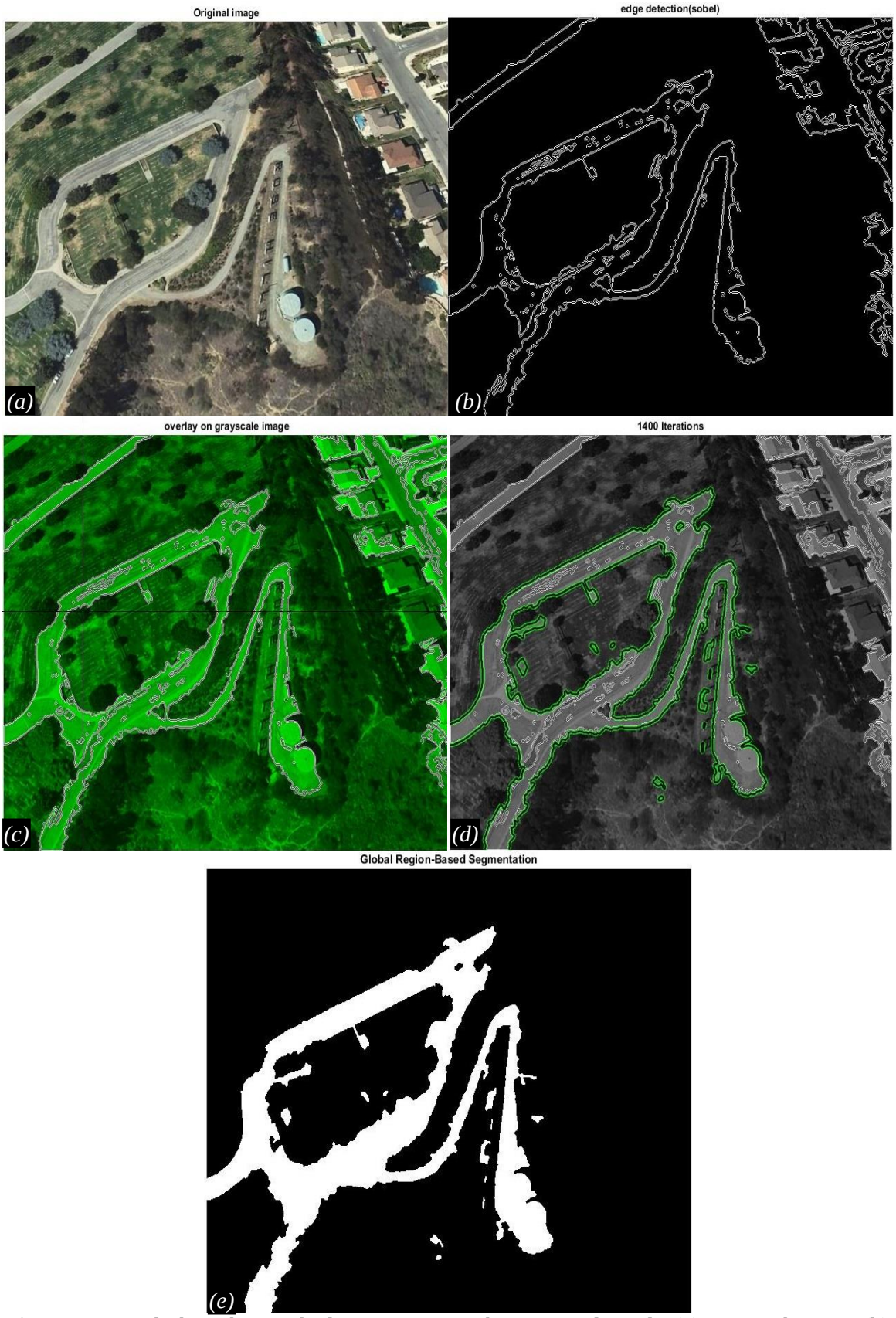

Fig. 3: *Proposed Algorithm Applied on an Image with Connected Roads. (a). Original Image, (b). Final Edge Detected Image, (c). Merged (Original and Edge Detected) Image, (d)Image with Active Contours, (e)Final Extraction of Road.*

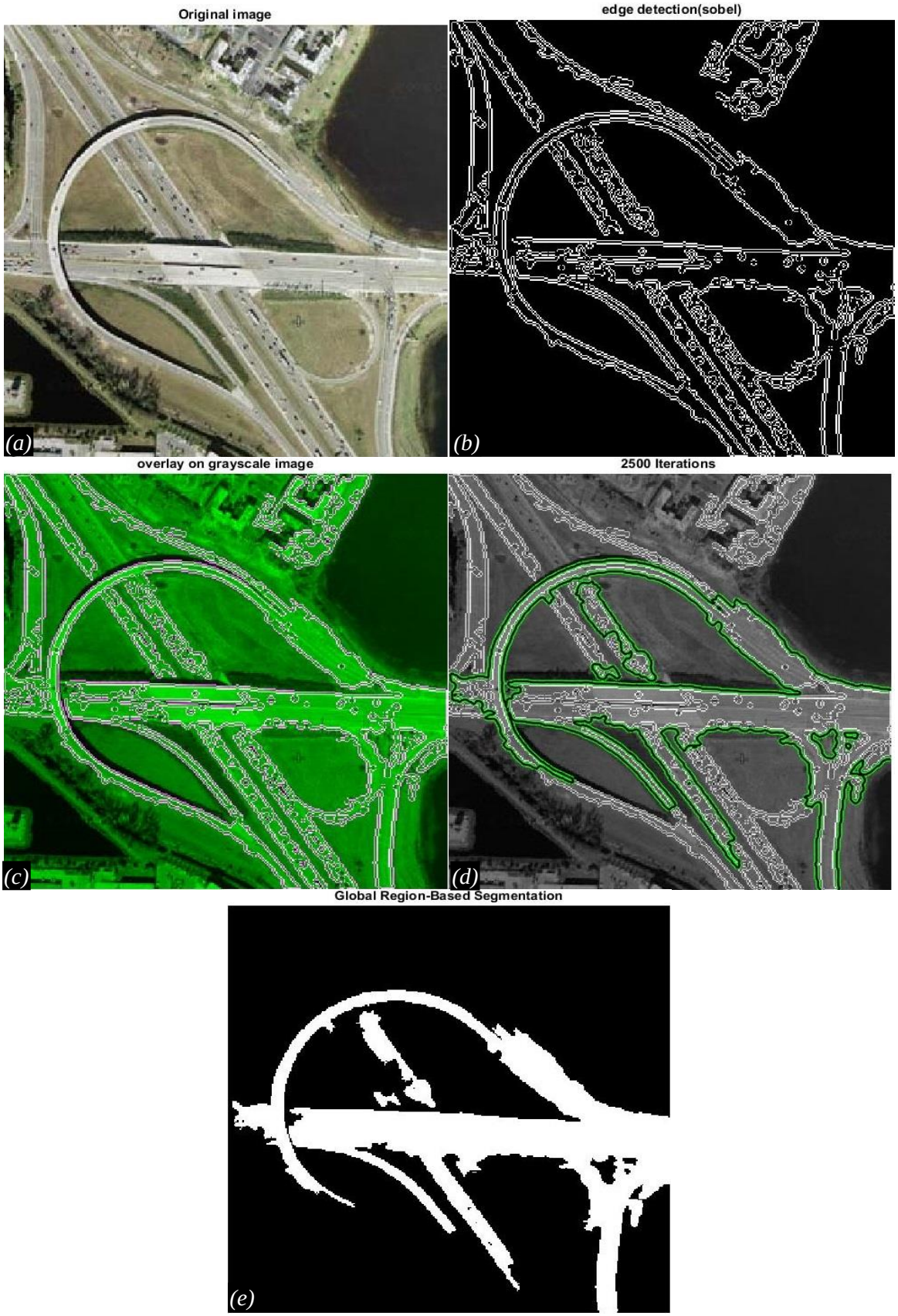

Fig. 4: *Proposed Algorithm Applied on an Image having Multiple Roads. (a). Original Image, (b). Final Edge detected Image, (c). Merged (Original and Edge Detected) Image, (d). Image with Active Contours, (e). Final Extraction of Road*

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