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Application of Spatial Information as a Nuclear Verification Technology

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1. Introduction

Recently, International Atomic Energy Agency (IAEA) has focused its efforts on strengthening nuclear verification capability to find undeclared nuclear activities. The Agency has proposed measures for enhancing these capabilities in the areas of : (i) environmental sampling, (ii) satellites imagery, and (iii) information on nuclear procurement and supply. Among them, remote sensing technologies using satellites imagery are reviewed in this paper for its applicability to the safeguards fields. Satellite imagery is routinely used for safeguards purposes such as the analysis of the member states' declarations and the planning of inspections and CA.

With satellite photographs of high resolution (~0.6m), information of objects on the ground can be accessed without visiting the place of interested. RS technology can help the Agency in confirming the operational status of nuclear facilities, and in understanding the features and changes of building in nuclear sites. Since the Agency has plans to enhance its analytic capabilities with the member states' assistance, so it is important to review various and advanced RS technologies to support the Agency.

2. Concept of Remote Sensing

2.1 Definition of Remote Sensing

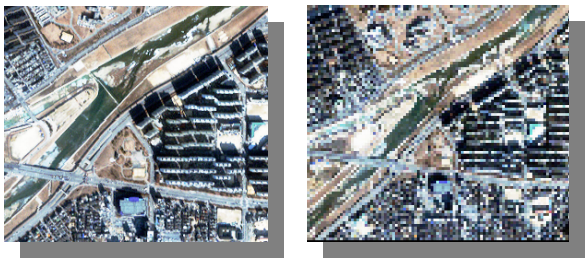
Remote sensing is the science of obtaining information about an object, area, or phenomenon through the analysis of the data acquired by a device that is not in contact with the object, area, or phenomenon under investigation. But it is usually limited to the technology to extract information from the image data which are achieved by sensors mounted on the airborne or space borne platforms.

2.2 Basic Theory

In order to collect data of ground objects or earth surface, sensor should gather reflecting electromagnetic waves from the targets. The reflecting electromagnetic waves have unique characteristics dependent on surface conditions and environmental parameters such as humidity, temperature, or content of air pollutants.

The achieved image can not convey the real value of the surface data due to the physical limitation of the sensors. The quality of the data is determined by the resolving power of sensor, which might be classified into four categories as described below.

(1) Spatial resolution : a measure of the smallest angular or linear separation between two objects that can be resolved by the sensor
(2) Spectral resolution : the number and dimensions of specific wavelength intervals in the electromagnetic spectrum to which a remote sensing instrument is sensitive
(3) Radiometric resolution : the sensitivity of a remote sensing detector to differences in signal strength as it records the radiance flux reflected or emitted from the terrain
(4) Temporal resolution : frequency of data acquisition over the area



4m × 4m resolution 16m × 16m resolution
Fig. 1. Images Comparison (Spatial Resolution)

3. Earth Observation Satellites

Since successful launching LandSat 1 in 1972, more than 20 EO (earth observation) satellites have been round earth orbit. In 1999, IKONOS was launched and started to provide high resolution satellite image with commercial purposes.

3.1 LandSat

LandSat is the first EO satellite for the purpose of assisting scientific researches with multi-spectral sensor.

- Swath Width : 185km
- Resolution : 30m (Panchromatic 15m)
- Sensor : Thematic Mapper, Multi-Spectral Scanner
- Revisit Time : 16 days

3.2 Kompsat-1

It is the Korea's first multi-purpose EO satellite, which was launched by KARI in 1999. It has a function of taking stereo type photographs to make digital elevation model.

- Swath Width : 17km
- Resolution : 6.6m
- Sensor : Electro Optical Camera, Ocean Scanning Multi-spectral Imager, Space Physics Sensor
- Revisit Time : 28 days

3.3 IKONOS

Launched in 1999, IKONOS started first to provide high resolution (~ 1m) image to private sector with commercial purposes.

- Swath Width : 11km
- Resolution : 4m(Multi-spectral), 1m(Panchromatic)
- Sensor : Panchromatic sensor, Multi-spectral sensor
- Revisit Time : 1.5~2.9 days (dependent on latitude)

3.4 QuickBird

Launched in 2001 after the failure of its predecessor QuickBird 1, it provides the finest spatial resolution in the commercial area.

- Swath Width : 16.5km
- Resolution : 2.4m(Multi), 0.6m(Panchromatic)
- Sensor : Panchromatic sensor, Multi-spectral sensor
- Revisit Time : 1~3.5 days (dependent on latitude)

3.5 RadarSat

Made by Canadian and launched in 1995, it has radar sensors to take ground images despite of bad weather conditions.

- Swath Width : 50km
- Resolution : 10m
- Sensor : Synthetic Aperture Radar
- Revisit Time : 24 days

4. Applications Using Spatial Imagery

4.1 Land Coverage Classification

Each pixel of satellite imagery contains specific data representing the surface information. If appropriate software technique is used, whole image pixels can be categorized automatically into land cover classes or themes based on the pixels' attribute, i.e., spectral pattern.

4.2 Feature Extraction

As an advanced technique of Classification, Feature Extraction is still under development for full automatic execution. The concept is to take out typical images such as building, road, or specified area based on user selection and pixel attribute.

4.3 3-D Terrain Analysis

Using stereo-typed images or electronic map with contour data, DEM(Digital Elevation Model) data can be constructed and used to make 3-D space in PC. Within this virtual space, terrain analysis can be performed which is not possible at the 2-D image.

4.4 Change Detection

This is a technique to find the change of land coverage characteristics using arithmetic operation between images taken with time interval. It can be effectively applied to the structures which should be regularly monitored such as suspicious military bases or nuclear facilities.

5. Recommendations and Conclusions

Although it is generally recognized that RS technology has contributed to find undeclared nuclear activities, its usage is still limited to visual analyzing satellite images as simple photographs. Since the skill for hiding clandestine structures or activities will evolve in line with the advancement of verification technology, it is required to develop new techniques to draw more correct information from imagery.

The verification capabilities with RS techniques can be enhanced by developing techniques in the following areas :

1) Expanding Application of SAR Image
2) Enhancing Image Analysis with High Resolution
3) Development of Change Detection Technique
4) Real-time Image Achieving and Analysis

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