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Generation of parcelation proposals aided by lidar derived spatial cues

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ABSTRACT

Periods of rapid urban development may only enable the documentation of land parcelation long after the actual construction has been completed. Such documentation may involve substantial effort, particularly in the case of large, densely-built regions. This paper proposes a method for generating parcelation proposals based on the geometric concept of equal partitioning and on existing, in situ, physical evidence. Airborne laser scanning data is used to generate partitions. Laser scanning data enables the detection of buildings around which parcel boundaries are established as well as weak cues that indicate the existence of physical parcel boundaries. We show that, even with modest resolution, such cues can be found within the data and utilized. Coverage of large geographic areas by airborne laser scanning data makes the proposed model applicable to wide regions.

1. Introduction

Cadastre is a land registration method designed to ensure the rights of individuals and the state of their property. In Israel, as in many other countries, the responsibility for managing these lands is partitioned between two governmental agencies: the Survey of Israel, the agency in charge of measuring and preparing cadastral maps, and the Land Registry Department within the Ministry of Justice, which is responsible for registration of land ownership. A third key player, the Ministry of the Interior, is responsible for preparing statutory land-use programs together with the regional and local planning committees. All three authorities are involved in an ongoing cycle of parcelation and re-parcelation of land. The first cycle of initial parcelation and registration of land ownership involves a land survey, preparation of cadastral maps, and the registration of ownerships. All subsequent re-parcelation cycles begin with a new urban or regional plan based on the existing cadastre, followed by preparation of mutation plans, updating the cadastre maps, and registration of the new and/or updated ownerships of the land re-parcelation (Forrai, Murkes, Voznesensky, & Klebanov, 2004). Due to changes in land ownership, new unions and subdivisions of parcels, and the constant necessity to redefine and update ownership boundaries, cadastral measurement is a continual process.

Modern cadastral mapping in Israel is based on the Torrens method of registration of titles and has been in effect since the 1920s. This system defines cadastral parcels and blocks, the latter of which is a subdivision unit usually containing 50–100 parcels. In Israel, cadastral surveys are carried out by the state and are linked to the national reference coordinate system. Measurements are recorded in field books and are used to determine the block boundaries, the parcels themselves, as well as other features such as buildings, fences, and electric poles. All cadastral-related measurements are depicted graphically on "field sheets". Preparation of the cadastral block maps is based on the field sheet, with maps consisting of all parcels in the block and related features. Cadastral maps contain neither the measured data nor any dimensions of the parcel boundaries, rather serving only as a graphical representation of parcel layout. Field books and field sheets serve as evidence for the statutory validity of the cadastral subdivision, and when necessary, for restoring cadastral boundaries (Shoshani, Benhamu, Goshen, Denekamp, & Bar, 2004).

This well-established sequence of urban/regional planning, which is followed by preparation of mutation plans, updating of cadastre maps, and registration of new land ownership, is disturbed when informal construction is carried out, insofar as informal indicates illegal, unauthorized, or non-officially approved land-use plans. In Israel, as in many other countries, these informal constructions are carried out only in two extreme cases. First, private citizens may bypass regulations and land-use formalism and construct houses without any legal permission, occasionally not even on their own land. The second case occurs when the state itself (e.g., governmental agencies or ministries) decides to bypass its own laws and regulations and build residential neighborhoods without formal plans or with unapproved land-use plans. Such a

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Fig. 1. An orthophoto map of a typical residential area (left); extracted edges (right).

governmental violation of the construction and housing laws and regulations occurred first in the 1950s and then again in the late 1980s and early 1990s. The first occurrence immediately followed the establishment of the state of Israel, when a huge wave of immigrants arrived and almost tripled the country's population within one decade. With neither sufficient time nor skilled manpower to begin an organized process of urban planning, surveying, and land ownership registration, the practical solution was to first build houses and only afterwards create a legal structure for the parcelation and registration of land ownership. The second period that necessitated a governmental bypass of construction laws and regulations happened within a short period of three to four years, with the arrival of almost one million immigrants from the former Soviet Union.

In all of these informal construction cases, there is a need to legalize the "illegally" constructed houses and neighborhoods. This legalization process is carried out by measuring the as-made built-up areas, proposing an *a posteriori* subdivision of the land, preparing mutation plans, depicting the actual land-use situation, and, finally, preparing cadastral maps and registering the ownership. In the process of measuring these areas, surveyors map buildings as well as fences, walls and other physical boundaries in order to propose a "reasonable" subdivision of the areas between and around existing houses. This task can be time-consuming and expensive, especially when performed on a large scale. This paper studies models for autonomous generation of a first parcelation proposal based on spatial cues. The proposed model has the advantage of providing a parcelation sketch for large regions with little intervention by an operator. The spatial cues include buildings as well as peripheral, weaker cues that may define the parcel boundary location. Airborne laser scanning data and images are used for this purpose.

2. The parcelation model

Delineation of parcel boundaries can be a laborious process if performed manually using photogrammetry or ground surveying methods. The process becomes even more involved in urban areas, which may be cluttered and at times not accessible.

In many cases, particularly in urban environments, spatial markers may delineate parcel boundaries. Such markers may involve borderlines, such as fences that surround buildings, or break lines, which delineate the ground level of buildings from the street. If recognizable, such boundaries can be used to generate a partitioning that often reflects the actual (or eventual) parcelation of cadastral blocks.

This work explores the level of automation that can be attained when generating parcelation proposals from remotely-sensed data. This partition, which documents the on-the-ground "facts," can then be further refined by a human expert who can add nuances and adjust for actual limitations and regulations.

Within the sensory data, images enjoy both high spatial resolution and high spatial accuracy. Fig. 1 shows an orthophoto of a residential neighborhood with two rows of buildings and fences surrounding them. The general partitioning is relatively clear. However, when translating this visual impression into autonomous image-based analysis, the limitations of such an approach can be readily seen. Using well-known machine-vision procedures, including line detection, edge detection and image segmentation (Castleman, 1996), the results clearly show that intensity edge-based data do not necessarily (in fact, hardly) reflect physical boundaries between real world objects. Essentially, image derived edges reflect a discontinuity in intensity and do not always reflect the outlines of physical objects. Identifying the edges that define objects within the complete edge map is practically impossible and is only possible in well-defined cases, such as buildings with relatively simple shapes and with guidance from external information sources (Croitoru & Doytsher, 2003; Suveg & Vosselman, 2001). Consequently, we turn to airborne laser scanning data as the primary source of information for the generation of parcelation proposals. In recent years, airborne laser scanning technology has become a dominant tool for large-scale topographical mapping. By documenting the terrain and objects on the terrain in high resolution and in 3D, laser scanning data facilitates a detailed, geo-referenced mapping of spatial objects. In terms of accuracy, a growing number of publications report accuracy levels on the order of ±10–20 cm in both elevation and position (Ahokas, Kaartinen, & Hyyppä, 2003; Filin, Avni, Marco, & Baruch, 2006).

Laser scanning data has so far been applied to cadastre in reference to 3D cadastre, and has been used as a means for assigning parcel heights either by plain association (Stoter & van Oosterom, 2006) or by following a geometric adjustment as proposed in Filin, Kulakov, and Doytsher (2005). In the present case, however, the choice of laser scanning data is not only driven by the ability to produce a detailed and accurate description of the topography but also by the detection and characterization of geographic objects that have distinct topographic signatures. Compared to standard image-based mapping, autonomous extraction of information is greatly enhanced with data that capture actual height information, e.g., laser scanning-driven building reconstruction and tree canopy modeling. However, while buildings or trees are dominant objects compared to their surroundings, natural boundaries are