SPATIAL TECHNOLOGIES FOR CRISIS MANAGEMENT

ПРОСТРАНСТВЕНИ ТЕХНОЛОГИИ ЗА УПРАВЛЕНИЕ ПРИ КРИЗИ

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Abstract*: Over the last decades the impact of natural disasters to the global environment is becoming more and more severe. In this context, satellite remote sensing, along with Geographic Information Systems (GIS), has become a key tool in flood risk management analysis. Remote sensing for supporting various aspects of flood risk management was investigated in the present thesis. In particular, the research focused on the use of satellite images for flood mapping and monitoring, damage assessment and risk assessment.*

Key words: *SPATIAL TECHNOLOGY, RISK MANAGEMENT, DISASTER, NATURAL HAZARDS, GEOINFORMATION TECHNOLOGY, REMOTE SENSING SYSTEM, GEOGRAPHIC INFORMATION SYSTEMS.*

1. Introduction.

The last two decades have witnessed the increasing use of satellite remote sensing for understanding the geophysical phenomena underlying natural hazards [3]. Being able to observe large portions of the Earth surface, to perform frequent and regular in time measures and with the capability to investigate in the different bands of the electromagnetic spectrum, satellite remote sensing allows to study phenomena not directly accessible with the traditional surveying techniques and ongoing situations difficult to identify in another way [4].

In the broadest sense, the measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study; e.g., the utilization at a distance (as from aircraft, spacecraft, or ship) of any device and its attendant display for gathering information pertinent to the environment, such as measurements of force fields, electromagnetic radiation, or acoustic energy. The technique employs such devices as the camera, lasers, and radio frequency receivers, radar systems, sonar, seismographs, gravimeters, magnetometers, and scintillation counters.

Today, we define satellite remote sensing as the use of satellite-borne sensors to observe, measure, and record the electromagnetic radiation reflected or emitted by the Earth and its environment for subsequent analysis and extraction of information.

Satellite remote sensing, along with Geographic Information Systems (GIS) – fig.1, has become a key tool in disaster risk and damage assessment analysis [5]. Satellite images, acquired during, before and after a flood event, can provide valuable information about flood occurrence, intensity and progress of flood inundation, river course and its spill channels, spurs and embankments affected/threatened etc. so that appropriate mitigation measures can be planned and executed in time.

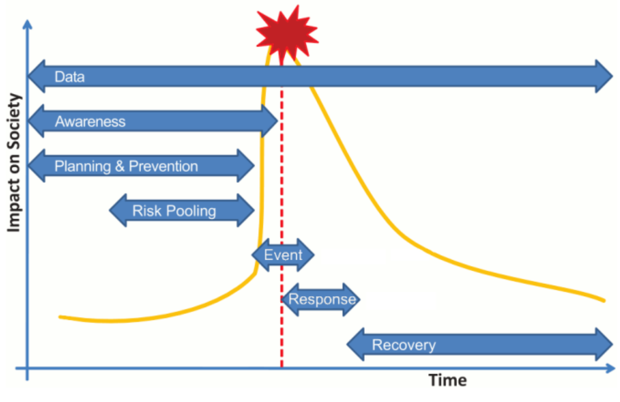

Figure 1. *Information support to Crisis management.*

Throughout the World in the recent past, whether it is a natural hazard or by the intervention of human activities, disasters have become an issue of rising alarm [11]. Natural disasters arise in many parts of the earth, and each type of disasters is confined to particular regions. It have been estimated that more than 95 percent of all deaths in developing countries were due to natural disasters. These places are particularly vulnerable to disasters because of densely packed population and poor infrastructures which gets coupled with unbalanced landforms and continuous exposure to severe weather changes.

Risk arises out of uncertainty. It is an inherent part of existence and is the chance of something happening as a result of a hazard or a disaster which will impact on community and environment. It is measured in terms of the likelihood of it happening and the consequences if it does happen that be tried to reduce the likelihood of risk effecting on community. The risk is the probability or chance that the hazard posed. Thus, it can be minimised by initially preparing a suitable risk management.

Risk Management is a process consisting of well defined steps which, when taken in sequence, support better decision making by contributing to a greater insight into risks and their impacts. It is as much about identifying opportunities as it is about used to avoid, reduce or control risks. The first step in the risk management process is focused on the environment to establish the boundaries in which risks must be managed and guide decisions on managing risks, and develop risk evaluation criteria. The second step involves identifying the risks which arise from aspects of the environment that will be established from previous step to develop a complete inventory of the risks and what each involves, by selecting suitable techniques to identify potential risks, examining sources of possible risks, pose a major threat to community. Assess and analyse the impact of the risks represent the third step, which involves deciding on the relationship between the likelihood (frequency or probability) and the consequences (the impacts) of the risks that be identified. The level of risk should be analysed in relation to what are currently doing to control that risk. Control measures decrease the level of risk, but there may be sufficient risk remaining for the risk to be considered with others. Risk evaluation will be clarified the following as the activity of risk managing and its outcomes, the degree of control over the risk, the potential and actual losses which may arise from the risk, and the benefits and opportunities presented by the risk. The next step is to treat the risks that be decided as unacceptable by identifying the options which could use to treat the risks, selecting the best option in terms of its feasibility and cost effectiveness, preparing a risk treatment plan, and implementing the risk treatment plan.

Figure 2: *Risk management*

The main concern of this thesis is the delineation of flood prone areas, the identification of damaged areas and the development of hazard maps indicating flood susceptible areas by means of geospatial approaches. In particular, the contribute of satellite remote sensing and GIS for flood mapping and monitoring, damage assessment and risk assessment was explored referring to selected cases of study.

2. Spatial technologies and risk management

Earth Observation System (EOS) otherwise known as Remote Sensing (RS) and GIS assist professionals of disaster management in a very effective manner and provides more precise data. With this technology it is ease to obtain homogeneous data covering the entire world over a short period of time. Remote Sensing involves in assessing the extent of damage incurred during the time of disaster, identification of possible escape routes and location of areas for storage of temporary housing.

Each sensor provides distinctive information about different properties of surface objects or the shallow layers of the earth. For instant to measure surface temperature thermal sensors are employed, microwave sensors used to detect dielectric properties. This in turn reveals the moisture content of surface soil or of snow. For details, see Appendix 1.

Being able to observe large portions of the surface of the Earth, to perform frequent and regular measures and with the capability to investigate in the different bands of the electromagnetic spectrum, satellite remote sensing allows to study and analyse phenomena not directly accessible with the traditional surveying techniques and ongoing situations difficult to identify in another way.

The last two decades have witnessed the increasing use of remote sensing for understanding the geophysical phenomena underlying natural hazards [4][10][3]. In particular, the development of new acquisition systems in the field of optical remote sensing, with the possibility to direct the sensor to specific areas, has enabled to increase the spatial and the temporal resolution of the satellite images, allowing theoretically to collect scenes of any part of the Earth surface with a time interval ranging between 1 and 7 days. Capable to collect data in all weather and lighting condition, active microwave sensors have proven to be useful to identify various spatial phenomena; especially in the context of natural disaster management, Synthetic Aperture Radar (SAR) images are used for detecting damaged areas and for the real-time monitoring of harmful events.

In this context, remote sensing provides valuable information helping to understand spatial phenomena and supporting the decision making with objective data. In particular, it can contribute to the disaster management activities through the identification of hazardous areas, the assessment of the damaged zones in a timely manner and assisting the recovery plans after the occurrence of a disaster.

3. Satellite remote sensing in the disaster risk management cycle

An increasing number of studies have been elaborated on the importance and applications of remote sensing, with particular reference to satellite remote sensing data, in the disaster risk management [3][10]. A major reason of using remote sensing in this field is that it is the fastest means of collection data for pre and post-event disaster studies [14].

Satellite remote sensing refers to the technology used for observing various earth phenomena with instruments that are typically on board a spacecraft. These observations consist of measuring the electromagnetic energy of phenomena that occur without physical contact with the object of interest. Therefore, to investigate the Earth's surface without being in contact with it is an important feature considering the limited accessibility of the areas affected by a disaster and, in many cases, their extension and imperviousness. In addition, bandwidths are a crucial component of remote sensing operations. In fact, the different bandwidths of the electromagnetic spectrum are related to certain phenomena and Earth parameters that can be monitored and analysed using various sensors.

Satellite remote Satellite remote sensing can provide valuable information in each phase of the disaster risk management cycle, helping to understand spatial phenomena and supporting the decision making with objective data [4][8]. It can contribute to the risk management activities through the identification of hazard areas, the assessment of damaged zones in a timely manner and assisting the recovery plans.

Each phase of the risk management cycle requires satellite images data with appropriate characteristics of spatial, spectral and temporal resolution depending on the kind of information to be obtained, such as physical indicators and measureable features, and the spatial scale of the analysed hazard [7].

In the mitigation stage, the remote sensing data are usually employed for mapping landscape features (i.e. land use/land cover) and for detecting potentially hazardous areas; therefore, the update representations of a territory is an important requirement to select useful satellite images. Furthermore, high spatial resolution images can allow for the identification of infrastructure and buildings in risk areas, for the hazards consequence assessment (vulnerability) and the potential losses evaluation.

In the preparedness phase remote sensing data can support the developing of risk maps and models, using the information obtained in the previous stage, which are generally used by authorities to communicate information about location and range of hazard to the community.

During the pre-event phases and recovery stage there is sufficient time for selecting appropriate remote sensing data; instead, the timeliness is a crucial factor in the response phase during which the rapid damage assessment is fundamental for efficient emergency services and to assist evacuation plans. Moreover, the availability of high spatial resolution images allows a detailed representation of the ongoing situation.

In the recovery stage, remote sensing data are used for post-disaster census information, for identifying the rebuilding sites and for the long term monitoring of the territory; in particular, remote sensing can support this stage providing time series images over large areas with both high and medium spatial resolution from which changes can be detected and quantified.

Satellite data support to disaster management and risk assessment is also defined by a set of interrelated activities or business processes, whichmay be grouped intothe following stages:

1. Initiation, including research to determine an observation strategyandpredictive capabilities;
2. Operational / steady-state event detection and response;
3. Disaster recovery, risk assessment, and mitigation.

Initiation

Operational activities are often preceded by *disaster management initiation*, with the following activities:

- Evaluate candidate satellite observations for use in disaster related applications (e.g., for predicting volcan-ic eruptions)
- Identify inputs for event detection; event triggers
- Identify indicators for situational awareness (e.g., flood extent)
- Define modeling elements (e.g., regional flood model)
- Define workflows and data flows for processing and delivery
- Identify automation opportunities (e.g., subscriptions, custom products)
- Develop methods for validating products
- Theseinitiation activities may be repeated any number of times, *e.g.*,to review and refine the observation strategy, incorporate new inputs, or revalidate predictive methods.

Event detection and response

Once initiation is complete, steady-state *event detection and response*may begin, with the following activities(depicted in Figure 3):

1. *Detect (and possibly predict) events* based on global or regional monitoring, models or reports from users;
2. *Monitor operations*–this operations shared awareness of a dynamic situation,enabling timely decisions about data assimilation, analysis, and dissemination;
3. *Task Sensors and acquire other data* for high-resolution observations of areas threatened or impacted by a disaster event;
4. *Modeland Predict* to pinpoint priority times and loca-tions forresponse and recovery efforts; and to better understand the natural phenomena.
5. *Analyzeand Interpret* data obtained via satellite or in situ sensors or other sources(this includesvalidatingthe resulting information products);
6. *Disseminate* visual products to end users, including reports or updates. (In fact, user access is potentially a part of any of the activities depicted here, allowing users to draw upon, or even to shape, the gathering, processing, or production of information.)

Figure 3 shows how these steady-state processes relate to each other: for example, when flood forecasting models detect a flood risk, decisionmakers may task a satellite to observe the affected area, and apply a variety of processing algorithms to interpret it. The resulting data, along with data from *in situ* rain and stream gauges, feeds another model to determine detailed flood areas.

Recoveryand mitigation

Following the detection and response phases, recovery and mitigation activities include the following processes:

- Overlay earth observations with data on settlements and infrastructure from many local sources (for damage assessment and recovery planning and prioritization);
- Periodic surveys to assess the progress of reconstruc-tion and recovery efforts;
- Review historical data (and where appropriate, conduct disaster simulations) to identify risk patterns and trends over time, and to quantify future risk (for budgeting and risk pooling / insurance). These studies also aim to understand the spatial variability of risk (for setting land-use policies or property values) and to characterize key risk factors (for improved environmental or development policies; and for infrastructure improvements where appropriate).
- Research towards improving disaster prediction, preparedness, or response, from recent experience.This may lead into, or combine with, the initiation activities outlined earlier.

Not every instance of disaster management or risk assess-ment will include all of these processes; however most will fit into some subset of Figure 3, and can thus trace their relationship with other processes.

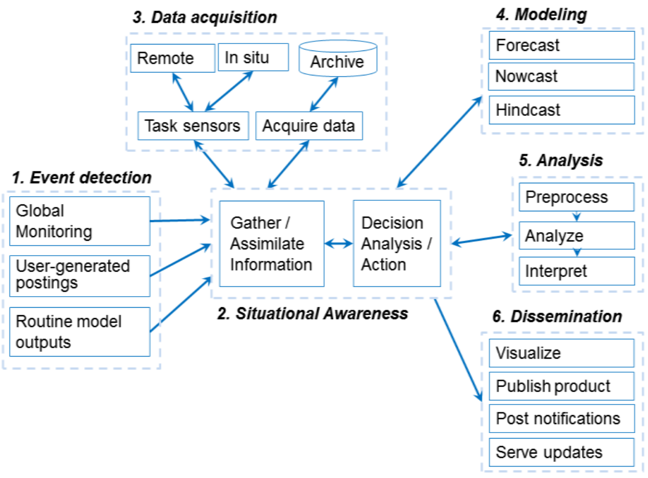

Figure 3. *Activities involved in the use of remote sensing in disaster management and risk assessement.*

4. Remote sensing and GIS tools.

Mitigation of natural disasters can be successful only when detailed knowledge is obtained about the expected frequency, character, and magnitude of hazardous events in an area. Many types of information that are needed in natural disaster management have an important spatial component. Spatial data are data with a geographic component, such as maps, aerial photography, satellite imagery, GPS data, rainfall data, borehole data etc. Many of these data will have a different projection and co-ordinate system, and need to be brought to a common map-basis, in order to superimpose them.

We now have access to information gathering and organising technologies like remote sensing and geographic information systems (GIS), which have proven their usefulness in disaster management.

First of all, remote sensing and GIS provides a data base from which the evidence left behind by disasters that have occurred before can be interpreted, and combined with other information to arrive at hazard maps, indicating which areas are potentially dangerous [8]. The zonation of hazard must be the basis for any disaster management project and should supply planners and decision-makers with adequate and understandable information. Remote sensing data, such as satellite images and aerial photos allow us to map the variabilities of terrain properties, such as vegetation, water, and geology, both in space and time. Satellite images give a synoptic overview and provide very useful environmental information, for a wide range of scales, from entire continents to details of a few metres. Secondly, many types of disasters, such as floods, drought, cyclones, volcanic eruptions, etc. will have certain precursors. The satellites can detect the early stages of these events as anomalies in a time series. Images are available at regular short time intervals, and can be used for the prediction of both rapid and slow disasters.

Then, when a disaster occurs, the speed of information collection from air and space borne platforms and the possibility of information dissemination with a matching swiftness make it possible to monitor the occurrence of the disaster. Many disasters may affect large areas and no other tool than remote sensing would provide a ma tching spatial coverage. Remote sensing also allows monitoring the event during the time of occurrence while the forces are in full swing. The vantage position of satellites makes it ideal for us to think of, plan for and operationally monitor the event [11]. GIS is used as a tool for the planning of evacuation routes, for the design of centres for emergency operations, and for integration of satellite data with other relevant data in the design of disaster warning systems.

In the disaster relief phase, GIS is extremely useful in combination with Global Positioning Systems (GPS) in search and rescue operations in areas that have been devastated and where it is difficult to orientate [5]. The impact and departure of the disaster event leaves behind an area of immense devastation. Remote sensing can assist in damage assessment and aftermath monitoring, providing a quantitative base for relief operations.

The volume of data needed for disaster management, particularly in the context of integrated development planning, clearly is too much to be handled by manual methods in a timely and effective way. For example, the post disaster damage reports on buildings in an earthquake stri cken city, may be thousands. Each one will need to be evaluated separately in order to decide if the building has suffered irreparable damage or not. After that all reports should be combined to derive at a reconstruction zoning within a relatively small p eriod of time.

One of the main advantages of the use of the powerful combination techniques of a GIS, is the evaluation of several hazard and risk scenarios that can be used in the decision - making about the future development of an area, and the optimum way to protect it from natural disasters.

Remote sensing data derived from satellites are excellent tools in the mapping of the spatial distribution of disaster related data within a relatively short period of time [14]. Many different satellite based systems exist nowadays, with different characteristics related to their spatial-, temporal- and spectral resolution.

Remote sensing data should generally be linked or calibrated with other types of data, derived from mapping, measurement networks or sampling points, to derive at parameters, which are useful in the study of disasters. The linkage is done in two ways, either via visual interpretation of the image or via classification.

The amount and type of data that has to be stored in a GIS for disaster management depends very much on the level of application or the scale of the management project. Natural hazards information should be included routinely in development planning and investment project preparation [4]. Development and investment projects should include a cost/benefit analysis of investing in hazard mitigation measures, and weigh them against the losses that are likely to occur if these measures are not taken.

Although the selection of the scale of analysis is usually etermined by the intended application of the mapping results, the choice of a analysis technique remains open. This choice depends on the type of problem, the availability of data, the availability of financial resources, the time available for the investigation, as well as the professional experience of the experts involved in the survey. See also Cova (2002) for an overview of the use of GIS in emergency management.

4.1. Remote Sensing Vs GIS

GIS (Geographic Information System) is a kind of software that enables:

- The collection of spatial data from different sources (Remote Sensing being one of
- them).
- Relating spatial and tabular data.
- Performing tabular and spatial analysis.
- Symbolize and design the layout of a map.

A GIS software can handle both vector and raster data (some handle only one of them). Remote Sensing data belongs to the raster type, and usually requires special data manipulation procedures that regular GIS does not offer. However, after a Remote Sensing analysis has been done, its results are usually combined within a GIS or into database of an area, for further analysis (overlaying with other layers, etc) [1]. In the last years, more and more vector capabilities are being added to Remote Sensing softwares, and some Remote Sensing functions are inserted into GIS modules.

4.2. Remote Sensing Vs Aerial Photography / Photogrammetry

Both systems gather data about the upper surface of the Earth, by measuring the Electromagnetic radiation, from airborne systems. The following major differences can be given:

- Aerial photos are taken by an analog instrument: a film of a (photogrammetric) camera, then scanned to be transformed to digital media. Remote Sensing data is usually gathered by a digital CCD camera.
- The advantage of a film is its high resolution (granularity), while the advantage of the CCD is that we measure quantitatively the radiation reaching the sensor (radiance values, instead of a gray-value scale bar). Thus, Remote Sensing data can be integrated into physical equations of energy-balance for example.
- An Aerial photograph is a central projection, with the whole picture taken at one instance. A Remote Sensing image is created line after line; therefor, the geometrical correction is much more complex, with each line (or even pixel) needing to be treated as a central projection.
- Aerial photos usually gather data only in the visible spectrum (there are also special films sensitive to near infrared radiation), while Remote Sensing sensors can be designed to measure radiation all along the Electromagnetic spectrum.
- Aerial photos are usually taken from planes, Remote Sensing images also from satellites.
- Both systems are affected by atmospheric disturbances. Aerial photos mainly from haze (that is, the scattering of light – the process which makes the sky blue),
- Remote Sensing images also from processes of absorption. Atmospheric corrections to Aerial photos can be made while taking the picture (using a filter), or in post-processing, as in done Remote Sensing. Thermal Remote Sensing sensors can operate also at nighttime, and Radar data is almost weather independent.
- In Photogrammetry the main efforts are dedicated for the accurate creation of a 3D model, in order to plot with high accuracy the location and boundaries of objects, and to create a Digital Elevation Model, by applying sophisticated geometric corrections. In Remote Sensing the main efforts are dedicated for the analysis of the incoming Electromagnetic spectrum, using atmospheric corrections, sophisticated statistical methods for classification of the pixels to different categories, and analysing the data according to known physical processes that affect the light as it moves in space and interacts with objects.
- Remote Sensing images are more difficult to process, and require trained personnel, while aerial photographs can be interpreted more easily.

5. Conclusions

This paper presents a general review on utilization of remote sensing and GIS for natural disaster management cycle. Remote sensing can be potentially employed to address various aspects of disaster management cycle. Rather focusing only on emergency response, it is essential to consider all facets of disaster management. Remotely sensed data extend their support to disaster management organizations via providing relevant and accurate information in a temporally, spectrally and spatially significant context. In addition to it, one should tailor the technologies owing to remote sensing to fulfill the desired requirements of the disaster organization. It is necessary to examine and evaluate the so far

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Appendix 1. EMR Wavelengths and Sensors

Wavelength	**Waveband**	**Applicable for**	**Sensors example**
Visible (VIS)	0.4-0.7mm	Vegetation mapping	SPOT; Landsat TM
Building stock assessment		AVHRR; MODIS; IKONOS	
Population density		IKONOS; MODIS	
Digital elevation model		ASTER; PRISM	
Near infrared (NIR)	0.7-1.0mm	Vegetation mapping	SPOT; Landsat TM; AVHRR; MODIS
Flood mapping		MODIS	
Shortwave infrared (SWIR)	0.7-3.0mm	Water vapour	AIRS
Thermal infrared (TIR)	3.0-14mm	Active fire detection	MODIS
Burn scar mapping		MODIS	
Hotspots		MODIS; AVHRR	
Volcanic activity		Hyperion	
Microwave (Radar)	0.1-100cm	Earth deformation and ground movement	Radarsat SAR; PALSAR
Rainfall		Meteosat; Microwave Imager (aboard TRMM)	
River discharge and volume		AMSR-E	
Flood mapping and forecasting		AMSR-E	
Surface winds		QuikScat radar	
3D storm structure		Precipitation radar (aboard TRMM)	