Remote Sensing for Disaster Monitoring and Mitigation in Malaysia

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Abstract

Remote sensing has been used widely for disaster management in terms of monitoring and mitigation operations. With advances in sensor technology and computation power, application of remote sensing has been enhanced with the availability of optical and radar images of the earth surface to complement the traditional black and white survey aerial photographs. Remote Sensing sensors are regularly flown on satellites such as European Remote Sensing (ERS), Japanese Environmental Resources Satellite (JERS), Radarsat, and SPOT. The image products may be ordered from the respective satellite operating agencies. However, the management of dynamic events such as natural disaster, search and rescue operations and surveillance requires real-time, on-demand, high resolution and all-weather data. Airborne sensors are vital to provide an effective disaster monitoring. In addition, it is important to have a central system for collecting, storing, processing, analyzing and disseminating value-added data and information to the relevant agencies in the management of major disasters in the country. This paper introduces the developments of remote sensing infrastructure and some of the research projects undertaken in Malaysia.

1. Introduction

The main aim of remote sensing is to develop techniques for the utilization of observations to derive information about the biophysical and geometrical properties of the targets without physical contact. Optical and microwave sensors are widely used to facilitate the research and development work.

The most important tools for remote sensing applications are the imaging sensors mounted on flying platform (aircraft or spacecraft) to produce pictures of the Earth surface. Optical sensors rely on the sun as the source of illumination. The intensity of reflected light or emitted infrared from the ground object depends on the time-of-day, direction of sunlight relative to the viewing angle, and cloud cover condition.

Microwave sensors operate based on the principle of radar. The main advantage of radar instruments is their ability to penetrate clouds, rain, tree canopies, and even dry soil surfaces depending on the operating frequencies. Objects below the forest canopy can be “seen” by the imaging radar. This leads to some interesting applications such as estimation of tree-trunk diameter, canopy biomass, and moisture content of leaves and soil. On the other hand, due to the persistent cloud cover in tropical climate, the use of microwave remote sensing technology is crucial and advantageous over optical technology in the tropics. In addition, since radar is an active instrument which provides its own illumination, it can operate in both day and night. The imaging outputs are more consistent because they are not affected by sunlight intensity or direction. Different polarizations of electromagnetic wave can be transmitted, therefore the multi-polarization backscattering responses can provide additional information of the ground objects.

The images produced by both optical and microwave sensors have shown many useful applications in natural resource management and environmental monitoring. These include agriculture, forestry, and range resources management; land use and mapping; Geology; water resources management; Oceanography; environmental management; and planning of infrastructure development and town. Disaster management is another very important remote sensing application. Nevertheless, it is very much related to the other applications mentioned above. For example, in the management of forest fire, one needs to know the crop types, crop acreage by species, biomass, moisture condition, and soil conditions in order to predict the spreading of the fire. After the disaster is over, land use map with detailed inventory information is needed to assess the damage and economic loss. In the management of landslide, one needs to know the land uses, mapping changes of major geologic units, delineation of unconsolidated rock and soils, and monitor modified slopes and deforestation in order to assess landslide risk and hazard and take the necessary proactive measures that will prevent the occurrence of major landslide or provide early warning to minimize loss of human lives. In flood monitoring and mitigation, one needs to know the normal water boundaries, channel networks of the terrain, mapping of floods and flood plains, and determine the water depth. It is also important to determine the effects of the natural disasters in terms of transportation disruption, economic loss, and epidemic proliferation. On needs to map and monitor water pollution and retrieve eddies and waves information from sensor images to assist in tracing of oil spills and other pollutants. One needs to process remote sensing data to detect haze and air pollution. Techniques are yet to be developed for remote sensing of tsunami. Real-time tsunami sensor network is normally use for early warning purposes. However, remote sensing techniques can be applied in mapping shoreline changes after the disaster.

Remote sensing research and development has seen many changes in the past few years. The disasters of tsunami in 2004 and hurricanes in 2005 have presented new challenges for geosciences and remote sensing scientists and engineers. Advanced applications can only be developed with the supporting research and development in sensor systems, theoretical modeling of wave-matter interaction, and controlled experiments. This article aims to give an overview of the developments of remote sensing infrastructure and some of the research projects undertaken in Malaysia.

2. Remote Sensing Development in Malaysia

A few groups of researchers have worked on remote sensing research for the past 30 years or so. The potential of remote sensing is enormous. The Malaysian Centre for Remote Sensing (MACRES) was established in 1988 by the government to intensify the R&D in remote sensing and to enhance the collaboration between the relevant agencies, universities and industry.

A National Resource and Environmental Management System (NAREM) was developed in 2001. It comprises three major components: NaSAT organizes remote sensing data into an integrated database; NaMOS consist of a collection of application packages employing model-based technique to support the various applications; and NaDES is a decision support system which provides the desired information to the data and application queries. NAREM application packages were developed through inter-agency collaboration involving natural resources agencies and universities for nine sectors, namely: agriculture, forestry, geology, marine, environmental management, hydrology, coastal, topography, and socio-economic, as well as the central planning authority of the government as the main user of the system. The applications include landslide hazard zoning, coastal sensitivity index, soil erosion, ground water potential, agro suitability zoning, and forest management. The system is also used to continuously monitor development activities on environmentally sensitive area in the country. Accordingly, reports are submitted on regular basis for activities affecting areas such as water catchments, highlands, forest reserves and wetlands.

Remote Sensing sensors are regularly flown on satellites such as European Remote Sensing (ERS), Japanese Environmental Resources Satellite (JERS), Radarsat, and SPOT. The image products may be ordered from the respective satellite operating agencies. However, the delivery of the image product on CD or tape may take substantial time. MACRES has established a ground receiving station (MGRS) at Temerloh to receive remote sensing data on real-time basis directly from the satellites of SPOT, Landsat, Radarsat and NOAA. The raw data can be converted to various levels of image products by the Data Processing System. The system was fully operational since 2002. It was later upgraded to receive MODIS data from Terra and Aqua satellites, and OCM data from Indian IPS-P4 satellite. With its 2500 km radius footprint coverage, the facility is capable of receiving satellite data of Malaysia, ASEAN countries, southern part of China and eastern part of India.

The MGRS will be upgraded to receive data from RazakSAT, the second remote sensing satellite of Malaysia. The payload of RazakSAT is a Medium Aperture Camera comprising 1 panchromantic-band sensor (2.5-m resolution) and 4 Multispectral sensors (5-m resolution). The small satellite will circulate on near-equatorial orbit (NEqO) at an altitude of 600-800 km and inclination of 7 – 9 degrees. Commercial LEO satellites that circle the earth on polar orbit will pass over the same spot along the equatorial belt around once every 21 days. The RazakSAT, being on NEqO, will see the same spot along the equatorial belt every 2 – 6 days but it will see Malaysia as many as 11 – 14 times a day. It will be able to provide timely data to its users in Malaysia as well as catering to the needs of countries located on the equatorial belt.

The management of dynamic events such as natural disaster, search and rescue operations and surveillance requires real-time, on-demand, high resolution and all-weather data. For this reason, MACRES is acquiring from China a Hyperspectral sensor (64 VIS/NIR, 2 SWIR, 1 MIR, 1 TIR; 3-m resolution at 1-km altitude) and an L-band Synthetic Aperture Radar (SAR, 3-m resolution), mounted on two different aircraft platforms. At the same time, Multimedia University (MMU) is collaborating with MACRES to develop a C-band airborne SAR. The prototype antenna, transceiver hardware and image reconstruction software have been implemented and tested [1]-[11].

Multi-temporal, multi-polarization, multi-look-angle, and multi-frequency SAR data are not readily available. Therefore, controlled experiments on natural targets are best conducted using a truck-mounted scatterometer. A C-band scatterometer [12] has been designed and constructed. It supports full-polarimetric measurements. The measured polarization responses for dihedral and trihedral corner reflectors show excellent match with the theoretical responses. The non-imaging sensor can be easily deployed to the measurement site such as a paddy field [13]. Measurement can be performed at various incident angles over the growth stages of the crop. The measurement results can be used to test the accuracy of theoretical models. An L-band scatterometer is being developed to complement the C-band system in future field measurements.

Theoretical modeling is important for understanding of the interaction between microwave and the earth terrain so that software algorithm can be developed to predict the radar returns from such medium. In order to validate the theory under controlled environment, measurements using anechoic chamber and scatterometer systems are conducted. A multipurpose anechoic chamber has been designed to operate over an extremely wide frequency range from 30 MHz through 18 GHz [14]. The geometry of the chamber is asymmetrical, consisting of a combination of rectangular and tapered volumes. The size of the chamber is 64' × 32' × 24' height. Less expensive absorbers can be used to obtain the required wideband performance made possible by the unique geometry. For Remote Sensing research, the chamber can facilitate both monostatic and bistatic microwave scattering measurements for a variety of incident/scattering angles and polarization configurations.

3. Disaster Monitoring and Mitigation Requirements

Remote sensing has been used widely for disaster management in terms of monitoring and mitigation operations. With advances in sensor technology and computation power, application of remote sensing has been enhanced with the availability of optical and radar images of the earth surface to complement the traditional black and white survey aerial photographs.

Data from both optical sensor (VIS and NIR) and SAR may complement each other to provide accurate detection of environmental hazard and monitoring of disaster. The required spatial resolution is in the range of 1 m – 20 m, while the required temporal resolution may be seasonal, daily, or event dependence. The revisit time of commercial remote sensing satellites is in the range of 5 – 24 days. They cannot provide timely data for disaster management applications. On the other hand, countries in the equatorial belt suffer from persistent cloud cover which severely hampers the application of optical satellite images. The use of microwave remote sensing technology is crucial and advantageous over the optical technology in tropical regions. Airborne SAR is particularly useful for disaster monitoring and mitigation operations.

In the event of a natural disaster, remote sensing processing system must be in place to monitor, model, and map natural hazards quickly and reliably. In addition, appropriate decision must be made for deployment of rescue teams to diminish possible threats to human safety and infrastructure. A national disaster monitoring and mitigation framework called NADDI has been developed to establish a central system for collecting, storing, processing, analyzing and disseminating value-added data and information to support the National Security Division and relevant agencies in the management of major disasters in the country. The system consists of three components: (i) Early Warning; (ii) Detection and Monitoring, and (iii) Mitigation and Relief.

The Early Warning component produces risk maps of areas that are susceptible to disasters. It also control a number of real-time alert systems installed at high risk area. The Detection and Monitoring component acquires remote sensing images from satellite-borne and airborne system as well as data from ground surveillance to provide near real time information on the exact locations and extent of the disaster to the disaster coordinating authority. The Mitigation and Relief component is an inter-agency activities carried out through a Disasters Management and Coordination Centre to mitigate and manage disasters. Disasters addressed by NADDI are flood, landslide, forest fire, oil spill and "hot-installations", and tsunami.

4. Remote Sensing Research at MMU

The research team at the Centre of Applied Electromagnetics of MMU has worked closely with MACRES for many years. The remote sensing research includes the development of Radar Sensors and Microwave Remote Sensing Applications. Theoretical models to study wave scattering mechanism (such as Renormalization Technique, Monte Carlo model, Dense Medium Phase and Amplitude Correction Technique, and Radiative Transfer Equation) have been developed and used in SAR image processing and analysis.

One of the research projects that the Centre is currently undertaking is modeling of landslide processes. Generally, landslide may be triggered by (i) Endogenic force – due to tectonic adjustment, usually the uplift processes that alters the surficial features of hill slopes; and (ii) Exogenic force - due to weather related phenomena such as storms, hurricanes, typhoons, sandstorms, and ground water depletions. The objectives of this project are to identify zones of landslide occurrence and the potential path(s) that the landslide will follow. Multiscale Mathematical Morphology techniques are used to produce multiscale Digital Elevation Models

(DEM) and extract ridge and channel networks of the terrain [15]-[17]. An example is shown in Fig. 1 and 2. Soil types, land use/land cover features, and mountain moist fields will be classified from airborne and space-borne remote sensing images. Certain models of landslide dynamics will be applied to multi-temporal remote sensing data to predict landslide risk and impact.

Fractal and multi-fractal based techniques are used in land use classification [18]. A Hybrid Entropy Decomposition and Support Vector Machine Method has shown promising results in agricultural crop types and growth stages classification from multi-polarization, multi-band, multi-temporal remote sensing data [19]. Fig. 3 shows the classification results of various techniques.

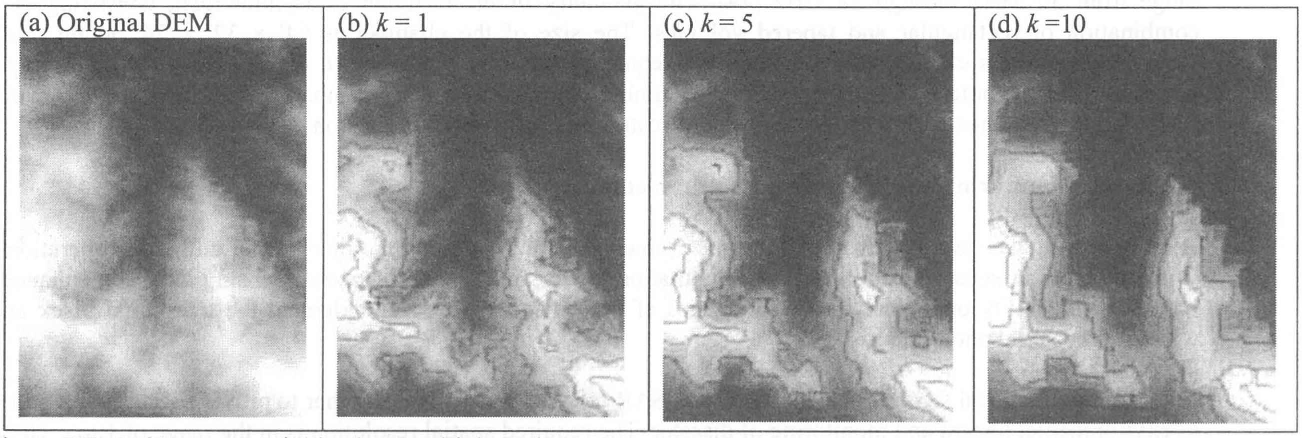

Fig. 1: DEM of Cameron Highlands at multiple scales.

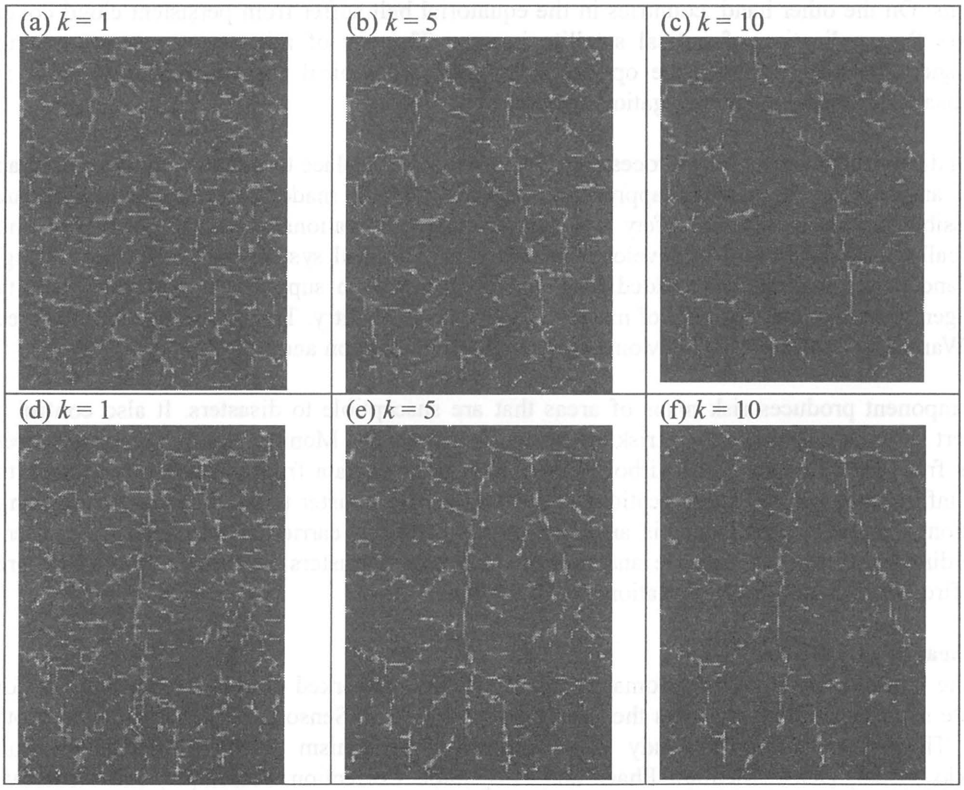

Fig. 2: (a-c) Multiscale ridge networks, and (d-f) multiscale channel networks extracted from the corresponding multiscale DEMs.

The Centre also participates in the Malaysian Antarctic Research Programme coordinated by the Academy of Sciences Malaysia (ASM) under a bilateral scientific cooperation between Malaysia and New Zealand. A multilayer model that represents the sea ice in terms of the wave-target interaction has been developed based on dense random medium modeling techniques [20]. The backscattering model take into account the sea ice thickness, dielectric constant, the brine and the bubble counts, and that the sea ice is covered by snow layer. Sea ice properties which affect the radar backscattering were investigated using remote sensing images and ground truth measurement data. The model is then used in the classification of sea ice at the Antarctic.

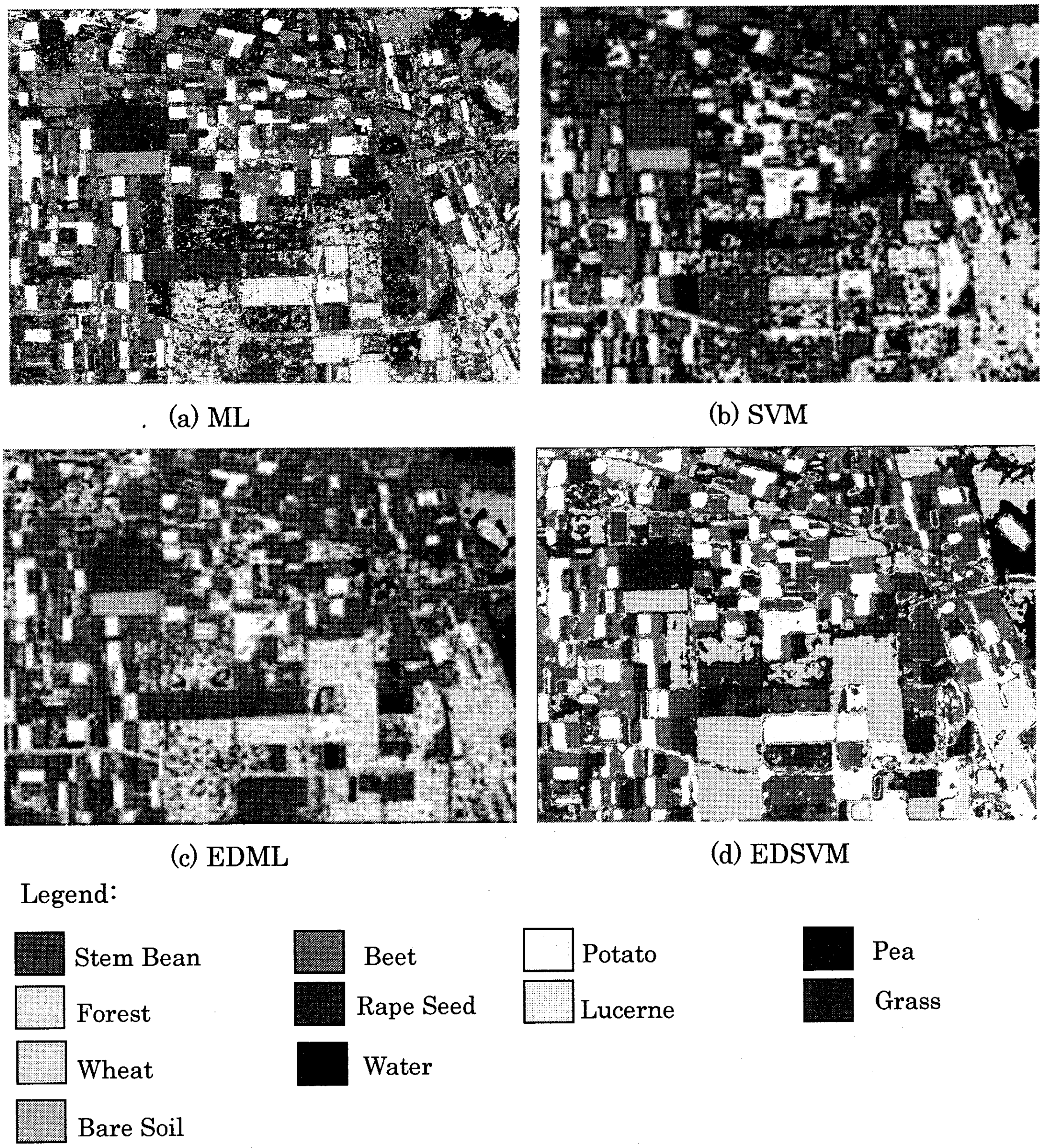

Fig 3: Classification of agricultural crop types on Flevoland image with optimum window size (a) ML, (b) SVM, (c) EDML (d) EDSVM for optimized window size

5. Conclusion

Remote sensing is very useful for monitoring the state of the Earth, increase understanding of Earth processes, and enhance predication of the behavior of the Earth system. Disaster monitoring and mitigation applications must be supported by other remote sensing applications such as land use classification, terrain mapping, forest inventory, etc. The management of dynamic events such as natural disaster, search and rescue operations and surveillance requires real-time, high resolution and all-weather data. Airborne sensors are vital to provide an effective disaster monitoring. It is important to have a central system for collecting, storing, processing, analyzing and disseminating value-added information to the relevant agencies in the management of major disasters.

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