The URBIS Project: Vacant Urban Area Classification and Detection of Changes

Gabriele Moser, Vladimir Krylov, Michaela De Martino, Sebastiano Serpico
Dept. of Electrical, Electronics, Telecommunication Engineering and Naval Architecture (DITEN)
University of Genoa, Genoa, Italy
Email: {gabriele.moser, vladimir.krylov, mdemartino, sebastiano.serpico}@unige.it

Abstract—The Urban Land Recycling Information Services for Sustainable Cities (URBIS) project aims to identify and monitor the vacant and abandoned zones in large urban zones (LUZ). High resolution remotely sensed multispectral images will be employed along with the available in situ data to perform classification and multi-temporal change detection on European LUZ in order to facilitate urban redevelopment monitoring. The activity builds on the result of a previous Atlas project that produced high-resolution land use maps for 305 European LUZ and their surroundings (with population over 100,000 inhabitants). This paper focuses on the presentation of URBIS project objectives and scope, and the methodology applied by the research unit at the University of Genoa for classification and change detection of vacant urban zones performed within this project.

I. INTRODUCTION

The general objective of the URBIS project is to develop, implement and validate in real environment services related to urban vacant land identification and use. Based on open geospatial data, the project deliverables aim to support planning of European Large Urban Zones (LUZs) in a sustainable way. The URBIS services will provide the basis of a system aiming at management and mitigation of urban sprawl in Europe. The specific objectives are as follows. Firstly, to assess the potential reuse strategies of vacant urban land based on its past uses and characteristics and through wide involvement of end-user organizations, to establish common ground for the development of URBIS services. Secondly, based on the existing Copernicus Urban Atlas maps (Atlas project, 2006, 2012 ongoing) [1] to develop a methodology for an inventory and typology of European vacant urban land with the aid of the analysis of multi-temporal imagery to determine potential constraints to redevelopment. Thirdly, to develop, implement and validate interoperable services on a number of representative land use zones across Europe under operational conditions in collaboration with several European practitioners. Finally, to support ongoing resource efficiency activities with respect to land as finite resource and support operational implementation and monitoring of upcoming EU “zero-net land take” policy communication.

The three main categories of URBIS services include baseline, update and thematic services. The baseline services include an initial inventory and typology of urban land (based on data from Copernicus Urban Atlas). This serves not only to identify sites that can be used for redevelopment, but also to detect sites that should be preserved and not used for further development (e.g. due to high ecological value). The update services consist in regular renewal of the vacant urban land inventory synchronized with the planned Urban Atlas updates. The thematic services target additional functionality tailored to end-users, like local authorities, policy makers, etc.

The deliverables of the project are intended for a wide range of users. Strategic users, such as local and regional authorities, European and national agencies in charge of urban planning, would directly benefit from URBIS services to perform monitoring and assessment of the implementation of particular territory planning policies. Operational users, such as industrial estates operators or private land developers are likely to require the URBIS services for their specific need such as a to know where to find suitable vacant sites within metropolitan areas and LUZs. Financial institutions might be interested in general land use data to improve project business plans and prevent excessive urban sprawl by banking incentives. The contributions of the URBIS project are depicted on a schematic flow land use chart in Fig. 1.

One main activity of the URBIS project is the implementation, test and validation of the above mentioned services in real environment within 3 already selected LUZs, which encompass a various set of specific criteria and requirements in the field of vacant land reuse. The 3 selected LUZs which will participate and contribute to the pilot studies are:

- Greater Amiens (France)
- City of Osnabruck (Germany)
- Moravian-Silesian Region (Czech Republic)

Fig. 1. Role of URBIS in the circular flow land use management concept (based on results of “Fläche im Kreis” project, 2005).

To appear in Joint Urban Remote Sensing Event (JURSE) 2015
The project activities started in April 2014 and its scheduled duration is of 3 years. The partners involved in the URBIS project are: Gisat S.R.O. (Czech Republic), Systèmes d’information Référence Spatiale (SIRS) SAS (France), Universitaet Osnabruce (UOS) (Germany), Universita Degli Studi Di Genova (UNIGE) (Italy), Projektkgroup Stadt und Entwicklungs, Ferber, Graumann und Partner (Stadt+) (Germany), Agence de Developpement et d’Urbanisme du Grand Amienois Association (ADUGA) (France).

This paper will focus on the methodological contribution of the research unit of the University of Genoa that will be developed for classification and change detection problems. The remainder of the paper is organised as follows. In Section II we discuss methodological approaches to classification and change detection of high resolution multispectral imagery in the scenario of vacant land processing. In Section III we present the problem of vacant land classification with several examples. Section IV presents the conclusions.

II. METHODOLOGY

A land-cover mapping task can be addressed on Earth observation data by a pattern-recognition approach and formalized as a supervised image-classification problem involving ground-truth data for training purposes. From the methodological standpoint, this problem has been extensively studied for several decades, involving progressively more advanced types of remote sensing data, from multispectral to hyperspectral, and from coarse to very high resolution (VHR). The current scientific development in this research area, coupled with the increasing computing capabilities provided by hardware-software platforms and architectures, make it feasible to successfully apply advanced remote sensing image classification techniques, not only in laboratory experiments but also when application-oriented or operational requirements need to be met.

Many methodological approaches have been introduced in the literature to address land-cover mapping from remotely sensed data. In particular, three currently topical and mature approaches, which rely on well-defined methodological bases have been experimentally found to be accurate and reliable tools in many land-cover mapping applications will be applied to LUZ mapping within URBIS by the research unit of Genoa: support vector machines (SVMs) [2], Markov random fields (MRFs) [3], [4], and region-based methods [5]. SVMs currently represent a well-established and widespread approach to remote sensing data classification based on the integration of methodological contributions stemming from diverse fields, such as statistical learning, convex optimization, and functional analysis. The vast diffusion of SVMs in learning applications acknowledges their role as a mature result of the development of pattern recognition in the last decades. In remote sensing, they are currently considered to be powerful tools for land-cover mapping because of the accurate results they have obtained in the classification of diverse types of satellite data. Their success in real-world applications, despite their intrinsically substantial computational burden, is currently feasible also because of the efficient numerical optimization strategies that have been developed and tailored for SVM-based learning, the small number of input parameters to be tuned, and most recently, the introduction of automatic optimization algorithms for these parameters [6].

MRFs are a wide class of flexible and powerful probabilistic models for the spatial-contextual information associated with images, and their use for classification benefits from the dependence among neighboring pixels to minimize the probability of classification error. Among the reasons for the relevance of MRFs in remote sensing, are a remarkable flexibility to incorporate multiple information sources in an image-analysis task and the accurate results they have provided in many analysis problems, such as remote sensing data classification, restoration, denoising, feature extraction, and multi-temporal analysis [4].

The role of spatial information modeling in remote sensing is now emphasized even further by the vast popularity gained by VHR satellite sensors during the last decade, an issue of primary importance in the analysis of urban areas. A third typical approach to classification, which is especially relevant for VHR images, is represented by region-based and object-based methods. They rely on the combination of classification and segmentation processes. A segmentation algorithm aims at partitioning an image into a set of homogeneous regions (or segments), which often correspond to objects or portions of objects. Multi-scale region-based methods represent especially effective tools: the key concept is to generate a collection of segmentation results corresponding to multiple spatial scales. It is expected that the main regions and structures in the scene will be identified at coarse scales, whereas smaller structures, objects and parts of objects will be apparent at fine scales. Multi-scale methods aim at advantage of this complementary information to model into the classification process the spatial-geometrical structure of the scene [4].

With regard to the detection of ground changes and to the analysis of the land cover transitions between multiple observation dates, the problem of the joint land-cover classification of multi-temporal satellite images have been addressed for several decades in the remote sensing literature [7], Fig. 2. Degree of Imperviousness map (©SIRS) of Sophia, Bulgaria in 2012.
several approaches, stemming from diverse fields such as probabilistic modeling, neural networks, and spatial-contextual modeling through relaxation, fuzzy, and MRF techniques, have been demonstrated to provide accurate results. Within these methodological strategies, a wide class of approaches are based on MRF models. Thanks to the aforementioned flexibility of the MRF family in incorporating multiple input sources of information, not only the spatial information associated with each image but also the temporal correlation associated with a sequence of images can be effectively modeled through a suitable MRF model. This approach is of great interest also for its ability to easily integrate different kinds of information (e.g., derived from a GIS or from region-based processing), in addition to the temporal, into a scene model. MRF modeling has recently attracted even greater attention as a feasible classification tool also as a result of the development of computationally efficient algorithms (e.g., graph cuts) for the related complex minimization [9] and parameter-estimation problems. These computational advances, coupled with the current hardware development, makes state-of-the-art MRF modeling a mature approach to the analysis of the temporal dynamic of land cover through multi-temporal Earth observations.

III. VACANT LAND CLASSIFICATION IN URBAN CONTEXT

When applied LUZ, several classes of vacant land typologies are of interest due to their distinct origins and varying strategies of their future redevelopment:

- **Greenfields** – land without former development and natural soils with no infrastructure connection;
- **Vacant or underused land** – previously used land no longer being used, e.g. with demolished construction sites;
- **Gaps in built-up areas** – mostly smaller sites with none or little infrastructure present;
- **Brownfields** - these could be industrial, military, commercial (greyfields), infrastructure, residential, cultural/social, agricultural sites that have been cultivated but are currently dis- or underused due to various demographic, economical and ecological reasons.

An important class of vacant land is given by impervious surfaces [10], [11]. Such surfaces are anthropogenic features through which water cannot infiltrate the soil, including roads, driveways, sidewalks, parking lots, rooftops, and so on, see an example of imperviousness map of Sophia, Bulgaria, in Fig. 2.

As can be seen from the above list of classes, the identification of vacant land is not restricted to any single standard class of landcover, see, e.g., a Copernicus Urban Atlas map of greater Amiens LUZ, one of the pilot sites of the URBAN studies presented in Fig. 3. Indeed vacant landcover types vary a lot and could be found inside many other classes – see, e.g., definition of brownfields above.

IV. CONCLUSIONS

The identification and classification of vacant sited in large urban zones is an important and timely problem in urban management and development. Corresponding methods are to
address the problem of urban sprawl based on the analysis of historical and new optical remotely sensed images.

One of the core aims of URBIS project is to explore the vast potential of cutting-edge image analysis approaches to the vacant land processing applications. The study and validation of the classification and change detection techniques will focus on European large urban zones and strengthen the link between methodology and this novel application.

ACKNOWLEDGMENT

Authors thank the European Community for funding the project "URBIS - URBan land recycling Information services for Sustainable cities” in the context of the CIP-ICT-PSP-Call7-2013 and all the project partners.

REFERENCES


