CLASSIFICATION OF NATURAL-TECHNOGENIC OBJECTS IN REMOTE SENSING APPLICATIONS

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ABSTRACT

The major natural-technogenic objects in remote sensing applications are specified in the paper. The paper shows the importance of modern monitoring technologies in order to provide broad picture of the current state of the object and its natural environment as a single system, including the possible changes in the current state and management of the system under normal and emergency modes with the visualization of results of data processing. The goal of the paper is to specify the most important monitoring objects within Latvia-Russia cross-border territory. Practical applications of remote sensing and geoinformation technology in different areas are considered in the paper as well. The worldwide best practices of the different object monitoring are examined and possible objectives, issues and benefits are defined. Some types of natural-technogenic objects are hold out for the further study in order to demonstrate the effectiveness of the developed integrated intelligent monitoring system.

1. INTRODUCTION

Humans have broadened their understanding over the years, about size, shape, and processes associated with earth, which in turn contributed in making sophisticated and accurate representation of the globe and its phenomena. Advancements in space technology, digital information, and communication technologies have stimulated the growth of earth-oriented information science/system, which helps in representing and modeling earth's phenomena in an efficient way (Anbazhagan, Subramanian, and Yang 2011).

It is hard to imagine modern human activities without using precise, independent and recurrently updated information. Satellite-based imagery is the source of such information. Nowadays we are witnessing more and more practical tasks being resolved with the help of remote sensing data (ScanEx 2012).

Natural resource management is a broad field covering many different application areas as diverse as monitoring fish stocks to effects of natural disasters (hazard assessment). Remote sensing can be used for applications in several different areas, including (El-Khoury 2012, Sherbinin et.al 2006):

- Geology and Mineral exploration (quarrying, the coordination of the wells and other resource-mining objects, geodynamics and monitoring of geological environment, deformation and displacement of engineering structures and soils, archaeological research)
- Hazard assessment (storm, flooding, fire, geothermal exploration, earthquake)
- Oceanography (ocean-atmosphere system, sea surface temperature and topography, ocean circulation, sea level variability, wind speed and stress, wave height, solar radiation flux at ocean surfaces, and sea-ice characteristics and ice motion, fisheries)
- Agriculture and forestry (soil properties, crop inventory and yield prediction, vegetation change, assessment of biodiversity)
- Land-use (land degradation, land-use change and sustainability trajectories, urban studies)
- Environmental monitoring (environmental treaties)
- Social Science (demography, human health and epidemiology, archaeology and anthropology, international relations, law and policy)

Geoinformation technologies and remotely sensed data, recently only in hands of large government and military institutions, are actively entering all the fields of the economy data (ScanEx 2012). This imposes new requirements on the dedicated software for remotely sensed data processing. First and foremost the high quality of the output image products should be ensured. At the same time this software should run on ordinary computers of average performance, provide for an advanced set of tools as well as be user-friendly and easy-to-use.

2. SPACE TECHNOLOGY FUNCTIONAL CAPABILITIES

Each application itself has specific demands, for spectral resolution, spatial resolution, and temporal resolution. For a brief, spectral resolution refers to the width or range of each spectral band being recorded. As an example, panchromatic imagery (sensing a broad range of all visible wavelengths) will not be as sensitive to vegetation stress as a narrow band in the red wavelengths, where chlorophyll strongly absorbs electromagnetic energy.

Spatial resolution refers to the discernible detail in the image. Detailed mapping of wetlands requires far finer spatial resolution than does the regional mapping of physiographic areas.

Temporal resolution refers to the time interval between images. There are applications requiring data repeatedly and often, such as oil spill, forest fire, and sea ice motion monitoring. Some applications only require seasonal imaging (crop identification, forest insect infestation, and wetland monitoring), and some need imaging only once (geology structural mapping). Obviously, the most time-critical applications also demand fast turnaround for image processing and delivery - getting useful imagery quickly into the user's hands.

The following main functional capabilities of the technology are required to provide monitoring of natural-technogenic objects:

1. Image filtration:
   - Edge Detection.
   - Smooth filters.
   - Speckle Noise filtering.
   - Morphological operations.
   - Texture features calculation.
   - Noise removal.
   - Values interpolation.
2. MODIS data thematic products:
   - Fire detection.
   - Clouds detection.
   - Snow and ice cover detection.
   - Land surface temperature calculation.
   - NDVI and EVI calculation.
   - Possibility to set threshold values during calculation.
3. Thematic processing of radar images:
   - Radar images segmentation using specific algorithms.
   - Oil spills detection.
   - Possibility to get statistic probability of assessing the pixel as oil spill.
   - Ship detection.
4. Solar radiation balance calculation:
   - Capability to calculate short-wave radiation.
   - Capability to calculate long-wave radiation.
   - Capability to calculate air and surface temperatures.
5. Hydrological modelling:
   - Possibility to model hydrograph.
   - Flooding modelling.
   - Freshets and overflows modelling.
   - Acquisition of water distribution model on the specified date.
6. 3D modelling and visualization:
   - Cloudiness, fogs, mists, smoke modelling.
   - Water surface modelling.
   - Trees modelling.

3. MONITORING OBJECTS CLASSIFICATION

The natural-technogenic objects of monitoring can be divided into three main classes:

1. Environmental and natural resources.
2. Natural disasters and industrial accidents.
3. Technogenic objects.

1. Environmental and natural resources monitoring

The studies of the dynamics of ecosystems changes in varying degrees, study of the influence of various natural and anthropogenic factors on the ecosystem, evaluation of natural resource management regimes etc. Possible objectives are:

Monitoring of ecosystems including:

- aerosols in atmosphere
- air pollution
- water pollution

Monitoring of natural resources, e.g.:

- an inventory of agricultural land
- forecast yields
- soil and banks erosion
- deforestation
- forest inventory
- analysis of rivers, lakes, seas ice cover
- analysis of the dynamics of groundwater
- water content of the rivers and lakes

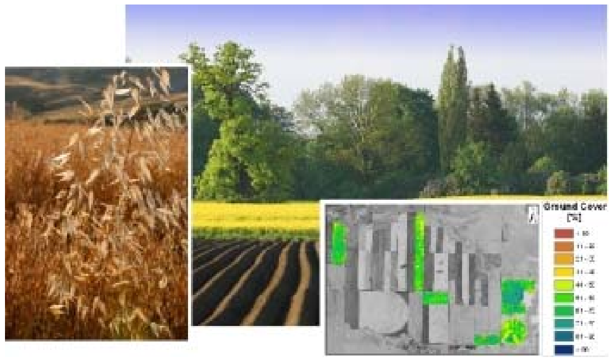

Figure 1: Environmental and Natural Objects

For example, remote sensing is determined as the most accurate tool for global biomass measurements because of the ability to measure large areas. Current biomass estimates are derived primarily from ground-based samples, as compiled and reported in inventories and ecosystem samples. By using remote sensing technologies, we are able to scale up the sample values and supply wall to wall mapping of biomass (Fatoyinbo. 2012).

Despite the continuous advances in information technology, remote sensing is the only observing platform capable of providing continuous information on biological and physical properties over vast areas of the ocean. Information on this whole range of processes is required for the comprehension of the marine system dynamics. Because the ocean is largely opaque over much of the usable electromagnetic spectrum, the ability of satellites to capture ocean properties is generally confined to the surface. Nevertheless, satellite-borne sensors provide us with a relatively large range of measurements such as sea surface colour, sea surface height, sea surface temperature, sea surface winds, sea surface salinity, waves, and to a lesser extent, current fields.

2. Monitoring of natural disasters and industrial accidents

Analysis of the factors that precede and accompany disasters and accidents.

Possible objectives are:

- monitoring of emergencies associated with natural and anthropogenic impacts
- simulation of emergency situations and prediction of their consequences
- planning of emergency and rescue operations in areas of natural and anthropogenic disasters

Figure 2: Natural Disasters and Industrial Accidents

Among all kinds of natural hazards of the world flood is probably most devastating, wide spread and frequent. Floods resulting from excessive rainfall within a short duration of time and consequent high river discharge damage crops and infrastructures. They also result in siltation of the reservoirs and hence limit the capacity of existing dams to control floods. For formulating any flood management strategy the first step is to identify the area most vulnerable to flooding.

Biomass burning has been a topic of research interest for many years due to the implications for climatic change as a result of landscape alteration and atmospheric loading of aerosols and trace gases from pyrogenic emissions (Fatoyinbo. 2012). Many of the channels available from a particular satellite sensor are useful for fire monitoring, for example aerosols can be monitored using the visible and near-infrared bands or burn scars can be monitored with the visible, near, and middle infrared bands. Burned area mapping, a commonly used metric, is important for estimating total biomass consumed and thus emission estimates.

Coastline mapping and coastline change detection are critical for safe navigation, sustainable coastal resource management and environmental protection. Zhang et al. [2010] developed a modelling methodology for simulation of long-term morphological evolution of the southern Baltic coast approving that the high-resolution process-based models are useful tools in helping for further understanding and quantification of mechanisms driving coastal evolution.

3. Monitoring of technogenic sphere

Diagnosis of the area topography, analysis and evaluation of forms, geometry and partition technogenic objects, the mapping of dangerous or potentially dangerous areas on the basis of different information available, diagnosis of soil corrosives, diagnosis of linearly extended objects with a precise identification of specific nodes and elements, etc.

Possible objectives are:

- identification of the technogenic objects (tanks, industrial buildings, roads, pipelines, power plants, fuel and freight terminals, ports, etc.) and their characteristics
- assessment and diagnosis forms, geometry, size of the object
- identification of potentially dangerous objects
- analysis of the topography of territory nearby the object
- identification and analysis of the pipeline routes
- analysis and evaluation of the dynamics of flooding of the monitored area

Figure 3: Technogenic Objects

There is hundreds of big nuclear energy and chemical enterprises in the world and the accumulated nuclear and chemical stocks are enough to destroy all living beings on earth several times. A chemical accident is a violation of production processes at chemical facilities accompanied by damage to and (or) destruction of pipelines, tanks, storage facilities, or transport means, which result in a release of chemically hazardous substances into the atmosphere or biosphere, endangering biocenosis and the lives and health of people (Menshikov, Perminov, and Urlichich 2012).

4. MAIN MONITORING OBJECTS IN LATVIA

In accordance to the Civil Defence Plan of Latvian Republic (Cabinet of Ministers 2011), following are main risks areas:

- storm, rainwater, snowfall, icing, blizzard;
- water flood;
- forest and turbary fire;
- oil and oil product pipelines;
- gas main and gas regulation stations;

- national and regional high-risk objects that produce, use, manage or store hazardous substances;
- hazardous substances leak;
- nuclear power plants that operates within the 300, 500, and 1000 km from the national boundary.

Water flood is one of the severest natural disasters resulting in heavy economic damage and casualties. Remote sensing techniques allow monitoring of water resources, including the development of hydrological digital model of topography, water basin detection, simulation of a leak direction and speed, verifying water quality and pollution movement (see Fig.4.), mapping of inundated territory during spring flood and overflow, detection of anthropogenic and natural changes of water mass. Based on the monitoring results following information for preventive measures could be collected:
- water level and ice drift in rivers;
- forecast of flooding areas;
- water basin inspection;
- the risk of soil erosion;
- etc.

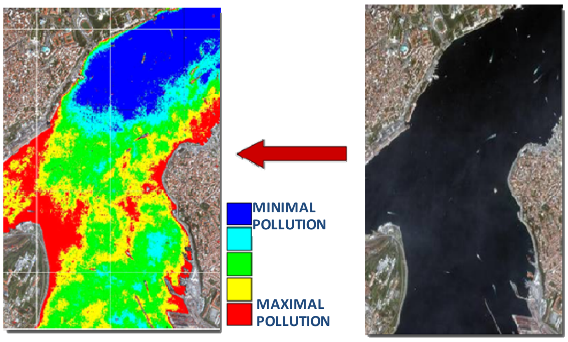

Figure 4: Monitoring of the Water Pollution (Rekod 2012)

Following are information necessary for early detection and liquidation of the disaster consequences:
- determination of the necessary level of water lowering;
- forecasting of the measures on the liquidation of consequences;
- region of antiepidemic action determination;
- dangerous object in the adjacent territory;
- etc.

Forest fires play a critical role in landscape transformation, vegetation succession, soil degradation and air quality (Chuvieco E., Aguado I., Yebra M. et al. 2010). Possibility of fire suppression on a small area, especially in high fire hazard, depends on timely detection and primary fire response (ScanEx 2012). The monitoring of forest fires usually include detection of the thermal anomaly and controlling of the fire propagation. Fire sites can be therewith interpreted both visually and automatically (infrared spectrum), using radiance temperatures of thermal channels. Algorithms of detecting fires in automatic mode are based on a considerable difference in temperatures between the ground surface (usually, not exceeding 10-250C) and the fire spot (300-9000C). Almost a hundredfold difference in thermal radiance of the objects is registered on the images, whereas the information received from the other spectral channels helps to discriminate the clouds.


Figure 5: Visual Imaging of Thermal Anomaly (Rekod 2012)

Following are information necessary for early detection and liquidation of the disaster consequences:
- determination of the fire propagation;
- possible scenarios of population evacuation from dangerous zone;
- forecasting of the possible fire propagation within the protected zone, where railways, gas and oil main is located;
- etc.

As recent events have shown, high-risks objects are facing increasingly complex issues in a continually evolving natural and business environment. Two issues stand out: companies are expected to operate closer to their maximum capacity therefore there is an increased need for accurate and better monitoring of the high-risks objects.

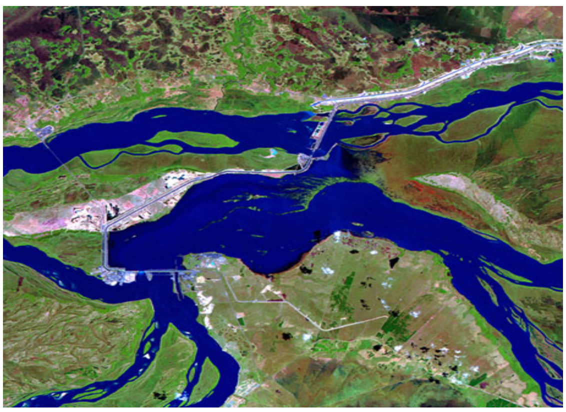
Figure 6: Monitoring of Hydroelectric Power Plant

Many tasks could be addressed to the monitoring issue of the high-risks objects, e.g.:
- controlling of the hydraulic structure condition (see Fig. 6);
- detection of technogenic explosion;

- controlling of hazardous substances propagation (see Fig.7.);
- observing of oil/gas main;
- emergency situation controlling in public services;
- etc.

Based on monitoring results, the following information for preventive measures could be collected:
- inspection of hazardous substances and high-risk object condition (electromagnetic radiation, temperature, amount of pollution, pressure, etc.);
- inspection of smoke covering in habitat areas;
- etc.

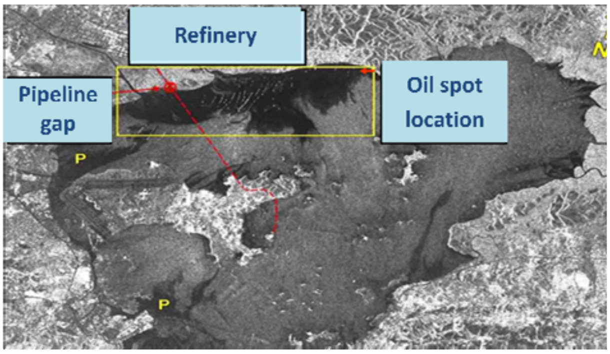

Figure 7: Oil Spill Detection and Monitoring (Rekod 2012)

The necessary information for early detection and liquidation of the disaster consequences are:
- forecasting of the measures on the liquidation of consequences;
- damage evaluation;
- possible scenarios of population evacuation from dangerous zone;
- forecasting of the possible hazardous substances propagation;
- etc.

The above mentioned objects are in a high priority for Latvian Republic to be monitored, therefore the analysis of application of remote sensing technologies for their monitoring is essential.

5. CONCLUSIONS

The monitoring of natural-technogenic objects is focused on the issues of changing ecosystem, geosystem, climate and providing services for sustainable economy, healthy environment and better human life by the following activities:

- Early warning of natural and anthropogenic disasters.
- Technogenic objects security.
- Land cover/land change, natural resource usage.
- Human health and the preservation of the environment.

The paper highlights the most crucial monitoring object in Latvia taking into account natural and business environments, namely water flood, water pollution, forest fires, and high-risk technogenic objects, especially big and small size hydroelectric power plants. The further research is aimed at analysing ground-space technologies and developing of monitoring objects conceptual models to be applied into the integrated intelligent platform developed within the INFROM Project.

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