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Identifying concentrated areas of trip generators from high spatial resolution satellite images using object-based classification techniques

Cláudia A. Soares Machado [a, *], Alessandra M. Knopik Beltrame [b], Eduardo J. Shinohara [c], Mariana A. Giannotti [a, 1], Laurent Durieux [d], Tânia M.Q. Nóbrega [e], José A. Quintanilha [a, 1]

[a] Laboratory of Geoprocessing of the Department of Transportation Engineering, Polytechnic School of the University of São Paulo (Escola Politécnica da Universidade de São Paulo – EPUSP), Av. Prof. Almeida Prado, Travessa 2, no. 83, São Paulo, SP, CEP 05508-070, Brazil
[b] SENAC – National Service of Commercial Learning (Serviço Nacional de Aprendizagem Comercial), Office of Graduate Geoprocessing, Brazil
[c] CETESB – SÃO PAULO STATE ENVIRONMENTAL AGENCY (COMPANHIA AMBIENTAL DO ESTADO DE SÃO PAULO), Av. Professor Frederico Hermann Júnior, 345. Prédio 12 – Alto de Pinheiros, São Paulo, SP, CEP 05459-900, Brazil
[d] IRD – Institute of Research and Development (Institut du Recherche et Developement), France
[e] Department of the Environment, Water Resources, Science and Technology of the State of Paraíba (Secretaria de Meio Ambiente, Recursos Hídricos, Ciência e Tecnologia do Governo do Estado da Paraíba – SEMARHCT), Brazil

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ABSTRACT

The urban environment is highly complex and heterogeneous and is characterised by rapid changes in its configuration and characteristics, which scholars have referred to as urban growth. However, urban growth is not synonymous with urban development. However, urban growth is not synonymous with urban development. For development to accompany growth, territorial ordinances must be adopted, which highlights the need for planning. The high frequency and broad scope of geographic alterations in the urban environment require quick and inexpensive methods to produce and update spatial information, such as those methods that depend on remote-sensing tools. The advent of remote-sensing satellite imagery with high spatial resolution introduced a new perspective from which to analyse and study urban areas, particularly with respect to the impact of transportation systems and human activities that operate in the midst of a global context that is looking for ways to promote a sustainable urban growth and development model. In this context, the present paper proposes a methodology for identifying useful urban features for transportation planning, particularly with respect to areas with higher concentrations of trip generators that are identified from satellite images, using object-based classification techniques. The proposed methodology for classifying images minimises costs and prioritises field activities related to research on trip generators, as well as origin/destination studies. The methodology was used in the city of João Pessoa, Paraíba State, Brazil with satisfactory and promising results.

Introduction

The urban environment is highly complex and heterogeneous and is characterised by rapid changes in its configuration and characteristics, which scholars have referred to as urban growth. However, urban growth is not synonymous with urban development. However, urban growth is not synonymous with urban development. Whereas the former indicates only an increase in the amount of urbanisation, the latter denotes an increase in quality combined with growth. For development to accompany growth, there must be territorial organisation and planning. However, for planning even to be possible, the urban growth observed in large- and medium-sized cities, such as those in Brazil, for example, requires constant and extensive mapping to update the applicable databases, particularly for spatial data (geographic). The intense urbanisation process demands substantial financial, time and human resource commitments to build and maintain geo-referenced databases that enable the government to manage and administer

* Corresponding author. Tel.: +55 11 30915174; fax: +55 11 30915716.
E-mail addresses: claudia.machado@usp.br, claudia.s.machado@uol.com.br, csmachado6@gmail.com (C.A. Soares Machado), alessandra.mkbeltram@sp.senac.br (A.M. Knopik Beltrame), eshinohara@sp.gov.br (E.J. Shinohara), mariana.giannotti@usp.br (M.A. Giannotti), laurent.durieux@ird.fr (L. Durieux), tanianobrega@aesa.pb.gov.br (T.M.Q. Nóbrega), jaquinta@usp.br (J.A. Quintanilha).
[1] Tel.: +55 11 30915174; fax: +55 11 30915716.

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the cities. As a result, there is a growing demand for accurate, reliable, fast and inexpensive information.

Thus, the high frequency and broad scope of geographical changes in the urban environment require fast and inexpensive methods to produce and update both medium- and large-scale spatial information for planning purposes (Freire, 2010). It is in this context that the use of remote-sensing tools has grown as an alternative to traditional methods of building and maintaining spatial databases because they are less costly, more agile and able to track changes and identify events in the physical environment that serve as tools for urban managers, particularly those working in transportation planning.

Remote–sensing techniques–image classification methods

The advent of remote-sensing satellite imagery with high spatial resolution introduced a new perspective to conducting analyses and studies of urban areas, particularly in examining the impacts of human activities on the planet (such as transportation systems); the introduction of such technology came at a time that is witnessing the growth of concerns about the need to find and promote a sustainable model for urban growth and urban development. The high resolution imagery expands the scope of research that detects changes in land use/land cover (LULC) and no longer restricts such research to environmental studies of natural resources and urban analysis on a global or regional scale. From that time forward, urban studies could be performed with much greater detail than previously. The classifications of LULC came to be determined more accurately; thus, urban sprawl could be detailed, for instance, through road system detection, the identification of different types of edification covers and the composition of bare soil, the determination of the species of urban vegetation, etc. The process of land urban image classification became systematic.

Based on the foregoing, many researchers have attempted to assess the impact of human activities on the urban areas and to understand and organise the contemporary and future urban environment. The demand for accurate and updated spatial information is essential for effective planning and managing cities. It is within this context that the use of remote-sensing science is emphasised because remote-sensing tools are capable of generating information for mapping, analysing and monitoring urban systems (Nóbrega et al., 2008).

Currently, pixel-based and object-based techniques are the most utilised methods of remote-sensing image classification. Pixel-based classification uses spectral information to categorise pixels into classes, whereas object-based classification uses contextual information (in addition to spectral information) to sort pixels into classes.

However, this rule is not absolute. It is possible to use some contextual information in the pixel-based approach. Stuckens et al. (2000) used the segmentation procedure to integrate contextual information with pixel-based methods to classify LULC in a metropolitan area and also in the postclassification, which led to improved results by reducing confusion among urban LULC categories, and overall accuracy was increased as a consequence of incorporating contextual information into the classification process. Puissant et al. (2005) examined the potential of the spectral/textural approach to improve pixel-based classification accuracy in classifying intra-urban LULC types and confirmed the utility of textural analysis to enhance the results, particularly in urban areas in which the images are spectrally more heterogeneous. Textural analysis utilising the post-classification process improves overall accuracy and reduces confusion among LULC classes. Esch et al. (2010) and Taubenböek et al. (2012) performed pixel-based classifications of urbanised areas on RADAR images and focused on a textural analysis to highlight regions that are extremely textured due to land surface heterogeneity, as is typical in urban areas.

Classifying remote-sensing data by using spectral, spatial and textural information in methods that apply these individually or in combination has increased their applicability for feature extraction and mapping (Tehrany et al., 2014). Depending on the type of analysis and imagery characteristics, these approaches (pixel-based and object-based) have both merits and drawbacks.

In some studies, both methods are used together to improve classification accuracy. For example, in Shackelford and Davis (2003), the two approaches were applied to the classification process of multispectral high resolution imagery data over urban areas to map LULC, whereas in Gutiérrez et al. (2012), the methods were used for LULC classification of medium resolution imagery.

In general, for urban studies undertaken using remote sensing with high resolution imagery, the object-based approach has been the most useful and has yielded good results. Yan et al. (2006) tested pixel-based and object-based classifications for land cover mapping in a coal fire area located in Wuda, Mongolia, China. A statistically rigorous comparison of the two approaches was undertaken in that study and determined that the overall accuracy of the object-based classification was higher than that obtained using the pixel-based method.

Cleve et al. (2008) used high spatial resolution imagery in the USA to analyse the expansion of urban development into wildland areas in Napa County, California to distinguish LULC categories. The authors explored the accuracy of pixel-based and object-based classification methods for mapping the wildland–urban interface, and their results indicate that object-based classification yielded higher accuracy than the pixel-based method.

Blaschke (2010) presented an overview of the development of the object-based method by means of a comprehensive literature review and concludes that the pixel-based paradigm is flawed and that the object-based method is making considerable progress toward the spatially explicit information extraction workflow that is required for spatial planning and for many monitoring programmes. Thus, Blaschke (2010) concludes that the object-based technique represents a significant trend in remote sensing and GIScience by meeting the demands of increasing the spatial resolution in imagery and the use of large amounts of geospatial data.

Newman et al. (2011) compared pixel-based and object-based classification to determine the effects of these two methods in a fragmentation analyses of Cockpit Country in Jamaica. According to these authors, both methods showed similar trends in fragmentation metrics; however, there were significant differences between them regarding the metrics that quantified landscape configuration. The authors affirmed that the object-based approach presents better results for landscape analyses than the pixel-based method.

Ouyang et al. (2011) affirmed that the object-based classification has demonstrated many significant advantages over other methods of classifying urban and/or forest ecosystems. These authors compared the effectiveness of object-based classification and pixel-based classification methods for mapping plants in a saltmarsh ecosystem through very high resolution imagery, and they concluded that the object-based method yields better results in terms of accuracy than the pixel-based approach because the object-based technique performance employs membership functions and a hierarchical approach with multi-scale segmentation.

Robertson and King (2011) compared pixel- and object-based classifications of Landsat Thematic Mapper data for mapping and analyses of LULC change in the mixed land-use region of eastern Ontario, Canada during the 1995-2005 period. The quantitative and