MEASURING AND MODELING URBAN DYNAMICS

Impact on Quality of Life and Hydrology

Overview of objectives and methods

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Project web site: http://www.mamud.be

Research project funded by Belgian Science Policy in the framework of Stereo II

Introduction

The world is urbanising at an increasing pace. Urban growth affects both the human and natural environment and demands effective urban management. This in turn requires reliable and sufficiently detailed information on the urban environment and its dynamics, including an understanding of urban change processes.
The MAMUD project will investigate how earth observation can contribute to a better monitoring, modeling and understanding of urban dynamics and its impacts on the urban and suburban environment. Contemporary high-resolution sensors like Ikonos and Quickbird allow a more detailed mapping of complex urban areas. This has substantially increased the potential of satellite remote sensing for urban change analysis. Then again, spectral unmixing allows us to interprete medium-resolution data from "older" sensors like Landsat TM/ETM+ or SPOT-HRV at sub-pixel scale. This offers the possibility to use historic time series of medium-resolution imagery in the monitoring and modeling of urban dynamics.

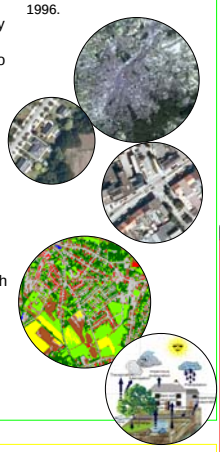
Analysing changes in urban land use is a key element in studying urban dynamics. Opposed to land cover, which refers to the physical properties of the earth's surface, land use is tied to socio-economic activities and cannot be directly inferred from spectral information. Previous studies, however, have demonstrated a relationship between the spatial structure of the built-up environment and its functional characteristics. A rather novel approach in this research area is to describe urban form and structure by means of spatial metrics. Spatial metrics describe various properties of the spatial heterogeneity and configuration of land cover in a given area. Originally developed for landscape ecological research, spatial metrics show a considerable potential to analyse urban environments.

Computer based urban growth models are used more and more often to understand the changes in urban form and their relationship to the urban development processes that drive them (or are affected by them). The performance of these models strongly depends on the availability of different types of data, needed for calibration and validation. One of the aims of this project is to examine how spatial metrics, derived from satellite imagery may complement existing land-use maps to calibrate and validate these land-use change models.

Spatio-temporal change in land-cover gradients and land use, obtained through analysis of time series of remotely sensed imagery, as well as future land-use patterns predicted by urban growth modeling, may be used to study demographic as well as environmental impacts of urban dynamics.
Finally, this project addresses one of the environmental impacts of urban dynamics: the change of hydrological characteristics such as increased urban runoff. In studying the effects of land-use change, hydrologists increasingly discover the possibilities of implementing remote sensing derived information.

"The evidence is compelling. As population growth will be virtually synonymous with urban growth in the coming decades, the focus of efforts at sustainable human settlements development must be on urban areas. Cities are where most of the world's population will live and work, where most economic activity will take place, where most pollution will be generated and most of natural resources consumed, with impacts which will be felt far beyond the city limits."

United Nations Centre for Human Settlements, 1996.



Objectives

Extraction of urban land-cover/land-use information and elevation data

Exploiting potential of multi-angle image acquisition (HiRes data)

➔To reduce impact of shadows and occluded areas on LULC classifications
➔To improve labelling of urban objects (e.g.: streets versus buildings)

Producing time-series of gradient information (Medium Res. data)

➔i.e. sub-pixel proportions of impervious surfaces and vegetation

Extracting historic info of 3D structure urban areas (HiRes stereo)

➔From high resolution stereoscopic archive imagery
➔Will complement temporal land-cover gradient with vertical urban dimension

Developing spatial metrics to describe urban form and structure

➔Link between remote sensing and inference of information on urban form and structure
➔Definition of metrics that describe urban morphological and structural dynamics
➔From high and medium resolution data
➔Examining potential of field-based versus object-based representations of urban areas

Examining potential of spatial metrics for urban growth modeling

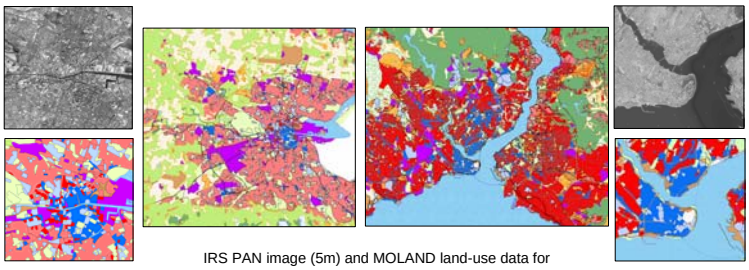
➔Metrics complement detailed land-use maps to calibrate spatially-dynamic land-use model

Measuring the impact of urban dynamics

➔Modeling population distribution
➔Integration of remote-sensing derived data in hydrological model

Study area

Research will focus on two urban areas in Europe (Dublin and Istanbul). Both are part of a European study called MOLAND (http://moland.jrc.it) of which output will be used in the project.



IRS PAN image (5m) and MOLAND land-use data for Dublin, Ireland (left) and Istanbul, Turkey (Right)

The figure above illustrates the general framework for analysis and modeling of spatial urban dynamics. The MAMUD project focuses on the link between remote sensing and spatial metrics, and on the link between spatial metrics and urban modeling.

Methods

Extraction of urban land-cover/land-use information and elevation data

- Developing a 3D model with Ikonos image triplets
  - ➔post-processing to reduce remaining occlusion zones and improve quality
- Examing potential to extract 3D information from archive imagery
  - ➔Images not explicitly recorded for stereoscopic purposes
  - ➔Quality and accuracy comparison with Ikonos triplet approach
- Supervised land-use/land-cover approach
  - ➔Using multi-angle information and DEM produced by 3D modeling
  - ➔Dealing separatly with shaded and non-shaded areas
  - ➔Classification developed and validated with HiRes reference data
- Extracting sub-pixel information on urban land-cover
  - ➔From time-series of medium resolution data
  - ➔With spectral Mixture Analysis
  - ➔Calibration and validation of SMA models for different time periods
- Extracting historic information on 3D structure of urban areas from HiRes stereo archive data

Developing spatial metrics to describe urban form and structure

➔Selection of spatially explicit metrics from literature review as well as definition of new metrics
➔Implemented and tested on land-cover and elevation data derived within the project
➔Examining the impact of spatial resolution
➔Analysis of metric sensitivity to uncertainty in gradient information
➔Definition of alternative typologies to describe urban form and structure with metrics
➔Development of a rule-based approach to detect irrational spatial-temporal changes

Spatial dynamic modeling of urban growth

➔Growth model with Cellular Automata, based on the MOLAND model
➔Can sptal patterns generated by the model also be discerned by the selected metrics?
➔Forecasting future land-use and urban growth patterns under alternative policy scenarios

Measuring the impact of urban dynamics

➔Population estimates based on land-cover and elevation metrics
➔Developing quality-of-life indicators to characterise the impact of urban development
➔Urban land-cover and land-use information as input to spatially distributed runoff modeling