Remote Sensing Data Processing for Environmental Modeling

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Abstract

This paper gives an overview of some on-going Sino-Euro projects related to environmental applications --including natural disasters. Remote sensing is used as the mean to provide large scale objective information of the Earth surface. We point out that Remote Sensing data can not only be used to picture or catch up an event --per-event or post-event analysis-- , but also can be used a priori, in order to provide by anticipation relevant information to decision makers. This can be achieved by coupling Remote Sensing image information extraction with high level models --such as hydrological/hydraulic models in the case of flood protection.

1. Introduction

"Sustainable development", "Environmental protection", are nowadays key words in rapidly growing economy societies. What can be the role of Remote Sensing ? Shall we say that it could contribute to develop a "Sustainable environment".

The scientific approach to study a given problem starts usually with the Observation, then Analysis, Modeling and at last Simulation in order to be able to reproduce the observed phenomena.

In our case, the studied phenomena is a geo-physical phenomena, very complex per nature: floods, air pollution, desertification, ... The observed data are provided from remote sensing or in-situ data. The aim we wish --ideally-- to reach, through Analysis, Modeling and Simulation, is to have a comprehensive understanding of this phenomena. It would thus enable to take actions for prediction, prevention, protection, i.e. to have a decision support for the management of the environment.

Remote sensing provides Observation Images. It gives a picture of the Earth at a given time --static data-- ; if multi-temporal acquisition is performed, a set of acquisitions then enables to survey the changes of the Earth surface.

Data need then to be analyzed in order to provide relevant information to be further used into a model. This is the role of Data/Image processing and understanding. Taking advantage of the large diversity of images ---multi-sensor, multi-temporal, multi-resolution--- and exogenous data, data fusion techniques play a major role.

Potential and limits of remote sensing data processing for environmental modeling can be understood through examples of applications. In the rest of this paper, we will introduce three Sino-EU joint projects illustrating two major environmental problems:

- Flood simulation (ANFAS project, FLOCODS project);
- Urban development planning.
2. **Flood simulation and decision support system**

Flood disasters are from the category of "flash event", and therefore particularly redoubtable because non-easly predictable. The traditional use of remote sensing data is to map the flood extent, if images have been acquired during the event. This processing is useful for flood impact assessment, that is, it is a post-event processing.

It is less common to use remote sensing data for the prevention or in preparation of emergency action planning. The use of remote sensing as pre-event analysis is very valuable and important for at least two major reasons: (i) used as information for prevention, remote sensing can provide some mean to reduce economic and social damage --we will explain how--; (ii) the acquisition of remote sensing data during a period where there is no disaster causes no problem --a contrario, the acquisition of images during a flood event cannot be ensured-- and therefore one can ensure to have robust information.

We introduce thereafter two projects related to decision support for flood damage reduction, namely the ANFAS project and FLOCODS project.

### 2.1 ANFAS project

**Context**

The project ANFAS ("Data Fusion for Flood Analysis and Decision Support System") belongs to the so-called : Information Society Technology program. That is, its main focus is to develop high technology system, at the service of the citizen. The idea behind the ANFAS project is that, although the natural disasters most of the time cannot be avoided, the damage they cause can be reduced by anticipation. ANFAS will develop scientific tools to provide rigorous information for decision support for the stakeholders.

The ANFAS project is a joint research project supported by the Chinese Ministry of Science and Technology 863 program, the European Commission 5th framework Information Society Technology program and the World Bank InfoDev program. It is a three years project, initialized in January 2000.

**Objective**

The objective of the project is to develop a Decision Support System for Flood prevention and protection. The ANFAS system could be used in preparation of forthcoming floods, that is : (i) to prepare possible reaction plans in case of crisis; (ii) to develop the river banks.

The application sites are on the Vah River (Slovakia), Loire River (France) and JingJiang reach on the Yangtze River, 80km downstream from the Three Gorges (China, Hubei Province). The three sites differ by their size --the site in JingJiang is several times larger than the site in Loire--; they are similar by the important economic activity and the high frequency of the floods in these regions.

The main principle of the ANFAS System is to perform flood simulation based on scenario defined by the user. It integrates hydraulic and hydrologic modeling, remote sensing, scientific computing, computer vision, internet technology, geographic information systems, and soil sciences expertise. The output of the simulation provides information to the user for decision support. The system is under a distributed architecture, works on Internet based on Web interface.

**International collaboration and Partnership**
The ANFAS project has been the first project to benefit from the agreements signed between the European Commission and the Chinese Government in 1998 and in use since Dec. 1999. These agreements allow the participation of the Chinese Institutions as full partners into the projects of the first activity thematic program of the European Commission.

The consortium involve a total of 13 partners, from five countries\(^1\). The project is coordinated in China by the Institute of Automation of the Chinese Academy of Sciences\(^2\). In Europe, the scientific coordinator is FORTH, the administrative coordinator is ERCIM.

**Technical tasks**

The project is organised into five main technical tasks:
- Preparation of a Geographical Information System database; this includes hydraulic data, geographical maps, data required for the simulation models, socio-economic data;
- Scene modeling from remote sensing images; it consists in extracting relevant information, from optical and radar high resolution images, for the hydraulic model and impact assessment model;
- Flood modeling and simulation; this task relies on the choice of existing hydraulic models and their adaptation to the pilot sites;
- Impact assessment and application; it is the basis for the decision support to be provided by the system; the key point is to transpose the output of the simulation models into relevant information to be used by the end-users;
- System integration.

**The role of remote sensing**

In ANFAS project, remote sensing data processing aims at deriving information about the observed scene. Data are optical, radar images (SPOT and ERS satellites) as well as digital elevation models (DEM) provided either from Lidar either from topographic maps. The information extraction from the scene can provide input features for the hydraulic model --dikes localization and high, river bed localization, steep slopes area, etc--- or for the assessment of economic damage caused by flooding --land-use map. The different sub-tasks undergone for this purpose can be listed as follows: (i) multi-modal data registration --in particular image to geographical information maps--; (ii) terrain classification and features extraction from 3D surface; (iii) interferometry processing.

The output results are integrated as new layers in the GIS database. Some illustrations of remote sensing data and results from automatic processing are shown in Figure 1.

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\(^1\) Partnership of the ANFAS project:
PR China: Institute of Automation (IOA) of the Chinese Academy of Sciences (CAS), Institute of Atmospheric Physics (IAP) of CAS, Institute of Remote Sensing Applications (IRSA) of CAS, Laboratory of Sedimentation of Wuhan University, Scientific Research Institute of ChangJiang River Water Resource Commission, France: European Research Consortium in Informatics and Mathematics (ERCIM), Bureau de Recherche en Géologie et Minerais (BRGM), Matra Systèmes et Information (MS&I), Institut National de Recherche en Informatique et Automatique (INRIA)
Greece: Foundation for Research and Technology-Hellas (FORT-H)
Slovakia: Institute of Informatics of the Slovak Academy of Sciences (II-SAS)
United Kingdom: University of Reading, Rutherford Appleton Laboratory of the Council for the Central Laboratory of the Research Councils (CLRC/RAL)

\(^2\) The project has been initially set up by Prof. Ma Songde, while he was President of the Institute of Automation, and O. Monga, France.
Fig. 1: ANFAS pilot site (Hubei Province)

Dikes extraction (in red) from the Digital Elevation Model (background)

Lidar data acquisition (UK)

SPOT images matching over JingJiang Reach

Dikes extraction (in red) from the Digital Elevation Model (background)
2.2 FLOCODS project

Context

FLOCODS (“Decision Support System for ecosystem upgrading and flood control in support of a sustainable development in the Red River System --China, Vietnam--”) is a two years research project initialized in October 2001, supported by the European Commission 5th framework INCO-Dev program.

Objective

FLOCODS is an interdisciplinary long-term research project on the functioning of the Red River System in flood seasons, facing increasing degradation of the ecosystem and climate changes. The overall objective of the project is to develop a Decision Support System (DSS) in support of ecosystem upgrading and flood control with particular emphasis on the Red River System (RRS). The DSS will provide decision-makers with an analytical tool to assess and evaluate ecosystem-upgrading and flood-control measures which fit into a sustainable use of natural resources in the Red River Basin, while reducing flood risks to an acceptable level and doing no harm to other interests.

The Red River takes its source in the Yunnan Province of China and continues up to the Gulf of Tonkin at the Vietnamese coast.

Partnership and cooperation

The FLOCODS project involves a total of 10 partners, among which six partners from Europe and four partners from Asia. The project leader is the University of Caen, France.

The plenary meetings take alternatively place in Asia (kick-off meeting held in Hanoi, Vietnam in Sept. 2001) and in Europe. Two visits of the pilot site have been organized up to now: on the Red River in Vietnam and on the Red River in the Yunnan Province of China.

Technical tasks

In the research phase, the Pilot System (PS) of the Decision Support System (DSS) to be developed has all the main characteristics of a full DSS with components for handling the data sets, models for predicting the floods and its socio-economic impacts, routines for visualising the input and output data sets, routines for extracting the necessary data sets from satellite images and components for performing impact analysis. The most advanced techniques in flood modelling as well as in computer vision for remote-sensing and GIS will be applied.

The main technical tasks (also called "Workpackages") of the all project are as follows:

- development of a Geographical information system data base
- hydrological modeling over the flood plain of the Red River basin
- hydraulic modeling of the Red River and principal confluents
- socio-economic conditions modeling
- remote sensing data processing
- development of the integrated DSS and validation

3 Partners of the FLOCODS project:
France : University of Caen, Polytechnique National Institute of Toulouse (INPT), Research Institute of Development (IRD) ; The Netherlands : University of Twente ; Portugal : National Laboratory of Civil Engineering ; Finland : PR Water Consulting ; Vietnam : Institute of Mechanics of Hanoi (IMH) , Department of Flood control and Dyke Management ; Thailand : Asian Institute of Technology (AIT) ; China : Institute of Automation of the Chinese Academy of Sciences.
The role of remote sensing

The specific contribution of the Institute of Automation is to develop robust methods for remote sensing images processing. It will, on one side, provide useful information for the hydraulic/hydrologic models and impact assessment model; on the other side, remote sensing is used to understand the past phenomena in correlation with floods --change of the river bed course, change of the land-use due to deforestation or extensive crops.

The approach is to perform fusion between different image sources and GIS data. The final result will be a description and representation of the scene --the Red River delta, the Yunnan RedRiver flood plain. This includes:

(i) the use of very low resolution images --NOAA, public access data-- in order to detect from images the flood prone areas;
(ii) the use of mid-resolution optical images Landsat for land use classification;
(iii) the use of low resolution images for landuse changes analysis;
(iv) the characterisation of the three-dimensional terrain surface in order to provide information --localisation of the river bed-- for the hydraulic modeling.

Pilot site of the FLOCODS project: the Red River, in China (Yunnan Province) and Vietnam.
3. **Urban development planning**

We introduce shortly in this section a project newly started, funded by the Chinese Ministry of Science and Technology 863 project, namely "Decision support system for urban development planning from multi-source data fusion". This two years research project involves two partners in China, the Institute of Automation of the Chinese Academy of Sciences and the Beijing Institute of Remote Sensing Information. Although this project is not an "international cooperation project" per see, we intend to develop and consolidate a partnership with Alcatel-Space in France.

The project's objective is to make use of satellite images and exogenous data to survey the urban growing and to provide decision support tools for development planning. The key aspect of the project is to propose to generate up-dated digital maps, to be included in a Geographical Information System, by fusion of old digital maps and recent very high resolution images. Digital map updating, together with a measure of the terrain elevation changes using differential interferometry processing, are the basic components to derive information for urban planning.

The output of this project could be coupled with high level mathematical models for environmental simulations, such as car traffic modeling or air pollution modeling.

4. **Conclusion**

This paper gives an overview of on-going joint projects in the field of environmental modeling using remote sensing images. It shows the wide potential of collaboration between European and Chinese partners, on a subject that is of priority importance for both sides. In the context of a newly set up "Global Monitoring for Environment and Security" (GMES) program in Europe, one can only fuse knowledge and expertise to participate together to a better understanding of the natural geo-phenomena of the Earth and Atmosphere.

**Acknowledgment**

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