3.1 INTRODUCTION

A novel method of information processing is quantum computing. The existing traditional method of information processing, is called classical information. Facets of computer science, information theory, and quantum mechanics combine to form Quantum Computing. The repression architectural of Von Neumann computers with the computational complexity of classical algorithms which often slow down, leads to a loss of information, making it necessary to find new way of obtaining that information. In a classical computer the storage is done in bits. The bits are independent of each other. The connectivity for those independent bits is done by the software components. No inter connectivity between the bits in the memory, leads to loss of information. Each independent bit will represent some property of the associated image viz., it's spatial or light strength. The retrieval of the image is carried out by fetching the binary data from hardware memory, by means of the independent property of bits. The inter connectivity is given in the quantum computing.

The study area imagery and software used for the computational image enhancement are explained. The implementation of the Quantum Fourier Transform based image enhancement and the implementation of the Modified Data Parallel Algorithm of Parallel Computing based image enhancement is discussed in this chapter.
An attempt has been made to improve the visual information using the QFT transform in the remote sensing data, for feature identification.

3.2 STUDY AREA

The input image which is taken for the study area is the multispectral images of the Linear Imaging Self Scanning Sensor-III (LISS-III), LISS-IV, and IKONOS. The LISS-III is of 24m Resolution with 23 * 23 Km of area covered, the LISS-IV is of 5m Resolution with 141*141 Km of area covered and IKONOS is of 4m Resolution.

The index map is shown in Figure 3.1. The study area covers different land classes. The land classes are agricultural area, coastal area and hilly areas. The Thiruvullur district, Tamil Nadu, India covering an agricultural area and coastal area, and Madurai district covering a Hilly area from the LISS-III are taken for the study purpose. From the LISS-IV, the district of Salem, Tamil Nadu, India, covering Hilly and Agricultural areas and Kanchipuram district, Tamil Nadu, India, covering Coastal area, are taken for the study.

Thiruvallur district is surrounded by Kancheepuram district in the South, Vellore district, Tamil Nadu, India in the west, the Bay of Bengal in the East and Andhra Pradesh State, India in the North. The district is spread over an area of about 3422 sq.kms. The coastal region of the district is mostly flat and dreary, but in the other parts, it is undulating and even hilly in some places.

The soil of the district is mostly sandy, mixed with soda or other alkalis or stony. Rocks found in and near the surface are in detached masses. Hence, the soil can't be termed as very fertile. The soil found nearer the sea coast is of the inferior erinaceous type, which is most suited for raising casuarina plants. No mineral of any importance is available in the district.
A few conical hills or ridges of small elevation exist like the St. Thomas Mount, Chennai, Tamil Nadu, India. Certain hillocks are found in Tiruttani, Tamil Nadu, India. Most of the hills and hillocks are rocky and no verdant vegetation is seen on the slopes of these hills. The area under forests in this district is quite meager. Madurai District is situated in South Tamil
Nadu state. It is bounded on the North by the districts of Dindigul, Thiruchirapalli, on the East by Sivagangai, on the West by Theni, and on the South by Virudhunagar. Salem is located in the north central part of the state, about 340 kilometres southwest of the state capital, Chennai.

Salem is a part of Kongu Nadu, an ancient division of Tamilakam, comprising the western part of Tamil Nadu, and is at the base of the popular tourist destination of Yercaud hills. The city is surrounded by hills on all sides: Nagaramalai in the north, Jarugumalai in the south, Kanjamalai in the west, and Godumalai in the east. It is divided by the river Thirumanimuthar in the main division.

Kancheepuram district is situated on the north east coast of Tamil Nadu and is adjacent to the Bay of Bengal and Chennai city and is bounded in the west by Vellore and Thiruvannamalai district, in the north by Thiruvallur district and Chennai district, in the south by Villuppuram district and in the east by the Bay of Bengal. The district has a total geographical area of 4393.37 Sq.Kms and coastline of 57 Kms.

In the LISS-III image the agricultural and coastal areas start from 13° 09' N to 79° 57' E. The hilly area starts from 9° 58' N to 78° 10' E. Figure 3.2 shows the original image of the LISS-III, covering the Agricultural Area. Figure 3.4 and 3.6 shows the original image of the coastal and hilly areas of the LISS-III.

In the LISS-IV image, the agricultural and hill areas start from 11° 39' N to 78° 12 ' E; and the coastal area starts from 12° 50' N to 79° 45' E. Figure 3.3 shows the original image of the LISS-IV covering the Agricultural Area. Figures 3.5 and Figure 3.7 show the unenhanced image of the coastal and hilly areas of the LISS-IV.
Figure 3.2 LISS-III image covering the Agricultural Area

Figure 3.3 LISS-IV image covering the Agricultural Area
Figure 3.4 LISS-III image covering the Coastal Area

Figure 3.5 LISS-IV image covering the Coastal Area
Figure 3.6 LISS-III image covering the Hilly Area

Figure 3.7 LISS-IV image covering the Hilly Area
The study area is Saidapet-Anna University, a part of the Chennai basin situated in the southern part of Chennai. It covers 13°00’ 32.39’N and 13° 00’ 23.93’N to 80°13’ 44.30’N and 80°14’ 36.47’N. The study area is 400 000 m² in extent, which covers Sardar Patel Road, Anna University, Adayar river, and Gandhi Mandapam. The IKONOS image is used for the computational application. The image is shown in Figure 3.8. The spectral characteristics of the IKONOS spectral bands are 1m black & white panchromatic 0.526-0.929 µm, 4m multispectral or 1m coloured blue 0.445-0.516 µm, green 0.506-0.595 µm, red 0.632-0.698 µm, infrared 0.757-0.853 µm. The product options available are black & white (panchromatic) production; the IKONOS panchromatic image is available with 1m resolution. Multispectral production 4m IKONOS multispectral image is available in 2 options; they are, one file with three spectral bands in natural colours (red, green, blue) or in pseudo colours (infrared, red, green) and four files, each of which corresponds to one spectral band (infrared, red, green and blue). The coloured image IKONOS is collected as the result of the pansharpening process, which combines the panchromatic image space information with the multispectral band visual information to produce 1m coloured production. The IKONOS image is available in 1m black & white and 4m multispectral. The Space Imaging centre supplies 1m black & white image in a separate file. The Multispectral image is supplied as a single file with three spectral bands in natural colours (red, green and blue) or in pseudo colours (infrared, red and green); or in four files, each of which corresponds to one spectral band (infrared, red, green and blue). The area under study covers a part of the Anna University buildings and swimming pool and Saidapet, Chennai, Tamil Nadu, India.

The major area covered in the urban region is of vegetation area, water bodies, major roads and minor roads. The Adayar river is behind the Anna University Chennai. It covers the Guindy National Park, the fly-over
near IIT Madras, Rajbhavan, Anna University main building. The map shows the railway line, major roads and other roads.

![Map showing railway line, major roads and other roads](image)

**Figure 3.8 Unenhanced IKONOS image covering the Urban Area**

### 3.3 QUANTUM COMPUTING AND PARALLEL COMPUTING FUNCTIONS IN MATLAB

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, one can solve technical computing problems faster than with traditional programming languages, such as C, C++, and FORTRAN.

Quantum computing uses unitary operators acting on discrete state vectors. MATLAB is a well known matrix computing environment, which makes it well suited for simulating quantum algorithms. The Quantum
Computing Functions (QCF) library extends MATLAB by adding functions to represent and visualize common quantum operations. The QCF shows how it can be used to simulate the well-known algorithms of quantum computing. The Quantum Fourier Transform (QFT) uses normalized basis functions (unlike the classical Discrete Fourier Transform) to represent a discrete state vector:

\[ |x> = \frac{1}{\sqrt{N}} \sum_{j=0}^{N-1} e^{2\pi i j/N} |j> \]  

(3.1)

As the basis is orthonormal, the QFT projections can be computed by the unitary transform:

\[
\text{QFT} = \frac{1}{N} \begin{bmatrix}
0 & 0^1 & 0^2 & 0^3 \\
0^1 & 0^2 & 0^3 & 0^4 \\
0^2 & 0^3 & 0^4 & 0^5 \\
0^3 & 0^4 & 0^5 & 0^6
\end{bmatrix}
\]  

(3.2)

where \( \omega \) is the \( N^{th} \) root of unity, \( e^{2\pi i/N} \).

The QCF library provides a `qft` function which creates QFT matrices for any \( N \): Creates QFT matrix with \( d \) rows and cols, where \( d=2^N \). The QFT is both unitary and hermetian, so the matrix obtained from the `qft` function can be used to transform in both directions. The QCF library includes the function `iplot` for visualizing complex vectors.

Parallel Computing Toolbox software allows offload work from one MATLAB session (the client) to other MATLAB sessions, called workers. Multiple workers to take advantage of parallel processing, can be used. Parallel Computing Toolbox software improves the performance of such loop execution by allowing several MATLAB workers to execute individual loop iterations simultaneously. Parallel Computing Toolbox software allows to
distribute that array among multiple MATLAB workers, so that each worker contains only a part of the array. Yet it can operate the entire array as a single entity. Each worker operates only its part of the array, and the workers automatically transfer data between themselves when necessary, as, for example, in matrix multiplication. A large number of matrix operations and functions have been enhanced to work directly with these arrays, without further modification.

3.4 IMPLEMENTATION OF THE QUANTUM TRANSFORM BASED ENHANCEMENT

Let an image $f$ be represented as a matrix of integer numbers. An image transform can generally process either the whole image or some subimage. Let us assume that the image size in $M \times N$

$$f = \begin{bmatrix}
  f(0,0) & f(0,1) & \ldots & f(0,N-1) \\
  \vdots & \vdots & \ddots & \vdots \\
  f(M-1,0) & f(M-1,1) & \ldots & f(M-1,N-1)
\end{bmatrix} \quad (3.3)$$

Transform matrices $P$ and $Q$ of dimension $M \times M$ and $N \times N$, respectively, are used to transform $f$ into a matrix $F$ ($M \times N$ matrix) of the same size,

$$F = P \, f \, Q \quad (3.4)$$

This can be written as

$$F(u,v) = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} P(u,m) f(m,n) Q(n,v) \quad (3.5)$$

$$u=0,1,\ldots,M-1 \quad v=0,1,\ldots,N-1$$

If $P$ and $Q$ are non-singular, inverse $P^{-1}$ and $Q^{-1}$ exist and the inverse transform can be computed as
\[ f = P^{-1} F Q^{-1} \]  \hspace{1cm} (3.6)

If \( P \) and \( Q \) are both symmetric, real and orthogonal, then

\[ F = P f Q \]

\[ f = P F Q \]

and the transform is an orthogonal transform. If \( P, Q \) are complex matrices, equations above still holds provided, they are Hermitian and unitary.

In this thesis, transformation operations are used for the remote sensing image enhancement technique. In the transformation operation enhancement technique, the satellite imagery is transformed and the inverse transform is applied. The transformed image is operated with zero memory operation, in which the pixel by pixel multiplication has been executed, for the generalised linear filtering. Figure 3.9 shows the Quantum image enhancement block diagram.

![Block diagram of image enhancement transformation](image)

**Figure 3.9 Block diagram of image enhancement transformation**

Image processing and analysis based on continuous or discrete image transforms is a classic processing technique. Transforms are widely used in image filtering, image data compression and image enhancement, etc. Image transform theory is a well known area characterized by a precise mathematical background, and image transform represent a powerful, unified area of image processing.

In digital image processing, the original input image which is in space domain is converted into frequency domain using transformation. The
input image in space domain is converted into frequency domain using Fast Fourier Transform (FFT). The desired algorithms are performed in the frequency domain for the image restoration, image enhancement, noise removal etc. The image in frequency domain is then transformed into space domain using Inverse Fast Fourier Transform (IFFT), for analysis. Till today many existing transformations like wavelet, curvelet are used in image enhancement.

The Quantum Fourier Transform (QFT) is proposed in this thesis for image enhancement. The original image is converted from space domain to quantum environment using the QFT. After this, the zero memory operations are processed for the image enhancement of the original image. After, the IQFT is applied to convert the quantum processed image into space domain for interpretation and analysis. The aim of the thesis is to study improvements in the image enhancement when the QFT and IQFT are used instead of FFT and IFFT. The computational benefit in terms of enhancement is discussed in chapter five, comparing with the original and quantum enhanced image.

3.5 IMPLEMENTATION OF THE MODIFIED DATA PARALLEL ALGORITHM IN IMAGE ENHANCEMENT

Image processing tasks are always computing intensive. Examples of common operations include histogram, contrast enhancement and filters. In general, the contrast enhancement algorithms task is accomplished by considering each pixel \( f(i, j) \) and the \( 3 \times 3 \) pixel neighborhood. The value of \( p(i, j) \) will be replaced appropriately. The new value of \( p(i, j) \) is calibrated as mentioned below. The formula to find the low frequency component pixels as

\[
\sum_{k=n}^{i-n} \sum_{l=n}^{j-n} P(K,l) \frac{1}{(2n + 1) - m_p} = m_p
\]  

(3.7)
For the case \( n=1 \) for 3*3 neighborhood the new pixel values will be as follows

\[
f(i,j) = m_p(i,j) + C[x(i,j) - m_p(i,j)]\text{ where } C=\text{constant}>1
\]  \hspace{1cm} (3.8)

In order to implement the serial version of the enhancement algorithm, the algorithm is implemented locally. In parallel programming there are two types: one is Task parallel and the other is Data Parallel. In Task parallel multiple workers work on different parts of the problem. There is no communication between the workers. The results are independent of the execution order.

In data parallel, the large data in one computer are processed for operation. The large data are separated as LAB 1, LAB 2, LAB 3 and LAB 4 as shown in the Figure 3.10, and then these data are operated by each worker. When the labs are interconnected the resulting image has stripes across it; this makes the data delete the boundaries.

![Figure 3.10 Data parallel algorithm applied to image](image)

The study comprises the Modified data parallel algorithm. The computing Modified data parallel algorithm is executed by the extraction of Red, Green and Blue bands of the satellite image and the extracted bands would be taken as LAB 1, LAB 2, LAB 3 and LAB 4; the various algorithms are operated on each of the labs by the workers, and then it is assembled for the enhancement.
This Modified data parallel algorithm allows us to clear the drawbacks of the Data Parallel algorithms. Data Parallel Algorithms were used only for small sized images. But the Modified Data Parallel Algorithm can be used for higher level image processing applications like satellite images.

The quality of an algorithm is difficult to evaluate. Besides this difficulty, one can come up with several wedges, like efficiency, portability, scalability, elegance, and modularity for the validation of the algorithms. In this thesis the algorithms are applied for image enhancement, as the concern is with the correctness and efficiency of the parallel algorithms. The quality of Parallel image enhancement is based on the visual interpretation of the enhanced image. A Concurrent Algorithm for Connected Set Filtering and its Application to Interactive Visualization is the modified data parallel algorithm.

The different bands in the multispectral image are extracted separately. In each extracted band, the process of histogram equalization is done. The histogram equalization on an input image distributes the gray level values within an image as evenly as possible. The goal of histogram equalization is a flat histogram. The function works with colour or gray scale images. With a colour image, the user specifies the band to be used for histogram calculations.

Then the sharpening algorithm is applied to extracted bands. The sharpening algorithm uses Laplacian filter with a mask of size three and sobel filter with a mask size of three are multiplied to obtain results.
After sharpening the images of extracted bands, the adaptive filtering operation is done. The adaptive filter is used in the images to remove short tailed noise, such as Uniform and Gaussian noises. In the adaptive filter, the average value of the set of pixels contained in the 3 x 3 filter window. The
filter size should be an odd integer. The processed extracted bands are assembled for the output, and then, the validation for the modified data parallel algorithm applied output image is done by using the histogram analysis.

The proposed enhancement techniques are done based on the transform enhancement and spatial enhancement techniques. The block diagram in Figure 3.11, explains the overall methodology. The quantum transformation is used in the transformation enhancement technique, and parallel computing is used for the spatial based enhancement.

The results of the two novel enhancement techniques are compared with those of the existing enhancement techniques. Then, the statistical analysis is done on both the enhanced images and the results are validated. The merits and demerits of the techniques were studied.

The necessary background of the quantum computing and parallel computing is explained in the chapter four. The chapter four deals the basics of computing and explains in detail about the quantum computing and parallel computing. So that one can understand how quantum Fourier transforms and modified data parallel algorithms are implemented in digital image processing.