Major Project

On

Road Extraction
from a High-Resolution Satellite Image

By

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On

Road Extraction from a High-Resolution Satellite Image

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology in Computer Science & Engineering

By

Dave Deep S.
(06MCE004)

Under Guidance of

Dr. A. R. Dasgupta
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DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING
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May 2008

This is to certify that Dissertation entitled

Road Extraction from a High-Resolution Satellite Image

Submitted by

Deep Dave

has been accepted toward fulfillment of the requirement for the degree of Master of Technology in Computer Science & Engineering

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CERTIFICATE

This is to certify that the project report compiled by **Mr. Deep S. Dave** student of **Master of Technology (Computer Science & Engineering)** belonging to **Institute of Technology, Nirma University, Ahmadabad** is original and bonafide work has been carried out by him. He has worked on **"ROAD EXTRACTION FROM A HIGH-RESOLUTION SATELLITE IMAGE"** for the duration of 8 months, starting from September 01, 2007 to April 30, 2008.

During his tenure at this Institute, he was found to be sincere and meticulous in his work. We appreciate his enthusiasm and dedication towards the work assigned to him.

We are hopeful that he will prove to be a good professional and wish him a grand success for his future.

Dr. A. R. Dasgupta
Distinguished Professor,
BISAG, Gandhinagar
Date : __________

Tejpal Singh
Director,
BISAG, Gandhinagar
Date : __________

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ABSTRACT

An efficient and general software for getting the idea of the road network in a given satellite image (normally a .tiff file) is to be developed. Satellite images are normally in .tiff file format which is most suitable where the information in the image is of more concerned. In color-based classification, the intensity values are specified for a particular set of objects. The image is then converted to bilevel format with the specified objects being highlighted. The satellite images are in RGB format. Existing algorithms suffer from defects of being slow and memory intensive. Therefore the main objective is to develop efficient software for extracting the road network in a given image automatically & semi-automatically with minimized user interaction. This dissertation presents algorithms for extracting the road network from satellite images in a platform independent language.

CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

RS	Remote Sensing
GIS	Geographic Information System
GPS	Global Positioning System
RGB	Red, Green & Blue components
JPG	Joint Photographic Experts Group
PNG	Portable Network Graphics
BMP	Bit Map Pixel
TIFF	Tagged Image File Format
IFD	Image File Directory
ASCII	American Standard Code for Information Interchange

1. INTRODUCTION

1.1 General

Bhaskarachrya Institute for Space Applications and Geo-Informatics (BISAG) is an organization which identifies & satisfies the needs of Gujarat state by facilitating the use of Remote Sensing (RS) [9], Geographic Information System (GIS) [9] and Communication Technology. It has also extended its work to Global Positioning System (GPS) [9].

The main objective of the organization is to establish and to carry on the administration and management of BISAG so that various developmental planning activities pertaining to agriculture, soil and land use, urban land use, water resources, water shed, marine applications, forest & environment, geology, training of grass-root level functionaries through satellite communication, etc. can be carried out effectively and economically.

It has a singular purpose to identify & satisfy the needs of Gujarat state by using remote sensing, GIS technology & satellite communication. It has mandate to apply the state of the art technology to create the GIS based decision support system for various infrastructure & resource utilities in Gujarat & promote, train & help users to establish their own GIS facility using satellite communication. To do all such activities, BISAG is armed with Scientists & Engineers.

A major area in which BISAG works is GIS (Geographical Information System). GIS[9,10] is used for digital databases & decision support systems. Here the databases can be represented graphically and then based on these databases, various types of decision support systems can be developed. Another major area is GPS (Global Positioning System).

On approaching the higher authorities, the various projects that the organization required came into light. On going through all the projects, the road extraction from a high-resolution satellite image[3,8] was found to be a very challenging job and so it was accepted by me. The job requires to find a road network in the given image.

1.2 Objective

Roads are so far the best means of transportation in the country. They are the best way to connect the most remote locations. The country has the largest rail network in the world but, still roads are the most suitable way to reach out to the remote places. So, getting the idea of the road network in a particular region is one of the important tasks.

In color-based classification, the RGB values are specified for a particular set of objects. The image is then converted to bilevel format with the specified objects being highlighted.

The main objective is to develop efficient software for extracting the road network in a given image automatically & semi-automatically to reduce the human efforts.

1.3 Scope

Conversion of any kind of image in .tiff file format will help the software to perform the next steps efficiently and effectively. The process of extracting the object of interest (here Road), is then applied to these images. The software takes any kind of image as an input and gives a .tiff image as an output. If the object is found properly, it can help in a very clear analysis of satellite data and in some cases even help in developing the roadmaps. E.g. the user may get the idea of connectivity in a given image.

The tasks performed by the software are:

1) Conversion of input image in .tiff file format if the input image is of format like .jpg, .png, .bmp, etc
2) Conversion of the .tiff image into a bilevel image based on intensity values.
3) Applying necessary algorithms to get the desired result.

1.4 Outline of thesis

This thesis is organized as follows:

- Chapter 2 provides the brief introduction about Geographical Information System (GIS) i.e. what is a GIS? , how GIS works? , how is it useful? , etc. It also gives some introduction about the Satellite Images [3,8]. Some of the special characteristics of the Satellite Images are given. The chapter gives a brief idea of TIFF[5] file format. Information regarding RGB Full Color TIFF Images is also given.

- Chapter 3 explains the steps for feature detection and the principles used for that. It gives some basic idea about Image Processing and one of its fundamental step i.e. Morphological Image Processing.

- Chapter 4 contains the details about the implementation. It covers the initial efforts to get the desired results, the complete flow of the final system and algorithms used at each step in the flow of the system.

- Chapter 5 presents the results for different test images. These test images are of different categories. An effort has been made to cover all possible categories in this section.

- Chapter 6 provides conclusion of the current work and possible directions for relevant future research.

2. LITERATURE SURVEY

2.1 Introduction to GIS

Geography is information about earth's surface and the objects found on it, as well as a framework for organizing knowledge. GIS[9,10] is a technology that manages, analyzes and disseminates geographic knowledge.

GIS is a technology that is used to view and analyze data from a geographic perspective. The technology is a piece of organization's overall information system framework.

GIS links locations to information (such as people to addresses, buildings to parcels, or streets within a network) and layers that information to give you a better understanding of how it all interrelates. You choose what layers to combine based on your purpose.

Most computer technologies are designed to increase a decision-maker's access to relevant data. GIS goes beyond mining data to give you the tools to interpret data, allowing you to see relationships, patterns, or trends intuitively that are not possible to see with traditional charts, graphs, and spreadsheets.

More than that, a GIS lets you model scenarios to test various hypotheses and see outcomes visually to find the outcome that meets the needs of all the stakeholders. For example, a retail manager looking to build a new store can analyze consumer demographics and the locations of competitors in relation to potential locations on a map along with drive-time analysis, environmental concerns such as wetlands or protected species that might hamper construction, or any number of siting criteria that would be too cumbersome to comprehend otherwise.

2.2 TIFF File Format

TIFF[5] is an image file format. A *file* is defined to be a sequence of 8-bit bytes, where the bytes are numbered from 0 to N. The largest possible TIFF file is 2**32 bytes in length. A TIFF file begins with an 8-byte *image file header* that points to an *image file directory* (*IFD*). An image file directory contains information about the image, as well as pointers to the actual image data.

A TIFF file begins with an 8-byte image file header, containing the following information:

Bytes 0-1: The byte order used within the file. Legal values are:
"II" (4949.H)
"MM" (4D4D.H)
In the "II" format, byte order is always from the least significant byte to the most significant byte, for both 16-bit and 32-bit integers. This is called *little-endian* byte order. In the "MM" format, byte order is always from most significant to least significant, for both 16-bit and 32-bit integers. This is called *big-endian* byte order.

Bytes 2-3: An arbitrary but carefully chosen number (42) that further identifies the file as a TIFF file.
The byte order depends on the value of Bytes 0-1.

Bytes 4-7: The offset (in bytes) of the first IFD. The directory may be at any location in the file after the header but *must begin on a word boundary*. In particular, an Image File Directory may follow the image data it describes. Readers must follow the pointers wherever they may lead.

The term *byte offset* is always used to refer to a location with respect to the beginning of the TIFF file. The first byte of the file has an offset of 0.

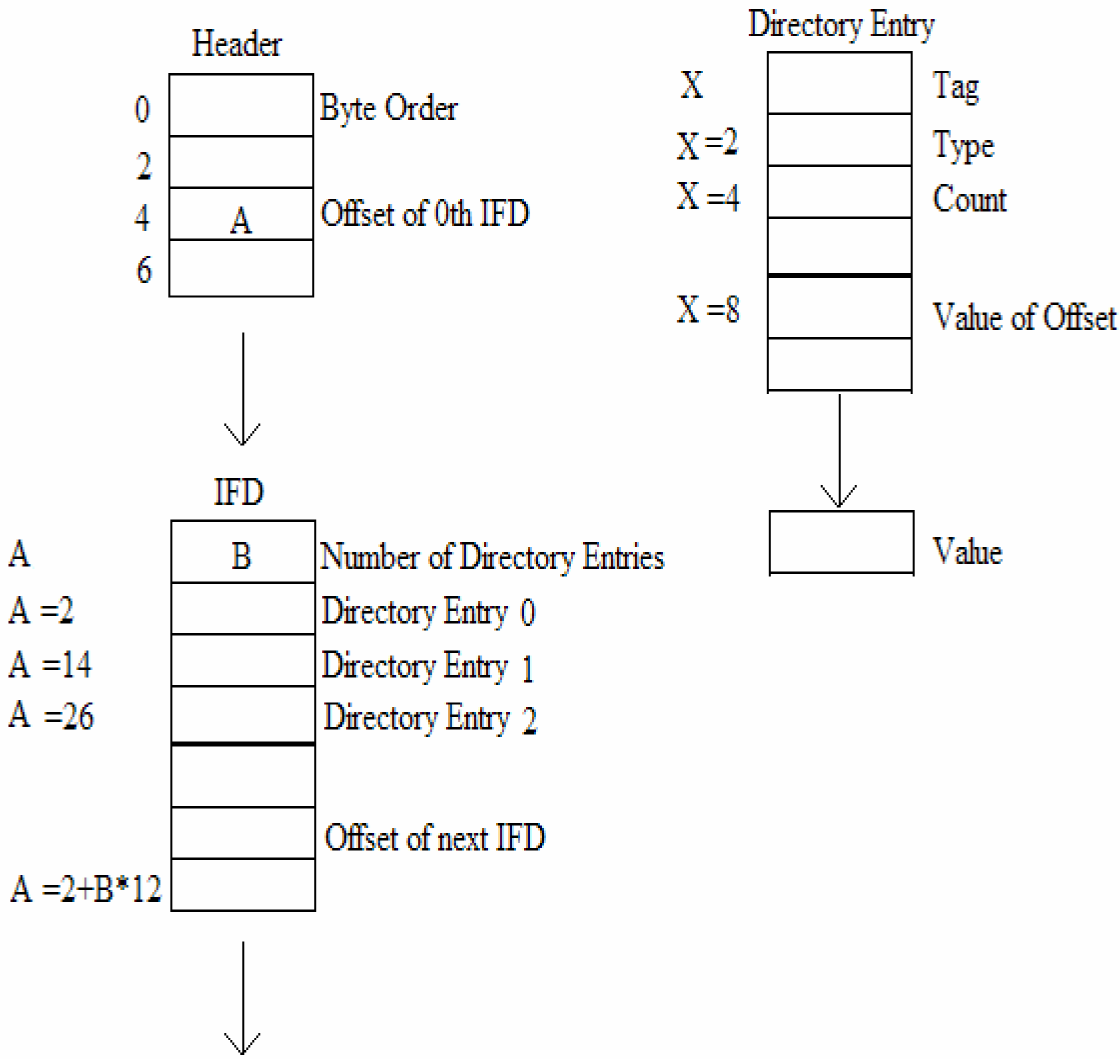

Figure 2.1 TIFF File Header

An *Image File Directory* (*IFD*) consists of a 2-byte count of the number of directory entries (i.e., the number of fields), followed by a sequence of 12-byte field entries, and followed by a 4-byte offset of the next IFD (or 0 if none). There must be at least 1 IFD in a TIFF file and each IFD must have at least one entry.

IFD Entry:

Each 12-byte IFD entry has the following format:

Bytes 0-1	The Tag that identifies the field.
Bytes 2-3	The field Type.
Bytes 4-7	The number of values, *Count* of the indicated Type.
Bytes 8-11	The Value Offset, the file offset (in bytes) of the Value for the field. The Value is expected to begin on a word boundary; the corresponding Value Offset will thus be an even number. This file offset may point anywhere in the file, even after the image data.

IFD Terminology:

A *TIFF field* is a logical entity consisting of TIFF tag and its value. This logical concept is implemented as an *IFD Entry*, plus the actual value if it doesn't fit into the value/offset part, the last 4 bytes of the IFD Entry. The terms *TIFF field* and *IFD entry* are interchangeable in most contexts.

Value/Offset:

To save time and space the Value Offset contains the Value instead of pointing to the Value if and only if the Value fits into 4 bytes. If the Value is shorter than 4 bytes, it is left-justified within the 4-byte Value Offset, i.e., stored in the lower numbered bytes. Whether the Value fits within 4 bytes is determined by the Type and Count of the field.

Count:

Count—called *Length* previously—is the number of values. Note that Count is not the total number of bytes. For example, a single 16-bit word (SHORT) has a Count of 1; not 2.

Types:

The field types and their sizes are:

1 = BYTE 8-bit unsigned integer.

2 = ASCII 8-bit byte that contains a 7-bit ASCII code; the last bit must be NUL (binary zero).

3 = SHORT 16-bit (2-byte) unsigned integer.

4 = LONG 32-bit (4-byte) unsigned integer.

5 = RATIONAL Two LONG: the first represents the numerator of a fraction; the second, the denominator.

In TIFF 6.0, some new field types have been defined:

6 = SBYTE An 8-bit signed (twos-complement) integer.

7 = UNDEFINED An 8-bit byte that may contain anything, depending on the definition of the field.

8 = SSHORT A 16-bit (2-byte) signed (twos-complement) integer.

9 = SLONG A 32-bit (4-byte) signed (twos-complement) integer.

10 = SRATIONAL Two SLONG's: the first represents the numerator of a fraction, the second the denominator.

11 = FLOAT Single precision (4-byte) IEEE format.

12 = DOUBLE Double precision (8-byte) IEEE format.

2.3 RGB Full Color Images

In an RGB image, each pixel is made up of three components:
Red, Green, and Blue. BitsPerSample = 8, 8, 8. Each component is 8 bits deep in a Baseline TIFF RGB image. Photometric Interpretation = 2 (RGB). There is no Color Map.

These are the required fields for RGB images (in numerical order):

Table 2.1 Required fields for RGB images

Tag Name	Decimal	Hex	Type	Value
Image Width	256	100	SHORT or LONG	
Image Length	257	101	SHORT or LONG	
Bits Per Sample	258	102	SHORT	8, 8, 8
Compression	259	103	SHORT	1 or 32773
Photometric Interpretation	262	106	SHORT	2
Strip Offsets	273	111	SHORT or LONG	
Samples Per Pixel	277	115	SHORT	3 or more
Rows Per Strip	278	116	SHORT or LONG	
Strip Byte Counts	279	117	LONG or SHORT	
X Resolution	282	11A	RATIONAL	
Y Resolution	283	11B	RATIONAL	
Resolution Unit	296	128	SHORT	1, 2 or 3

3. REVIEW OF STEPS FOR FEATURE DETECTION

3.1 General

3.1.1 Introduction

An image may be defined as a two dimensional function, *f(x, y)*, where *x* and *y* are *spatial* (plane) coordinates, and the amplitude of *f* at any pair of coordinates (*x, y*) is called the *intensity* or *gray level* of the image at that point. When *x, y,* and the amplitude values are all finite, discrete quantities, we call the image a *digital image*. The field of *digital image processing* refers to processing digital images by means of a digital computer.

There are three types of processes: low-level processes, mid-level processes and high-level processes. Low-level processes involve primitive operations such as segmentation (partitioning an image into regions or objects), descriptions of those objects to reduce them to a form suitable for computer processing, and classification (recognition) of individual objects. A mid-level process is characterized by the fact that its inputs generally are images, but its outputs are attributes extracted from those images (e.g., edges, contours, and the identity of individual objects). Finally, higher-level processing involves "making sense" of an ensemble of recognized objects, as in image analysis, and, at the far end of the continuum, performing the cognitive functions normally associated with vision.

3.1.2 Fundamental Steps

Fundamental Steps in Digital Image Processing can be divided into two broad categories: methods whose input and output are images and methods whose input may be images, but whose output are attributes extracted from those images[2,6].

Image Acquisition could be as simple as being given an image that is already in digital form. Generally, the image acquisition stage involves preprocessing, such as scaling.

Image Enhancement is used to bring out the details that are obscured, or simply to highlight certain features of interest in an image.

Image Restoration is an area which deals with improving the appearance of an image. The restoration techniques tend to be based on mathematical or probabilistic models of image degradation.

Color Image Processing is an area which is of significant importance in the field of digital image processing. Color is used also as the basis for extracting features of interest in an image.

Wavelets are the foundation for representing images in various degrees of resolution.

Compression, as the name implies, deals with the techniques for reducing the storage required to save an image, or the bandwidth required to transmit it.

Morphological Processing deals with tools for extracting image components that are useful in the representation and description of shape.

Segmentation procedures partition an image into its constituent parts or objects. Autonomous segmentation is one of the most difficult tasks in digital image processing.

Representation and Description almost always follow the output of the segmentation stage, which usually is raw pixel data, constituting either the boundary of a region or all the points in the region itself.

3.2 Morphological Image Processing Operations

Some of the basic Image Processing Morphological Operations are given below:

1. Erosion
2. Dilation
3. Opening
4. Closing
5. Thinning
6. Thickening
7. Skeletonization
8. Pruning

By combining these operators one can develop algorithms for many image processing tasks, such as feature extraction, image segmentation, image sharpening, image filtering, etc [2,6].

Apart from these morphological operations various other methods can be used to obtain the desired results by applying those methods on the input image.

3.2.1 EROSION

Erosion is one of two fundamental operations in Morphological image processing on which all other morphological operations are based. The operation is a subset of set theory, where each pixel in an image is considered to be a member of a set of pixels, rather than the usual interpretation of an image being a strict function of two dimensions.

Erosion: Let A denote a binary image and B denote a structuring element. Then the erosion of A by B is given by:

$$A \odot B = \{z \mid (B)_z \subseteq A\} \quad \text{... 3.1}$$

3.2.2 DILATION

With A and B as sets in Z^2, the dilation of A by B is defined as

$$K = \max\{k \mid (A \Theta kB) \neq \varnothing\}. \quad \text{... 3.2}$$

$$A \oplus B = \{z \mid (\hat{B} \cap A \neq \varnothing\} \quad \text{... 3.3}$$

This equation is based on obtaining the reflection of B about its origin and shifting this reflection by z. The dilation of A by B then is the set of all displacements, such that $\hat{B}$ and A overlap by at least one element.

3.2.3 OPENING

Opening generally smoothes the contour of an object, breaks narrow isthmuses, and eliminates thin protrusions. The opening of set A by structuring element B, denoted by $A \circ B$, is defined as

$$A \circ B = (A \Theta B) \oplus B. \quad \text{... 3.4}$$

Thus, the opening of A by B is the erosion of A by B, followed by a dilation of the result by B.

3.2.4 CLOSING

Closing also tends to smooth the sections of contours but, as opposed to opening, it generally fuses narrow breaks and long thin gulfs, eliminates small holes, and fills gaps in the contour. The closing of set A by structuring element B, denoted by $A \bullet B$, is defined as

$$A \bullet B = (A \oplus B) \Theta B. \quad \text{... 3.5}$$

Thus, the closing of A by B is the dilation of A by B, followed by a erosion of the result by B.

3.2.5 THINNING

The thinning of a set A by a structuring element B, denoted by $A \otimes B$, can be defined in terms of hit-or-miss transforms:

$$A \otimes B = A - (A * B) \quad \text{... 3.6}$$

$$= A \cap (A * B)^c \quad \text{... 3.7}$$

The more useful expression for thinning A symmetrically is based on a sequence of structuring elements:

$$\{B\} = \{B^1, B^2, B^3, ..., B^n\} \quad \text{... 3.8}$$

Where B^i is rotated version of B^{i-1}. Using this concept, thinning can be defined as a sequence of structuring elements as

$$A \otimes \{B\} = ((...((A \otimes B^1) \otimes B^2)...) \otimes B^n). \quad \text{... 3.9}$$

The process is to thin A by one pass with B^1, then the result with one pass of B^2, and so on, until A is thinned with one pass of B^n. The entire process is repeated until no further changes occur.

3.2.6 THICKENING

Thickening is morphological dual of thinning and is defined by the expression

$$A \odot B = A \cup (A * B) \qquad \text{... 3.10}$$

Where B is the structuring element suitable for thickening. As in thinning, thickening can be defined as a sequential operation:

$$A \odot \{B\} = ((...((A \odot B^1) \odot B^2)...) \odot B^n). \qquad \text{... 3.11}$$

3.2.7 SKELETONIZATION

The skeletonization is the method to detect regions and objects in digital images. The skeleton[1] of A can be expressed in terms of erosions and openings. That is, it can be shown that

$$S(A) = \bigcup_{k=0}^{K} S_k(A) \qquad \text{... 3.12}$$

With

$$S_k(A) = (A \Theta kB) - (A \Theta kB) \circ B) \qquad \text{... 3.13}$$

Where B is the structuring element, and $(A \Theta kB)$ indicates k successive erosions of A:

$$(A\Theta kB) = (...(A\Theta B)\Theta B)\Theta...)\Theta B \qquad ... 3.14$$

k times, and K is the last iterative step before A erodes to an empty set. In other words,

$$K = \max\{k \mid (A\Theta kB) \neq \varnothing\}. \qquad ... 3.15$$

3.2.8 PRUNING

The pruning algorithm is a technique used for digital image processing based on mathematical morphology. It is used as a complement to the skeleton and thinning algorithms to remove unwanted parasitic components.

The process in itself will remove all branches shorter than a given number of points, for character recognition for example on skeletons of the letters. The pruning algorithm starts at the end points and recursively removes a given number *N* of points from each found branch. After this step it will apply dilatation on the new end points with a $(2N)/(2N+1)$ structuring element of 1's and will intersect the result with the original image. If suppose a parasitic branch is shorter than four points and we try to remove all the branches that are short, after the fourth step the branch would be removed and no end point would be remaining there. A normal branch would be four points shorter also but after the second step it would go back to its original size.

4. SYSTEM DESIGN, ARCHITECTURE & IMPLEMENTATION

4.1 Flow of the System

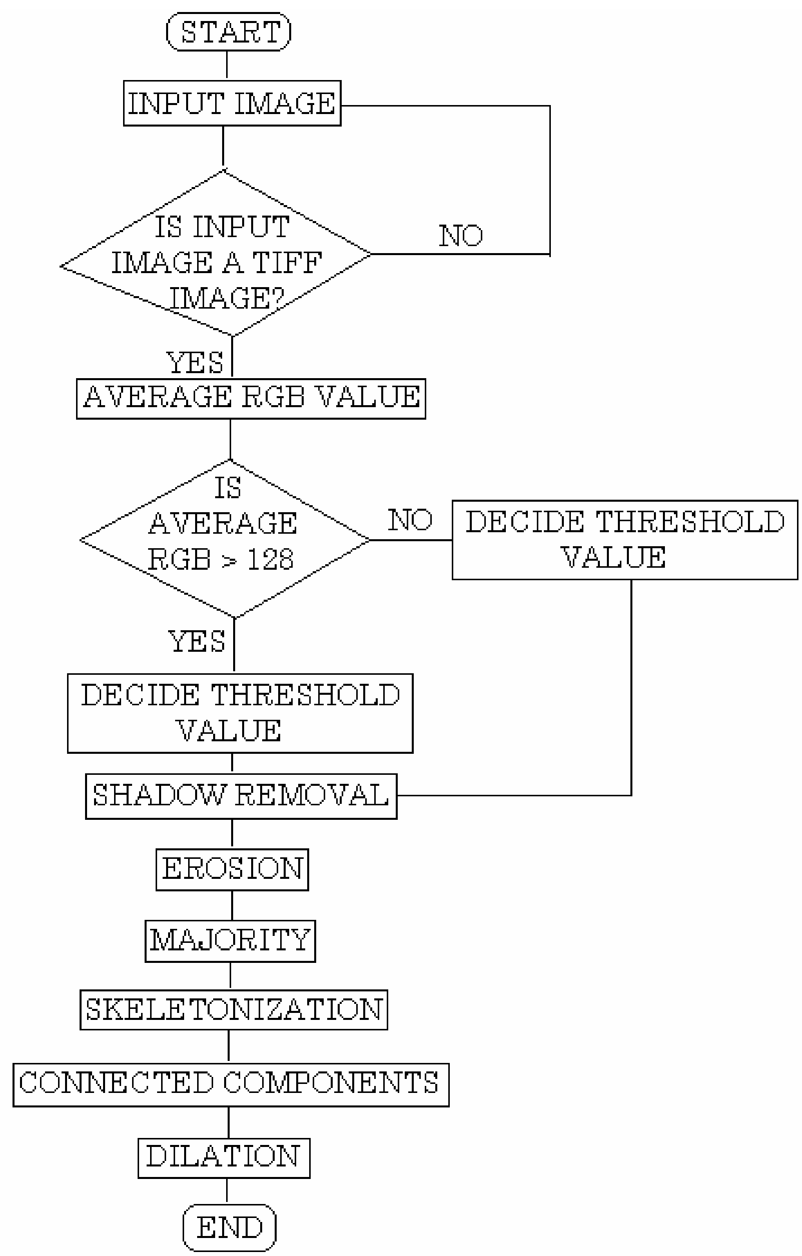

Figure 4.1 Flow of the Algorithm

4.2 Algorithm Analysis

To implement the algorithm for Road Extraction based only on intensity values, one needs to get a proper image on which experimental results can be obtained. BISAG provided me one of the most suitable images for applying my algorithm & check its efficiency.

Figure 4.2 Original Satellite Image

The given image is the Original Image which is taken as an experimental image for this algorithm. The image is of Ahmedabad city given by BISAG.
The image contains the road network which is the main object of interest. The image also contains other objects like some buildings, garden & ground.

4.2.1 Algorithm for Average RGB value

To apply any Morphological Operation on the input image, first of all proper analysis of image is necessary. From my initial results I found that there was a significant difference between the results of the bright and dark images. For bright images the results were easily obtained, whereas for the dark images more manual operations were needed. When an automatic or semi-automatic system is being developed, at that time the manual efforts should be minimized. For that the system must be able to take decisions based on the inputs. For this system, it must take decision to apply proper algorithm on the input image to get the desired results based on the brightness of the input image. To decide the brightness of the input image, I divide the input images in two broad categories: Bright Images and Dark Images.

Now, to decide whether the input image is a bright image or a dark image, I use one of the most essential characteristic of the image, i.e., the intensity value of the image. Each pixel of an image will contain some RGB value which decides the color of that pixel. To find the average RGB value means to find the average values of each of the R, G and B components. For that first of all the size of the input image will be found. Then for each pixel the value of its R component will be acquired. All these values will be summed up. The total of these values will be divided by the size of the image to get the average value of the R component for the given image. The same logic will be applied to the image to find the average value of G component and the average value of B component. Each pixel can have 256 (0-255) different values for each R, G and B components. If the average value of the R component, the average value of the G component and the average value of the B component is above 127, then the image is said to be a bright image. If all these values are below 128, then the image is said to be a dark image. If any of the three components has a different range of value than the other two components, then the image category will be decided based on certain other conditions.

4.2.2 Algorithm for Shadow Removal

To remove the shadow from the image some basic steps need to be applied. A careful observation of the image shows that in the image where there are shadows, the intensity values are very less.

To remove the shadows one needs to change the lower values of R, G & B with some other values of R, G & B which form the Gray color suitable for the given image.

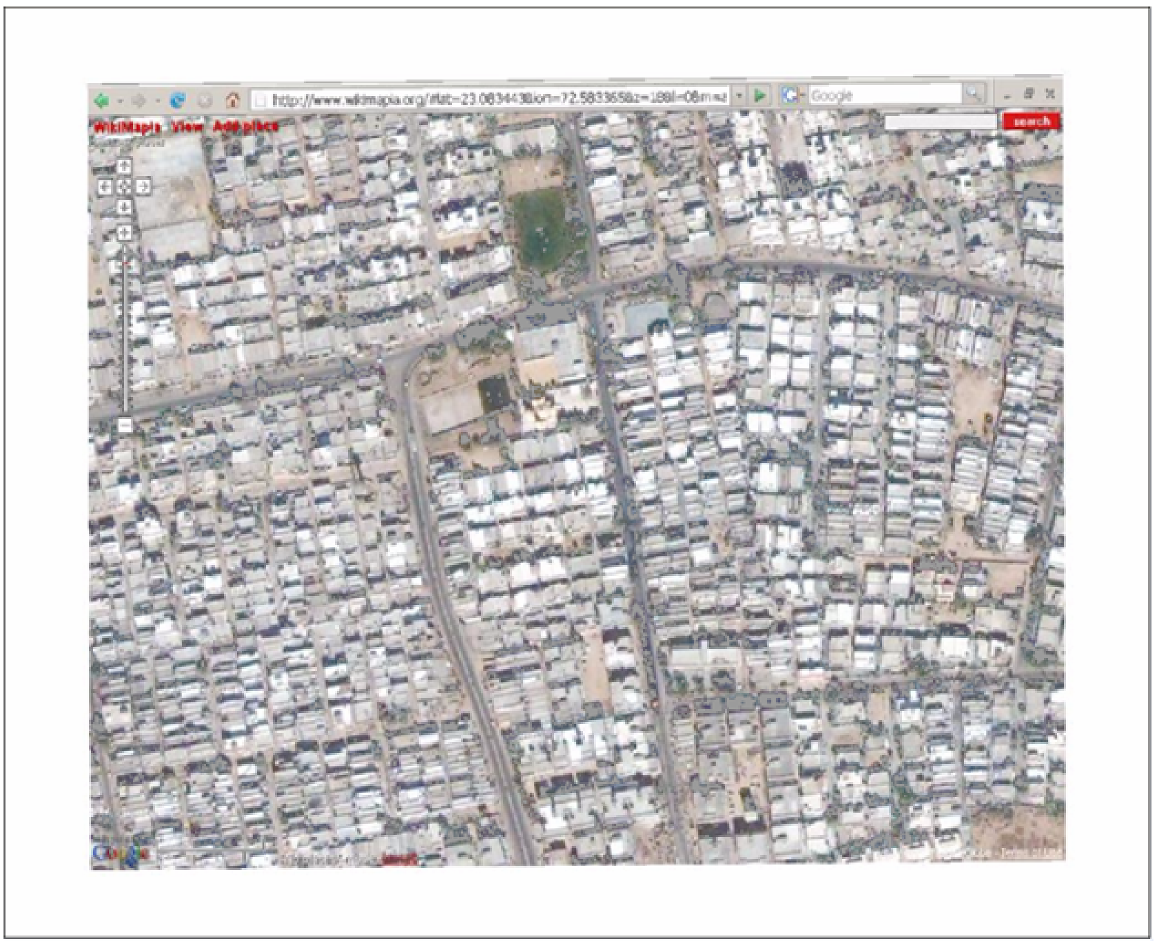

Figure 4.3 Result after applying the shadow removal logic

To decide the values of R, G & B which form the Gray color the average values of R, G & B of the given image should be calculated.

Once the average values of R, G & B of the given image are calculated, then the check is performed whether the average values are above 127 or below 128.

If the average value for one of the component differs from the other two, then the majority is taken into consideration and the image falls in the category which is decided by the majority.

Once the category of the image is decided, then the threshold values for Gray color & the other threshold values are decided based on the formula.

Let r, g & b be the Red, Green & Blue component's average value.

r' = r/2;
g' = g/2;
b' = b/2;

the values of R, G & B components forming the Gray colors are r'', g'' & b'' respectively.

r'' = (r + r')/2;
g'' = (g + g')/2;
b'' = (b + b')/2;

After finding the suitable value of Gray color, the low values of R, G & B in the original image are replaced with the newly found values.

This makes the image look better for further processing as the shadows in the image are almost removed.

4.2.3 Algorithm for Bilevel Conversion

After shadow removal, the image needs to be converted into a bilevel image. For that certain threshold values are decided for the R, G & B components of the image. Using these threshold values the image is converted into a bilevel image by making all the R, G & B components 0 or 255. The result is given here.

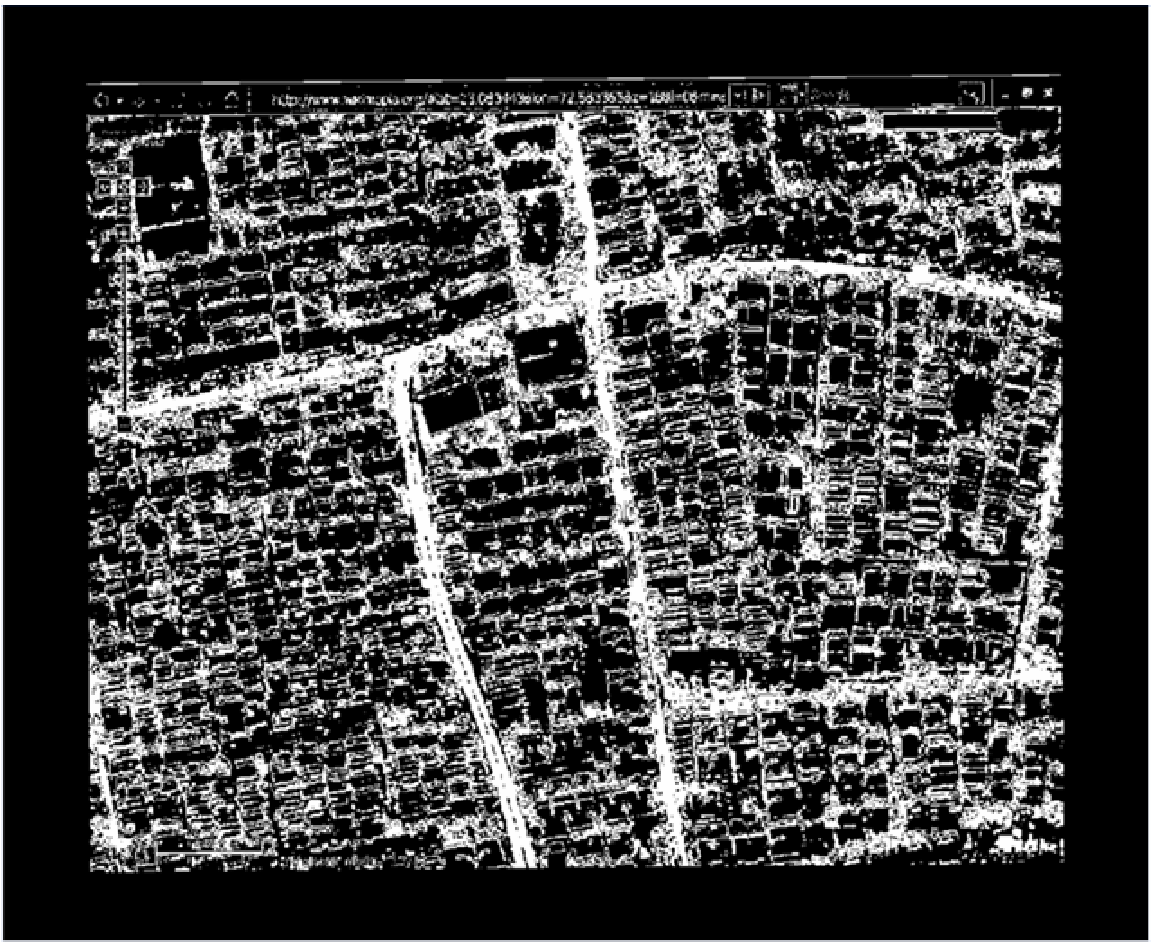

Figure 4.4 Result after converting the image into a bilevel image

4.2.4 Erosion

Once the image is converted into a bilevel image, then morphological operations are applied. The first operation that is applied is Erosion. In this all the unnecessary components are removed from the image and the object of interest (i.e., Road) is highlighted.

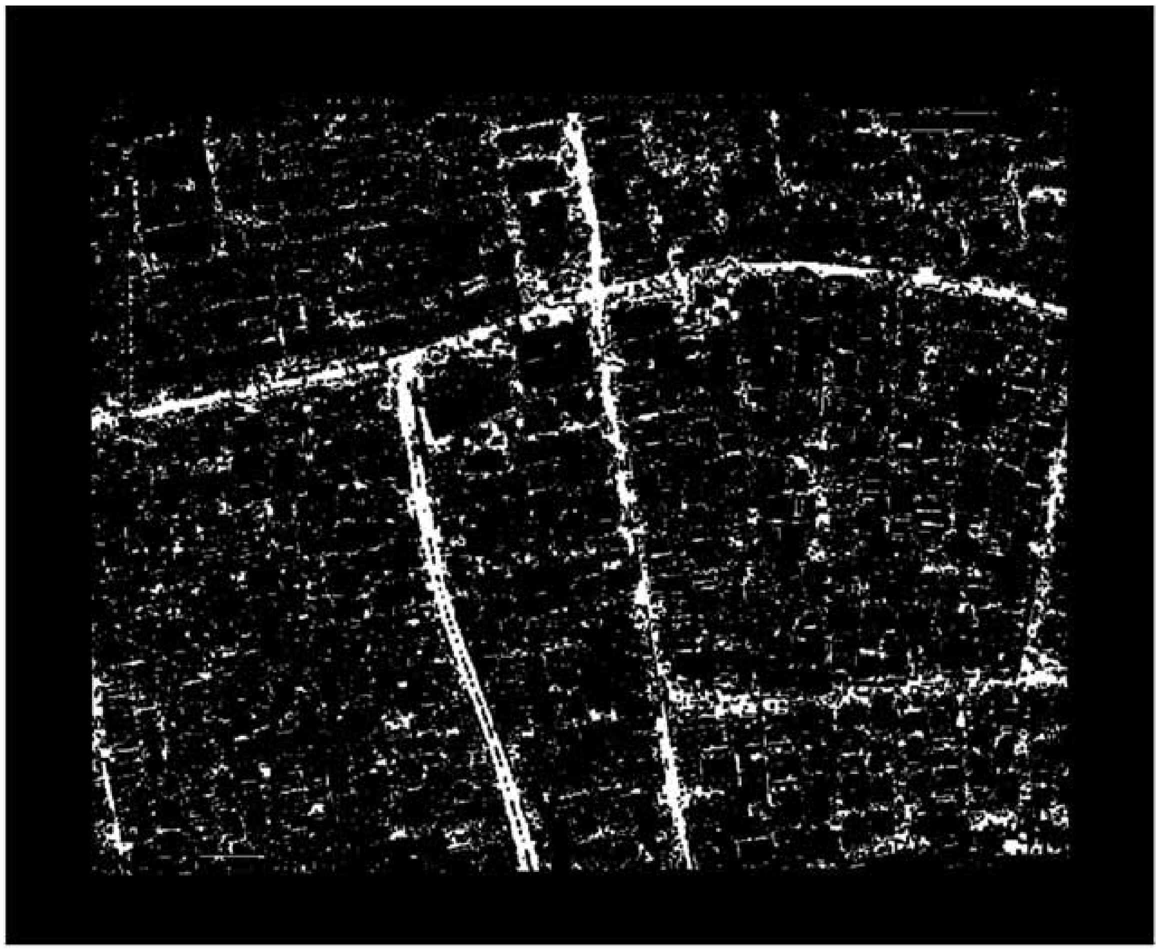

Figure 4.5 Result after applying Erosion

4.2.5 Majority

After applying erosion operation, the image is still not up to the mark. So, one of the most effective tools in these conditions is the majority operation. In this the mask is decided (possibly a small mask) & then the values of the pixels under the mask are observed. All the values of the pixels under the mask are then replaced with the value which is in majority.

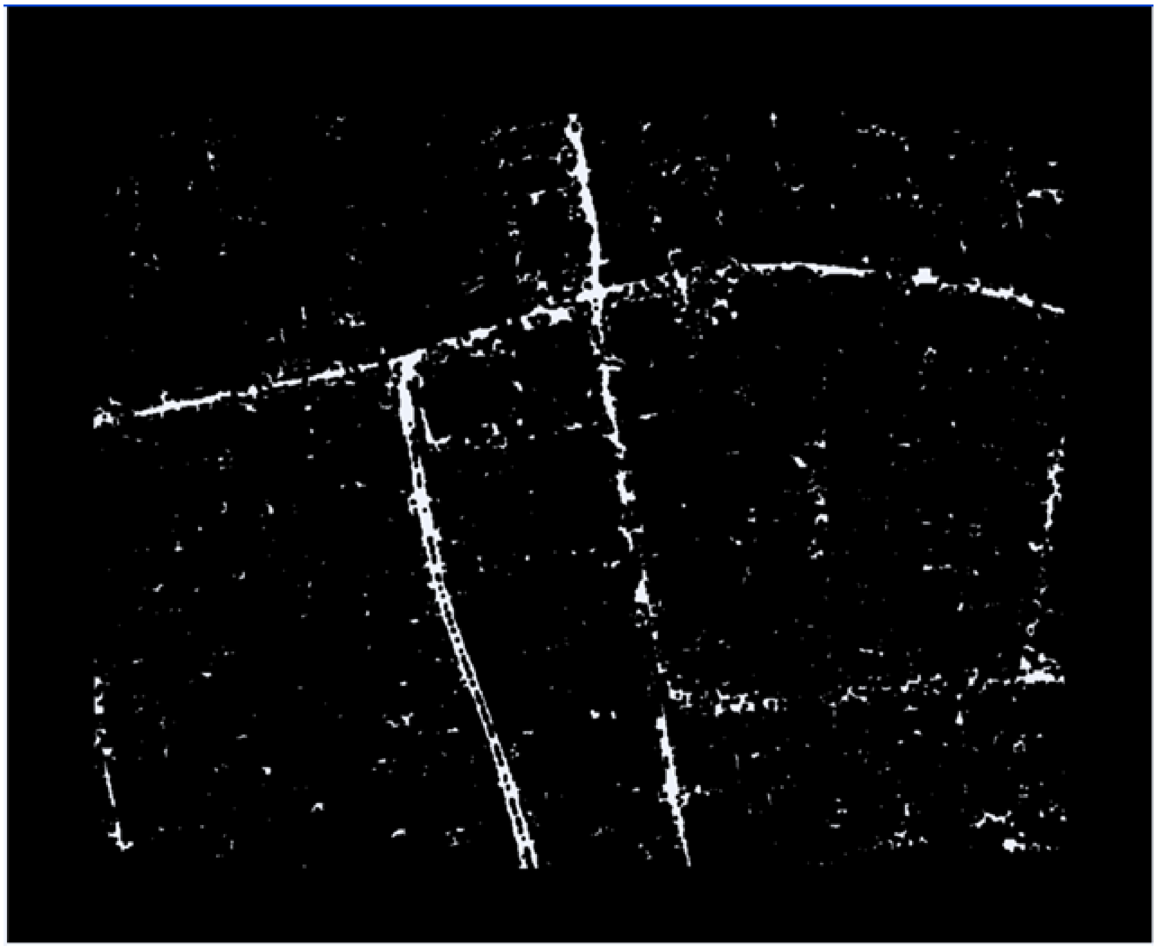

Figure 4.6 Result after applying Majority Operation

4.2.6 Find the Boundary Pixels

Here, after applying the majority operation one needs to apply skeletonization[1]. For that first of all boundary pixels are detected. The result here shows the boundary pixels with some different intensity values to differentiate them from other pixels.

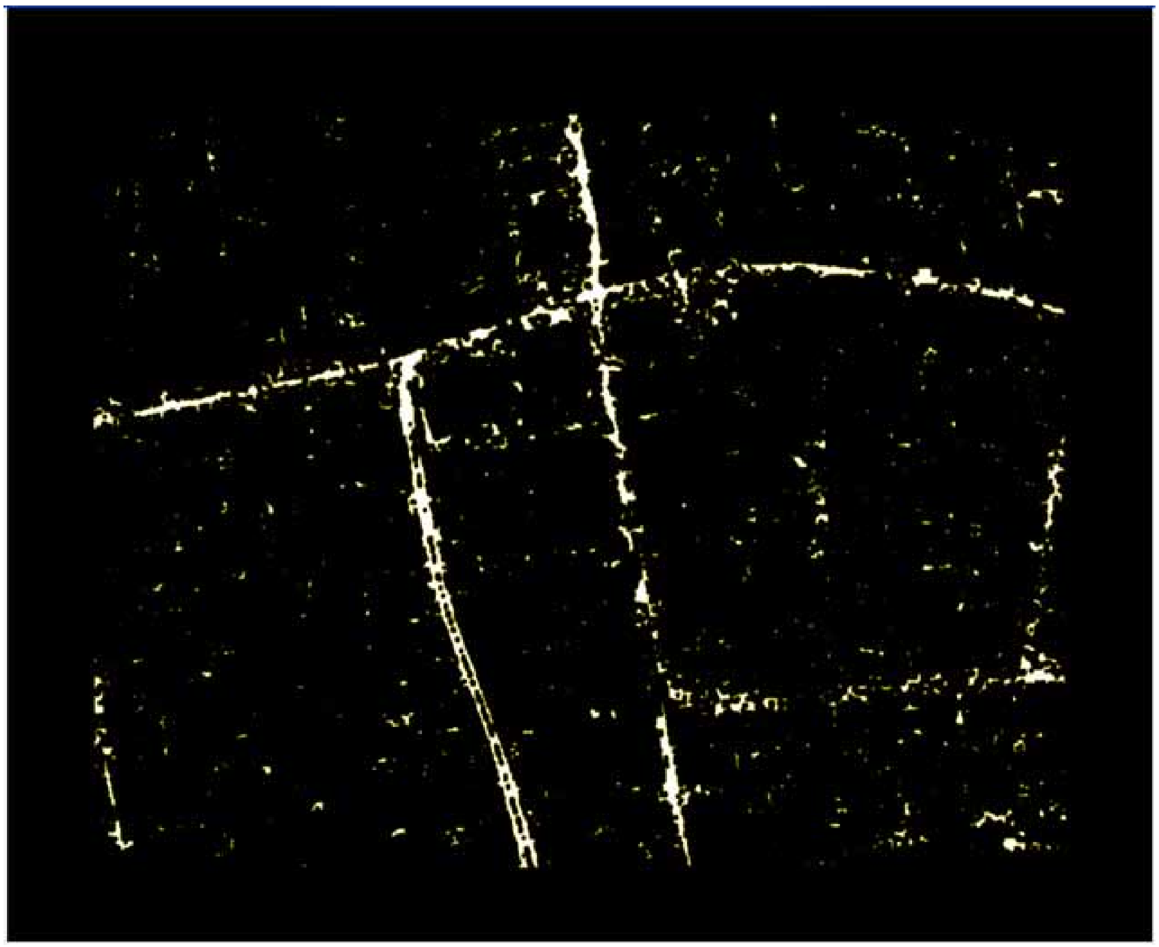

Figure 4.7 Result after finding the Boundary Pixels

4.2.7 Skeletonization

After finding the boundary pixels, we apply thinning algorithm to find the skeleton[1] of the image. In some cases simply applying thinning will not give proper result as it thins the feature from all the sides. Instead of doing that, a modified logic is applied in which if there is any single pixel thick line (which is obviously the boundary pixel), then those pixels are not removed. This gives better result as shown in the figure. Here the negative of the image is shown to make the feature clearly visible.

Figure 4.8 Result after applying Skeletonization

4.2.8 Connected Components

After getting the skeleton[1] of the image, the image needs to be cleaned. For that the unwanted components (i.e., noise) should be removed. To remove noise, the connected components[4] are found. For every set of connected components, some threshold value is decided. If the number of connected components crosses the threshold value, then they are kept intact. Otherwise, all the pixels representing that component are assigned value 0. In short, the component is removed. Here also the negative of the image is shown to make the result clearly visible.

Figure 4.9 Result after applying the logic of connected components

4.2.9 Dilation

Finally the dilation operation is applied on the result of the previous operation. By applying the dilation operation up to a certain limit, the object of interest can be obtained successfully. The result of applying the dilation operation is shown in the result. From the result one can easily make out where is the road in the input image.

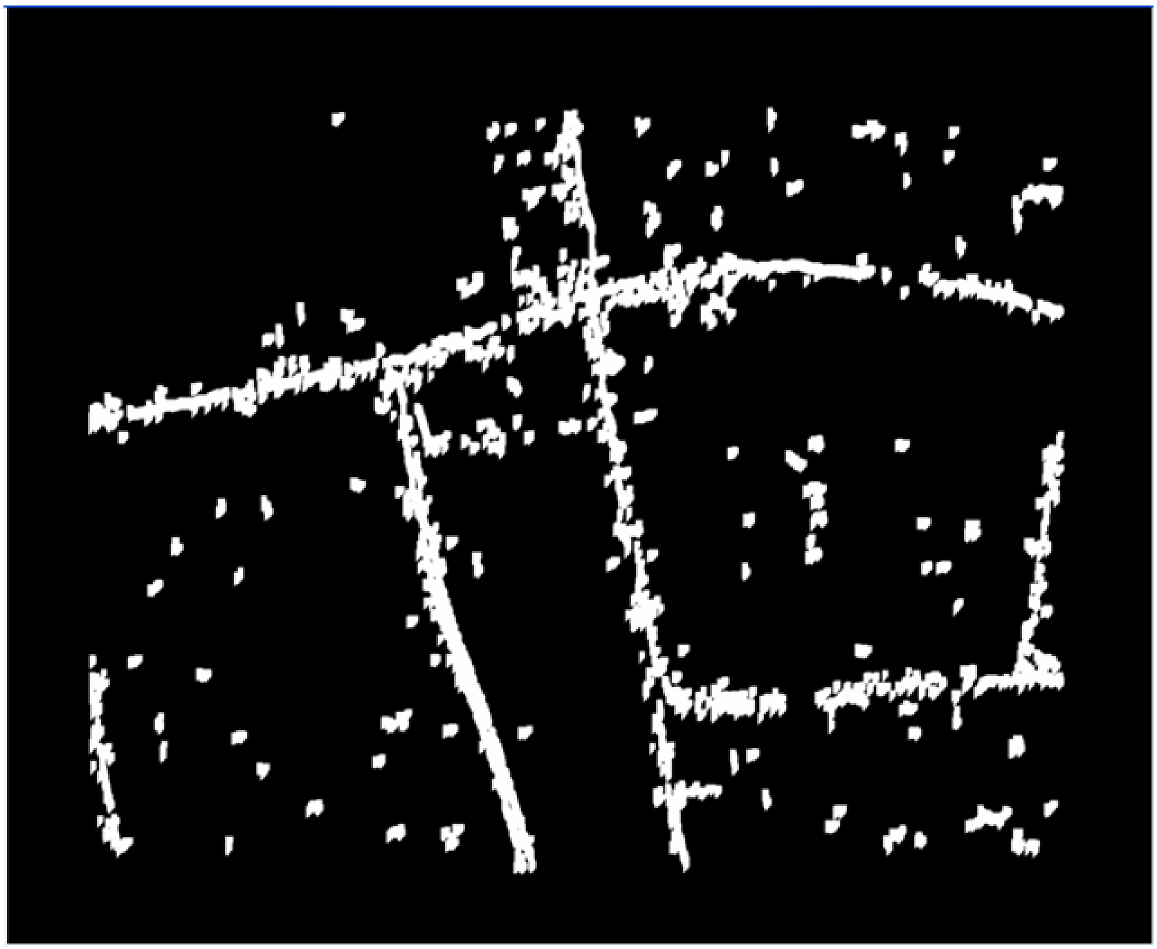

Figure 4.10 Result after applying the dilation operation

4.3 Platform Used

There are many options for developing these kind of algorithms. Some of these options are very suitable for Image Processing while some others are not much. After doing a careful analysis of all the available options I decided to go for Java[7] as a platform for developing these algorithms.

Java has certain advantages over the other languages and tools like VC++ & MATLAB, the two which are considered to be suitable for Image Processing. The first and most important advantage of Java is that it is Platform Independent. Due to this it is very easy for any user to use the Java programs on any Operating System by just getting the runtime environment. Another major advantage is that Java is Open Source. This makes it most suitable contender.

Another major advantage which also makes Java far ahead from other contenders is the processing time. Java is much faster than other suitable contenders for processing the images according to the algorithm. Here, a comparison is given which shows the average time taken for each algorithm by Java and MATLAB.

Table 4.1 Average time taken for each step by Java and MATLAB

	Java	MATLAB
Shadow Removal	500ms	15.797s
Bilevel Conversion	515ms	25.578s
Erosion	515ms	3.910s
Majority	2.265s	2.660s

5. TESTING RESULTS & ANALYSIS

5.1 Test Images

Some other images were taken as test images to prove the efficiency and effectiveness of the algorithms. Some of the test images are given here. The experimental results are given in the next section.

Figure 5.1 A test image of Kutch Region

Figure 5.2 A test image of Expressway near Nadiad

The given image is of the expressway between Ahmedabad & Vadodara. The image shows the exit near Nadiad. Here an interesting design of road network is given and the result of this image will prove the effectiveness of the algorithm up to some extent.

Figure 5.3 A test image of a bridge on the river near Vadodara

Here the given image is of the bridge on the river Mahi at the place called Sindharot near Vadodara. The given image contains the road as well as the water portion of the river. It is rather difficult to extract a road in the dark images like the one given here. So, if the result of this image is acceptable than one more time the algorithm will prove its effectiveness.

5.2 Experimental Results

Here, the result after applying the algorithm on the image of Kutch region is given. As shown in the image, the road passing through the wasteland area in the original image is clearly extracted.

Figure 5.4 Result of the image of Kutch Region after applying the algorithm

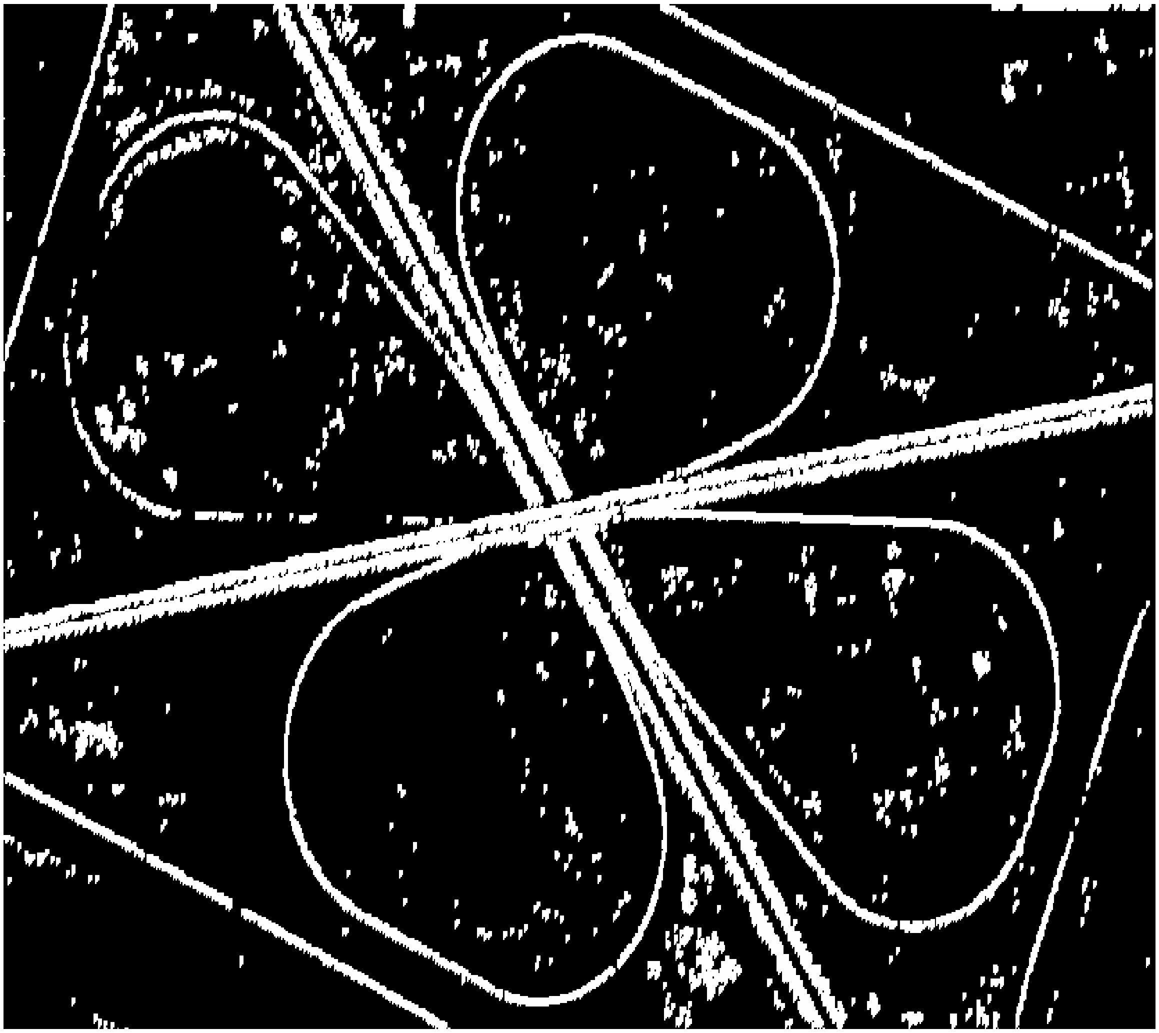

Figure 5.5 Result of the image of expressway after applying the algorithm

Here, as shown in the image, the road network in the given image is almost clearly extracted. One can easily make out where is the road portion in the given image. The connectivity is also good except at few places.

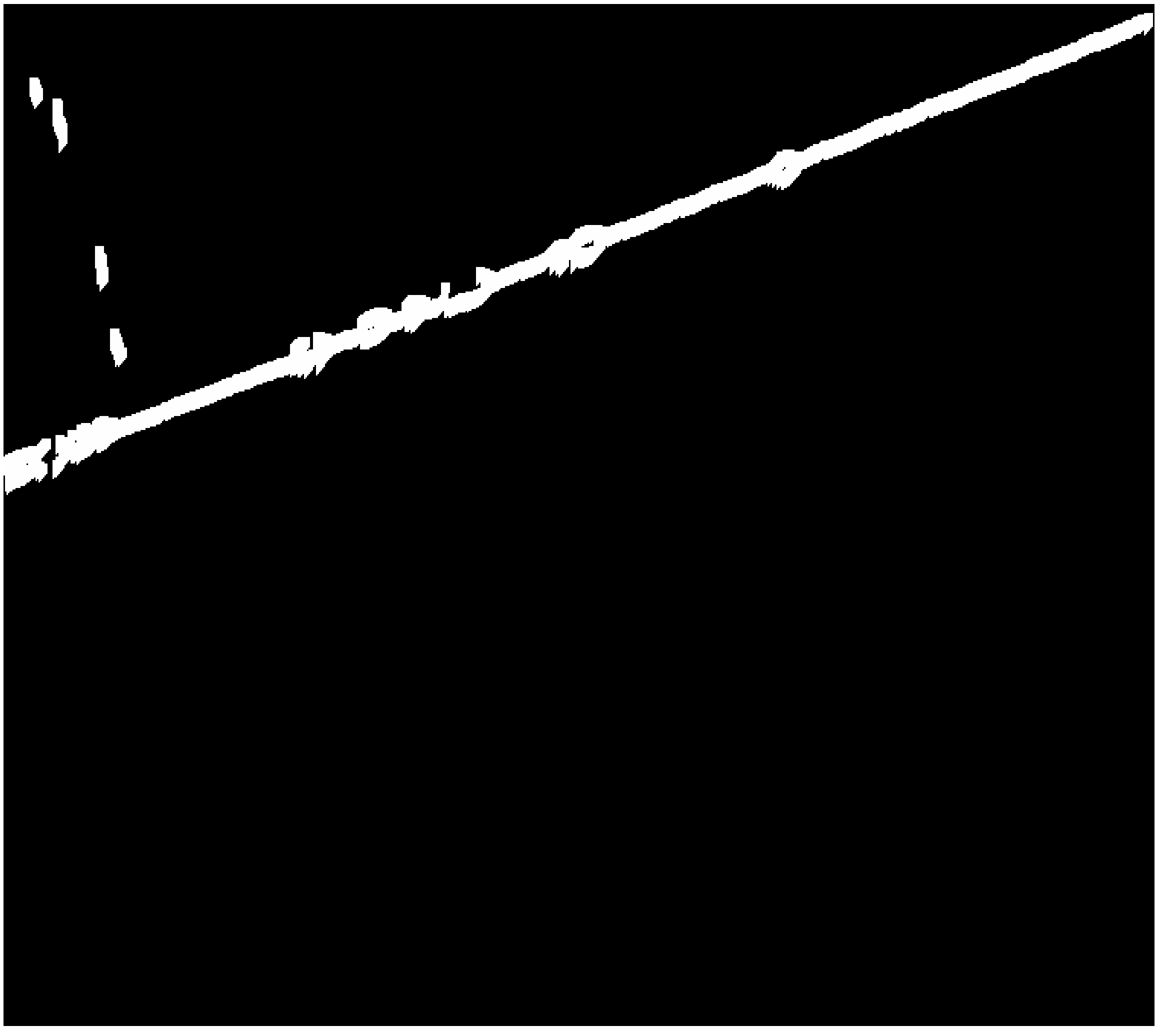

Figure 5.6 Result of the image of the bridge after applying the algorithm

Here, the most difficult part of the task is proven to be up to the standards. As discussed in the earlier chapters, if the image is dark then the algorithm has to make some extra efforts to get the desired results. Here, the given image was in the 'dark' category as the color of the water portion in the river was covering most of the portion of the image. But, still the result obtained by applying the algorithm is very good.

6. CONCLUSION AND FUTURE WORK

6.1 Conclusion

Here, the aim was to find the feature of interest (i.e., road) from the satellite image. The algorithms developed here use only intensity values and some conventional and unconventional logic of digital image processing.

The results obtained show that the algorithms are efficient but still some improvement is required to get 100% results.

To improve the results, a certain sequence of algorithms should be applied iteratively but, the limit on the number of iterations should be adaptive.

6.2 Future Enhancements

The results here find the major roads in the image. The work can be extended to find the minor roads in the high resolution image.

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