Keynote-III Advances in Digital Image Processing and Remote Sensing Techniques for Coastal Applications using Satellite Images

Dr. Raju Aedla¹, G. S. Dwarakish² and D. Venkat Reddy³

¹Graduate School of Science and Technology (GSST), Kumamoto University, Kurokami, Kumamoto, JAPAN
²Professor & Head, Department of Applied Mechanics & Hydraulics, National Institute of Technology Karnataka (NITK), Surathkal, Post Srinivasanagar – 575025, Mangalore, D.K., Karnataka, INDIA
³Professor, Department of Civil Engineering, National Institute of Technology Karnataka (NITK), Surathkal, Post Srinivasanagar – 575025, Mangalore, D.K., Karnataka, INDIA
Email: rajuaedla.nitk@gmail.com, dwaraki.gs@gmail.com, dvr1952@gmail.com

Abstract

Remotely sensed satellite images are used in many earth science applications such as geosciences studies, astronomy, and geographical information systems. One of the most important quality factors in satellite images comes from its contrast. Contrast enhancement is frequently referred to as one of the most important issues in image processing. Contrast is created by the difference in luminance reflectance from two adjacent surfaces. Image enhancement is one of the most interesting and important phase in the domain of digital image processing. The present study introduce the developed contrast enhancement algorithms for coastal applications such as, automatic shoreline detection, suspended sediment transport and land use and land cover assessment for Mangalore Coast, West Coast of India.
Keywords: remote sensing, image enhancement, contrast enhancement, clipped histogram equalization, sediment transport, shoreline change, land use and land cover

INTRODUCTION

Remotely sensed satellite images are used in many earth science applications such as geoscience studies, water resources and coastal processes. In order to conserve sustainable development of coastal zones, it is essential to develop accurate and complete databases by continuous monitoring of coastal zones. Monitoring and development of database for large and inaccessible coastal areas is complex through conventional methods, because of huge man power, cost ineffective and time consuming by these methods. The advanced scientific tools of Remote Sensing, Geographical Information System (GIS) and Global Positioning System (GPS) are overcoming the drawbacks of conventional methods used in coastal studies and provide accurate database. By integrating, the generated database can be efficiently analysed using these tools to develop proper coastal zone management plans.

The moderate and high spatial resolution and multi-spectral remotely sensed data generated from various satellite platforms provide detailed information about coastal zones. Due to inherent advantages such as easy availability, synoptic and repetitive global coverage, multi-spectral and moderate to high spatial resolution, the remote sensing data is more suitable for coastal zone monitoring and management studies in an efficient manner.

REMOTE SENSING

Remote Sensing (RS) is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand and Kiefer 1994). In Earth's perspective, remote sensing is the process of obtaining the information about the Earth's surface features using on-board sensors or camera systems from the satellite platform without being in direct contact with it. The data collected by these sensors are in the form of electromagnetic energy (EM) which are emitted or reflected by the object at different wavelengths depending on its physical properties. In addition to this, objects emit radiation depending up on their temperature and emissivity. Every pixel of the digital remote sensing data represents an average value of the EM energy and is recorded as a Digital Number (DN). The recorded energy at
Different wavelengths follow a pattern which is the unique characteristic of that object and is known as the spectral signature of the object or class. Proper interpretation of the spectral signature leads to the identification of the object and segregation of different classes. Certain regions or bands of the electromagnetic spectrum are optimum for obtaining biophysical information. The bands are normally selected to maximize the contrast between the object of interest and its background.

Remote sensing is a process enabled for mapping, monitoring and management of various resources namely, agriculture, forestry, geology, water, ocean etc. Indian Remote Sensing Satellites (IRS) such as IRS-1A (1988), IRS 1B (1991), IRS-P2 (1994), IRS-1C (1995), IRS-P3 (1996), IRS-1D (1997), IRS-P4 Oceansat-1 (1999), IRS-P6 Resourcesat-1 (2003), IRS-P5 Cartosat-1 (2005), IRS-P7 Cartosat-2 (2007), Oceansat-2 etc. facilitate a variety of applications including natural resource monitoring, environmental assessments and disaster management related activities. After the successful launch of Bhaskara I and Bhaskara II in 1979 and 1981 respectively, India launched the first remote sensing satellite IRS-1A in 1988 for various land-based applications. IRS-P5 Cartosat-1 is mainly planned for cartographic applications with two PAN cameras that take black and white stereoscopic pictures of the earth in the visible region of the electromagnetic spectrum with spatial resolution of 2.5 meters.

IRS-P6 Resourcesat-1 is launched in 2003 with LISS-IV camera (5.8 m resolution), LISS-III (23.5 m resolution) and AWiFS (60 m resolution). It is a follow-on satellite for Earth observation that will provide continuity to IRS-1C and 1D and enhances the service capabilities in the areas of agriculture, disaster management, and land and water resources with better resolution imagery. IRS-P4 was the first Indian satellite for Ocean applications launched in 1999 with on-board an Ocean Colour Monitor (OCM) and a Multi-frequency Scanning Microwave Radiometer (MSMR) cameras. OCM is a solid state camera operating in eight narrow spectral bands with 360 m spatial resolution and collect data of chlorophyll concentration, detect and monitor phytoplankton blooms and obtain data of atmospheric aerosols and suspended sediments in the water. MSMR, which operates in four microwave frequencies both in vertical and horizontal polarisation is used to collect data of sea surface temperature, wind speed, cloud water content and water vapour content in the atmosphere above the ocean.

The Indian satellites with their improved spatial resolution, extended spectral range and increased repetitivity leads new studies of coastal zone. Preliminary analysis of IRS-IC, ID data indicates that coral reef zonation,
identification of coastal vegetation and mangroves, mudflats, beach, dune vegetation, saline areas, etc. as well as suspended sediment patterns along the coast. IRS-IC Linear Imaging Self Scanner (LISS) III and Panchromatic (PAN) merged data are more suitable for coral reef zonation studies through identification of reef crest, algal ridge, reef edge, moat, coral knolls, reef platform, reef flat. The PAN data combined with the LISS III and LISS IV data provides detailed information about area of reclamation, construction of coastal structures and ecologically sensitive areas, which are vital for the coastal zone regularity authorities, while developing comprehensive Integrated Coastal Zone Management Plan (ICZMP).

GEOGRAPHICAL INFORMATION SYSTEM

A Geographical Information System (GIS) is defined as “a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes” (Burrough 1998). GIS is capable of handling both spatial data and attribute data of earth surface features. GIS permits to automate mapping and also got the capability of recording and analyzing descriptive characteristics about earth surface features (Lillesand et al. 2004). A Data Base Management System (DBMS) is built in GIS to store and manipulate attribute data of features and it is designed with user friendly commands in Structured Query Language (SQL). GIS has the ability to spatially interrelate multiple types of information stemming from a range of sources. GIS convert data from one coordinate system to another, to understand the characteristics of the various types of coordinate systems, either by using raster or vector data format.

SATELLITE DIGITAL IMAGE PROCESSING

Digital image processing system consists of the computer hardware and the image processing software needed to analyze digital image data (Jensen 1996). Satellite digital image processing is categorized into image rectification and restoration, enhancement and classification. The image rectification and restoration are initial processes of raw image data to correct geometric distortion, to calibrate the data radiometrically and to eliminate noise exist in the satellite data (Lillesand and Kiefer 1994). The image rectification and restoration processes are often termed as pre-processing procedure, because they normally precede with further manipulation and analysis of the image data to extract specific information. The enhancement procedures are applied to image data in
order to effectively display the data for subsequent visual interpretation. It involves techniques for increasing the visual distinction between features in a scene. The image classification is to automatically categorize all pixels in an image into land cover classes or themes. Generally, multispectral data are used to perform the classification, and the spectral pattern present within the data for each pixel is used as numerical basis for categorization. That is, different feature types manifest different combination of DNs based on their inherent spectral reflectance and emittance properties.

**DIGITAL IMAGE ENHANCEMENT**

Image enhancement is one of the most interesting and important phases in the domain of digital image processing. It is used to transform an image, based on the psychological characteristics of the human visual system (Neycenssac 1993). Image enhancement algorithms are applied to remotely sensed data to improve the appearance of an image for human visual analysis or occasionally for subsequent machine analysis. In most of the satellite images the quality factor comes from its contrast. Image enhancement techniques improve the quality of an image as perceived by a human. A wide variety of image enhancement techniques are used for improving the image quality such as, contrast stretch, density slicing, edge enhancement, and spatial filtering. After the image is geometrically and radiometrically corrected, image enhancement is applied separately to each band of a multi-spectral image.

**FILTERING TECHNIQUES**

Filtering is the process that selectively enhances or suppresses particular wavelengths or pixel DN values (brightness values) within an image. Spatial frequency describes the brightness values over a spatial region and defined as the number of changes in brightness value per unit distance for any particular area of an image. If an area in an image has very few changes in brightness value, then it is referred to as low frequency area and similarly, if the brightness values change dramatically over a short distance it is stated as high frequency area. Spatial approach is necessary to adopt to extract qualitative information from remotely sensed imagery using two different methods such as convolution filtering in the spatial domain and Fourier analysis in the frequency domain. Convolution filtering is relatively easy to understand and used to enhance low-frequency and high-frequency regions, in addition to edges in the
imagery. Fourier analysis mathematically divides an image into its spatial frequency components, resulting in a Fourier transform of the image. Low-pass or low-frequency filters are used to block the high frequency details in an image, and high-pass filters are applied to remove the slowly varying components and enhance the high-frequency local variations in an image.

Median filter is the non-linear, low-pass filter useful for removing noise in an image, by which individual pixels are missing. Median filter contains a spatial filtering operation, selects the median value of the nine pixels of 3x3 convolution mask and it is placed in the central value of the mask or kernel. The convolution masks of median filter are 3x3, 5x5, 7x7 and 5x5 and 7x7 Octagonal. Median filter reduce the variance of the intensities in the image.

**PRINCIPAL COMPONENT ANALYSIS**

Principal Component Analysis (PCA) or Kar-hunen-Loeve analysis is used to compress the information content of a number of bands of imagery into just two or three transformed principal component images (Press et al. 1992, Wang 1993). The transformation of the raw remote sensor data using PCA, results a new principal component images that may be more interpretable than the original data (Singh and Harrison 1985). Principal component analysis is a pre-processing transformation that creates new images from the uncorrelated values of different images. The aim of PCA is to translate or rotate the original axes, so that, the brightness values on original axes are redistributed on to a new set of axes or dimensions. Principal component transformations are used for spectral pattern recognition as well as image enhancement. PCA operates on all bands together and describe the data more efficiently than the original band reflectance values. The first principal component accounts for a maximum portion of the variance in the data set, often as high as 98%. Subsequent principal components account for successively smaller portions of the remaining variance. Principal component images may be analysed as separate black and white images, or any three component images may be colour coded to form a colour composite. Principal component enhancement techniques are particularly appropriate in areas where little a priori information concerning the region is available.
COASTAL PROCESSES

Coastal zone is the triple interface of the land, ocean and atmosphere. Cracknell (1999) defined coastal zone as the region between the 200 m bathymetric contour at sea to the 200 m elevation contour on the land. Coastal zones are one of the most complicated ecosystems with a large number of living and non-living resources (Constanza et al. 1997). Coastal zones are exposed to a series of dynamic natural processes like coastal erosion, sediment transport, environmental pollution, and coastal development that usually causes changes in long and short time spans. Shoreline is the line of contact between the high water line and the shore (CERC 1984). It is one of the 27 features recognized by International Geographic Data Committee (IGDC) (Li et al. 2001). It undergoes short-term and long-term changes, caused by hydrodynamic changes (e.g. river cycles, sea level rise), geomorphological changes (e.g. barrier island formation, spit development) and other factors (e.g. sudden and rapid seismic and storm events) (Scott 2005). The study of shoreline change rate is essential for development of setback planning, hazard zoning, erosion-accretion studies, regional sediment budgets and conceptual or predictive modeling of coastal morphodynamics (Sherman and Bauer 1993; Al Bakri 1996; Zuzek et al. 2003; Maiti and Battacharya 2009). Digital Shoreline Analysis System (DSAS) is a freely available software tool under ArcGIS for calculation of shoreline changes along the coast and it computes the rate-of-change statistics for a time series of shoreline vector data (Crowell and Leatherman 1999).

Sediment transport monitoring and understanding is essential due to the adverse effects like siltation of harbours, accumulation of sand bars to create navigational hazards, seasonal blockage of estuaries or degradation of coastal environment. Remote sensing satellite images provides periodic, integrated, and synoptic views for determination of net direction and distribution of alongshore sediment transport economically, efficiently and quickly (Kunte and Wagle 1993). The penetration depth of electromagnetic (EM) energy is influenced by the material content and/or size of the suspended sediments (Whitelock et al. 1978). Turbid water is more reflective than clear water both in the visible and near infrared regions of the EM spectrum.

Land use and land cover image classification is always a difficult task and the characteristics of the resulting land-cover maps derived from different satellite images are not always the same (Bonnett and Campbell 2002). Multi-temporal remotely sensed data are often used in understanding seasonal variations of land-cover and also in improving
the land cover classification accuracy (Schriever and Congalton 1995). Multi-spectral classification is one of the most frequently used methods of information extraction. Multi-spectral classification is performed using variety of algorithms, including hard classification methods using supervised and unsupervised classification, soft classification techniques using linear spectral mixture modelling, fuzzy c-means classifiers, artificial neural networks and support vector machines and hybrid approaches using ancillary (collateral) information.

Based on the advantages of remotely sensed data, it is widely used in coastal applications to conserve sustainable development of coastal zone management. Monitoring of coastal zones using low contrast satellite images is difficult and loss of information will be the maximum during interpretation of images. To overcome the drawbacks of low contrast satellite images, various contrast enhancement techniques were developed and histogram equalization is an extensively used well-known method. It is possible to improve the quality of the images through histogram equalization based techniques and it can be improved the identification and extraction of features from images for further analysis without loss of information. It is also possible to extract the information of isolated coastal regions from the enhanced images and these enhancement methods offer to develop automatic feature detection from the satellite images. The present study provides the scope to develop contrast enhancement techniques for accurate study and management of coastal zones using satellite images.

In the present paper, Clipped Histogram Equalization (CHE) based contrast enhancement algorithms for Automatic shoreline detection, Suspended sediment transport and Land Use and Land Cover (LULC) assessment are presented.

**AUTOMATIC SHORELINE DETECTION AND ANALYSIS**

For automatic shoreline detection, CHE-based contrast enhancement algorithm has developed to enhance coastal objects and to improve the contrast between the land and water objects. The developed CHE-based method highlighted the coastal objects without introducing any additional noise. The enhanced coastal objects were segmented using thresholding operation. Geometrically corrected and orthorectified band 4 (NIR) grey scale 8-bit (intensity value range between 0 and 255) IRS P6 LISS–III (2005, 2007, 2010) and IRS R2 LISS–III (2013) pre-monsoon (January to May) remotely sensed satellite data sets were considered for
shoreline detection and analysis. At near infrared (NIR) wavelength region water appears dark because of its strong absorbance and areas with mainly vegetative or exposed soil appear brighter in the image because of their strong reflectance. To improve the sufficient intensity contrast between the land and water regions and to avoid the complexity in detecting shoreline edges from satellite images a CHE-based contrast enhancement has been developed. CHE-based techniques were more suitable and efficient for contrast enhancement and brightness preservation of the satellite images.

Figure 1  The complete methodology of automatic shoreline detection process using IRS-P6 LISS III 2010 satellite image

SUSPENDED SEDIMENT TRANSPORT

Regular study of sediment dynamics by conventional point measurements using ships or boats are limited due to extremely poor spatial coverage that too for a particular time and very high cost of conducting such surveys. Ocean colour sensors onboard satellites provide synoptic view, high repetitive and are excellent tools to map and monitor sediment patterns, assess relative changes in sediment concentrations and retrieve sea surface velocities using multi-temporal remotely sensed satellite images (IOCCG 2000, Garcia and Robinson 1989).

In coastal applications, it is very difficult to study turbidity pattern and sediment plumes along the coast using low resolution remote sensing images. Digital Image enhancement techniques enhance contrast among
features for better detection of coastal geomorphic units, underwater bed flow structures and mapping of sediment plumes to understand the distribution and concentration of suspended and settled sediments.

In the present study, an image enhancement technique was developed using Clipped Histogram Equalization (CHE) based contrast enhancement and Principle Component Analysis (PCA) methods to map suspended sediment transport and its distribution along Mangalore Coast, West Coast of India.

**Figure 2** Sample stations located on FCC-3 image as per the studies carried out by Dwarakish et al. (2010) and Avinash et al. (2012)
LAND USE AND LAND COVER ASSESSMENT

Land use and land cover monitoring scenarios using remotely sensed satellite data are becoming more prevalent in remote sensing applications. LULC mapping from multi-spectral satellite image data was based on spectral differences in land cover categories. Since only a limited number of land cover types are desired in most cases, the images contain redundant information which is unnecessarily complicates the digital mapping process. To improve the accuracy assessment of LULC classification and to avoid the complexity in classifying the mixed pixel, the present study developed a new clipped histogram equalization based algorithm for LULC classification.
Figure 3  Supervised classification images of New Mangalore Port Trust (NMPT) area

(A). General (B). Developed Methods
CONCLUSIONS

The drawbacks of conventional shoreline extraction are overcome by the developed clipped histogram equalization based contrast enhancement and thresholding based algorithm has shown better positional accuracy of 96%, when compared to GPS survey values. The established integrated CHE-based contrast enhancement and PCA based algorithm for suspended sediment transport mapping has shown better tonal variation of sediment concentration. The distribution and direction of sediment map matches well with the results of Dwarakish et al. (2010) and Avinash et al. (2012) and the developed contrast enhancement algorithm for SSC distribution along Mangalore Coast using OCM data is satisfactory. The combined CHE-based contrast enhancement and PCA based algorithm improved the accuracy of classification of land use and land cover.

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