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A system to detect houses and residential street networks in multispectral satellite images

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Abstract

Maps are vital tools for most government agencies and consumers. However, their manual generation and updating is tedious, time consuming, and expensive. To address these concerns, we are developing automated techniques. In this paper, we restrict our attention to residential regions. These regions provide a challenge, testing the current limits of automated image analysis. Such regions are also typically areas of rapid growth and development and, therefore, are of interest from the applications perspective. In previous studies, we introduced statistical measures to extract these kinds of regions from satellite images [in: Proceedings of the International Conference on Pattern Recognition, vol. 1, 2002, p. 127, IEEE Trans. GeoRS (2003), IEEE Trans. PAMI]. As the next step toward automatic map generation, here we introduce a novel system to detect houses and street networks in IKONOS multispectral images. These images have one meter panchromatic resolution with 4 m resolution in the spectral bands. Our system consists of four major components: multispectral analysis to detect cultural activity, segmentation of regions of possible human activity (based on the surface material), decomposition of the segmented images, and graph theoretical algorithms over the decompositions to extract the street network and to detect houses. We tested our system on a large and diverse data set. Our results indicate the usefulness of our system in detecting houses and street networks, hence generating automated maps.

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1. Introduction

Government agencies, civil defense organizations, relief agencies, and consumers depend heavily on maps to support their missions and activities. Konecny and Schiewe [4] summarize some facts regarding manual map generation. According to their analysis, 33.5% of the world was mapped at 1:25,000 scale (around one meter per pixel resolution) as of 1993. This resolution is vital for mapping most mature cities (such as European cities) because their buildings and street networks are in close proximity. For this scale, the annual manual map generation rate is around 2.8%. Similarly, the annual manual map updating rate is around 4.9%. Konecny and Schiewe underscore the urgency to automate map generation: ''On average, maps of 1:25,000-scale are 20 years out of date and 1:50,000-scale sheets may be 40 (or more) years old.'' Considering that a house can be built less than a year (and destroyed in minutes), and larger buildings can be built within two to three years, the inadequacy of current map updating rates is clearly evident.

Aerial and satellite images can provide a solution to the automatic map generation problem. Collecting data around the world with aerial sensors takes around five years (as reported by Konecny and Schiewe). More promisingly, collecting data around the world using the commercially available, high-resolution (one meter per pixel panchromatic and 4 m per pixel multispectral) IKONOS satellite images takes a matter of months and requires no access to airspace. Compared to the current 20 year updating period, IKONOS imagery provides the most promising avenue to solve the map generation problem. While the advent of commercially available, high-resolution satellite imagery addresses the data collection issue, the rate at which these sensors provide data currently far exceeds the rate at which those data can be analyzed.

1.1. Overview

To address these problems, we introduce an automatic street network and house detection system using commercial IKONOS satellite images as input. We focus on to detect houses and street networks in residential regions, which have been identified in advance using the techniques in [1–3]. Detecting houses is far more challenging than detecting larger buildings for several reasons. First, their footprints are relatively small. Second, occlusion by nearby trees is common. Third, in some neighborhoods, houses may come in fairly complex shapes. Analogous problems (small cross-section, overhanging trees, and winding curves) present challenges for street detection in residential regions.

The system described here comprises four main parts, all operating on the 4 m resolution, multispectral bands. First, we introduce measures on multispectral images